Process performance evaluation of the contact stabilization system at Birzeit University

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Abstract: The purification capacity of the contact stabilization system at Birzeit University campus has been studied for two years. The oxidation capacity of organic matter, ammonium oxidation, and denitrification potential were determined. The reduction of chemical oxygen demand (COD) was 85%, and the effluent COD concentration was less than 110 mg/l (the average value was 88 mg/l). Suspended solids were removed with equal efficiency. The aerobic stabilization of organic solids was efficient, and no excess biosolids (sludge) had to be removed. High nitrification (70% of the influent nitrogen were nitrified) could be maintained at 15 °C, and 42% of the oxidized nitrogen was denitrified. The specific oxygenation capacity of the treatment system is relatively high and reached about 5 kwh/kg COD. The specific wastewater treatment cost is about 0.52 US$/m^3 or about 58 US$ per population equivalent per year. Based on the results obtained, batch operation and intermittent aeration of the biological process are suggested to achieve high effluent quality and to reduce power consumption.

Keywords: activated sludge, contact stabilization system, effluent quality standards, nitrification, nitrogen removal, purification capacity.

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Biographical notes

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1 Introduction

In Palestine, the present water supply and sewerage systems with large wastewater treatment plants serve only the urban population. In 1997 about 78% of the total population of Palestine (West Bank) was served by public water supply, and almost 24% by public central sewerage systems (Abu Madi *et al.*, 2000). Less than 5% of collected urban sewage is partially treated in the existing overloaded central sewage works (MOPIC, 1998). In sparsely populated Palestinian rural and semi-urban communities, which form about 60% of the total population in the West Bank, different wastewater treatment options must be developed and adopted for protection of the aquatic environment.

The water quality of groundwater wells and some freshwater springs is showing signs of nitrate pollution (Mukhallalati and Safi, 1995; Alawneh and Al-Sa'ed, 1997). Among the nitrogen pollution sources are untreated municipal sewage from urban areas, domestic discharges and septic tanks from Palestinian rural communities and Israeli colonies, and excessive fertilizer usage. Control of biological nutrients (N and P) discharged from large and small point sources is of special interest in order to protect the aquatic environment from pollution.

Several attempts have been made to develop wastewater management strategies for the Palestinian urban areas (Gearheart *et al.,* 1994; Nashashibi and van Duijl, 1995; PWA, 1998). Beside applied research studies a number of biological treatment technologies for small rural communities have been introduced and installed (Mustafa, 1996; Zimmo *et al.,* 1999; Zimmo *et al.,* 2000). Most of the rural sewage treatment plants, installed to serve less than 1000 people, use the attached growth (trickling filters) and natural treatment processes preceded by septic tanks. Trickling filters and natural treatment processes are simple in operation and maintenance, require few skilled personnel and have low capital investment and annual running costs.

Rural small sewage treatment plants show a good removal rate for organic matter but are poor in nitrogen removal. In this study the process performance of the small-scale sewage works at Birzeit University campus, which uses the contact stabilization process, was examined. The treatment efficiency and other operational parameters were also investigated.

2 Experimental plant and methods

2.1 Layout, design dimensions and operation

Domestic wastewater from all the buildings, including the main restaurants and cafeterias as well as various laboratories, of Birzeit University campus is collected with a central sewerage network. Part of the collected sewage is pumped while the rest flows by gravity into the sewage treatment plant. At present Birzeit University has almost 4000 students and staff, and the amount of sewage collected and treated is about 60 m^3 per day.

Preaeration of wastewater influent is accomplished in the holding tank to freshen the sewage and control odour problems. A schematic flow diagram of the contact stabilization system is illustrated in Figure 1. From the holding tank the influent is pumped to the aeration basin, where a long period of aeration is combined with a high sludge biomass, resulting in a low organic load.

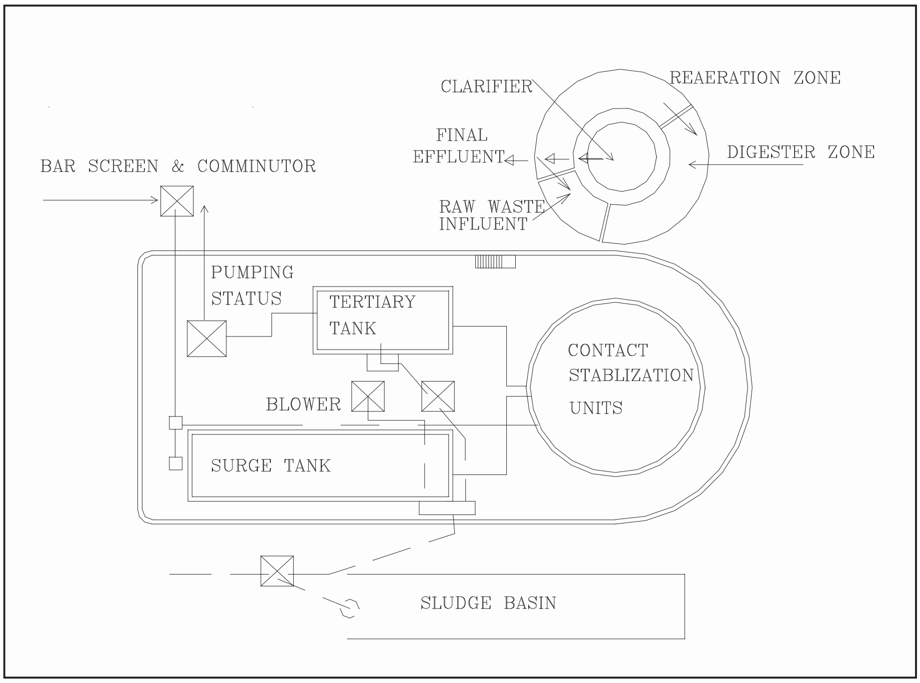

Figure 1 Schematic flow diagram of the contact stabilization system at Birzeit University.

After the biological unit the treated effluent is separated from the suspended solids in an integrated circular secondary tank. The treated effluent is further treated in a slow sand filter to remove suspended solids, viruses and microbial pathogens. Excess sludge is pumped from the preaeration zone to the aerobic digestion zone. Minimal excess biosolids are removed from the sludge stabilization tank. For safety reasons, no agricultural usage is practised. The treated effluent is used for landscape irrigation at Birzeit University campus.

3 Analytical methods

Influent and effluent samples were analysed for total chemical oxygen demand (COD), total nitrogen (TKN), ammonium (NH_4^+-N), nitrite (NO_2^--N), nitrate (NO_3^--N) and total phosphorus (tot-P). The same parameters were measured on filtered samples, where portions of the samples were filtered through GF/A glassfibre filters. Analyses were conducted according to the Standard Methods (APHA, 1992). A dissolved oxygen (DO) probe (Hach Model DO175) and a pH probe (Hach Model EC10) were used to determine DO and pH values.

4 Results and discussion

4.1 Raw wastewater characteristics

The wastewater from the campus is collected in separate sewer networks. The wastewater characteristics from Birzeit University are slightly diluted and do not reflect a typical rural domestic sewage. The reason for this is that most of the students stay for a short period of time in the university campus. Raw wastewater quality based on average values is presented in Table 1.

Table 1 Average concentrations of raw wastewater (mg/l, unless otherwise stated).

Parameter	Concentration
BOD	220
COD	488
SS	300
TKN	75
NH_4^+-N	58
NO_2^--N	0
NO_3^--N	0
Tot-N	75
Tot-P	3.4
Temperature (°C)	19
pH	7.4
Dissolved oxygen (DO)	1

4.2 Organic carbon

Total and soluble COD concentrations in the influent and effluent of the sewage works over the last two years of the monitoring programme are shown in Figure 2. During the winter season, the effluent COD concentrations are sometimes higher than in the summer period.

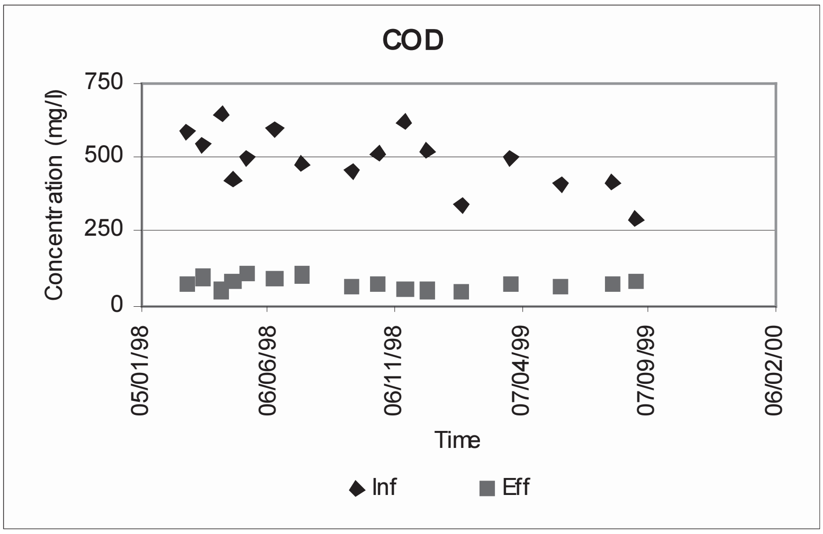

Figure 2 Influent and effluent COD concentrations during the monitoring period.

4.3 Nitrogen removal rates

Usually, the high-rate contact stabilization process does not produce good results for nitrification and denitrification. The nitrification rate is measured indirectly as the ratio of NO_3^--N to NH_4^+-N in the effluent of the biological process. About 70% of NH_4^+-N is nitrified. However, only 42% of nitrate is biologically denitrified. The nitrification rate is illustrated in Figure 3. It is well known that biological denitrification cannot be achieved without nitrification. When the water temperature falls below 10 °C, the nitrification rate decreases.

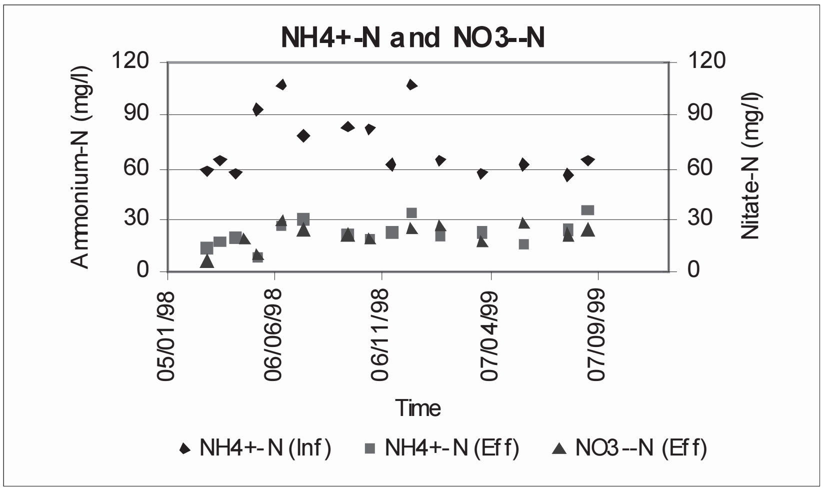

Figure 3 Ammonium (influent and effluent) and nitrate (effluent) concentrations.

The nitrification rates achieved in the contact stabilization process are low compared with those achieved in oxidation ditches and conventional activated sludge systems. This might be due to extensive hydrolysis of biomass in the sludge stabilization tank, or to a low sludge age or to a low MLSS concentration in the aeration tank. Also, competition for dissolved oxygen between carbonaceous heterotrophs and autotrophic nitrifiers in the aeration tank might be a reason for low nitrification activity. Since denitrifiers are anoxic heterotrophs, and the oxygen concentration in the aeration tank is not regulated, the denitrification process is probably negatively affected by a high oxygen concentration in the aeration tank and in the raw influent from the holding tank. Also, a low COD concentration might have affected the denitrification process. Enhancement of biological nitrogen removal can be achieved through regulation of the DO concentration and by feeding part of the stabilized sludge into the holding tank. This is under investigation.

4.4 Annual capital and running expenditure

The sewage works at Birzeit University campus was installed in 1980. Capital and operational expenditure (CAPOEX) is an important measure in the water industry, which gives an indication of the cost-effectiveness of a sewage facility. The estimation of CAPOEX of wastewater treatment alternatives helps the design engineer and decision-makers decide which treatment option to select with respect to cost effectiveness, easy operation and maintenance.

Generally, the CAPOEX items of a treatment plant consist of the annual capital and running costs. The capital investment costs are calculated using the annuity factors with respect to the annual rate of interest and the lifetime of plant processing units. The operational expenditure (OPEX) or the annual OMR includes personnel, energy, laboratory analysis, sludge management, maintenance, operation and repair.

The annual capital and running costs were estimated using an annuity factor and assuming 20% of the total capital costs for electromechanical parts and 8% annual rate of interest. The lifetimes of the civil works and the electromechanical parts were assumed to be 35 and 18 years, respectively.

The specific cost for wastewater treatment using the contact stabilization system was estimated to be about 58 US$/(PE year) or 0.52 US$/m^3. The cost of energy is about 45% of the total CAPOEX, which exceeds the average energy consumption rate for advanced sewage treatment plants. This cost can be reduced through dissolved oxygen regulation in both the holding and the biological units. Compared with the sewage costs in some member states of the European Union, the specific costs obtained from the Birzeit sewage works was within the range 56–125 US$/(PE year) (Pecher, 1995; Firk and Mertsch, 1998; Rudolph and Kraemer, 1999).

5 Conclusions and recommendations

There is a lack of data on the efficiency of present urban sewage works, and the published data on wastewater characteristics are not reliable. Moreover, little technical information on biological nutrient removal in contact stabilization systems is available. Hence, the authors studied the process performance of a small-scale contact stabilization system with special reference to organic carbon and biological nitrogen removal processes. As a result of the monitoring programme over the last two years the following conclusions and recommendations can be made:

- The contact stabilization process has a good efficiency in BOD, COD, and SS. The average effluent concentrations were all below international prescribed quality standards. Thus it can be recommended for rural communities and semi-urban areas.
- Partial nitrification and denitrification processes were achieved. High oxygen contents and low COD to N ratios are behind low denitrification rates in the sludge stabilization tank. Low MLSS and competition between heterotrophs and autotrophic nitrifiers have a negative impact on the nitrification process in the aeration tank.
- The CAPOEX costs for wastewater treatment using the contact stabilization system are reasonable and even affordable for the Palestinian rural and semi-urban areas. However, these can be reduced if internal process modifications are made and additional process regulatory devices are installed.

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