

IMPACT OF LARGE LOAD VARIATIONS ON PERFORMANCE OF AN ACTIVATED SLUDGE PROCESS

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MANAGING CHANGE OF GRADES CONTROLS THE LARGE VARIATIONS OF LOAD APPLIED TO THE BIOLOGICAL TREATMENT IN A BLEACHED CHEMITHERMOMECHANICAL PULP MILL.

THE DONOHUE MATANE, INC., COMMERCIAL BLEACHED chemithermomechanical pulp (CTMP) mill restarted its operations at the beginning of June 1995. The pulp mill has a reception system and a chip handling system that supply two systems. Each system has two primary refining lines intersected by a pulp interstage washing system before the secondary refiners. Modern cleaning and screening systems precede the decker where the two lines join. The pulp undergoes bleaching in two stages, P1 and P2, by a hydrogen peroxide process. Flakt dryers supply a Sunds defibrator that forms the bales. The bales have four cakes that a conveyor carries to a Hepburn press before wrapping. The two systems use a common network of white water and refining of rejects.

The pulp comes from two species—hardwood or softwood at different freeness and brightness levels. For softwood pulp, the CSF is 100–500 mL, and brightness is 60–80% ISO. For Aspen pulp, the values are 130–450 mL and 70–85%, respectively. Monthly planning alternates the two species considering the intrinsic variables in the management of the mill.

The Donohue Matane mill has an activated sludge effluent treatment system. A primary clarifier precedes this treatment system, and a secondary clarifier follows it. It has a BOD₅ treating capacity of 43,440 kg/day.

Two phases control the management of the large variations of load. The first phase is the control of the BOD₅ applied load. The BOD relates directly to the daily tonnage, the wood species, and the brightness. Its estimation enabled us to establish the change of grades. Judicious establishment of the production calendar reduces the impact of the large variations of load on the biological treatment.

The second phase is the control of the biological treatment. The control strategy relies on the regulation of the parameters of operation. Their values derive from target parameters such as the ratio of food (F) to microorganism (M) and the age of the sludge. The designation for this ratio is F/M.

DESCRIPTION

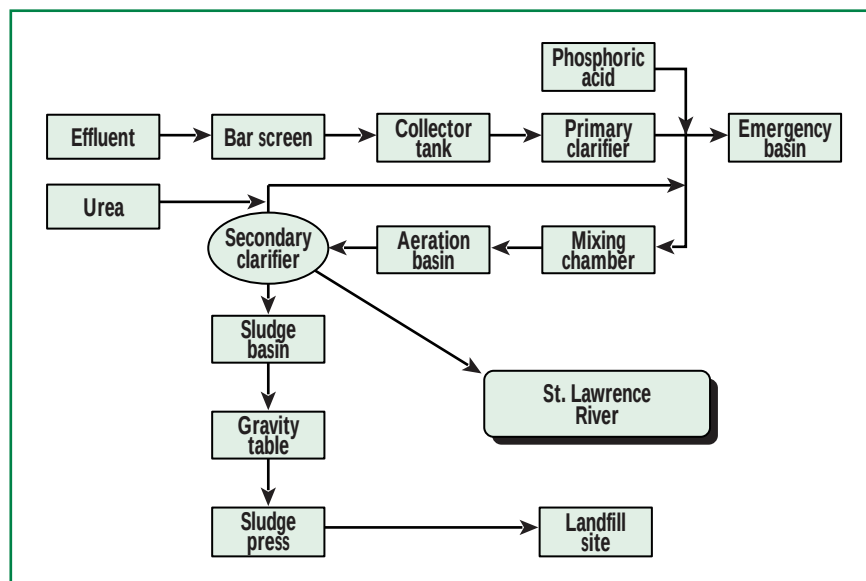
The water treatment station has the six parts shown in Fig. 1:

- Bar screen
- Emergency basins
- Primary clarifier
- Aeration basin
- Secondary clarifier
- Activated sludge dewatering system.

The bar screen removes solid waste of substantial size. This operation occurs with the help of a 6-mm spacing grill installed in the inflow canal of the effluent to the collector tanks where it is then pumped into the primary clarifier.

The next station has two emergency basins of 3000-m³ capacity each. The primary clarifier with a diameter of 28 m and a depth of 4.5 m removes the material in suspension by clarification. Feeding of the waste water uses a central column with a rake attached to the bottom of the sedimentation tank. This rake brings the sludge into a well at the center of the sedimentation tank for pumping to a sludge dewatering system. The flow of the effluents occurs under gravity from the primary clarifier to the St. Lawrence River.

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1. Diagram of the purification station

Grade	Hypothesis	Period 1 July 1 to Sept. 4	Period 2 Sept. 5 to Dec. 23	Period 3 March 4 to April 10
110/120S60	20	35	34	26
110/250S70	40	43	54	
110/250S80	60	71	47	
500/550S80	60	69	63	
130H70	70	76	86	
250/275/325H85	85	140	112	89

1. BOD₅ load in kg/a.d. ton

The reduction of the dissolved organic matters occurs in the aeration basin by the activation of microorganisms. The aerated lagoon has a capacity of 37,600 m³. It is 130 m long, 60 m wide, and 7.5 m deep. Nutrient addition occurs as phosphoric acid and urea. Oxygen comes from three blowers of 672 kW each for a total of approximately 104 m³/min. The intervention of 21,500 fine air bubble diffusers installed at the bottom of the basin gives uniform distribution of this air volume. The secondary clarifier is 35 m in diameter and 5 m in depth. Its first function is to prevent rejection of biological sludge generated by the biodegradation of the organic matters to the river. It also concentrates the sludge for recirculation and for draining.

The functioning principal of the secondary clarifier is the same as that of the primary clarifier. From the secondary clarifier, the waste sludge goes to the sludge treatment system with effluent discharge to the river.

The sludge treatment system has two gravity tables each followed by a Tassler screw press. Addition of polymers to the primary and secondary sludge helps to obtain 25% dryness. At the press exit, the sludge goes

onto a truck for transportation to the mill's landfill site.

A commercially available data base software program keeps track of the process. This data base contains all the measurable variables and all the calculable variables. A daily report has a page showing the important variables in the control of the biological treatment, tendency figures, data compilation graphs of the last thirty days of operation, and the applicable government regulated items such as the BOD₅ and total suspended solids (TSS) allocations.

The two main limitations of the treatment station are its maximum theoretical capacity of BOD₅ for treatment and its maximum capacity to dehydrate sludge. These two capacities are surpassed when producing hardwood at a certain tonnage.

CONTROL OF THE LOAD

The control of the total daily load applied to the biological treatment respects two important principals—reduce the load shocks and remain within the limits of the capacity of the biological treatment. The esti-

estimated daily load is the product of the estimated BOD₅ load in kg/a.d. ton and the daily tonnage. Some parameters that have the most influence on the BOD₅ load are the wood species, the grade, the age of the chips, and the total load of the chemical products used in the production of the pulp.

The BOD₅ load in kg/a.d. ton is an intrinsic property of the wood species used. It is often 30–50% higher with hardwood than with softwood at the same freeness and level of brightness. Freeness, species—softwood or hardwood, and level of brightness define a grade. The brightness has a more significant impact on the BOD₅ load than the freeness. The BOD₅ load varies proportionally with the brightness. The increase in brightness corresponds to a higher consumption rate of chemical products in the production of the grade. This increase is more apparent when using old chips to maintain the same level of brightness within a same grade. The aging of the chips is therefore a factor to the increase of this load. In production, the total alkali consumption rate and the peroxide used are the most influential variables for the BOD₅ load. Optimization of the operating parameters of the mill and

an administrative productive training program for operating personnel resulted in a lower BOD₅ load in kg/a.d. ton.

Table I shows the average loads measured in kg/a.d. ton at the time of production of a particular grade. The hypothesis column represents the average BOD₅ loads used for the startup of the mill and the loads used before the production of each grade. Note that the average BOD₅ load for period 1 for hardwood is very high. This is due to aging of the aspen chips. The averages of the BOD₅ load lowers between period 2 and period 3 because of the optimization of the parameters of operation of the mill. Considering these results, we can say that the use of fresh chips and the optimization of the mill operation helped lower the average BOD₅ load in kg/a.d. ton.

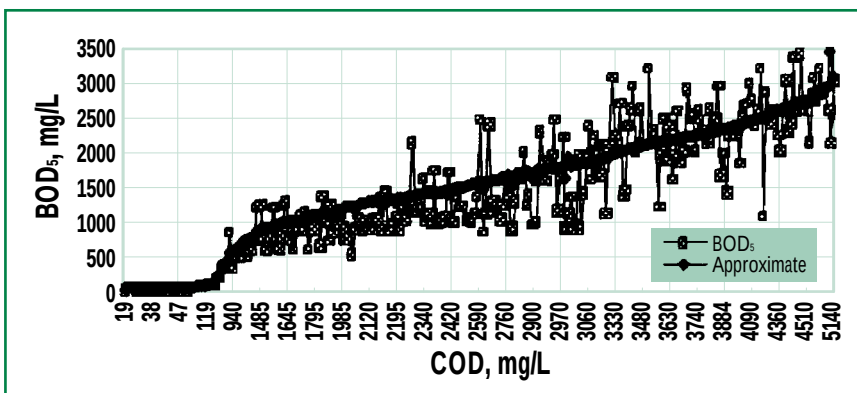
Figure 2 shows the ratio of BOD₅/COD from daily tests made on the mill effluent. In the daily control of the biological treatment, this ratio corrects the daily estimated load of BOD₅ to bring COD closer to its real value. This appraisal shows two main guidelines for the control of the BOD₅ load. One is that lowering of the load shocks minimizes the gradient of the daily BOD₅ load applied to the biological treatment according to the time and prevents the abrupt rise or drop of jumps as much as possible. The other is establishing an optimum level of pulp production greater than the capacity of the biological treatment.

Using these two principals, **Fig. 3** shows a production calendar according to the BOD₅ estimation in kg/a.d. ton and the tonnage of pulp produced.

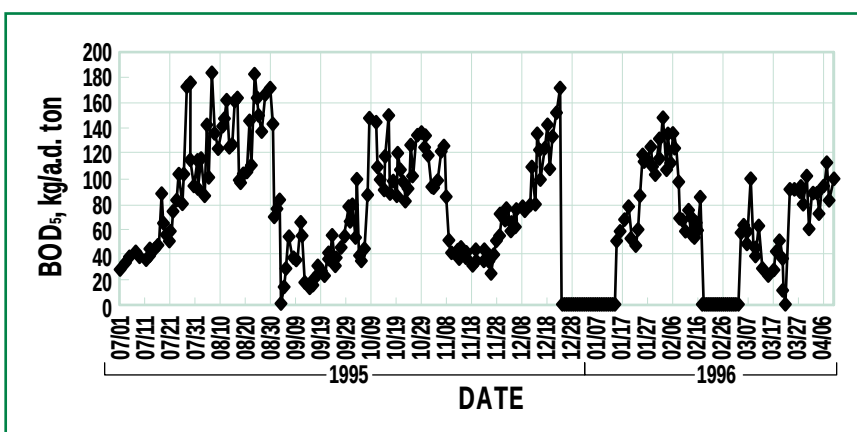
Figure 4 shows that a judicious choice of the production calendar gives a periodical variation in the time of the daily load. **Figure 5** shows this is nearly a sinusoidal curve. This approach allows the biological treatment to adapt itself to these changes easily.

TREATMENT CONTROL

Measurement of the efficiency of a biological treatment mostly uses its efficiency in removing the BOD₅ and the level of rejects to the final effluent of TSS. To meet government regulations, the following level for the removal of the BOD₅ is necessary:



2. Relation between BOD₅ and COD



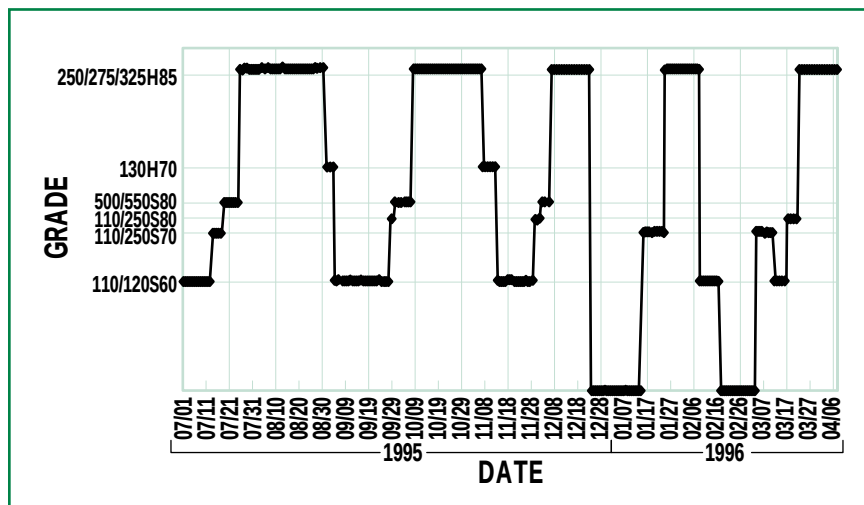
3. BOD₅ load in kg/a.d. ton

$$\text{Level} = 1 - 100(\text{BOD}_5 \text{ to the final effluent} / \text{BOD}_5 \text{ at the entry of the primary clarifier}) \quad (1)$$

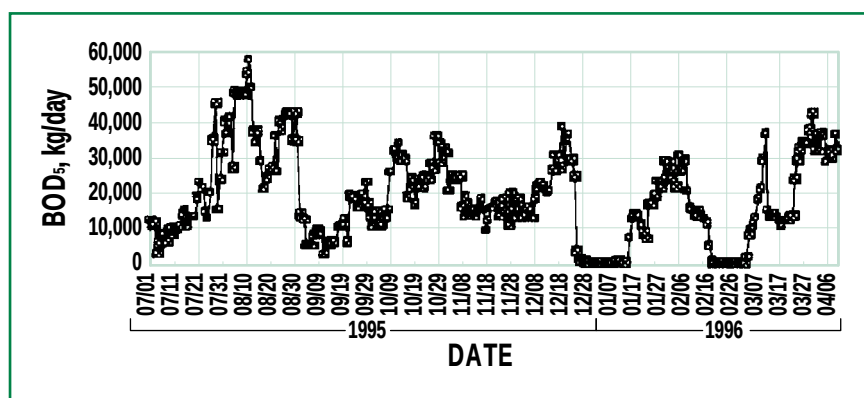
A level of 90% for the softwood production periods is sufficient. The increase in the daily load applied to the biological treatment during the hardwood production periods requires the removal of an amount of the BOD₅ more than 95%. The efficiency of a treatment depends primarily on the biological activity. The latter measures itself by many variables of which the most important are the following:

- F/M ratio
- Mixed liquor suspended solids (MLSS)
- Age of the sludge
- COD
- Dissolved oxygen (DO)
- Oxygen uptake rate (OUR)
- Sludge volume index (SVI)
- pH
- Temperature and residual nutrients in the phosphoric acid and urea.

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4. Production calendar by grade



5. BOD₅ load in kg/day

A preestablished F/M ratio allows calculation of the quantity of MLSS (M) necessary for the degradation of the BOD₅ starting from the daily BOD₅ (F) load.

The age of the sludge is an important factor in the efficiency of the system. Calculation occurs daily using the recirculation (RAS) with checking by microscopic examination of a sample taken from the MLSS. The RAS and the waste activity sludge (WAS) control these two parameters. An increase of the load corresponds with an increase of the RAS and a decrease of the WAS and vice versa.

In the daily control, the variable that best indicates the efficiency of the biological treatment in the degradation of the BOD₅ is the percentage of COD removal. This is the following:

$$\text{Percentage of COD removal} = 1 - 100(\text{COD to the final effluent} / \text{COD at the entrance of the primary clarifier}) \quad (2)$$

Figure 6 shows the evolution of the percentage of the removal of BOD₅ and of the COD with time. A percent-

age removal of COD more than 70% corresponds to a percentage removal of BOD₅ above 95%. The percentage removal of COD therefore becomes the most important variable in the daily control of the biological treatment.

Control of the DO occurs with the help of the outflow of the blowers. It is at a higher value than 1 mg O₂/L. During the changes of grade and species, the DO is at higher values of 3–4 mg O₂/L to favor better biological activity.

The OUR is an indicator of the biological activity. It varies inversely to the DO and in the same direction as the growth of the microorganisms. It is important at the time of a change of grade and species of lower loads toward higher BOD₅ loads, since its increase indicates a MLSS expansion.

The SVI is another indicator of the age of the sludge if no other problem occurs in the biological treatment such as nitrogen deficiency or an excessively low or high pH or DO. The SIV must be lower than 150 mL/g. A SVI higher than this value indicates a lower age of sludge and vice versa. If the SVI is

high, the RAS increases and the waste lowers. If it is low, the opposite occurs. Note that if the calculated age of the sludge using other methods is 6–10 days, we try to identify the problem that prevents sedimentation and determine its solution.

The pH is 6.5–8.5 with control by addition of caustic soda or acetic acid. On softwood, a lowering tendency is observed and the caustic soda is added in low dosage. The temperature of the aerated lagoon largely affects the activity of the microorganisms. Adjustment of the MLSS concentration—higher in winter than in summer—generally compensates for its effect. With heat exchangers on the mill effluent, the temperature is 25–35°C, although some temperatures above 40°C did occur during the summer. Solutions to solve these problems are under study.

Calculation of the nutriment—phosphoric acid and urea—uses the rule of thumb of 1 kg phosphorous and 5 kg nitrogen for 100 kg BOD₅. Control is daily with the measurement of the residual nutriment to the final effluent. These are at phosphorous levels of 0.5–1.5 mg/L

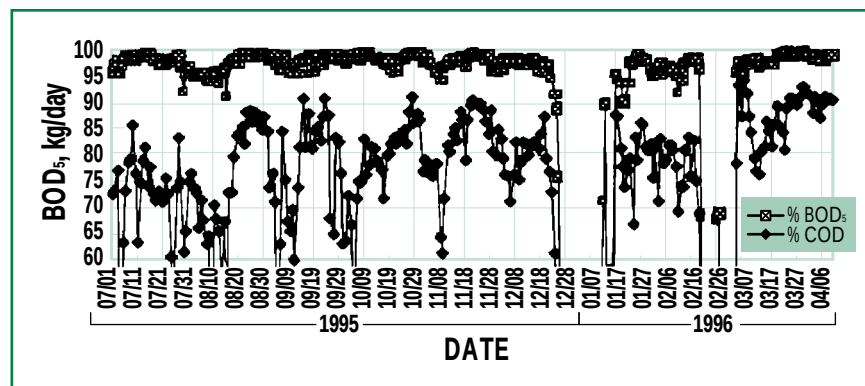
and nitrogen levels of 1–2 mg/L.

The software program compiles all the variables daily for analysis to adapt the biological treatment to the BOD₅ load variations and to control it to maintain its efficiency in the degradation of this load to values higher than 95%. To establish the operating parameters of the biological treatment vs. the load variations, two variables are necessary—the F/M ratio and the age of the sludge.

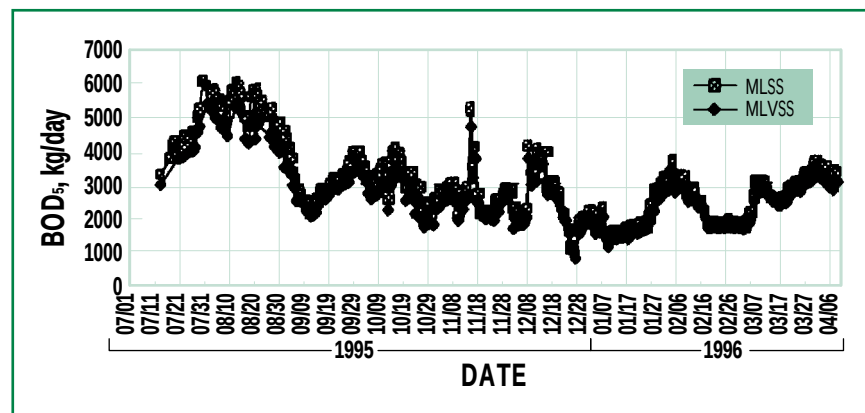
The F/M ratio is the relation between the production and the biological treatment. The daily BOD₅ load (F) modulates with the choice of a production calendar as Fig. 5 shows. To favor a better adaptation of the biological treatment to these variations, the MLSS must vary in the same way as the F. Starting from a preestablished F/M, we must therefore bring the biological treatment to a level of MLSS necessary to biodegrade the corresponding F. **Figure 7** shows the evolution of the MLSS and mixed liquor volatile suspended solids (MLVSS) with time.

Maintaining the F/M ratio to a desired value by variation of the MLSS is simply control and operation by the age of the sludge. At the startup of the mill, the recommended age of the sludge was 6–10 days for an F/M of 0.25. An efficient BOD₅ removal above 95% was obtained as Fig. 5 showed except the hardwood period during August. After one year of operation, certain problems of sludge bulking, foam, and toxicity occurred.

During the hardwood production period in August, the F/M was 0.25 with the MLSS approximately 5,000 mg/L. The production of the biological sludge had become so excessive that it surpassed the capacity of the gravity tables and the sludge presses. The incapacity to waste the biological sludge caused an important loading of the secondary clarifier—a sludge blanket of 4.5 m, an increase of the age of the sludge, and the start of sludge bulking. During this period even when the mill operated at 50% of capacity, record levels of BOD₅ in kg/a.d. ton were met and the daily BOD₅ load exceeded the theoretical capacity of the biological treatment of 43.44 tons/day. Two factors contributed to this phenomenon—the use of old aspen chips and the fact that the operation of the mill was not optimal. These problems were solved by using an F/M of 0.4 as **Fig. 8** shows for the hardwood production period in April.



6. Percentage removal of BOD₅ and COD



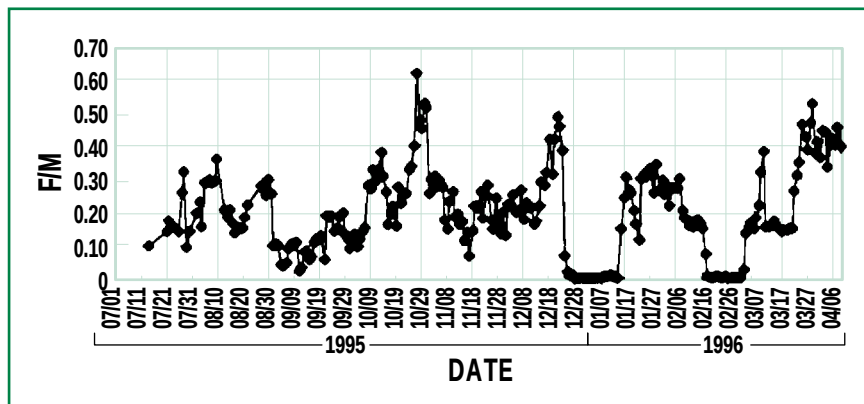
7. MLSS and MLVSS in the aerated basin

During this period, the use of fresh chips of 0–10 days and the optimization of the operation of the mill translated itself to a drop of the BOD₅ average load at 89 kg/a.d. ton and a rise of the production at 75% of the nominal capacity of the mill for a daily applied load to the biological treatment of 94% of its theoretical capacity. The MLSS was approximately 3,000 mg/L. The biological activity increased to result in a very high OUR and a low DO. Besides eliminating the sludge proliferation problem, the efficiency of the biological treatment in the removal of the BOD₅ was more than 99% compared with the period in August where it was 90–97%.

Foaming problems occur when passing from a hardwood species to a softwood species. Reduction of the load amplifies these problems. When the foam is excessive, aqueous defoamers are added to the mixing basins. To ease load shocks, the MLSS are lowered before a change of grade or species of a higher load toward a lower one while maintaining the efficiency of the removal of the BOD₅ from the biological treatment.

Toxicity is a problem generally met during the production of hardwood pulp. Toxicity and the other problems caused by the variation of the daily load of BOD₅ and its impact on the biological treatment are presently

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8. F/M ratio

the subject of a research project carried out in collaboration with the Pulp and Paper Research Center of Quebec University.

CONCLUSION

The control of F is managed by a production calendar that is judiciously planned by the sales department and the production team to lower the impact of the large variations of the BOD₅ load. The optimization of the opera-

tion of the mill, the use of fresh chips, and an awareness of the operating personnel contribute considerably to reducing the BOD₅. The use of aspen from eastern Quebec doubles the supply of the BOD₅ load compared with the use of softwood as raw material. This adds to approximately 90 kg/a.d. ton. The use of an F/M ratio of 0.4 instead of 0.25 allows for an operation of the treatment at a lower M value with a lower generation of sludge. This considerably reduces the cost of exploitation related to the dehydrating and the disposal of the sludge. TJ

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