DEVELOPMENT AND CONTROL OF MICROÖRGANISMS IN A PULP AND PAPER MILL SYSTEM

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Received for publication, December 15, 1932

INTRODUCTION

The purpose of microbiological investigation in the paper industry is, in general, twofold: to control the development of undesirable microörganisms and to utilize those whose activities may be advantageous in papermaking processes. This paper presents some of the microbiological problems involved in the control of the former group.

The invasion of pulp and paper mills by microörganisms and their subsequent development usually results in economic loss and impaired quality, through the formation of mill slimes and the deterioration or discoloration of pulp and paper. In addition, the considerable degree of pollution in mill process-water serves to emphasize the importance of hygienic qualities and refinements in paper products for personal and medical uses, and in paper wraps or containers for foods.

INVASION OF MILL SYSTEM BY MICROÖRGANISMS AND THEIR DEVELOPMENT

Microörganisms invade pulp and paper mills with water supplies and to some extent with raw materials utilized in the manufacture of paper. The preliminary treatment of pulp wood in the sulphite digesters exerts a definite sterilizing effect (140 to 145°C., with a possible maximum of 155 to 160°C., Johnsen, 1927). Numbers of microörganisms are effectively reduced in groundwood pulp due to the high temperatures attained during grinding. Although subject to wide variation, these temperatures, usually
in the vicinity of 85°, are quite insufficient to eliminate spore-forming bacteria. In one mill, pure cultures of Bacillus vulgaris were obtained from the hot groundwood.

The pulp stream, in the course of its progress, receives large inoculations of organisms from growth accumulations within the mill system and, supplying as it does a water solution and suspension of inorganic and organic nutrients (Fritz, 1931), rapid development of microorganisms results. Since the groundwood contains almost all the constituents of the wood itself (Sutermeister, 1929), an excellent carbohydrate-rich medium is provided. The rapid growth of organisms in the sulphite system indicates that the sulphite pulp stream furnishes an adequate food supply. Distribution of microorganisms takes place through air dissemination of spores and the continuous circulation of white water and stock. In the case of the groundwood mill, counts ranging from two to three million bacteria per cubic centimeter of white water and stock have been obtained during slime trouble. Inasmuch as the fresh water supply was adequately chlorinated, the inoculations came directly from bacterial and fungus development within the system.

The masses of growth built up on surfaces over which pulp suspensions flow, are spoken of collectively as slimes. Pulp and paper mill slimes are, therefore, accumulated microbiological growths, composed heterogeneously of microorganisms, products of growth, fiber, and inorganic debris. The heterogeneous nature of slime growths is emphasized by Fritz (1931) who states that no fungus, or limited association of fungi, can be held universally responsible for the trouble. This statement is abundantly confirmed in the present investigation.

The ability to form viscous growths or close masses of mycelium on appropriate surfaces is characteristic of the microorganisms developing in pulp and paper mill systems. The types and degrees of viscosity which they reveal on carbohydrate media, vary with the different species, from the gelatinous or viscid bacterial growths, similar to the cellulase slimes described by Beijerinck (1912), to the doughy and rubbery formations of Oidium and certain yeast-like fungi. The compact, matted
masses of mycelium formed by Actinomyces and other filamentous organisms, introduces another slime factor of far-reaching importance in paper manufacture.

The bacterial slime-formers isolated thus far, may be grouped under the following genera:

**Achromobacter**—A number of species were studied which, in all probability, should be placed in this genus. The isolations resemble, more or less closely, several of the species described by Bergey (1930). Among them are *A. geminum* (*B. geminus-major* Ravenel); *A. pinnatum* (Ravenel) Bergey; *A. ambiguum* (Wright) Bergey; *A. reticularum* (Jordan) Bergey; *A. viscosus* (Adametz) Bergey.

**Escherichia**—One species was encountered corresponding to the description of *E. gastrica* (Ford) Bergey. This organism produced a thick, viscous, yellowish growth on potato-glucose agar, while on beef-peptone agar the development was abundant, spreading, and somewhat rugose.

**Aerobacter**—Organisms typical of *A. aerogenes* (Kruse) Beijerinck and *A. cloacae* (Jordan) Bergey occurred prominently.

**Pseudomonas**—*Ps. viscosa* (Frankland) Migula was isolated once.

**Bacillus**—*B. vulgatus* Trevisan, isolated from certain tenacious deposits, produced very viscid growths on enrichment media. *B. vulgatus* was found also in hot groundwood taken directly from the grinder pit. In its descriptive features, this organism is entirely typical. *B. vulgatus* forms an abundance of levan in the sucrose medium used by Hibbert (1931) and it is mentioned by Beijerinck (1912) as one of the levulan-forming bacilli. *B. subtilis* (Ehrenberg) Cohn also appeared among the slime-formers.

In addition to the bacterial slimes there are those formed essentially by Oidium, Monilia, and related yeast-like fungi of doubtful identity. The growths produced by these forms are usually doughy or rubbery, effectually resisting control measures. They develop rapidly on carbohydrate media and possess the ability to build up tenacious growths within the mill system. The cultural features of these organisms have been studied in the laboratory using glycerol and potato decoction media. The growth masses consist of a form of gelatinized cellulose.
The importance of filamentous fungi of the mold type is stressed by Fritz (1931), who states that the bulk of the slime in her investigations was composed of these forms. *Aspergillus fumigatus* var. is representative of a considerable number of isolations made at this laboratory whose activities extend to active pulp deterioration, including the production of sliminess, discoloration, and cellulose decomposition. This group includes members of the genera Aspergillus, Aerostalagmus, Alternaria, Cladosporium, Chaetomium, Trichoderma, and Penicillium. In a few cases cultures of filamentous fungi were obtained which could not be identified, due to the failure to produce fruit bodies under the cultural conditions provided. Schmid (1930) refers to Trichoderma and Cladosporium as important slime-forming organisms. Reference is made by Pattillo (1931) to *Paxillus panuoides* Fries as one of the producers of sliminess and pulp deterioration.

The filamentous bacteria have received considerable attention in this connection. An Actinomyces proved to be the predominating form in slime from a section of one mill. The alga-like bacteria have been identified with various similar conditions by Schmid (1930), Pattillo (1931), Boruff and Stoll (1932), and Gesell (1932). Members of the Chlamydobacteriaceae are conspicuous among the causal species.

This brief discussion illustrates the diversity of the slime flora and the heterogeneity of the growth accumulations. The subject of microbial development in pulp and paper mills can not be restricted to slime troubles alone. It includes such associated effects as pulp discoloration and decay, also the formation of decomposition products, which frequently impart objectionable odors to pulp and paper.

**METHODS OF INVESTIGATION AND CONTROL**

The procedure adopted in this investigation was to analyze process-water and stock at significant stages in the operation, using standard bacteriological methods. Through this means information may be secured relative to sources of contamination, the distribution of organisms throughout the system, the points at which stock may receive inoculations of organisms from slime.
deposits, and the effectiveness of chemical treatments. In order to interpret these results correctly, one must be thoroughly acquainted with the methods and conditions obtaining at the mill under investigation.

Periodically throughout the year, the slime deposits may accumulate sufficiently to cause losses in production and time and to endanger quality. In order to determine the predominating forms, samples are examined microscopically and culturally with the aid of various special media. Potato-glucose agar, prepared according to Fritz (1923), malt-extract agar, groundwood-glucose-peptone agar, and potato-glycerol medium have proved useful in this portion of the work. The control measures recommended will depend upon the nature of the causal microorganisms and upon local mill conditions. The requirements imposed by these factors are sufficiently definite to influence the procedure to be followed. None of the methods of treatment commonly used at present are effective for all types of slime.

Chlorination, utilized at the outset as the most economical and effective method of control, continues to play an important part in slime prevention. The usual applications of chlorine are, however, rendered quite inadequate, due partly to the rapid dissipation in strength which chlorine undergoes in the presence of organic matter, and also to the phenomenon of chlorine tolerance exhibited by many predominating slime-formers. Oidium, Aspergillus, and Actinomyces, for example, are able to resist five parts per million of chlorine. Tonney (1930) reports wide variations in the amounts of chlorine necessary to kill spore-forming bacteria. Spores of Bacillus vulgaris and Bacillus subtilis required 280 and 160 parts per million respectively. These organisms are reported among the slime-formers isolated during this investigation.

Neither straight chlorination nor the ammonia-chlorine treatment is able to reach the organisms causing the most troublesome slimes. Speaking of bacterial growth in pipe sediment, Baylis (1930) states:

Water containing organic matter that settles or attaches itself to the side of the pipes may produce a coating so thick that even though the water contains considerable residual chlorine there will be a zone
of chlorine-free water within the coating or within the sediment where bacteria may grow abundantly.

Once the slime growths have incrusted pipe lines and accumulated in thick, adherent layers in the pulp-handling equipment, chests and tanks, a laborious, time-consuming clean-up must be made, during which the system is rid of these deposits. This is accomplished by physical means (scraping, hosing out, brushing, sluicing) aided by the use of alkali which exerts a solvent action on slime. This general procedure is a necessary preliminary in combating slime troubles. Steps must then be taken to prevent fresh development of slime-forming organisms—an undertaking which will depend upon the local situation. Where conditions will allow, heavy applications of chlorine may be introduced into the system which, aided by the use of chlorinated fresh water wherever possible, will effectively reduce bacterial numbers throughout the mill. In one instance of serious slime trouble due to bacteria, this method resulted in the removal of over 90 per cent of the bacterial contamination of white water and stock. In cases where an excess of chlorine would prove particularly dangerous to operative efficiency through its bleaching or corrosive action, copper compounds may be employed, alternately or simultaneously with moderate chlorination. Sometimes direct applications of calcium hypochlorite will successfully prevent slime development. Vigilance in detecting and removing growth accumulations and the practice of mill sanitation are the most important aids to slime prevention.

REFERENCES

Baylis, J. R. 1930 Water Works and Sewerage, 77, 337.