Analysis of Factors Influencing Population Dynamics of Slime Forming Bacteria at Selected Sites on the Ohio River

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Introduction

Biofouling of condenser tubes at Clifty Creek Station, an electric power generating facility on the Ohio River in Southern Indiana, occurred in March 1976. Analysis of condenser tubes revealed biofouling was due to bacterial adhesion inside condenser cooling tubes. Bacteria isolated from condenser tubes produced copious layers of slime. Similar biofouling due to bacteria occurred at Cardinal Plant and Tanner's Creek Plant on the Ohio River in Southern Ohio and Indiana.

This study was undertaken to evaluate seasonal population trends of bacteria in the Ohio River intake water at Cardinal Plant, Clifty Creek Station, Kyger Creek Station and Tanner's Creek generating facilities from May, 1978 through April, 1979. A weekly comparison was made between total aerobic bacteria and slime forming aerobic bacteria and between total gram negative aerobic bacteria and slime forming gram negative aerobic bacteria. Statistical models, involving selected measured variables at sites, were used to gain insight to factors influencing bacterial populations in intake water.

These results represent the first attempt at elucidating factors influencing bacterial populations in Ohio River intake water at the sites noted. This paper includes summarized information from a more comprehensive evaluation of aquatic bacterial populations by McComish and Hendrickson (2). Funding for this work was provided by American Electric Power Service Corporation, Ohio Valley Electric, and Indiana-Kentucky Electric Corporation.

Study Sites

The study sites were located on the Ohio River in Southern Ohio and Indiana. These sites were selected because they were all locations of electric generating facilities previously experiencing bacteria slime buildup in condenser tubes; Cardinal Plant near Brilliant, Ohio; Kyger Creek Station near Gallipolis, Ohio; Tanner's Creek Plant near Lawrenceburg, Indiana; and Clifty Creek Station near Madison, Indiana.

Methods and Materials

Triplicate samples of intake water were collected weekly, kept cold, and usually processed within 48 hours. Bacteriological samples were prepared by plating water samples on Standard Methods Agar and MacConkeys Agar. Plates were incubated at ambient temperature (72°F, 22C) for 5 days and total bacterial and slime bacterial counts obtained. Slime formation was confirmed by stringy consistency of the colony and capsule formation. Each bacterium confirmed as a slime producer was identified using API 20E strips. Chemical analyses were performed according to Standard Methods for the Examination of Water and Wastewater (1). Limnological characteristics examined for inclusion in statistical evaluation and model formulation included intake water temperature, pH, biochemical oxygen demand (BOD_5), ammonia, alkalinity, hardness, turbidity, total dissolved solids, and sulfate.

Statistical analyses were conducted using a DEC-10 system and standard analytical computer procedures.

Results and Discussion

Seasonal Bacterial Populations

Bacterial population numbers in intake water varied seasonally from May 1978 through April 1979. The total bacterial population fluctuated widely from 10,000/ml to near or in excess of 100,000/ml.

Total slime bacterial population numbers in intake water at all sites were generally much lower than total bacterial population numbers except from late July through early November 1978 when they were quite similar. This strong trend of total slime bacteria population dominance is evident when total slime bacteria are evaluated as a percentage of total bacteria at sites (Figures 1-4). Total slime bacteria at all stations were usually less than 20% of total bacteria except during the July to November period noted when it made up from about 50-95%.

Total gram negative bacteria essentially followed the same seasonal pattern as described for total bacteria at each site. Population levels were, however, lower by about a factor of 10 with only a few exceptions.

Discriminant Analysis Models

Discriminant analysis was applied to prediction of bacterial population percentages for total slime bacteria of total bacteria and for gram negative slime bacteria of total gram negative bacteria. This was accomplished by using two population groups (group 1: 0-49.9% and group 2: 50.0-100.0%) for percent slime bacteria (TABLE 1) and for percent gram negative slime bacteria (TABLE 2).

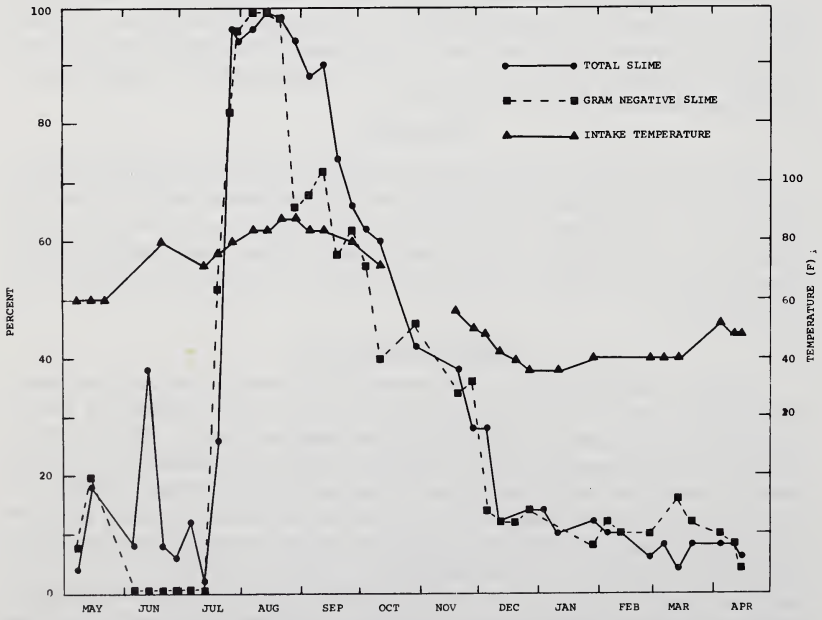

FIGURE 1. *Percent total slime bacteria and gram negative slime bacteria with temperature at Cardinal Plant from May, 1978 through April, 1979.*

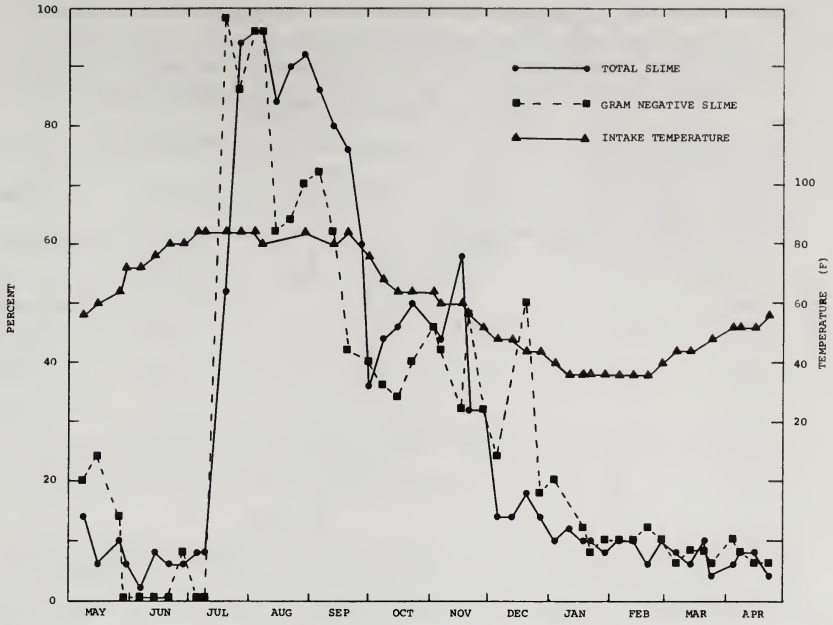

FIGURE 2. *Percent total slime bacteria and gram negative slime bacteria with temperature at Clifty Creek Station from May, 1978 through April, 1979.*

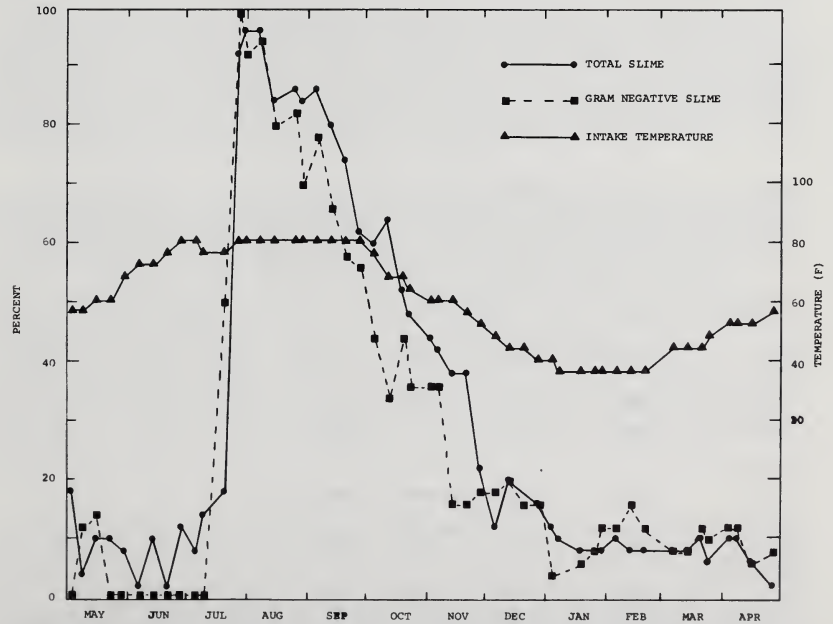

FIGURE 3. *Percent total slime bacteria and gram negative slime bacteria with temperature at Kyger Creek Station from May, 1978 through April, 1979.*

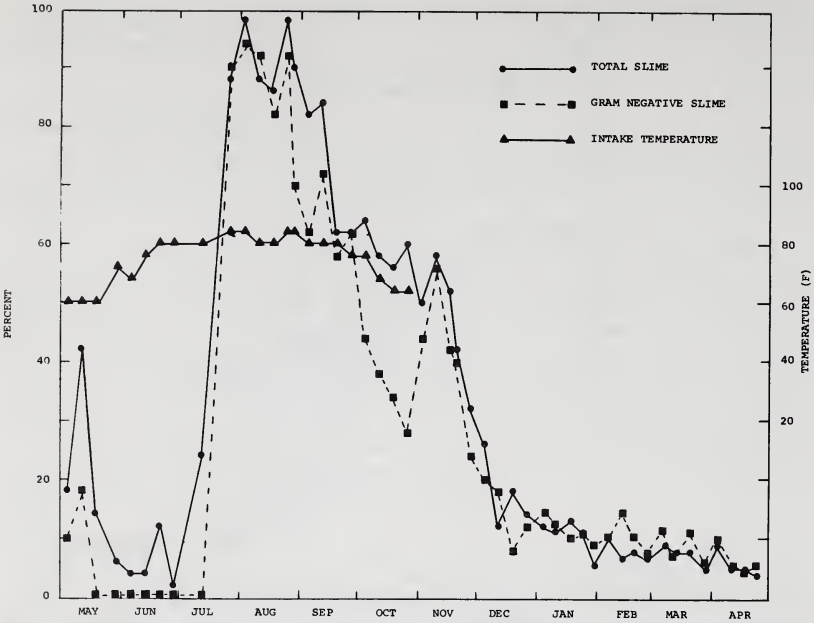

FIGURE 4. *Percent total slime bacteria and gram negative slime bacteria with temperature at Tanner's Creek Plant from May, 1978 through April, 1979.*

Percent slime bacteria of total bacteria were classified into group one correctly 71% of the time and into group two correctly 93% of the time for data combined from stations over the 12 month period using intake water temperature, ammonia, and BOD_5 as discriminators (TABLE 1). Models for individual sites ranged from 74-100% correct prediction of either group. Significant variables (F test, 95% level)

TABLE 1: *Models of discriminant analysis allowing classification of percent slime bacteria of total bacteria into two population groups 0-49• and 50.0-100.0•, using intake water temperature, ammonia, and BOD_5 at sites combined and separated for data collected from May, 1978 through April, 1979.*

Models	Functions				Predicted Correctly (%)*		
	Temperature	Ammonia	BOD_5	Constant	Group 1 0-49.9	Group 2 50.0-100.0	Combined Overall
Combined Sites	-0.0624	-0.1845	0.0990	4.3552	71	93	77
Cardinal Plant	0.0561	-2.6043	**	-2.9990	74	85	78
Clifty Creek Station	0.0455	-1.7031	0.6674	-3.5519	90	100	92
Kyger Creek Station	0.0641	**	0.1621	-4.0990	81	92	85
Tanner's Creek Plant	0.0175	-2.6727	-0.3927	2.5690	86	100	91

* Classified using discriminant model for prediction.
** Variable rejected for use in formulating discriminant model.

TABLE 2. *Models of discriminant analysis allowing classification of percent gram negative slime bacteria of total gram negative bacteria into two population groups. 0-49.9• and 50.0-100.0• using intake water temperature, ammonia, and BOD_5 at sites combined and separated for data collected from May, 1978 through April, 1979.*

Models	Functions				Predicted Correctly (%)*		
	Temperature	Ammonia	BOD_5	Constant	Group 1 0-49.9	Group 2 50.0-100.0	Combined Overall
Combined Sites	0.0621	**	**	-3.9687	68	95	74
Cardinal Plant	0.0644	-2.4820	**	-3.8011	73	93	83
Clifty Creek Station	-0.0271	4.5277	**	0.0296	74	100	76
Kyger Creek Station	0.0651	-0.3363	0.1746	-3.6879	81	92	84
Tanner's Creek Plant	0.0826	-1.3090	-0.6628	-2.9407	91	100	94

* Classified using discrimination model for prediction

** Variable rejected for use in formulating discriminant model.

allowing group predictions included: intake water temperature, ammonia and BOD_5 at Clifty Creek Station and Tanner's Creek Plant, but only intake water temperature and ammonia at Cardinal Plant, and intake water temperature at Kyger Creek Station.

Results were similar for percent gram negative slime bacteria of total gram negative bacteria as shown for total bacteria (TABLE 2). Gram negative slime bacteria were correctly predicted for groups one and two for combined data in 68 and 95% of the cases, respectively, using only intake water temperature as a discriminator. Models for individual sites ranged from 73-100% correct prediction. Models for Kyger Creek Station and Tanner's Creek Plant utilized intake water temperature, ammonia, and BOD_5 while Cardinal Plant and Clifty Creek Station used only intake water temperature and ammonia.

It is significant to note that intake water temperature was an important discriminator at all stations. Inspection of graphs of percent slime bacteria and gram negative slime bacteria (FIGURES 1-4) show intake water temperatures increasing to about 80°F (27C) by mid July. After mid July and into September, intake water temperatures remained high (at or near 80°F, 27C). This was the same period of total slime bacteria and gram negative slime bacteria population dominance at all sites. While other variables such as ammonia and BOD_5 were involved in predictive models, temperature is clearly the major factor influencing the aquatic bacterial population. It appears that the slime forming bacteria were better adapted than non slime forming bacteria to the prevailing ecological conditions, especially temperature, during the sample period.

Summary and Conclusions

Selected physical, chemical and bacteriological data were collected from May 1, 1978 to April 30, 1979 at four electric generating facilities on the Ohio River: Cardinal Plant, Clifty Creek Station, Kyger Creek Station and Tanner's Creek Plant. The data were used in computer analyses to formulate statistical models. Seasonal population trends were examined in relation to selected measured variables. Major conclusions are as follows:

1. Total bacterial numbers were variable between about 10,000-100,000/ml during the sample period.
2. Discriminant models were formulated to predict slime bacteria as a percentage of total bacteria and to predict gram negative slime bacteria as a percentage of total gram negative bacteria. Water temperature was the major discriminating variable common to all models formulated. Classification of bacteria as dominant or subdominant was correctly accomplished using the models from 68-100% of the time.
3. Slime bacteria dominated bacterial populations from mid July through September when river intake water temperatures were above or near 80°F (27C). Ecological conditions, especially elevated temperature, apparently favors the slime forming bacterial population of the river system during mid to late summer.

Literature Cited

1. AMERICAN PUBLIC HEALTH ASSOCIATION, AMERICAN WATER WORKS ASSOCIATION and WATER POLLUTION CONTROL FEDERATION. 1976. Standard Methods for the Examination of Water and Wastewater. Amer. Pub. Health Assoc. 874. p.
2. MCCOMISH, THOMAS S. and DONALD A. HENDRICKSON. 1979. Computer statistical analysis of factors influencing condenser performance at four electric generating facilities. Final Report American Electric Power Service Corp., Ohio Valley Electric, and Indiana Kentucky Electric Corp. (mimeograph). 69 p.