Microbial Slime in Papermaking Operations- Problems, Monitoring and Control Practices

A.G. Kulkarni, R.M. Mathur, R.K. Jain and Abha Gupta

Central Pulp and Paper Research Institute, Post Box No. 174, Saharanpur-247 001 (U.P.)

ABSTRACT

Paper machine systems usually support significant growth of micro-organisms due to congenial and favourable conditions persisting during the manufacture of papers. The pH, elevated temperatures, high nutrient levels and increased reuse of process water make a paper mill system a perfect breeding ground for microorganisms. Uncontrolled microbial growth in the system results in reduced product quality, odour problems, safety issues and lost production. Microbiological control has become a necessary part of continuous paper and board production to ensure trouble free running of the paper machine without slime induced paper breaks and the resultant loss in production. The tolerance of a system to various contamination is mill and machine specific. Today, it is necessary to adopt a correct slime control programme. Due to the limited information and facilities available, it is often difficult to choose the right type and dosage of slimicides. Slime growth control techniques being adopted in Indian paper industry are based on the use of chlorophenols and mercury based compounds which are found to be mutagenic or carcinogenic and have a serious environmental impact due to high level of residual toxicity. Central Pulp and Paper Research Institute in the recent past has developed sufficient expertise in the area of identification of various types of microbial deposits. The present paper highlights the studies being carried out at the Institute on physico-chemical, and microbiological characterisation of the biofilms (slime) collected from an agro-based mills and control of microbial growth using identified ecologically compatible and environment friendly biocides.

INTRODUCTION

Paper mill slime is the accretion or accumulation in paper machine caused by certain microorganisms in presence of fibres, fillers and other wet end additives. Tighter limitations being placed on fresh water use and wastewater disposal have forced the paper industry to close up their back water system. This factor coupled with use of higher filler levels, increased use of secondary fibres and wet end additives have created severe problems of formation of uncontrolled growth of microbes (slime) in paper machine which leads to variety of process, quality and maintenance problems in paper machine, corrosion and odour which ultimately causes increased maintenance and production cost.

Conventional slimicides used in the past have not been found ecologically compatible and environmentally acceptable. Today due to changing customer's consciousness towards environmentally clean products, industry will be forced to find out alternative slime control additives,which are environmentally acceptable.

Central Pulp and Paper Research Institute (CPPRI) undertook a study on the control of microbial slime growth in paper machine in agro-based & recycled based paper mill employing alternate ecologically compatible slimicides. Slime control unit was designed and placed in paper machine white water loop which indicated a fast build up of microbial slime on a wood panel fixed up in the unit.Biofilm samples collected from the wood panel at different time intervals were subjected to detailed analysis in respect of physio-chemical, biochemical and microbiological characterizations. The detailed analysis coupled with efficacy test of the slimicides procured from an international company, against the identified microbes indicated a good response towards use of alternate, ecologically compatible slimicide for the control of slime growth in paper machine.

The present article highlights efforts being carried out at CPPRI on control of slime formation in paper machine in an agro-based mill using ecological compatible slimicide.

EXPERIMENTAL

Material and Methods

Slime Monitoring and Collection Unit

Slime build up in paper machine and white water loop is a dynamic process and depends upon various factors like raw materials, fillers used, temperature, pH, etc. of the white water. To study the slime build up trends in paper machine an online slime collection and monitoring unit was fabricated and installed in different sections of the paper machine. The unit is shown (Fig. 1).

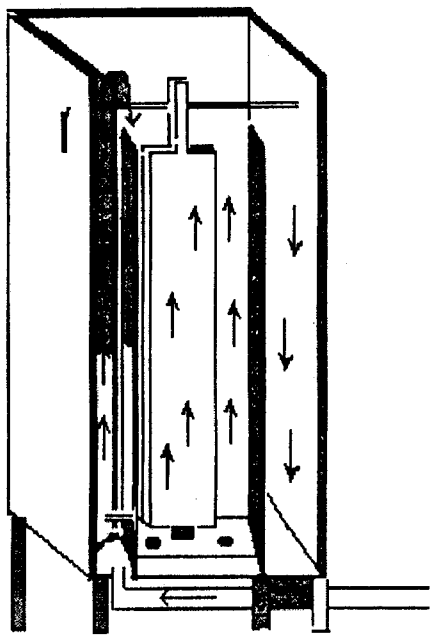

Fig. 1 Slime Collection and Monitoring Unit

Total Biofilm amount analysis

Total amount was estimated from dry weight of biofilm growth, on slime collecting unit fabricated at CPPRI and put up in the paper machine white water circuit in an agro based mill, at fixed time intervals.

Biofilm components

Fig. 2 shows the various components of the biofilm.

Estimation of total inorganic and organic contents

Total inorganic and organic were measured by standard methods by making ash at 650°C for one hour.

Extraction of extracellular polysaccharide (ECPs) and protein

Biofilm sample were extracted by cold aqueous extraction techniques where in slime was suspended in 8.5% NaCl containing 0.22% formaldehyde. The solution was chilled and mixed in homogeniser and centrifuged at 12,000 rpm for 30 min (1). Supernatant containing ECPs and proteins were estimated as follows:

(a) Estimation of extracellular polysaccharides (ECPs)

Quantitative estimation of ECPs were carried out using phenol-sulphuric acid method of Dubois etal. by measuring the absorbency at 488 nm (2).

(b) Estimation of Total Proteins

Cell mass was indirectly quantified by measuring total protein according to Lowry etal by measuring the absorbency at 660 nm (3).

Microbial assay of various white water and other samples

Total microbial assay of various samples of white water, pulp stocks and slime was carried out by standard pour plate method in nutrient agar medium carried out by serially diluting the samples in normal saline solution to a appropriate concentration in triplicates. Colonies were counted in plates having optimum numbers of colonies i.e. between 30 to 300 by colony counter.

Relative population density test

Diluted biocide at concentration of 0.5, 1, 5, 7, 10 and 15 ppm were added to sterile tubes containing suspended cell pellets in 0.2 m phosphate buffer at pH 7.0. The tubes were shaken at 230 rpm at 37°C. Aliquots were removed at regular interval of 2, 4, 6, 8 and 24 hrs and microorganisms were enumerated by standard pour plating method on nutrient agar plates. The percent reduction was determined by comparing with initial bacterial count.

RESULTS AND DISCUSSION

Formation of slime in paper machine takes place as the white water is enriched with substrate and environmental

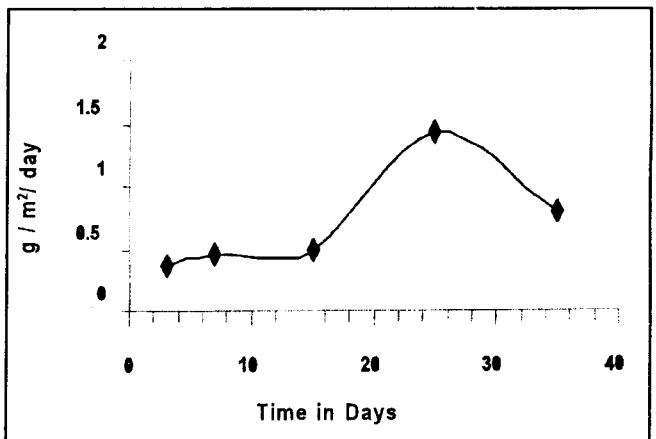

Fig. 2 Trend of Slime Build up in Paper Machine in an Agro Based Mill Producing Bleached variety of Paper

conditions as temperature, pH etc. are favourable for microbial growth which thereby become a continuous and uncontrollable phenomena.

Slime build up trend in paper machine

Slime build up in paper machine and white water loop is a dynamic process and depends upon various factors like raw materials, fillers used, temperature, pH, etc of the white water. One of the mills was selected by IARPMA and studied for its slime deposit trend in the paper machine by using slime collection unit shown in Fig. 2. The deposits on wooden panel were collected and quantified in a particular area which shows the slime build up trend in paper machine is more or less a sigmoid curve as shown in Fig. 3. There is a steady increase of slime formation form 0.4 g/m^2 at 3rd day upto 1.4 g/m^2 on 25th day onwards, slime deposition does not grow further with time. Studies shows that, maximum growth takes place between 21-28 days which then starts sloughing up of the slime to the white water system with the shear force of the white water. Even after a complete and effective caustic boil out programme, slime deposit starts from the 3rd day.

Microscopic examination of slime

The slime deposited on the wooden panel was collected and studied for is microscopic observation and isolation of bacteria responsible for slime formation. The different microbial colonies isolated from the slime deposited on the wooden panel are shown in Fig. 4 and mainly shows filamentous bacteria responsible for slime deposition.

Characterisation of slime and white water samples

An integrated approach has been adapted for physico-chemical, biochemical and microbiological analysis of various slime sample collected from time to time as shown in Fig. 4 Table-1. Shows the analysis data of slime samples the wooden panel and of the slime collection samples collected from various points like paper machine wall, wall

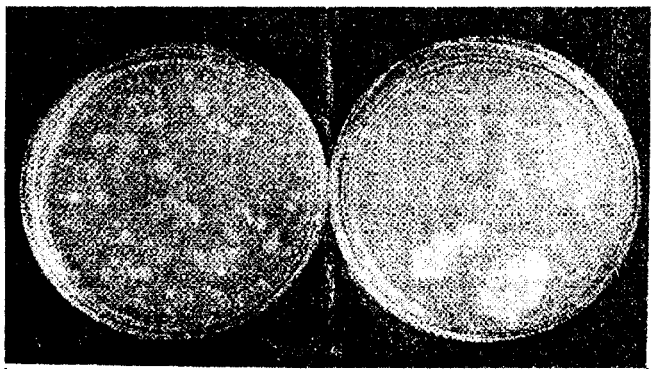

Fig. 3 Integrated Approach for Biofilm (Slime) Characterisation

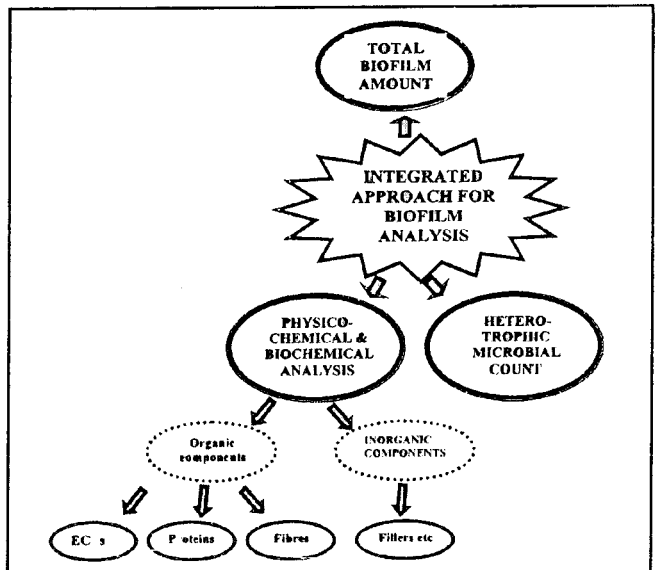

Fig. 4 Bacterial Colonies Isolated from Slime Sample Collected from the Wooden Panel

of krofta, silo etc. It is clear from the result that though the organic and inorganic composition of the slime collected from slime collection unit is similar in composition with that of mixed slimes, the ECPs level is almost double in case of mixed slime as compared to slime of slime collection unit. It is established that these mixed slime are matured and old deposits and have more secretion of ECPs which is the main cause of agglomeration of fibres fillers and microorganisms. This is the problem- creating agency in paper web on the machine resulting in frequent paper breaks.

Microorganisms reach from one part to the other part of the white water loop through backwater, so it is essential to study the degree of contamination through microbial count in the different parts of the paper machine section. Table 2 shows the microbial count of white water collected from different points of the white water loop as well as process water for papermaking. Results shown in Table 2 clearly indicate that the process water contains as many as $3.3x10^2$ numbers of viable microorganisms per millilitre and this number is too high and causative reason of continuous addition of microorganisms to the system. Samples from white water storage tank and premachine chest shows a very high enumeration of $1.1x10^6$ and $5.8x10^6$ respectively, this may be due to improper cleaning and stagnant stock/ white water. This high microbial stock could work as the seed of slime formation.

Determination of efficacy of various slimicides

Before going for slime control programme, it is essential to understand the active compounds present in the slimicide. The same was tested and has been tabulated along with

Table-1 Physicochemical, Biochemical and Microbial Analysis of Slime Samples

Parameters	Collection Points		
	Slime from Slime Collection Unit	Mixed Slime	Back water
Total organics, % (w/w)	31.00	32	-----
Total inorganic, % (w/w)	69.00	68	-----
Fibres, % (w/w)	29.2	---	---
ECPs, % (w/w)	0.325	0.62	50 µg/ml
Proteins, % (w/w)	0.226	0.21	255 µg/ml

Table-2 Microbial Assay of White Water/ Slime Samples at Various Points in an Agro-Based Paper Mill

Sl. No.	Sample Collection Points	Heterotrophic viable microbial count (CFU)
1.	Slime collection unit	1.56×10^7/gm
2.	White water storage tank	1.1×10^6/ml
3.	Krofta	3.2×10^5 /ml
4.	Pre machine chest	5.8×10^6 /ml
5.	Head box	3.1×10^5 /ml
6.	Wire part	9.5×10^5 /ml
7.	Process water	3.3×10^2 / ml

Table-3 Some of the Identified Slimicides and their Active Principles

Slimicide Code	Active ingredient
Slcd-1	Glutaraldehyde
Slcd-2	2,2, Dibromo 3-Nitrilo-Propionamide
Slcd-3	5-Chloro-2 Methyl-4 Isothiozolin-3-One+2, Methy1,4, Isothiazolin-3-1.
Slcd-4	2, Bromo-2 Nitropropane-1, 3 Diol
Slcd-5	Tetrakis Hydroxymethyl Phosphonium Sulphate (THPS)
Slcd-6	Methylene Bis Thiocyanate (MBT)
Slcd-7	MBT
Slcd-8	THPS + MBT
Slcd-9	Unknown
Slcd-10	Unknown

their active compounds and shown in Table 3.

Table 4 shows the relative population density test and reduction in the microbe using different slimicides at different time periods (Slcd-1 is being excluded as it is not found to be environmental friendly). The significance of relative population density test implies the effectivity of the test slimicides against the tested (predominant microorganisms present in the white water as well as slime samples) microorganism. The test being performed in nutrient both medium, tested microorganism gets ample of balanced nutrient required for its growth and regeneration, however the effect of slimicides can be interpreted from the rate of kill. The table shows Slcd-7

Table-4 Results of Relative Population Density Test of Identified Slimicides at Different Time Periods

Slimicide Code	Time in hour					
	0	0.5	2.5	3.5	5	24
	Bacterial enumereation in CFUs					
Slcd-2	182×10^5	35×10^5	26.5×10^5	35.1×10^5	47×10^5	95.2×10^5
Slcd-3	182×10^5	40×10^5	5.7×10^5	1.15×10^5	1.9×10^5	67.2×10^5
Slcd-4	182×10^5	55×10^5	3.6×10^5	1.5×10^5	0.6×10^5	10.8×10^5
Slcd-5	182×10^5	15×10^5	7.5×10^5	18.2×10^5	47.5×10^5	64.8×10^5
Slcd-6	182×10^5	84×10^5	3×10^5	6.2×10^5	18×10^5	72×10^5
Slcd-7	182×10^5	85×10^5	2.55×10^5	6.5×10^5	15.5×10^5	61.6×10^5
Slcd-8	182×10^5	30×10^5	4.7×10^5	8×10^5	4.5×10^5	84.8×10^5
Slcd-9	182×10^5	60×10^5	3.6×10^5	6.1×10^5	9.5×10^5	76.8×10^5

Table-5 Percent Reduction During Efficacy Test of Identified Slimicides at Different Time Pereiod

Slimicides	Time				
	^{0}Hr	15 Min	45 Min	2 Hr	24 Hr
Slcd-2	0	90.0	98.2	99.3	96.8
Slcd-3	0	90.9	99.9	99.4	99.8
Slcd-4	0	99.3	98.3	99.5	99.9
Slcd-5	0	64.5	69.0	93.6	97.1
Slcd-6	0	83.6	95.2	98.5	99.7
Slcd-7	0	84.5	95.9	98.4	99.8
Slcd-8	0	84.5	94.5	99.0	99.5
Slcd-9	0	90.9	98.4	95.8	99.9
Slcd-10	0	81.8	99.2	99.8	98.3

and Slcd-4 have a very effective antibacterial activity against the test microorganism (both are THPS based slimicides) where as Slcd-3 and Slcd-5 have better killing activity at 2.5 hr to 5.0 hr. In comparison, the biocidal activity of the Slcd-5 is best as it has a very consistent activity and at 24 hr also, its action is more in comparison to other slimicides.

The efficacy test of selected slimicides was carried out against the consortium of microorganisms present in the white water system. This test was carried out under dynamic conditions of shaking at 130 rpm and 35°C in a rotary shaker cum incubator after addition of 20 ppm of slimicide to the test sample of white water collected from the mill to simulate the mill conditions. Since the mill white water contains a number of microorganism of different groups, this test is very much effective and necessary to study the action of slimicide as broad spectrum, which is effective against diversified group of microorganisms. Table-5 shows Slcd-5 is highly effective and reduces 99-3% of the microbial count within 15 minute of time period, whereas Slcd-9, Slcd-2 and Slcd-3 reduce 90-91% within 15 minute of time period.

CONCLUSION

Detailed characterization of the slime with respect to physiochemical, biochemical and microbiological aspects and improved monitoring in terms of slime build up helped in understanding the nature of slime and how to control it in an effective and efficient way. Relative population density test and efficacy test using the new slimicide on the slime samples collected from slime collection unit and white water samples from various points of paper machine loops were effective on controlling the microbial growth (slime) in paper machine in an agro-based mills. Use of slimicide in combination with biodispersant could be used to achieve optimal slime control programme in terms of efficiency and cost. The programme is being continued at the Institute for promotion of the ecologically compatible slimicides in Indian Paper Industry, which will prove to be more environmental friendly.

ACKNOWLEDGEMENT

The authors are thankful to Shri Parmod Jain, President, IARPMA, for entrusting the above study to CPPRI. The authors also wish to acknowledge their sincere thanks to Mr. Manoranjan Manthan and Dr. Vasantha, V. Thakur for their technical support in the above studies.

REFERENCES

1. Xiaogi zhang; Paul Bishop and Margaret, J. Kupferla. Water Sci. Tech., 37, 4-5, 345-378 (1998).
2. Dubois, M, Gillers, K.A., Hamilton, J.K. Rebers, P.A. and Smith, F., Anal. Chem., 28 (3), 350-356 (1966).
3. Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall, R.J.J. Biol. Chem. 193, 265-275, (1951).
4. Fries, RE., Tappi Paper makers Conf., 237-239, (1984).
5. Sanborn, J.R., Lockwood Trade, J., p. (1965).
6. Hollis, G.G., Tappi Alkaline Paper making, p. (1985)
7. Dyek, A.W.J., The Paper Industry, Publ. 273-274, (1962).
8. Kanto C., Bratar J; Stenquist, B., Svensk Paper Stidn, 99, (2) 29-30, (1966).
9. Van Haute, E:., Pulp Pap. Eur., 2, (2), 11-13, (1997).
10. Van Haute E:., Pira Annual Conf., Chemicals in Paper Making, Manchester, U.K., (1997).