Identification of filamentous organisms in nutrient removal activated sludge plants in South Africa*

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Abstract

Filamentous bulking sludges are found in about three quarters of 33 biological nutrient removal activated sludge plants surveyed in South Africa. The five most frequently dominant filamentous organisms in the mixed liquor of these plants are (i) Type 0092, dominant in 82 % of plants, (ii) Type 0675 in 45 %, (iii) Type 0041 in 39 %, (iv) *Microthrix parvicella* in 33 % and (v) Type 0914 in 33 %. These five filamentous organisms are also the most frequently dominant ones in foams on 18 of the plants – Type 0092 has the highest frequency of dominance in the foam at 78 %, followed by *M. parvicella* in 50 %, Type 0041 in 33 %, Types 0675 and 0914 in 22 % each. Only *M. parvicella* and *Nocardia* were found to selectively accumulate in the foam, but *Nocardia* was dominant in only 22 % of foams. Some non-specific and specific bulking and foaming control measures against these filaments are briefly discussed.

Introduction

In a review of the future of biological phosphorus removal in the activated sludge system, Marais (1987) noted that biological excess P (and N) removal is now a firmly established phenomenon, the mechanisms of which are fairly well understood; further research into this phenomenon *per se* will provide greater clarity, but technically today there is adequate understanding to exploit it at full scale. He concludes that the future of biological P (and N) removal no longer depends on a better understanding of these phenomena, but on how to deal with important ancillary problems that have been identified in operating nutrient removal plants. Of these problems, the control of the growth of filamentous organisms in nutrient removal plants is one of great importance; these organisms are the principal agents causing bulking and/or foaming in activated sludges. Three other problems were identified by Marais (1987) viz.

- augmentation of volatile fatty acid content of the waste water by acid fermentation, to obtain greater P removal;
- effective back-up systems to cope with the massive P release by mechanical malfunctions, in particular aeration breakdown; and
- handling and disposal of P removal sludges to limit P feed-back to the system by supernatants arising from these operations.

Bulking due to excessive growth of filamentous organisms causes a deterioration in the mixed liquor settleability. The filament lengths extending into the bulk liquid form weblike structures which cause either the floc structure itself to be diffuse or bridging between the flocs. From measurements of the total extended filament length (TEFL) and settleability in terms of the diluted sludge volume index (DSVI) (Ekama and Marais, 1984), Lee *et al.* (1983) showed that at DSVI's above 150 m*l*/g, the filamentous organisms commence to dominate the behaviour of the settling sludge, at which DSVI, the TEFL is 30 km/g. As a rough guide therefore a bulking sludge can be accepted as one having a DSVI > 150 m*l*/g. The sludge volume index (SVI) is not as discerning as the DSVI and rather poor in identifying a bulking sludge; taking note of reported data, one can accept, roughly, that an SVI between 100 and 200 m*l*/g possibly is a bulking sludge and an SVI > 200 m*l*/g usually is.

Sludge settleability governs the daily flow and load that can be treated in an activated sludge plant; the operating experience of Northern Works (Johannesburg) clearly demonstrates this (Osborn *et al.*, 1986). The influent peak wet weather flow (PWWF) sets the overflow rate (m/h) in the secondary settling tank and the daily mass of COD treated sets the sludge concentration in the biological reactor. Ekama and Marais (1986) showed that a sludge with a DSVI of 150 m*l*/g can be satisfactorily handled in the settling tank up to a maximum overflow rate of 1 m/h at a mixed liquor suspended solids (MLSS) of 3,5 g/*l*. If the DSVI deteriorates to 200 m*l*/g the maximum overflow rate reduces to 0,6 m/h at 3,5 g/*l*, or, the overflow rate can be maintained at 1 m/h provided the reactor MLSS concentration is reduced to 2,4 g/*l*. These reductions result in about 33 % less flow and load which can be treated in the plant. In contrast, if the DSVI is reduced to 100 m*l*/g the overflow rate increases to 1,8 m/h at 3,5 g/*l*, or, the reactor concentration can be increased to 5,4 g/*l* at an overflow rate of 1 m/h. These increases allow both the flow and load to be increased by about 67 % compared to those at a DSVI of 150 m*l*/g. This is more than twice the flow and COD load at a DSVI of 200 m*l*/g.

Clearly the settling tank is the bottle-neck which limits the flow and COD load that can be treated in a plant. A bulking sludge effectively reduces the time period over which the plant will attain its design load – a plant with a DSVI of 200 m*l*/g will have to be extended within this period compared to a plant with a DSVI of 100 m*l*/g. Not achieving the expected treatment load in the original plant, and requiring extensions earlier, clearly have major financial implications. Controlling, or preferably eliminating bulking, therefore, holds promise of major financial savings.

Over the past ten years biological nutrient removal activated sludge plants have become the preferred method for removing nutrients from municipal waste waters in South Africa. There are principally two reasons for this: Compared to chemical precipitation, biological nutrient removal costs less and minimises mineralisation of inland water resources. Today there are about 45 nutrient removal plants in operation, of varying size, ranging from 2 to 150 M*l*/d, with a total design capacity of about 1 200 M*l*/d.

In a recent survey (Blackbeard and Ekama, 1984 and Blackbeard *et al.*, 1986), bulking (and foaming) was identified as a problem of considerable magnitude in activated sludge plants in South Africa. This survey covered 111 plants, of which 26 were nutrient removal ones. Evaluation of the data from the nutrient removal plants indicates that these plants also are plagued by sporadic bulking (and foaming) incidents – indeed, a greater percentage of the nutrient removal plants (84 %) reported bulking and foaming problems than the non-nutrient removal plants (62 %). Clearly, amelioration of bulking (and foaming) would greatly facilitate operation of these plants and probably allow treatment of higher flows and COD loads.

At the University of Cape Town, research into amelioration of filamentous bulking in nutrient removal plants has been underway for the past three years, and is still continuing. This research involves

- identification of the nuisance filaments;

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- investigation of non-specific (chlorination); and
- specific [e.g. selectors or dissolved oxygen (DO) control] bulking control procedures.

This paper presents the results of the identification work. Some experiments on chlorination of nutrient removal sludges have been conducted and are reported by Lakay *et al.* (1987). Research into specific bulking control procedures is currently in progress and some of the results are briefly discussed below.

Materials and methods

Data collection for identification of filaments

Filamentous organism identification results from 26 nutrient removal plants included in the original survey of all activated sludge plants (Blackbeard *et al.*, 1986), were accepted for this survey of nutrient removal plants. Letters requesting a sample of mixed liquor and foam (if present) were sent to 15 nutrient removal plants not included in the original survey. Samples from 7 plants were received. Hence 33 nutrient removal plants are covered in this survey which represents about three quarters of these plants in South Africa.

Mixed liquor and foam samples were analysed according to the technique of Eikelboom and Van Buijsen (1981). In this technique the different filamentous organisms are identified by their staining (Gram and Neisser) and morphological characteristics such as false and true branching, presence of sheath and/or crosswalls, size and shape of cells in the filamentous organisms, location in floc and motility. The characteristics of a particular filamentous organism are compared with the identification keys of Eikelboom and Van Buijsen from which the type can be established. In this technique, incidental information such as floc size and shape and protozoal faunas is recorded.

The presence of filamentous organisms in a sample is judged from five standpoints. These are defined in detail in Jenkins *et al.* (1984) (see also Blackbeard *et al.*, 1986), but are summarised briefly below for convenience because they are frequently used in the discussion of the results of this survey:

(1) *Overall abundance* – the overall abundance of all types of filamentous organisms in a sample. A category type system is adopted in which the overall abundance is subjectively scored on the following scale: 0 – none; 1 – few; 2 – some; 3 – common; 4– very common; 5 – abundant and 6 – excessive.
(2) *Occurrence* – the presence of a particular filamentous organism type in the sample.
(3) *Rank* – abundance of a particular filamentous organism type relative to the others; the most abundant one is ranked 1, second most abundant 2, and so on, up to 6, if as many as 6 types are present.
(4) *Dominance and secondary* – for overall abundance levels of 3 or lower, usually the filamentous organism ranked 1 is dominant and the ones ranked 2 or lower are termed secondary. However, for overall abundance levels of 4 or higher, filamentous organisms ranked 1 to 3 may all be dominant and then those with rank 4 or lower are termed secondary. Usually, the dominant filamentous organisms are the major cause of the bulking problem; the secondary ones generally do not contribute significantly to the problem.
(5) *Individual abundance* – the level of abundance of a particular filamentous organism type on the basis of the same category system outlined in (1) above. Dominant and secondary filamentous organisms can also be judged in terms of the individual abundance level; in this event, filamentous organisms with individual abundance levels of 4 or higher are termed dominant and those with individual abundance levels of 3 or lower are termed secondary.

In the microscopic analysis, mixed liquor samples were judged also as bulking or non-bulking on the basis of the overall abundance level: Samples with abundance levels of 4 or higher, i.e. very common, abundant or excessive, were termed bulking and those with 3 or lower (i.e. common, some, few or none) were termed non-bulking (Blackbeard *et al.*, 1986).

Results

Filamentous organisms in mixed liquor samples

Classification of a sludge sample into bulking and non-bulking groups by means of overall abundance allows a rough indirect approximation of the bulking problem in nutrient removal plants without knowing the sludge settleability: of the 33 plants, 4 have overall abundance levels of 6 (excessive), 13 have 5 (abundant), 7 have 4 (very common), 6 have 3 (common), 3 have 2 (some) and none have 1 (few) and 0 (none). Hence 24 plants have overall abundance levels of 4 or higher so that roughly three quarters of the plants can be said to have bulking problems. This compares well with the 84 % of nutrient removal plants that reported bulking problems in the original survey and confirms that bulking is a problem of considerable proportions in these plants. The problem may not yet be manifest in settling tank operation, because the plants may not be up to design load – from the survey information, two thirds of the plants are below two thirds of the design flow.

The results of the frequency of occurrence and frequency of dominance of the filamentous organisms in the mixed liquor samples of the nutrient removal plants are set out in Table 1. Only one sample per plant was included in Table 1. This sample was selected as follows: where a number of samples from one plant were analysed over a period and overall abundance remained reasonably constant, an average sample was selected; where samples differed more markedly in overall abundance, the sample having the greatest number of filamentous organisms was selected;

FREQUENCIES IN ALL MIXED LIQUOR SAMPLES

OCCURRENCE	78	68	86	48	41	51	29	33	32	21	1	6	8	4	
DOMINANCE	34	16	14	20	24	17	9	14	1	2	0	1	2	3	

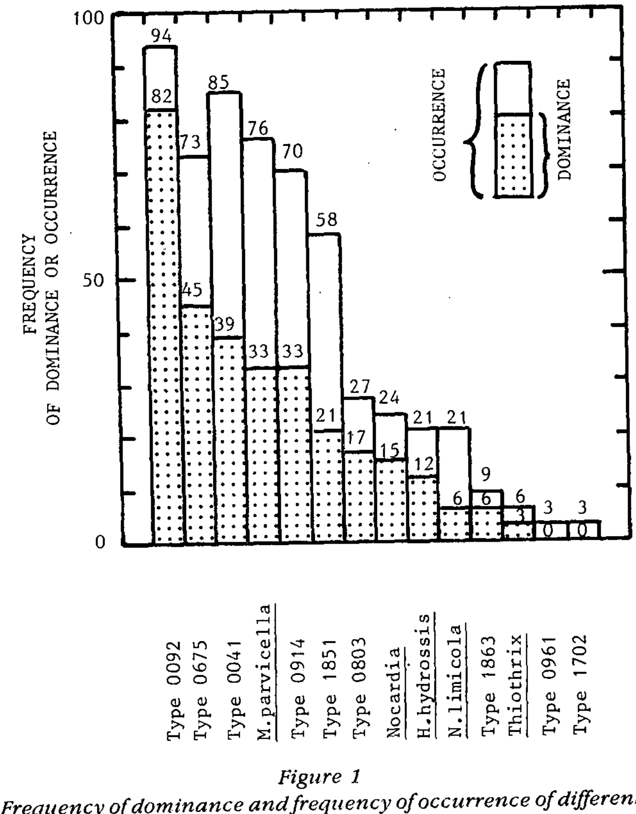

Figure 1

Frequency of dominance and frequency of occurrence of different filamentous organism types in the mixed liquor of biological nutrient removal plants ranked in descending order of frequency of dominance. For comparison, the frequencies of dominance and occurrence of the filamentous organism types in the mixed liquor of all activated sludge plants found by Blackbeard et al. *(1986) are given at the top of Fig. 1 (see Table 1).*

where more than one module of a multi-module plant was sampled, the module containing the filamentous organism population most typical of all the modules was selected.

The results listed in Table 1 are shown graphically in Fig. 1 in which the filamentous organism types are arranged from left to right in descending order of frequency of dominance. The frequencies of dominance and occurrence found in the survey of all activated sludge plants are given at the top of Fig. 1. From Fig. 1, the six most frequently dominant filamentous organisms, in descending order, are Type 0092 in 82 % of plants, Type 0675 in 45 %, Type 0041 in 39 %, *Microthrix parvicella* in 33 %, Type 0914 in 33 % and Type 1851 in 21 %. These six filamentous organisms are also the most frequently occurring ones but in a slightly different order, i.e. arranged in decreasing frequency of occurrence they are Type 0092 in 94 % of plants, Type 0041 in 85 %, *M. parvicella* in 76 %, Type 0675 in 73 %, Type 0914 in 70 % and Type 1851 in 58 %. The six most frequently dominant filamentous organisms in nutrient removal plants are also the six most frequently dominant filamentous organisms in all activated sludge plants, but are ranked in a different order. For all activated sludge plants, the six in descending order are Type 0092 with frequency of dominance of 34 % followed by Type 0914 with 24 %, *M. parvicella* with 20 %, Type 1851 with 17 %, Type 0675 with 16 % and Type 0041 with 14 %.

Insofar as nutrient removal plants are concerned, clearly reduction or elimination of Types 0092, 0675, 0041, *M. parvicella* and Type 0914 is likely to make a considerable contribution to reducing bulking in these plants.

TABLE 1
FREQUENCY OF DOMINANCE AND FREQUENCY OF OCCURRENCE OF FILAMENTOUS ORGANISM TYPES IN MIXED LIQUOR SAMPLES FROM NUTRIENT REMOVAL PLANTS (LEFT) AND ALL ACTIVATED SLUDGE PLANTS (RIGHT) IN SOUTH AFRICA*

Filamentous organism type	South Africa			
	Nutrient removal plants		**All activated sludge plants	
	+Dominance	++Occurrence	+Dominance	++Occurrence
Type 0092	82 (1)	94 (1)	34 (1)	78 (2)
Type 0675	45 (2)	73 (4)	16 (5)	68 (3)
Type 0041	39 (3)	85 (2)	14 (6)	86 (1)
M. parvicella	33 (4)	76 (3)	20 (3)	48 (5)
Type 0914	33 (5)	70 (5)	24 (2)	41 (6)
Type 1851	21 (6)	58 (6)	17 (4)	51 (4)
Type 0803	17	27	9	29
Nocardia	15	24	14	33
H. hydrossis[1]	12	21	1	32
N. limicola[2]	6	21	2	21
Type 1863	6	9	0	1
Thiothrix	3	6	1	6
Type 0961	0	3	2	8
Type 1702	0	3	3	4
Number of samples	33		96	
Number of plants	33		96	

* For a comparison with the frequencies of dominance of filamentous organisms in USA, European and West-German Plants, see Blackbeard *et al.*, 1986.
** Data from Blackbeard *et al.*, 1986 for bulking and non-bulking sludges.
+ Percentage of plants in which particular filamentous organisms were dominant.
++ Percentage of plants in which particular filamentous organisms were present.
( ) Denotes rank in descending order.
1 *Haliscomenobacter hydrossis.*
2 *Nostocoida limicola*

Filamentous organisms in foam samples

Of the 26 nutrient removal plants covered in the original survey, 15 sent foam samples and in the follow-up survey of the remaining 15 nutrient removal plants 3 sent foam samples. Of the 18 foam samples analysed for filamentous organisms, 13 (72 %) had overall abundancies of 4 or higher; this filamentous organism content in the foam would be comparable to the filamentous organism content of a bulking sludge, and may be indicative of a potential foaming problem. The severity of the foaming problem would depend on whether or not the foam is trapped and accumulated on the reactor or clarifier surface.

The frequency of dominance and frequency of occurrence of filamentous organisms in the foam samples are set out in Table 2. For comparison the results of Blackbeard *et al.* (1986) for all activated sludge plants are also given. The nutrient removal plant data are shown graphically in Fig. 2 wherein the filamentous organisms are arranged in decreasing frequency of dominance. At the top of Fig. 2 the results of Blackbeard *et al.* (1986) are given.

FREQUENCIES IN ALL FOAMING SAMPLES

OCCURRENCE	73	59	73	51	46	41	43	14	27	5	22	1	5	22	
DOMINANCE	46	46	14	8	11	30	5	3	11	0	0	0	0	0	

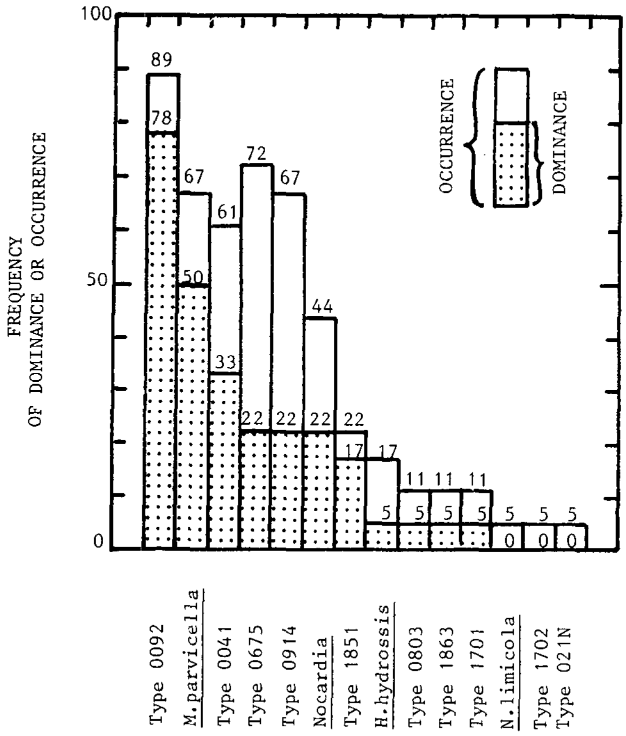

Figure 2
Frequency of dominance and frequency of occurrence of different filamentous organism types in the foam of biological nutrient removal plants ranked in descending order of frequency of dominance. For comparison, the frequencies of dominance and occurrence of the filamentous organism types in the foam of all activated sludge plants found by Blackbeard et al. *(1986) are given at the top of Fig. 2 (see Table 2).*

The six most frequently dominant filamentous organisms in the foam of nutrient removal plants (when present) in descending order are Type 0092, dominant in 78 % of foams, *M. parvicella* in 50 %, Type 0041 in 33 % and Types 0675, 0914 and *Nocardia* in 22 %. These six filamentous organisms are also the six most frequently dominant filamentous organisms in all activated sludge plant foams (Table 2); in these foams, Type 0092 and *M. parvicella* are also ranked first and second respectively at 46 % each, but the other four filamentous organisms are in a different order compared to nutrient removal plants, with *Nocardia* 3rd at 30 %, Type 0041 at 14 %, Type 0914 at 11 % and Type 0675 at 8 %.

TABLE 2: FREQUENCY OF DOMINANCE AND FREQUENCY OF OCCURRENCE OF FILAMENTOUS ORGANISMS IN THE FOAM OF NUTRIENT REMOVAL PLANTS IN SOUTH AFRICA.

Filamentous organism	Nutrient removal plants		*All activated sludge plants	
	+Dominance	++Occurrence	+Dominance	++Occurrence
Type 0092	78 (1)	89	46 (1)	73
M. parvicella	50 (2)	67	46 (2)	59
Type 0041	33 (3)	61	14 (4)	73
Type 0675	22 (4)	72	8 (6)	51
Type 0914	22 (5)	67	11 (5)	46
Nocardia	22 (6)	44	30 (3)	41
Type 1851	17	22	5	43
H. hydrossis	5	17	3	14
Type 0803	5	11	11	27
Type 1863	5	11	0	5
Type 1701	5	11	0	22
N. limicola	0	5	0	1
Type 1702	0	5	0	5
Type 021N	0	5	0	22
Number of plants	18		37	

* Data from Blackbeard *et al.* (1986)
\+ Percentage of plants in which particular filamentous organism was dominant
++ Percentage of plants in which particular filamentous organism was present
( ) Denotes rank in descending order.

An impression of those filamentous organisms which may cause foaming problems can be obtained by comparing the frequency of dominance of filamentous organisms in the foam with that in the mixed liquor; those that are significantly more frequently dominant in the foam can be said to selectively accumulate in the foam and are not present due to incidental entrapment in the foam from the mixed liquor. Such a comparison is given in Table 3. Of the six most frequently dominant filamentous organisms in the foam, *M. parvicella* and *Nocardia* are dominant more frequently in the foam than in the mixed liquor of nutrient removal plants as well as all activated sludge plants (Table 3). This is to be expected because *M. parvicella* and *Nocardia* are notorious for causing nuisance foams. (Jenkins *et al.*, 1984; Blackbeard *et al.*, 1986).

In all activated sludge plants, Type 0092 is more frequently dominant in the foam than in the mixed liquor and from this observation Blackbeard *et al.* (1986) tentatively suggested that this filament possibly also is a foaming filamentous organism. In nutrient removal plant foams, Type 0092 has the highest frequency of dominance at 78 %, and is approximately equally frequently dominant in the mixed liquor at 82 %. Hence, from the nutrient removal plant data, it would appear that Type 0092 is incidentally entrapped in foam from the mixed liquor.

Discussion and conclusion

1. Filamentous bulking appears to be a problem of considerable proportions in nutrient removal activated sludge plants. Of 33 plants surveyed (out of a total of about 45 in South Africa), 27 had bulking sludges (overall abundance ≥ 4).
2. The five most frequently dominant filamentous organisms identified in the mixed liquor of nutrient removal sludges are (i) Type 0092 dominant in 82 % of plants, (ii) Type 0675 in 45 %, (iii) Type 0041 in 39 %, (iv) *M. parvicella* in 33 % and (v) Type 0914 in 33 %. These five filamentous organisms are among the six most frequently dominant filamentous organisms in all activated sludge plants (96 surveyed by Blackbeard *et al.*, 1986). Except for Type 0914, these filamentous organisms are classified by Jenkins *et al.* (1984) as follows: Type 0092 and *M. parvicella* low food-to-microorganism (F/M) ratio (long sludge age); Types 0675 and 0041 low F/M and nutrient deficiency. The consistent dominance of Type 0914 in South Africa's long sludge age plants (nutrient removal and non-nutrient removal) suggests that Type 0914 possibly should be classified as a low F/M filamentous organism.

TABLE 3: COMPARISON OF THE FREQUENCY OF DOMINANCE OF FILAMENTOUS ORGANISMS IN FOAM AND MIXED LIQUOR SAMPLES FROM NUTRIENT REMOVAL PLANTS.

Filamentous organism	Frequency of dominance in Nutrient removal plants in		*All activated sludge plants in	
	Foam	Mixed liquor	Foam	Mixed liquor
Type 0092	78	82	46	34
M. parvicella	50	33	46	20
Type 0041	33	39	14	14
Type 0675	22	45	8	16
Type 0914	22	33	11	24
Nocardia	22	15	30	14
Type 1851	17	21	5	17
H. hydrossis	5	12	3	1
Type 0803	5	17	11	9
Type 1863	5	6	0	0
Type 1701	5	–	0	–
N. limicola	0	6	0	2
Type 1702	0	0	0	3
Type 021N	0	–	0	–
Number of plants	18	33	37	96

* Data from Blackbeard *et al.* (1986).

3. Application of nutrient removal technology will be greatly facilitated, with substantial savings, if bulking can be ameliorated by controlling the growth of the above filamentous organisms either by non-specific (chlorination) and/or specific bulking control procedures. At the University of Cape Town, non-specific bulking control with chlorination has been investigated (Lakay *et al.*, 1987) and specific bulking control measures against Type 0092 and *M. parvicella* are being investigated.
4. Chlorination of the inter-reactor flow between the final primary anoxic and aerobic reactors in a laboratory-scale modified UCT nutrient removal plant for 3 successive weeks at a dose of 4 gCl/kgMLSS.d for the first week and 8 gCl/kgMLSS.d for the following two weeks had the following results: DSVI decreased from 230 to 48 m*l*/g with complete elimination of Type 0914 and a major reduction of Types 0092 and *M. parvicella;* nitrification-denitrification efficiency was not significantly affected; P removal was unaffected for the first two weeks but reduced from 20 to 14 mgP/*l* during final week; P removal recovered completely within a week of termination of chlorination (Lakay *et al.*, 1987).
5. Specific bulking control measures against *M. parvicella* and Type 0092 are being investigated. *M. parvicella* can be controlled in single reactor extended aeration pilot plants with intermittent aeration (like Ditch-type or Carousel plants) by switching to continuous aeration with a DO of 2 to 3 mg/*l* (Gabb *et al.*, 1987). From this work, Gabb *et al.*, 1987 concluded that *M. parvicella* is a low DO filament under long sludge age (low F/M) conditions. This conclusion is supported by Slijkhuis

(1983), who from pure culture studies, found *M. parvicella* to be a strict aerobe with a very low half-saturation coefficient for dissolved oxygen, and Osborn *et al.* (1986) who found that in surface aerated nutrient removal plants, a reduction in SVI is obtained by increasing aeration power input to the aerobic zone when *M. parvicella* is one of the dominant filaments in the mixed liquor.

6. From 5 above it appears that *M. parvicella* thrives in periods or regions of low DO concentration (but not anoxic or anaerobic) and elimination of these regions by improving oxygen input and mixing may ameliorate *M. parvicella* bulking. This conclusion finds support from the observations by Barnard and Hoffmann (1986) who found that diffused air bubble aeration systems produced better sludge settleability than mechanical surface aeration; bubble aeration systems have a more uniform DO distribution and better mixing than mechanical surface aeration – with the latter, the DO tapers off from 2 to 3 mg/*l* at the aerator to often 0,0 mgO/*l* furthest from the aerator and in the bottom of the reactor. Unfortunately they did not identify the filamentous organism types, in particular the role of *M. parvicella,* in the settleability differences. Both Osborn *et al.* (1986) and Barnard and Hoffman (1986) suggest that better oxygen distribution and mixing in the aerobic zone would improve sludge settleability and the latter writers propose that installing draft tubes for mechanical surface aerated plants, to improve the pumping effect, would go a considerable way to achieving this. From 5 above, these measures probably would be appropriate for situations where *M. parvicella* is one of the problem filaments.
7. Laboratory-scale research is in progress to identify specific control measures for Type 0092, but it is still too early to come to any conclusions.
8. Evaluation of foam samples from 18 nutrient removal plants indicated that foaming also can be a problem at these plants. The five most frequently dominant filamentous organisms in the foam are Type 0092 in 78 % of plants, *M. parvicella* in 50 %, Type 0041 in 33 %, and Types 0675 and 0914 in 22 % each. These five filamentous organisms are also the most frequently dominant in mixed liquor samples of nutrient removal plants. Only *M. parvicella* and *Nocardia* accumulate selectively in the foam from the mixed liquor – frequency of dominance of *M. parvicella* in the foam and mixed liquor is 50 % and 33 % respectively and that of *Nocardia* in the foam and mixed liquor is 22 % (ranked 6th) and 15 % (ranked 8th) respectively. However, Type 0092 is the *most* (ranked 1st) frequently dominant filament in both the foam and mixed liquor (78 % and 82 % respectively).
9. Although the cause of foam formation by *M. parvicella* and *Nocardia* is currently being investigated by a number of research groups, little has been published regarding prevention of growth of these filamentous organisms. At present, physical removal and avoidance of recycling of foam is the best solution to foaming problems (Jenkins *et al.,* 1984; Hart, 1985). Often foam from scum traps (which invariably are grossly undersized) is returned to the head of the plant via waste sludge, wet well and gravity thickener overflow. Also waste sludge is abstracted below the surface, and baffle walls on the reactors prevent foam from moving along the reactor surface. These practices and design features cause foam to be trapped in the reactor and build up to large volumes over several weeks. Selective and regular removal of surface foam usually will eliminate what otherwise will develop into a severe foaming problem, due to accumulation. A novel satellite flotation scheme for the selective removal of *Nocardia* and *M. parvicella* from the mixed liquor has been developed recently by Pretorius and Laubscher (1987).

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