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MANAGEMENT OF TOXICITY EFFECTS IN A LARGE WASTEWATER TREATMENT PLANT

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ABSTRACT

An unusually severe case of toxicity accompanied by activated sludge filamentous bulking was observed at the wastewater treatment plant Sao Paulo-Barueri. Treatment efficiency of the plant, operated without major problems for more than five years before, was significantly hindered for almost six months. Occurrence of toxic shocks was confirmed partly directly but mostly indirectly by inhibition of nitrification and biological phenomena related to toxicity. Several measures adopted, including the recycled activated sludge chlorination, are described in the paper. © 1997 IAWQ. Published by Elsevier Science Ltd

KEYWORDS

Toxicity; activated sludge filamentous bulking; inhibition of nitrification; MICROTOX; recycled activated sludge chlorination; *Thiothrix sp.*

INTRODUCTION

The wastewater treatment plant Sao Paulo-Barueri is the largest treatment plant in Latin America. In 1976, a study projected for the year 2000, which was the horizon of that study, treatment of 63 m^3/s at Barueri, distributed into 9 modules, 7 m^3/s each. The next plan, elaborated in 1989, interestingly introduced decentralisation of wastewater treatment in the Great Sao Paulo metropolitan area and reduced the presumed capacity of Barueri for the year 2005 to 28.5 m^3/s, distributed into 3 modules 9.5 m^3/s each. Several other wastewater treatment plants were conceptualised (Susano, Pinheiros, San Miguel, Parque Novo Mundo, ABC, Santo Amaro) with presumed flows from approximately 1.5 to 3 m^3/s each at the turn of the century. At present, further reduction of the total wastewater discharge is anticipated.

It has to be noted that the industrial wastewater pretreatment program started several years after the first module at Barueri was commissioned. Also, tankers with certain industrial wastewaters (chemical, pharmaceutical etc.) are accepted to be discharged directly into the plant inlet. Both activities and their control are still at an early development stage and the plant is thus exposed to toxicity.

THE TREATMENT PLANT

The treatment plant has been designed as a conventional activated sludge system with average aeration detention time of 6 hours (presently 4 to 5 hours). WWTP Barueri consist of pretreatment (screens, grit

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traps, preaeration) and one module of the original design for 7 m^3/s. The module consists of units shown in Table 1. The module is subdivided into two sections (sub-modules), each of them having 2 groups of aeration tanks consisting of two aeration tanks (first section with aeration tanks marked as 1ab, 2ab, second section with aeration tanks marked 3ab and 4ab) and 6 final clarifiers. Those two sections can be operated somewhat independently in parallel, the most important as well as interesting feature being the hydraulic design pattern of the first section (1ab & 2ab) as nearly plug-flow, second section (3ab & 4ab) as nearly complete mixing.

Primary sludge is thickened in 4 gravity thickeners and wasted activated sludge in 6 dissolved air flotation units. After anaerobic digestion, sludge is dewatered on filter presses with addition of lime and ferric chloride.

Table 1. Main liquid train treatment units

	Number	Dimensions m	Type
Primary clarifiers	8	95 x 18 x 3.5	Scraped rectangular
Aeration tanks	8	130 x 25.5 x 6	Dome aerators
Secondary clarifiers	12	ϕ46 x 4	Circular, suction type

OPERATION

Since the plant was designed as conventional, effluent standards for settleable solids, total suspended solids, COD and BOD5 only have been set up.

Table 2. Comparison of typical and required effluent concentrations

Value	Settleable solids	TSS	COD	BOD_5
	ml/l	mg/l	mg/l	mg/l
Typical	0.12	19.2	55.7	33.2
Effluent standard	1	50	80	40
Typical as % of required	12	38	70	83

As can be seen from Table 2, the limiting indicator is BOD because its typical concentration reaches 83% of the effluent standard. The reason why BOD effluent concentrations are relatively high is the partial nitrification in the system. Thus BOD (conventional, nitrification non-inhibited) includes both carbonaceous and nitrification oxygen demands.

The plant suffered during initial periods of operation by temporary filamentous sludge bulking, mainly in the section operated as complete mixing (aeration tanks 3ab, 4ab). Several measures to suppress bulking have been applied and successfully implemented whenever necessary. In general, the operation was satisfactory for about five years, until the events described in this paper, and in line with the effluent standards applied and design expectations. Required effluent standards are to be maintained in at least 80% of grab samples. Performance index is defined as average fraction of effluent concentration values within the standard.

As can be seen in Figure 1, the required value of the performance index (0.8) was constantly and safely achieved and exceeded until April 1995 and then broken for four consecutive months and again in November 1995.

Average values of DSVI (diluted sludge volume index) oscillated around 100 ml/g except in February-March 1994 in complete mixing (sections 3ab, 4ab). That episode of sludge bulking is believed to be a consequence of high temperature (southern hemisphere late summer) and impoundment in the trunk sewer caused by high level of sewage in the receiving/pumping well at the plant. After the level in the receiving well was lowered, no bulking occurred for over a year.

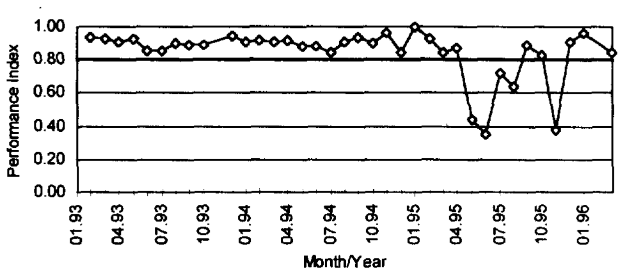

Figure 1. Development of average monthly performance index.

TOXIC SHOCKS

Initiation of the crisis

On 10 April 1995, during the night shift, a strong phenolic smell was detected at the primary clarifiers area. Incidentally, earlier the same day the local supervisory authority took samples which showed excellent performance (BOD 18.1; COD 36.0; TSS 9.0, all values in mg/l,). Two days later, on 12 April, the following effluent concentrations were found: BOD 47.5 mg/l; COD 89.1 mg/l and TSS 27 mg/l. The activated sludge system clearly received a toxic shock which hindered biological activity and significantly decreased treatment performance. There was no bulking at that time yet.

The system gradually recovered and on the 17 April the performance was back to normal: BOD 26.5; COD 44.5; TSS 10.8, all in mg/l. However, by coincidence, the same day (actually again at night time) the local authority sampling technician, when taking samples, identified a strong phenolic smell. Subsequent analyses for phenol indicated a concentration of 49 mg/l in the plant influent. It was estimated that the shock load of phenol might have been between 3 and 5 tons. There was presumably also a high load of accompanying phenol derivatives. Next analysis, on 19 April, documented a collapse of the system indicated by effluent concentrations: BOD 108; COD 161.6; TSS 42.8.

Clearly, at least two toxic shocks occurred in April. The first one noted was fully understood only retrospectively, after the mighty second shock.

Development of the crisis and actions taken

DSVI increased rapidly early in May to unmanageable values of 300 ml/g and over. Actions started on May 6 when intermittent feeding was introduced. Because no improvement could be observed, massive transfer of primary solids into the aeration tanks started on 15 May. Both actions were correct and proved very efficient. DSVI dropped from 300 ml/g and over to almost normal values, 150-160 ml/g in one week, from 15 to 22 May. At that time, based on experience gained in previous years, it was presumed that the episode terminated, and normal operation restarted. This unfortunately appeared not to be the case. Enormous bulking reappeared at the end of May.

It was confirmed that one of three filament species was *Thiothrix sp.* which forms long and rigid filaments dominantly contributing to high DSVI. *Thiothrix sp.* is a mixotrophic bacteria which normally gains energy from oxidising sulphides to sulphur. All potential sources of sulphide were examined and it was finally discovered that occurrence of *Thiothrix sp.* coincided with temporarily interrupted sludge dewatering. Sludge dewatering had to be interrupted earlier in consequence of less sludge production, loss of sludge through clarifiers and transferring primary sludge into aeration tanks where it was stabilised and its quantity thus significantly decreased. Essentially, there was nothing to dewater. Because of this situation, iron (originally as ferric chloride used for sludge conditioning) was missing in the system to which it is normally recycled from filterpresses cleaning etc. Thus sulphide from the influent and from sources within the plant was not precipitated as iron sulphide and was available to *Thiothrix* which could grow excessively.

It was hypothesised that once *Thiothrix sp.* is knocked down, the other two filaments (Type 021N and *Sphaerotilus sp.*), if still present, can be suppressed by routinely applied anti-bulking measures (intermittent feeding, selector, primary solids transfer into aeration tanks).

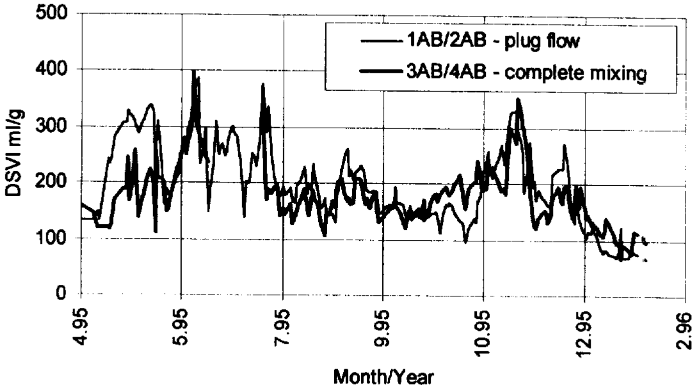

Figure 2. Development of DSVI after the toxic shocks.

Three key decisions were made:

a) Iron in form of ferrous sulphate solution was dosed to the plant influent on the weekend 23-24 June.
b) Shock chlorinating of recycled activated sludge (RAS) was prepared to be available if needed.
c) Sludge dewatering was restarted because enough sludge was already produced again.

The situation in late June rapidly improved and the starting position for July was good. DSVI values dropped to 140 ml/g, a value at which the plant can be operated without difficulties. Early in July, however, massive bulking developed very rapidly again. On 9th July, the clarifiers were totally out of control and suspended solids were being lost at concentrations up to 1á000 mg/l. Thus the ultimate decision was taken - to chlorinate the recycled sludge.

CHLORINATION OF RECYCLED ACTIVATED SLUDGE

The aim of chlorination of RAS is:

- to hit specifically filaments reaching out of the compact flocs and thus to lower SVI, while not damaging non-filamentous micro-organisms and thus preventing sludge deflocculation and treatment efficiency;
- to chlorinate during as short period as possible.

The DSVI target value was initially set to 200 ml/g and later on lowered to 150 ml/g.

Control parameters of chlorination. The control parameters used were:

a) Dose of chlorine.
b) Concentration of chlorine at the dosing point.
c) Frequency of sludge exposure to chlorine.

d) Sludge volume index (conventional and diluted).

e) Microscopic observations which identify damages to filaments, non-filaments, protozoa etc. (as well as disappearing sulphur or PHB granules etc.).

f) Decoloration of sludge (non-quantitative parameter).

g) Turbidity.

h) Sludge blanket level in clarifiers.

Results of chlorination. Figure 3 shows general development of DSVI in relation to chlorination periods.

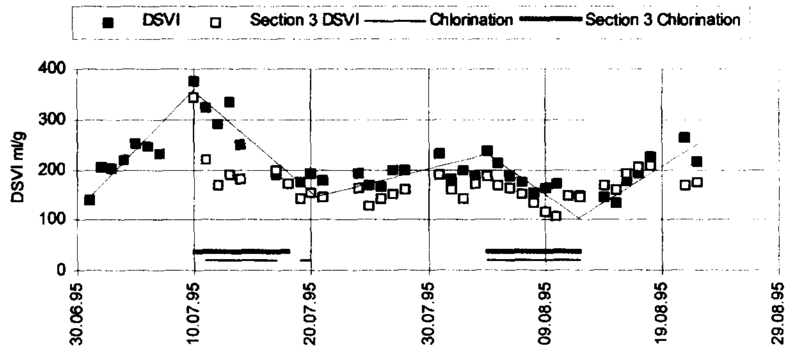

Figure 3. DSVI in systems 1 and 3 July-August.

It can be seen that the situation was critical before the first chlorination. Bulking was sufficiently suppressed by chlorination but it re-established soon after chlorination stopped.

Figures 4 to 7 show the course of chlorination of RAS in system 1 in July and August. Results in system 2 were similar.

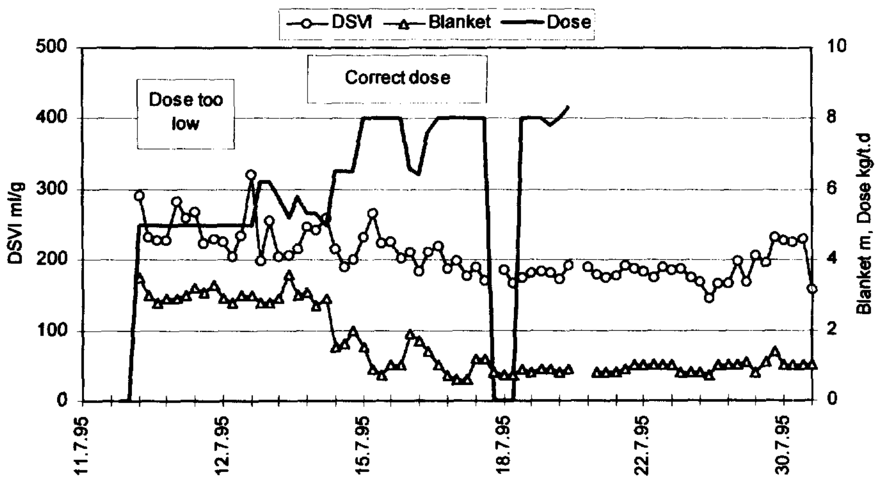

Figure 4. The course of chlorination in July.

It is important to realise that the sludge blanket height (the object of control) reacts faster and more sensitively to chlorination than sludge volume index. Control has thus to be based on the blanket height rather than on SVI.

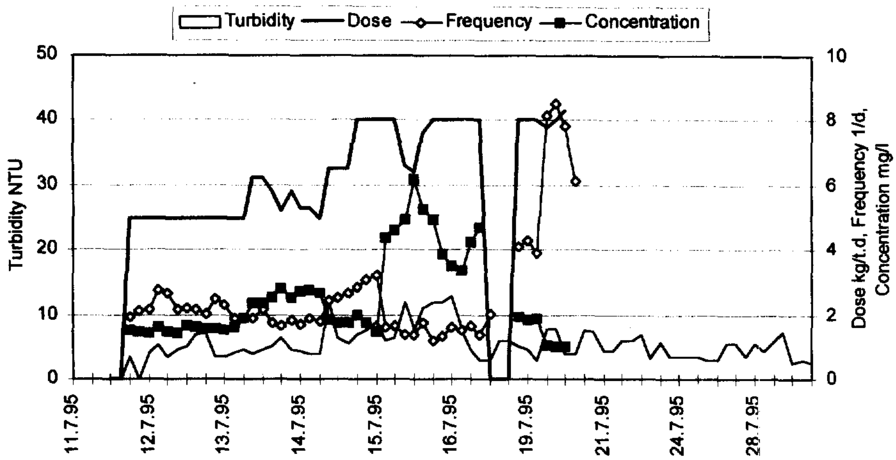

Figure 5. Development of selected control parameters during chlorination in July.

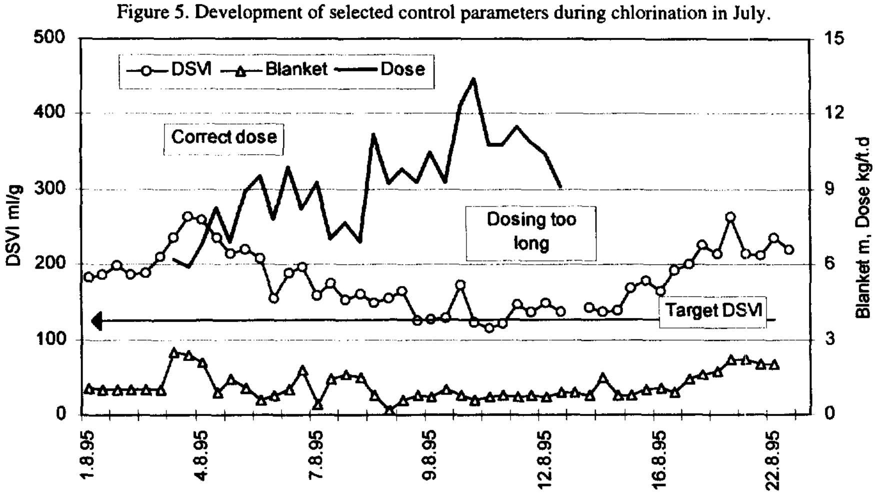

Figure 6. The course of chlorination of system 1 in August.

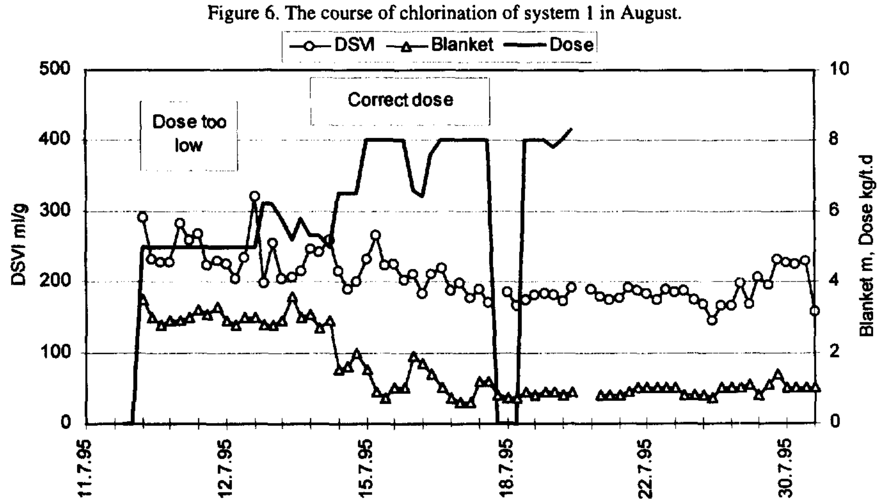

Figure 7. Development of selected control parameters during chlorination in system 1 in August.

It can be seen from Figure 5 that turbidity of MLSS supernatant was generally below 10 NTU. Dosing was retrofitted at the end of the experiment so that frequency of contact could be increased from 2 d^{-1} up to 8 d^{-1}.

In contrast, during chlorination in August, see Figure 7, contact chlorine concentration was too high and frequency of exposure too low, which resulted in transient deflocculation.

The chlorination period in August was too long. Clarifiers were perfectly manageable as soon as DSVI approached about 150 ml/g and sludge blanket height was close to 1.5 m.

Though RAS chlorination was successful in principle, it was not able to restore the required treatment efficiency, as can be seen from Figure 1. Yet, efficiency in July/August was better than in May/June.

TOXICITY EVALUATION

Except for the phenolic shocks in April, no other specific compounds were detected. Thus a generic approach had to be taken.

As reported in literature, the most common phenomena related to toxicity are:

a) Poor removal of soluble COD and BOD;
b) Low respiration rates;
c) Slow growth of biomass (less wasted sludge);
d) Population dynamics irregularities (filamentous and non-filamentous bulking, changes in protozoa species occurrence);
e) Flocculation irregularities (small and loose flocs, pin-point flocs, low sludge settling velocities etc.);
f) Poor or non-existent nitrification at conditions where it normally occurs.

All the above features were observed and some more in addition:

g) Scum on all aeration tanks that increased day by day;
h) Gradual disappearance of ciliates - some were dead, some indicating very little activity;
i) Enormous abundance of flagellates.

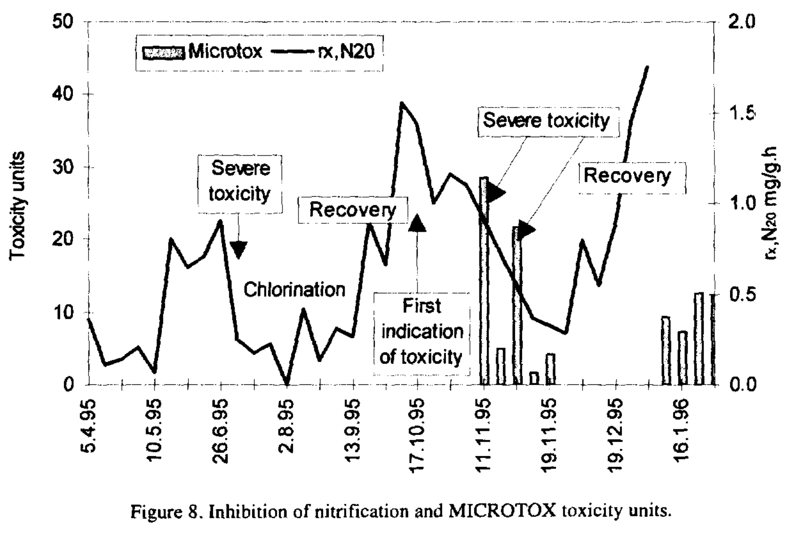

Figure 8. Inhibition of nitrification and MICROTOX toxicity units.

Nitrification rates r_XN_{20} (approximated by ammonia removal rates and corrected for temperature) normally reach values from 1.5 to 2 mg/g.h. As can be seen from Figure 8, inhibition of nitrification reflects the toxic shocks in April. Then low nitrification occurred from July to mid September. In November, toxicity started to be measured by MICROTOX. Decreasing rate of nitrification corresponded to high toxicity.

CONCLUSION

The treatment plant Sao Paulo-Barueri was exposed to several toxic shocks. Toxicity manifested itself in serious hindering of treatment efficiency as well as in population dynamics features such as filamentous bulking, reduction of occurrence of ciliates and increased numbers of flagellates.

Previously successfully applied measures to control filamentous bulking (in non-toxic situations) such as intermittent feeding, selector and primary solids transfer into aeration tanks largely failed. Chlorination of recycled activated sludge assisted in preventing huge loss of suspended solids from final clarifiers but had a short time effect only.

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