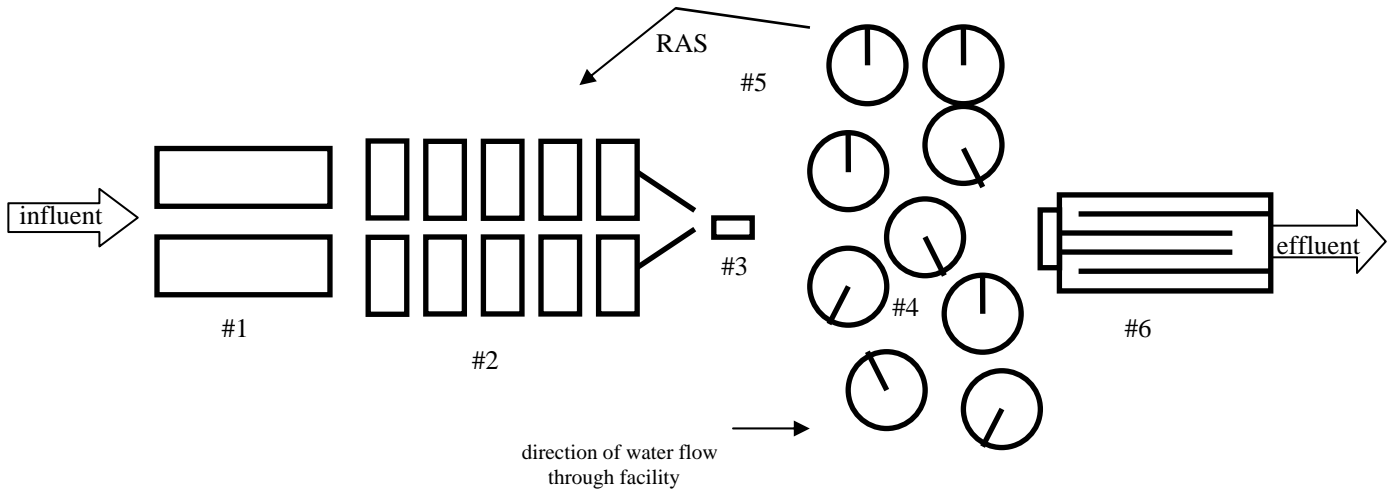


Appendix 1. Partial schematic of secondary sewage treatment at Fields Point WWTF.

(Detention times calculated from NBC Equipment Date records using design average flow)



#1 primary clarifiers; #2 aeration tanks; #3 mixed liquor chamber*; #4 final (or secondary) clarifiers*; #5 return activated sludge system; #6 chlorine contact tanks*. * Sampling sites to be discussed in Materials and Methods section or Appendices.

#1 Primary clarifiers: These four settling tanks collect finer solids on the bottom by reducing the velocity of flow. Grease and scum is skimmed from the surface. Detention time: 2.6 hours.

#2 Aeration tanks: These tanks contain a fine bubble aeration system which increases the dissolved oxygen level in the water and promotes growth of microorganisms that consume the organic matter in the wastewater. The influent is inoculated with RAS (see #5) at this stage. The aeration tanks and step #4, the final clarifiers, are called the secondary treatment process. Detention time: 3.5 hours.

#3 Mixed liquor chamber: This chamber acts as a collection point for the water from the aeration tanks and a distribution center as the wastewater is divided to the final clarifiers.

#4 Final (secondary) clarifiers: These, like the primary clarifiers, allow the finer particles to settle and the scum to collect on the surface to be removed by a skimmer. There are nine final clarifiers at Field's Point. Six clarifiers on average are on-line at a time. Detention time: 4.3 hours.

#5 Return activated sludge system: The solids that settle to the bottom are considered the activated sludge (primarily microbe laden organic matter). A portion of the activated sludge, the RAS, is returned to the aeration tanks to inoculate more recent influent with established populations of organisms. The rest, called waste activated sludge (WAS), is shunted elsewhere in the facility to be further condensed and disposed of as dry solids. The adjustment of the ratio of RAS to WAS is one control mechanism of the plant operators. In August 1998, the FPWWTF RAS:WAS averaged 12.23 MGD: .62 MGD, or 20:1.

#6 Chlorine contact tanks: This final stage doses the secondary treated wastewater with hypochlorite and allows the wastewater to flow through maze-like channels to allow extended exposure at the given concentration of chlorine before exiting the plant and being diluted in the Narragansett Bay. Detention time: 18 minutes.

Appendix 2. Glossary

BOD - biochemical oxygen demand

F/M ratio (Food/Mass ratio) - amount of food available to organisms

MCRT- mean cell residence time

MLDO – mixed liquor dissolved oxygen

MLSS - mixed liquor suspended solids

MLVSS - mixed liquor volatile suspended solids

NH₃ - ammonia

Sludge age – amount of time organisms have to reproduce in reactor

SVI - sludge volume index

TSS - total suspended solids

Appendix 3. Preliminary Investigation of FPWWTF Fecal Coliform Problems

Primary researcher: Phil Albert, Chief Sanitary Engineer

Data evaluated: log effluent fecal coliform data, influent water temperature, flow, chlorine dose, chlorine use, effluent ammonia nitrogen, ammonia nitrogen removed, effluent TSS, MLSS, MLVSS, and MCRT (see glossary),

136 observations, January 1995 – September 1997

Results of regression analyses (dependent variable: log fecal coliform):

	All Data (136 observations)	January-June Data (72 observations)	July-December Data (64 observations,)	July-December 1995 Data (26 observations)
Temperature (water)	0.33 (.11)	0.43 (.08)	-0.077 (.01)	-0.054 (.002)
NH ₃ removed	0.25 (.06)	0.30 (.09)	-0.062 (.004)	-0.258 (.07)
MLSS	-0.24 (.06)	-0.21 (.05)	0.014 (.0002)	-0.417 (.17)
Chlorine dose	0.24 (.06)	0.32 (.10)	-0.033 (.001)	0.028 (.0008)
MLVSS	-0.23 (.05)	-0.21 (.04)	-0.023 (.0005)	-0.532 (.28)
Chlorine use	0.18 (.03)	0.27 (.07)	-0.082 (.007)	0.022 (.0005)
Flow	-0.17 (.03)	-0.19 (.04)	-0.097 (.009)	0.017 (.0002)
MCRT	-0.09 (.01)	-0.06 (.003)	-0.093 (.009)	-0.244 (.06)
Effluent NH ₃	-0.09 (.01)	-0.25 (.06)	0.213 (.05)	0.292 (.09)
Effluent TSS	0.07 (.004)	0.12 (.01)	0.078 (.006)	0.051 (.003)

Appendix 4. Prechlorination – Post-chlorination (effluent) fecal coliform comparison.

Introduction

Several factors caused NBC to believe the efficiency of chlorine was a source of effluent fecal coliform problems at FPWWTF. A pilot study of ultraviolet (UV) disinfection performed at Bucklin Point WWTF, NBC's other wastewater plant, in 1993, showed consistently better effluent fecal coliform results from the UV method of disinfection (Cote 1993). Wanner (1994) indicates that the presence of nitrates and nitrites (the by-product of nitrification) in the wastewater entering the chlorine contact chambers can lead to coupling of the chlorine to form chloramines which are less effective disinfection agents. This information was supported by an investigation of fecal coliform problems at BPWWTF between 1992-1995. Fecal coliform problems correlated with nitrifying conditions (the presence of nitrifying bacteria and/or septic conditions in some of the plant's tanks) which increased the concentration of nitrates and nitrites in the wastewater. Secondly, the fecal coliform problems also correlated with increased amounts of filamentous bacteria in the mixed liquor and presumably the wastewater entering the chlorine contact chamber. This condition supported another hypothesis of causation that the filaments, or floc associated with them, acted as a shield for fecal coliform bacteria and thus provided a physical barrier that reduced chlorine efficiency.

This portion of the study is intended to further localize the fecal coliform problem to the chlorine contact chamber. The hypothesis is the variation in the post-chlorination (effluent) fecal coliform does not show consistent correlation with the prechlorination fecal coliform levels.

Materials and Methods

Twenty grab samples of prechlorinated wastewater were taken from the trough of the Sigma composite sampler located in the water pumping station of FPWWTF^{A1} between June and September of 1998,. The sample times were synchronized with the routine daily grab sampling of final effluent, generally 12:30 p.m.^{A2}. All fecal coliform samples were taken in sterile 150 mL Pyrex® water collection bottles and processed within two hours of sample collection. Insulated coolers with ice packs were used to transport the samples between facilities.

^{A1} Initially, it was hypothesized that a grab sample from the trough of the Sigma composite sampler would represent the fecal coliform level in the prechlorinated wastewater of the plant differently from hand-composited samples taken directly from the weirs of all the on-line clarifiers, as the Sigma sampler only samples from 6 of the 9 operational clarifiers. A preliminary study was run comparing these two types of samples. See Appendix 3 for details.

^{A2} The final effluent sample was taken from the discharge of the chlorine contact tank. No delay between the sample times was used because the detention time in the chlorine contact tank is only 20 minutes, and the proximity of the sampling times for prechlorinated wastewater and the final effluent was beneficial as a control for other environmental factors which could potentially affect the chlorination process.

Similar sampling was performed in a different study between August and October of 1996. The data from these 20 sampling dates was analyzed as well. Log fecal coliform values were used in all analysis.

Results

The prechlorination fecal coliform results for 1996 and 1998 showed enormous variation between 21,000 and 2,800,000 MPN. However, the 1998 data showed less variation and had a smaller mean perhaps representing more thorough and consistent primary and secondary treatment in recent years. The post-chlorination fecal coliform results showed relatively consistent variation in both 1996 and 1998 with a slightly lower mean in 1998. The range was 2 to 900 MPN. The days of effluent fecal coliform permit exceedances did not correlate with the days of maximum prechlorination fecal coliform levels.

Conclusions

The lack of correlation between the effluent fecal coliform permit exceedances and prechlorination fecal coliform maximums supported the hypothesis that the problem with fecal coliform levels occurred because of varying efficiency of the chlorination stage.

Appendix 5. Prechlorination fecal coliform comparison of Sigma sampler and Hand-compiled samples.

Introduction

Field's Point WWTF has nine clarifier tanks. Three of the tanks began operation only in 1997 while the other six have been operational since 1987. A Sigma composite sampler for taking periodic bioassay samples is attached to the older six clarifiers. Of the nine operational tanks, an average of six are on-line at a time. The comparison of hand-compiled grab samples and the grab sample taken from the trough of the Sigma sampler was made in an effort to establish if the Sigma sampler, a faster and more consistent method of sampling, provides accurate prechlorination fecal coliform results despite only sampling a subset of the on-line clarifiers.

Materials and Methods

Hand-compilation samples were collected from the overflow weirs of each on-line clarifier. The other sample was taken from the trough of the Sigma composite sampler located in the FPWWTF water pumping station. All fecal coliform samples were taken in sterile 150 mL Pyrex® water collection bottles and processed within two hours of collection. The hand-compilation was made in 1L polyurethane Nalgene® bottles. All samples were taken at 12:30 p.m. each sample day. A total of twenty samples were collected on ten separate dates. Triplicate tests were run on four separate dates, twice on each sample.

Multiple tube fermentation technique, as described in *Standard Methods* (AHPA, 1995) was used to generate an MPN (most probable number) of fecal coliform bacteria for both types of samples.

Results

A graphical comparison was made of all clarifiers sampled for each parameter. No clarifier appeared consistently higher or lower for any parameter assessed.

Conclusion

While the number of sample dates was undoubtedly limited, the conclusion reached is that the variation of results of the multiple tube technique within a single sample is greater than that shown between different samples. The Sigma sample was accepted as an appropriate measure of prechlorination fecal coliform levels.

Appendix 6. Final Clarifier Comparison.

Introduction

The central focus of this study, the attempt to correlate both mixed liquor microbial populations and related ecological parameters with effluent fecal coliform levels, is based on the premise that each tank of the final clarifiers provides consistent treatment to the flow of wastewater. This portion of the study was designed to test whether this assumption was supported by empirical evidence. The hypothesis was final clarifier tanks show no significant difference from each other in abundance and diversity of protozoa and filamentous bacteria and also depth of transparency.

Materials and Methods

The samples for the microscopic analysis were taken in 1L polyurethane Nalgene® bottles. Ten sample visits were made at various times of day (7:30 a.m., 10:00 a.m., and 12:30 p.m.). Of nine operational final clarifiers, the plant had an average of six final clarifiers on-line throughout the study. The clarifiers are numbered 1-3, and 8-13. (Clarifiers numbered 4-7 no longer exist.) The two groups of clarifiers 1-3 (operational since 1997) and 8-13 (operational since 1987) have separate splitter boxes at the discharge from the aeration tanks. Samples were taken from each of these two groups and two samples from group 8-13 were taken each time as well to look for possible biological distinctions within this group. Each sample time, #2, #8 or #10, and #13, or three of an average of six on-line clarifiers were sampled for a total of 30 samples.

In order to concentrate the organisms, the final clarifier samples were allowed to settle with loosened caps for surface aeration before being analyzed. Comparisons of densities of organisms between final clarifier and mixed liquor samples is not justified because of the different method of sample preparation. The microscopic analysis assessed seven groups of organisms. Direct counting method was used for amoeba, flagellates, free swimming ciliates, stalked ciliates, rotifers and worms. A relative abundance (0-6) score was used for assessing filamentous bacteria. Three slides for each final clarifier sample were examined.

A Secchi disk was used to measure transparency of the water in the clarifier tanks. Secchi disk transparency readings (meters) were made on all on-line final clarifiers when final clarifier samples were collected. Readings were made at the same time samples were collected (10 times on six clarifiers each time) for a total of 60 transparency measurements. The final clarifier depth of blanket (D.O.B.) data taken in the shift closest to the sample time, measured using a transparent, rigid tube, were obtained from the operations crew at FPWWTF and also used as a basis for final clarifier comparison.

Results

All three clarifiers showed significant microscopic population variation between days. The microorganisms which appeared in greater abundance, such as flagellates and free swimming and stalked ciliates, were easier to compare than those which were generally rare or absent, such as amoeba, rotifers and worms. The transparency also showed much variation between days but little variation between clarifiers. The range of depths of transparency was .29 to 2.05 meters.

Conclusions

The inter-tank variation was insignificant. This study supported the hypothesis that the tanks received wastewater of comparable composition from the mixed liquor chamber and that any changes occurring in the wastewater between the aeration tanks and the chlorine contact chambers was consistent through all tanks.