A Comprehensive Study on Disinfection Conditions in Public Swimming Pools in Pinellas County, Florida

Study Conducted
by
The Pinellas County Public Health Unit
and
The Occidental Chemical Corporation

Presented on Behalf of The Pool Study Team
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A Comprehensive Study on Disinfection Conditions in Public Swimming Pools in Pinellas County, Florida

Study Team

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Introduction

This presentation summarizes the disinfection results obtained from a comprehensive study on public swimming pools in Pinellas County, Florida. The study was conducted during the July-November, 1992 time period and was similar to the one carried out on 1500 pools in Pinellas County between 1973 and 1981. Although the 1992 study involved only 486 test pools, it was considerably more comprehensive than the 1973-81 study.

The study was conducted by a team of personnel from the Pinellas County Public Health Unit and the Occidental Chemical Corporation. It was very complex and required personnel with the appropriate professional background and experience.

The study produced some results that the pool study team found to be interesting and have some educational value. For this reason, the pool study team wanted to share the disinfection part of the study with you.

Purpose

The primary purposes of the study were:

- to determine the microbiocidal effectiveness of stabilized and unstabilized free chlorine in outdoor swimming pools
- to generate data that would enable the Pinellas County Public Health Unit to better understand the effects of various chemical and physical variables on the operation and physical conditions of the public swimming pools in their district.

Results/Conclusions

The salient results/conclusions of the disinfection study were:

- Free chlorine had more influence on the bacteria populations, and thus, the disinfection conditions, than all of the other variables.
- The proportion of bacteriologically unsatisfactory pools decreased significantly when the free chlorine concentration was 1 ppm or more.
- The proportion of bacteriologically unsatisfactory pools did not increase in the stabilized chlorine treated pools even when the cyanuric acid concentration exceeded 100 ppm.
- The results of the study verified the results of the 1973-81 Pinellas County, Florida study on 1500 pools.
- Free chlorine and clear water were found to be the best criteria for judging at poolside whether a pool is probably bacteriologically satisfactory for swimming.
- Adding pH and cyanuric acid as pool judgement criteria did not increase the relative ratio of bacteriologically satisfactory-to-unsatisfactory pools; it only decreased the number of pools that would be deemed satisfactory for swimming by the sanitarian or pool operator.
- Public swimming pools are more likely to be bacteriologically satisfactory for swimming if the 1.0 - 5.0 ppm free chlorine standard of the Florida Swimming Pool Code is applied instead of the 1.0 - 3.0 ppm free chlorine standard often applied by other
- The incidence of algae decreased significantly at free chlorine concentrations of 3 ppm or more.
- The incidence of algae did not increase in the stabilized chlorine treated pools even when the cyanuric acid concentration exceeded 100 ppm.

Discussion of Results

The conclusions of this study are based on results obtained from statistical analyses of data collected from 486 test pools. The test was designed so that the data would be as statistically valid as possible. This was achieved by:

- selecting a group of pools that would provide proper representative weighting of the pertinent variables;
- collecting data on each variable from each test pool;
- recording the data accurately in a computer database.

The test pools were selected with the aid of computer statistical programs and a database of > 2207 public swimming pools monitored by Pinellas County. This data analysis step produced some interesting results. For example, they showed that:

- ~ 95 % of the pools were located in apartment, condominium and tourist facilities;
- The average volume was < 35,000 gallons with ~ 95 % of the pools being < 60,000 gallons;
- ~ 58.7 % of the pools were treated with trichloroisocyanuric acid tablets.

The data used in the statistical analyses to determine the effects of various variables on the disinfection conditions of the test pools were generated from the variables in the following categories:

- Bacteria populations (Heterotrophic, Total coliform and Non-coliform)
- Water chemistry (chlorine, pH, TDS, total alkalinity, etc.)
- Turbidity
- Sanitizers (trichlor, bleach, cal hypo, etc.)
- Environmental characteristics (bather load, rain, etc.)
- Swimming pool characteristics (volume, surface type, surface conditions, etc.)
- Time (day, month, etc.)
- Algae (black, yellow, etc.)

The data for the water chemistry variables were obtained from measurements made on water samples at the sites of the test pools during unannounced inspections by the sanitarians from the Pinellas County Public Health Unit. The bacteriological data were generated from microbiological analyses of special water samples taken by the sanitarians. The bacteriological analyses were carried out by the Pinellas County Water Systems Laboratory as per standard protocols. The data for the other variables (pool characteristics, environmental, time, etc.) were obtained by physical measurements or visual observations by the sanitarians.

All data were recorded on data sheets by the sanitarians and then transferred to a master database by professional computer data entry personnel. The master dataset was then formatted and subjected to several statistical analyses techniques by a team of Occidental Chemical Corporation personnel. All of the statistical results and conclusions were reviewed by the pool study team for accuracy and validity.

It should be noted that the data were collected only once from each test pool. Also, all of the data were used in the statistical analyses even though the pool study team knew there were errors. This approach was employed because pool operators and public health units typically use one-time measurements to judge whether a pool is satisfactory or unsatisfactory for swimming. Thus, this approach provided the pool study team with the opportunity to assess the effectiveness of the various pool judgement procedures (swimming pool codes, etc.) and the relative importance of the variables used by the procedures on a "real world basis".

The first phase in the statistical analysis of the data involved the identification of variables that had the greatest influence on the disinfection conditions of the test pools. This objective was achieved with a correlation analysis technique which determined mathematically what variables had statistically significant relationships with the populations of Heterotrophic, Total coliform and Non-coliform bacteria. Heterotrophic and Total coliform bacteria are used by public health units to determine the disinfection conditions of drinking water and swimming pools. The pool study team used the Non-coliform bacteria analyses to determine if the Total coliform bacteria analyses were valid. The results clearly indicated that:

- **Free chlorine had more influence on the bacteria populations, indicators of disinfection conditions, than all other variables.**
- Batherload, cyanuric acid, total dissolved solids and water temperature had statistically significant influences on the bacteria populations but their influences were not as great as free chlorine.
- Filtration and pH did not have influences on the disinfection conditions in this study, apparently because the filtration systems were in good working condition and the pH's in most of the pools were < 7.8.
- None of the other variables had statistically significant influences on the disinfection conditions.

The results of the correlation analyses were printouts of mathematical coefficients. Hence, it was difficult to envision the quantitative effects of each variable on bacteria populations. As a consequence, a special data analysis technique was utilized to generate graphical illustrations that would make it easier to visualize the results. This step was achieved by a) calculating the statistical average of the dependent variables, bacteria populations, at specific concentrations of the independent variable (e.g., free chlorine, batherload, cyanuric acid, etc.) and b) plotting the statistical averages of the dependent variable as a function of the independent variable. The results **(Figures 1 - 11)** of this data analysis technique revealed that:

- The populations of the Heterotrophic, Total coliform and Non-coliform bacteria fell from unsatisfactory levels when the free chlorine was 1 ppm or more **(Figures 1 - 3)**.
- The population of the Total coliform bacteria increased as batherload increased **(Figure 4)**. Since the correlation analyses also indicated that the free chlorine decreased as the batherload increased **(Figure 5)**, this result simply indicated that the chlorine sanitizer had not been fed fast enough to maintain the free chlorine at sufficient levels to offset the contaminants (bacteria, sweat, etc.).
- The population of the Heterotrophic bacteria decreased as the cyanuric acid concentration increased **(Figure 6)**. The correlation analysis indicated that this effect was statistically significant because the data in **Figure 7** showed that the free chlorine concentration increased as the concentration of cyanuric acid increased.
- The Total coliform and Non-coliform bacteria populations increased when the total dissolved solids exceeded 3,000 ppm **(Figures 8 and 9)**. There was no obvious explanation for this relationship. One possible one is that pools with high total

dissolved solids have more colloidal suspensions of water insoluble materials that are not removed by filtration. Since bacteria can become imbedded in these particles, they can not be contacted readily by the free chlorine until the particle is chemically destroyed by the free chlorine. As a result, the bacteria populations would tend to be higher in pools with high total dissolved solids.

- The Total coliform and Non-coliform bacteria populations increased with increases in water temperature **(Figures 10 and 11)**. These relationships were not surprising because bacteria grow faster in warm water than in cold.

Since the results of the correlation analyses and the special data analysis technique demonstrated that free chlorine had by far the greatest influence on the bacteria populations and hence, disinfection conditions, the second phase of the data analysis involved the use of bacteria and free chlorine to develop models that enabled the pool study team to assess:

- the effectiveness of the procedures typically used by pool operators and public health units to judge whether a pool is satisfactory for swimming and
- the relative importance of the variables commonly used in pool judgement procedures.

The model data analyses were carried out in the following manner.

The **first step** involved the use of a model that determined the number and percentage of pools that had bacteria populations at or below the maximum contamination levels deemed necessary to meet the bacteria standards for swimming pool and drinking water. Note, this data analysis model **(Model A)** did not take into consideration free chlorine, pH or cyanuric acid measurements. The results **(Figure 12)** indicated that **80.2 %** (390 of the 486 test pools) were bacteriologically satisfactory for swimming and drinking water.

In the **second step,** the number and percentage of pools that would have sufficient (1.0 - 5.0 ppm) free chlorine to control the bacteria populations at or below the maximum contamination levels for pools and drinking water were determined. Note, this data analysis model **(Model B)** did not take into consideration the bacteria, pH and cyanuric acid data. The results in **Figure 13** showed that **69.1 %** (336 of the 486 test pools) had 1.0 - 5.0 ppm of free chlorine. These results obviously indicated that some of the pools in the Model A analysis had free chlorine concentrations of more than 5.0 and less than 1.0 ppm. However, the results did not indicate if all of the pools with 1.0 - 5.0 ppm of free chlorine were bacteriologically satisfactory for swimming.

In the **third step,** the bacteria and free chlorine criteria of Models A and B were combined and used to determine the number and the relative percentage of pools that were bacteriologically satisfactory for swimming and had sufficient free chlorine to maintain these desired bacteriological conditions. This model **(Model C)** data analysis was carried out by defining two pool categories:

- **SAT Pools:** pools satisfactory for swimming
- **UNSAT Pools:** pools unsatisfactory for swimming

and sorting the pools on the basis of the criteria shown below.

A swimming pool was placed in the **SAT** pool category if the pool **met every one** of the following criteria:

- Free chlorine: 1.0 - 5.0 ppm;
- Heterotrophic bacteria: < 501 CFU/ml;
- Total coliform bacteria: 0 CFU/100 ml; and
- Non-coliform bacteria: < 201 CFU/100 ml.

A swimming pool was placed in the **UNSAT** pool category if the pool **failed to meet one or more** of the criteria for the **SAT** pool. Thus, a pool was identified as an **UNSAT** pool if:

- Free chlorine: < 1.0 ppm or > 5.0 ppm; or
- Heterotrophic bacteria: > 500 CFU/ml; or
- Total coliform bacteria: > 0 CFU/100 ml; or
- Non-coliform bacteria: > 200 CFU/100 ml.

The results **(Figure 14)** of the **Model C** data analysis showed that **59.7 %** (290 of the 486 test pools) were judged to be **satisfactory for swimming** and **40.3 % were not.** They also clearly demonstrated how many pools were actually bacteriologically satisfactory for swimming and had sufficient (1.0 - 5.0 ppm) free chlorine to probably maintain satisfactory bacteriological conditions.

At first glance, these results were rather surprising since the results with the Model A data analysis technique above showed that 80.2 % of the test pools were bacteriologically satisfactory for swimming and only 19.8 % of the pools were not. However, examination of the data for the **UNSAT pools category** in greater detail revealed there were:

- **A subcategory of pools that met all of the bacteria criteria for the SAT pool category but failed to meet the free chlorine criterion because the free chlorine was < 1.0 ppm.** These pools obviously had sufficient free chlorine prior to the inspection because the bacteria population could not have possibly met bacteria criteria of the SAT pool category if the free chlorine had been < 1 ppm for several hours. Thus, the study team concluded that a) sufficient contaminants had been introduced to these pools only a few hours before the inspection to cause the free chlorine to fall below 1 ppm and b) not enough time had elapsed to allow the bacteria to grow to population levels that would exceed the maximum contamination levels and make the bacteriologically unsatisfactory for swimming.

- **A subcategory of pools that met all of the bacteria criteria for the SAT pool category but failed the free chlorine criterion because the free chlorine was > 5.0 ppm.** These results were not surprising since the probability is very high that the bacteria populations will be very low at free chlorine concentrations > 5.0 ppm.
- **A subcategory of pools that failed to meet the free chlorine criterion because it was < 1.0 ppm and at least one of the bacteria criteria for the SAT pool category.** These results were not surprising since the probability is very high that pools with < 1.0 ppm of free chlorine for any length of time will have bacteria populations above the maximum contamination levels for pools.
- **A subcategory of pools that met the free chlorine (1.0 - 5.0 ppm) and the Heterotrophic bacteria criteria. However, they failed to meet the Total coliform bacteria criterion because the Non-coliform bacteria population was > 200 CFU/100 ml.** These pools were probably bacteriologically satisfactory for swimming because the relationship between Heterotrophic bacteria and Total coliform populations **(Figure 15)** showed that if the Heterotrophic bacteria was < 500 CFU/ml, the probability was very high that the Total coliform bacteria would be essentially 0 CFU/100 ml and meet this criterion for SAT pools. Furthermore, the sanitarian would probably have deemed these pools satisfactory for swimming. In view of these facts, the pool study team considered placing these pools in the SAT pool category. This action would have raised the number and percentage of pools judged to be satisfactory by Model C to 304 and 62.6 %, respectively. But they elected to stick to the rigid criteria of Model C and leave the pools in the UNSAT category.
- **A subcategory of pools that failed to meet the free chlorine and the Heterotrophic and Total coliform bacteria criteria.** This subcategory contained 31 pools and had very high (> 10 ppm) free chlorine which indicated that the pools had probably been shocked just prior to the inspection.

After reviewing the results for the Model C data analysis, the pool study team decided that the results were logical. This was because the data are based on one-time grab samples of the water from each test pool. As a consequence, the data are only snapshots of the conditions of the test pool at the time the water samples were taken. Hence, they do not provide a historical picture of the disinfection conditions for each pool. Therefore, one would expect to find that bacteria and water chemistry conditions of some test pools would satisfy the criteria for **SAT** and **UNSAT** pools perfectly whereas there would always be a group of pools that didn't fit in either category very well but still had to be deemed **UNSAT** pools. **However, the data did provide a "real world" perspective of the conditions in the pools.**

Although the **Model C** data analysis technique is the only way to determine whether pools are bacteriologically satisfactory for swimming and have sufficient free chlorine to control the bacteria below the maximum contamination levels, it is not a practical method for judging whether pools are satisfactory for swimming. This is because bacteria analyses are time consuming and cost prohibitive. As a result, public health units and pool operators rely on the traditional variables of free chlorine, pH and clear water to judge whether a pool is probably bacteriologically satisfactory for swimming. Experience has shown that this is a practical and cost effective approach. However, sometimes the pool judgement procedures contain several variables. As a result, they are more complicated, thereby making it difficult for the pools to be in compliance with swimming pool codes. For this reason, the next steps in this part of the data analysis focused on determining the relative importance of pH and cyanuric acid.

In the **fourth step,** the **Model D data** analysis technique was used to determine the effect of pH. This was achieved by taking Model B, adding pH (7.2 - 7.8) as an additional criterion and then conducting the data analysis. The results **(Figure 16)** showed that only **58.6 % (285 of 486 test pools)** would be deemed satisfactory for swimming. Obviously, the percentage of satisfactory pools with Model D was significantly less than with Model B and the decrease in percentage was due to the addition of pH to the judgement model.

The effect of cyanuric acid was determined in the **fifth step** by taking Model D, adding cyanuric acid (100 ppm) as an additional criterion and then conducting the **Model E** data analysis. Thus, the criteria for **Model E** were: 1) free chlorine (1.0 - 5.0 ppm); 2) pH (7.2 - 7.8); and 3) cyanuric acid (100 ppm). **Model E is basically the Florida Swimming Pool Code.** The results **(Figure 17)** of the data analysis showed that **only 41.4 % (201 of the 486 test pools)** would have been deemed **satisfactory** for swimming by the sanitarian and **60.6 % would not. This significantly lower percentage of satisfactory pools is due to one factor--the 100 ppm cyanuric acid limit.**

In the **sixth step, Model F** was used to generate data that permitted the team to **compare the effectiveness of other state swimming pool codes to the Florida swimming pool code.** This task was achieved by changing the free chlorine standard of the Model E (Florida code) from 1.0 - 5.0 to 1.0 - 3.0 ppm and then carrying out the data analysis. The results **(Figure 18)** for **Model F** revealed that **an even lower percentage, 20.8 % (101 of the 486) of the test pools** would have been judged **satisfactory for swimming** and **79.2 % would not. This very low percentage of satisfactory pools is due to a combination of two factors: 1) the 100 ppm cyanuric acid limit; and 2) the narrower free chlorine range of 1.0 - 3.0 ppm.**

Figure 19 summarizes the results of all of the model analyses. They obviously demonstrate that the number of the test pools that were deemed satisfactory for swimming decreased significantly as the complexity (use of more judgement criteria) of the pool judgement model increased from the simplest models **(Models A and B)** to the more complex models **(Models E and F).**

Many will argue that using more complex judgement models is a sound approach because the more variables (or criteria) that are monitored the greater the probability that the pools will be bacteriologically satisfactory for swimming. This would be true if the criteria were surrogates of the bacteria indicators. **However, Models B, D, E and F do not utilize bacteriological data as judgement criteria. Therefore, the results for**

these models do not indicate how many of the pools deemed satisfactory for swimming by the models were actually bacteriologically satisfactory for swimming.

For this reason, data analyses were conducted to determine how many of the pools judged to be satisfactory for swimming by **Models B, D, E and F** were actually bacteriologically satisfactory for swimming. This objective was achieved utilizing the bacteria criteria from Model C to conduct the data analysis on each model. The results which are summarized in **Figure 20** revealed that with:

- **Model A,** which used bacteria criteria only, **390 (80 %) of the 486** test pools were **bacteriologically satisfactory** for swimming and **96 (20 %) were not.**
- **Model B,** which used free chlorine as the only criterion, **290 (86.6 %) of the 335 pools** were **bacteriologically satisfactory for swimming** and **45 (13.4 %) were not.**
- **Model C,** which used the bacteria and free chlorine criteria from Models A and B, **100 %** of the 290 pools judged to be satisfactory for swimming were **bacteriologically satisfactory for swimming** and **none** were **bacteriologically unsatisfactory for swimming.**
- **Model D,** which used free chlorine and pH as the only judgment criteria, **245 (86 %)** of the **285 pools were satisfactory for swimming from a bacteriological standpoint and 40 (14 %) were not.**
- **Model E (Florida swimming pool code),** which is basically Model D plus the 100 ppm cyanuric acid as an additional judgment criteria, **173 (86.1 %) of the 201 pools judged to be satisfactory were bacteriologically satisfactory for swimming and 28 (13.9 %) were not.**
- **Model F, basically the same as Model E but with a narrower free chlorine criterion (1.0 - 3.0 ppm instead of 1.0 - 5.0 ppm), 86 (85.1 %) of the 101 pools were bacteriologically satisfactory for swimming and 14 (14.9 %) were not.**

The combination of these results were very surprising indeed. This is because they indicated that regardless of what judgment model was used outside of the bacteriologically rigid Models A and C, the **relative percentage of bacteriologically satisfactory and unsatisfactory pools remained essentially the same, ~ 86 and 14 %, respectively.** Thus, the addition of each additional judgment criterion to a procedure did not change the relative percentage of bacteriologically satisfactory and unsatisfactory pools; it only reduced the number of pools judged to be satisfactory for swimming. In other words, **using a complex judging method does not result in a more effective pool judgement procedure; it only increases the number of pools that will be rejected.**

Data analyses were also conducted to determine if **algae** had an effect on the disinfection conditions of the test pools. The results **(Figure 21)** showed:

- Algae was observed in **39.9 %** (194 of 486) the test pools.
- Black algae was present in **35.4 %** of the 486 test pools, especially in plaster pools with surfaces in poor condition.
- Yellow algae was present in only **6.6 %** of the 486 test pools.

The results of an extent of growth data analysis revealed that the sanitarian had to kneel at pool side and look into the water to find algae in **82.5 %** of the algae pools. Thus, the extent of growth of algae in 82.5 % of the pools was barely perceptible.

The results of the correlation data analyses and the special graphing data analyses revealed:

- **There were no statistically significant relationships between algae and bacteria populations.**
- **Free chlorine had more influence on the incidence of black and yellow algae than any of the other variables (Figures 22 and 23).**

In view of these results, the pool study team then determined what free chlorine concentration would most likely minimize the incidence of algae in pools. **The results of this data analysis showed that the algae free pools had an average free chlorine concentration above 3.0 ppm whereas pools with algae averaged nearly 1 ppm less (Figure 24).** They also indicated that a higher free chlorine concentration was required to minimize the presence of algae in pools than was required to maintain satisfactory bacteriological conditions.

These results prompted the pool study team to conduct a data analysis to determine the proportion of pools with and without algae in the pools judged satisfactory for swimming by the pool judgement models Models A - F. The results **(Figure 25)** showed that the **relative percentages of pools without and with algae were ~ 61 and 39 %, respectively, regardless of the model.** They also indicated that free chlorine is the most effective criterion to use to determine if the pool has sufficient free chlorine to minimize algae. Thus, the use of more complex pool judgement models does not necessarily increase the probability of minimizing the incidences of algae; **maintaining sufficient free chlorine concentrations in the pools is still the most effective approach.**

These results were very surprising and interesting because they indicated that it **was possible for a pool to have algae and still be bacteriologically satisfactorily for swimming. They also indicated that it is easier to maintain bacteriologically satisfactory conditions than it is to keep a pool free of algae.**

Summary

The results of this study clearly demonstrated that:

- Free chlorine has by far the greatest influence on the disinfection conditions and the incidence of algae in pools than any other variable.
- Other variables can affect the disinfection conditions but their effects can be easily controlled by maintaining free chlorine at the appropriate concentration continuously.
- Swimming pool operations that use a 1.0 - 5.0 ppm free chlorine range have a greater probability of being bacteriologically satisfactory for swimming than those that use a 1.0 - 3.0 ppm range.
- Higher (3.0 ppm or more) free chlorine concentrations are required to reduce the incidence of algae than are required to maintain adequate disinfection conditions.
- High cyanuric acid did not negatively impact the disinfection conditions or the incidence of algae.

On the basis of the results of this study, we conclude that it was more important to maintain the proper level of free chlorine in the swimming pool continuously than to be concerned about the cyanuric acid concentration limit of 100 ppm. This conclusion is based on the fact that the results demonstrated that swimmers are not at risk bacteriologically in swimming pools with high cyanuric acid concentrations as long as the free chlorine is maintained at 1.0 ppm or more continuously. Thus, the results indicate that it is feasible to raise the cyanuric acid limits significantly above the current limit of 100 ppm and still have the swimming pools sanitized satisfactorily.

Allowing higher cyanuric acid levels in and applying the 1.0 - 5.0 ppm free chlorine standard of the Florida code to public swimming pools, most of which are located in apartment and condominium facilities, would provide greater freedom for the swimming pool operations with regard to free chlorine concentrations and choice of sanitizers. For these reasons, the EPA and the state swimming pool regulatory agencies should be petitioned to increase the free chlorine and cyanuric acid standards for public swimming pools.

FIGURE 1: EFFECT OF FREE CHLORINE ON HETEROTROPHIC BACTERIA POPULATION

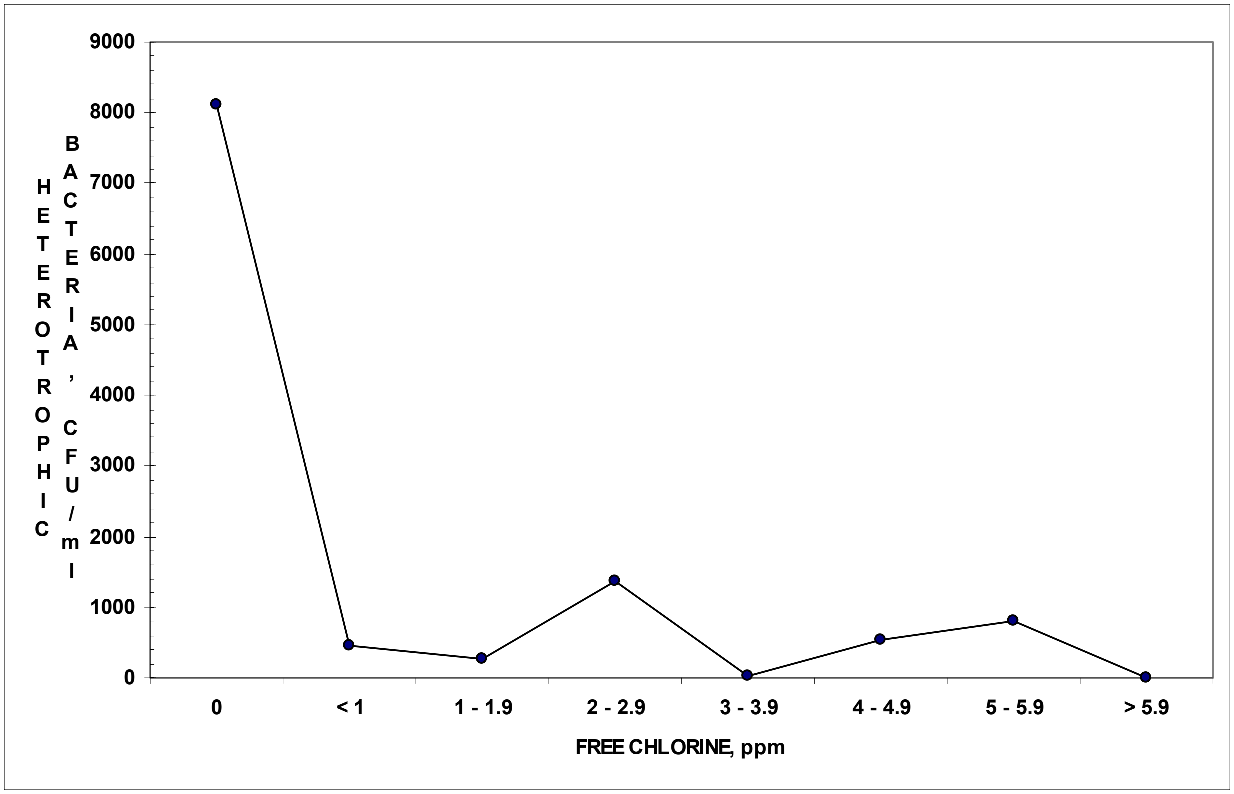

FIGURE 2: EFFECT OF FREE CHLORINE ON TOTAL COLIFORM BACTERIA POPULATION

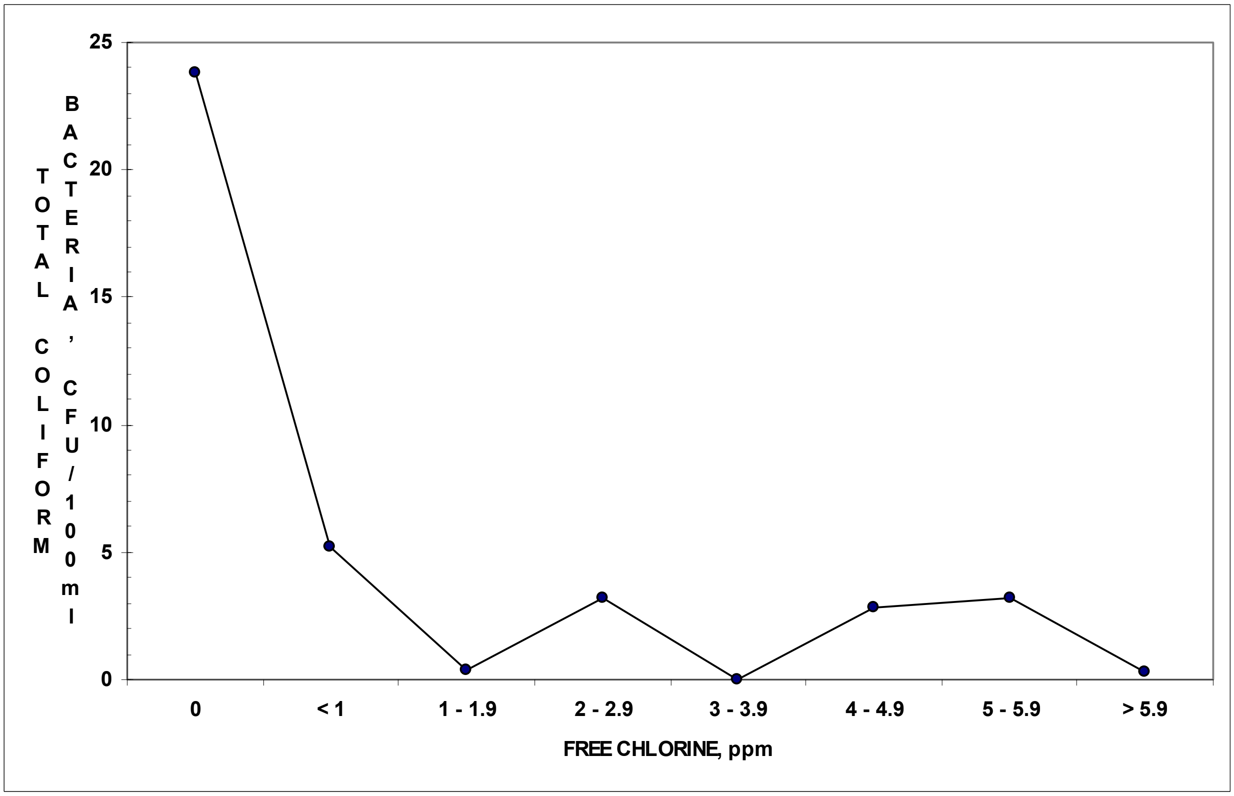

FIGURE 3: EFFECT OF FREE CHLORINE ON NON-COLIFORM BACTERIA POPULATION

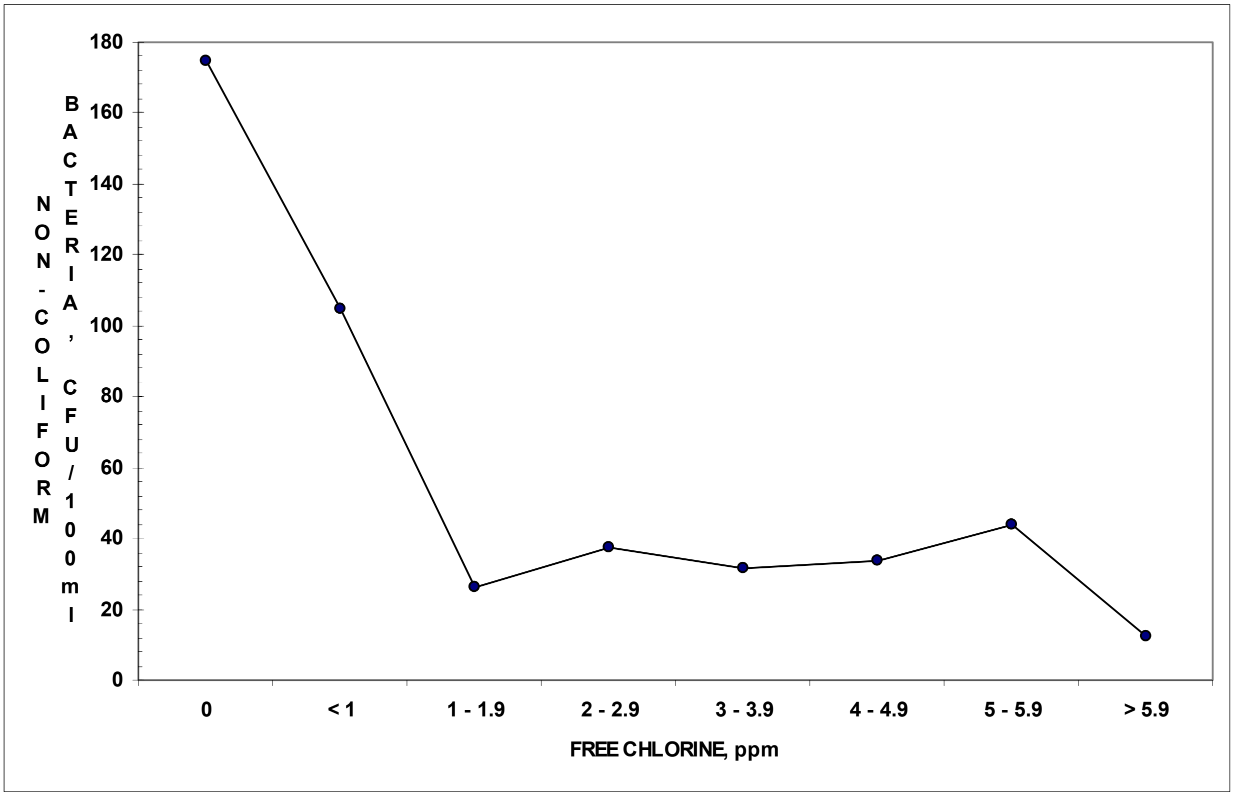

FIGURE 4: RELATIONSHIP BETWEEN TOTAL COLIFORM BACTERIA POPULATION AND BATHERLOAD

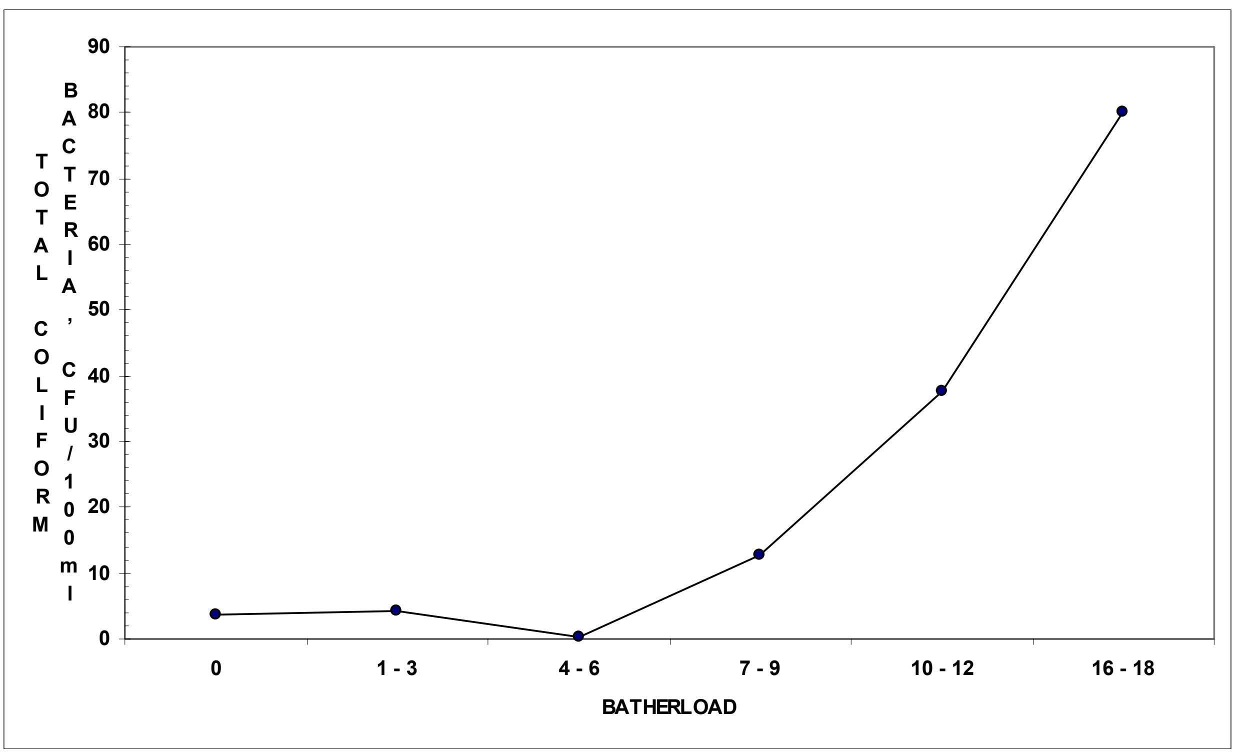

FIGURE 5: RELATIONSHIP BETWEEN FREE CHLORINE AND BATHERLOAD

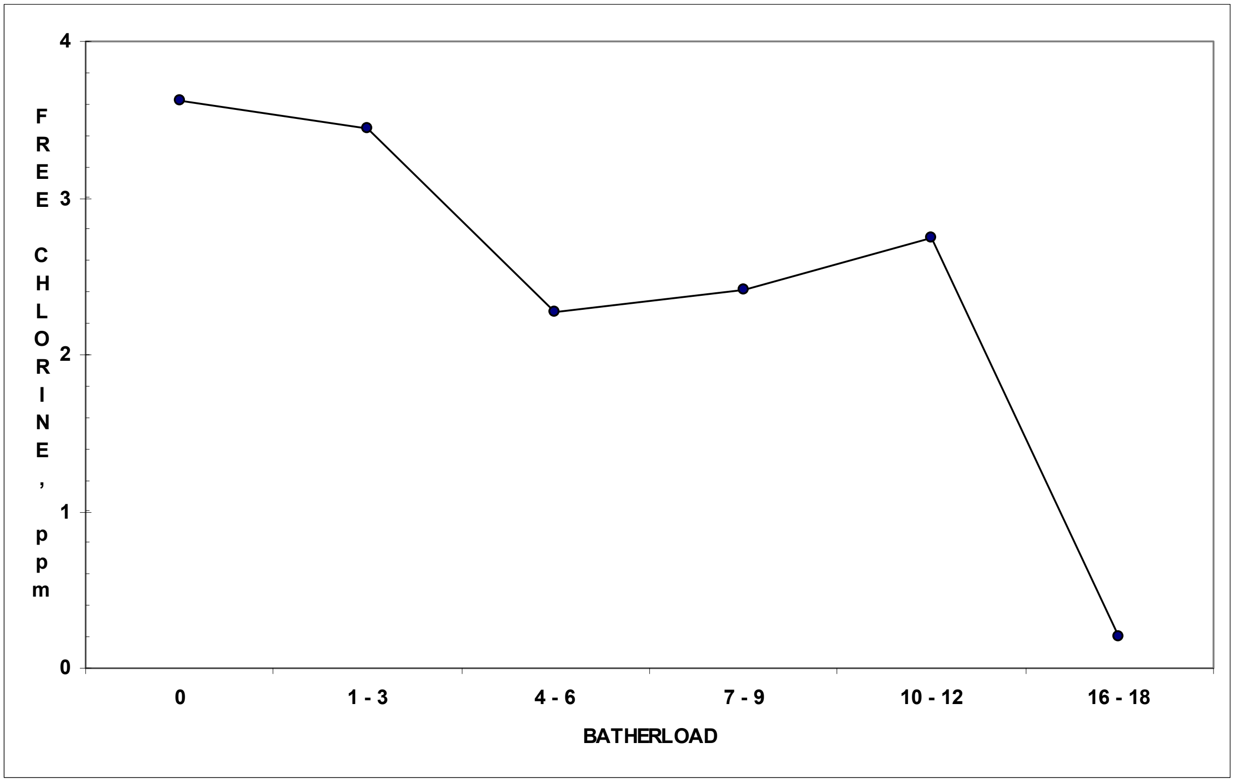

FIGURE 6: RELATIONSHIP BETWEEN CYANURIC ACID AND HETEROTROPHIC BACTERIA POPULATION

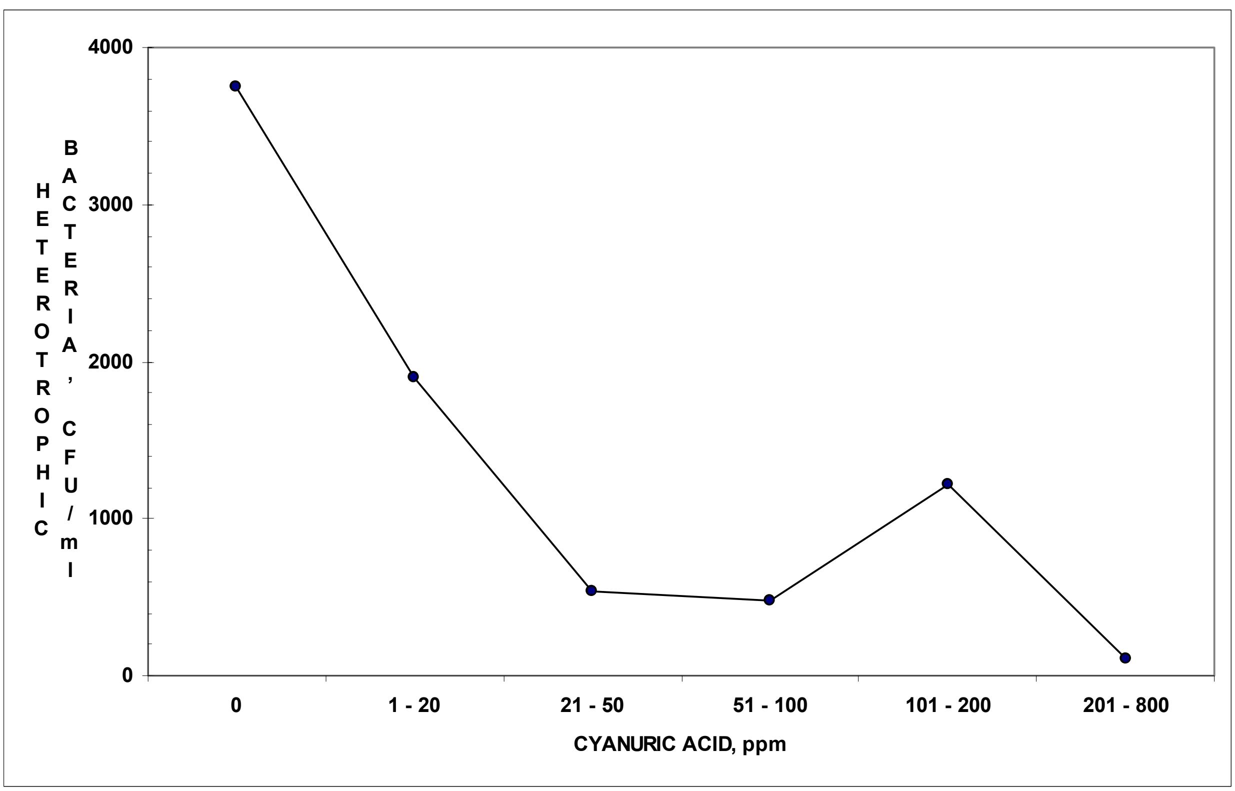

FIGURE 7: RELATIONSHIP BETWEEN CYANURIC ACID AND FREE CHLORINE

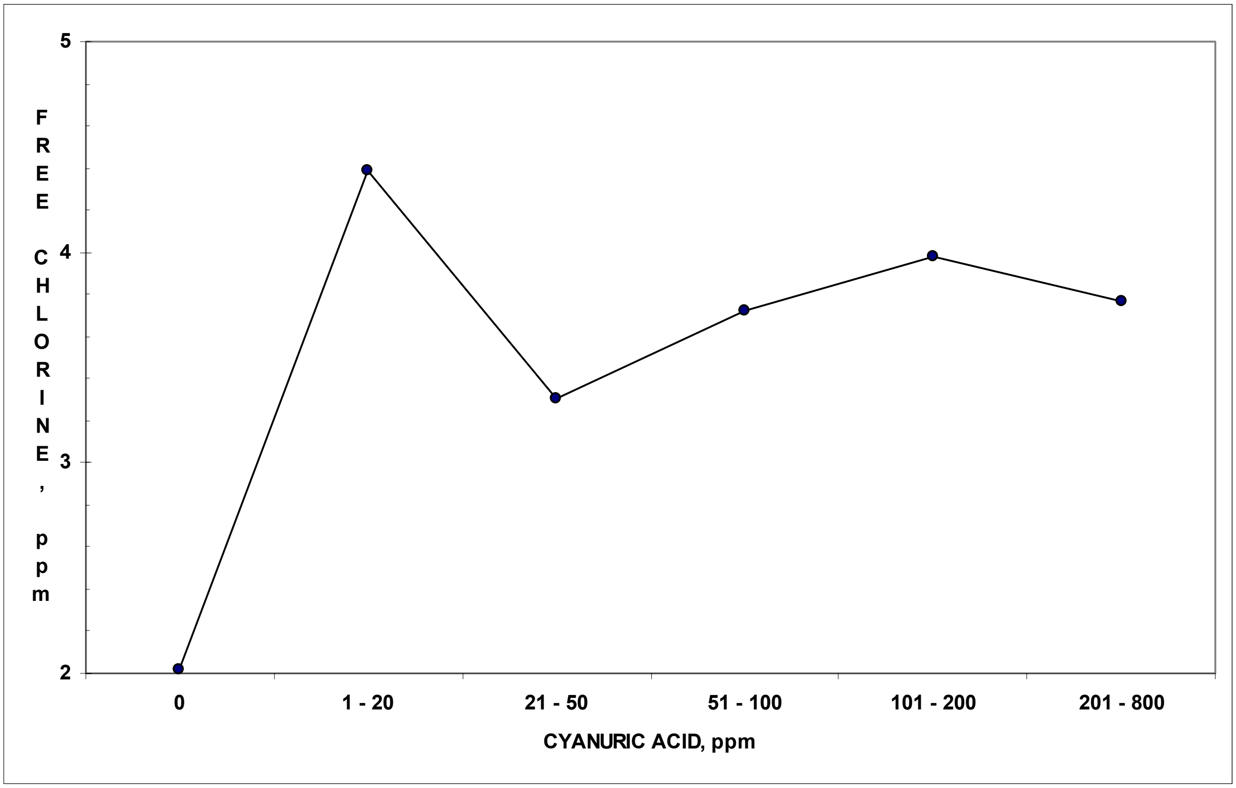

FIGURE 8: RELATIONSHIP BETWEEN HETEROTROPHIC BACTERIA POPULATION AND TOTAL DISSOLVED SOLIDS

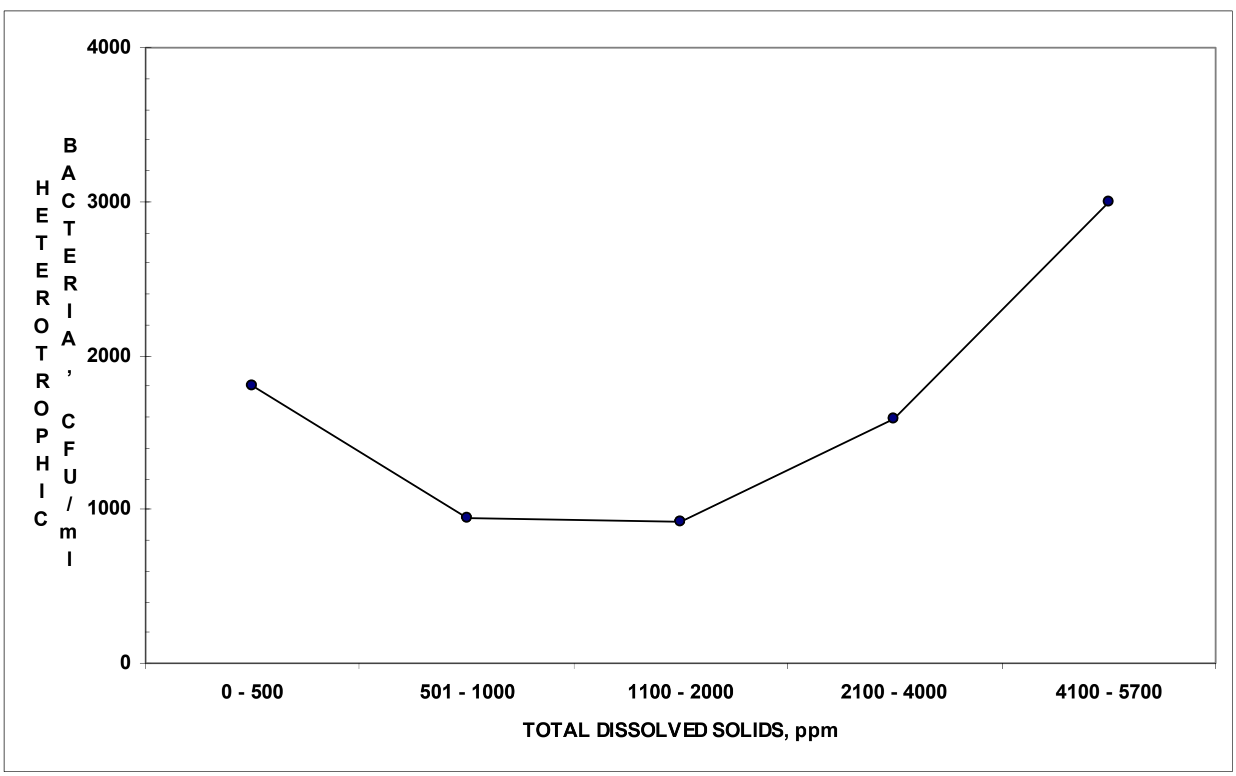

FIGURE 9: RELATIONSHIP BETWEEN TOTAL COLIFORM BACTERIA POPULATION AND TOTAL DISSOLVED SOLIDS

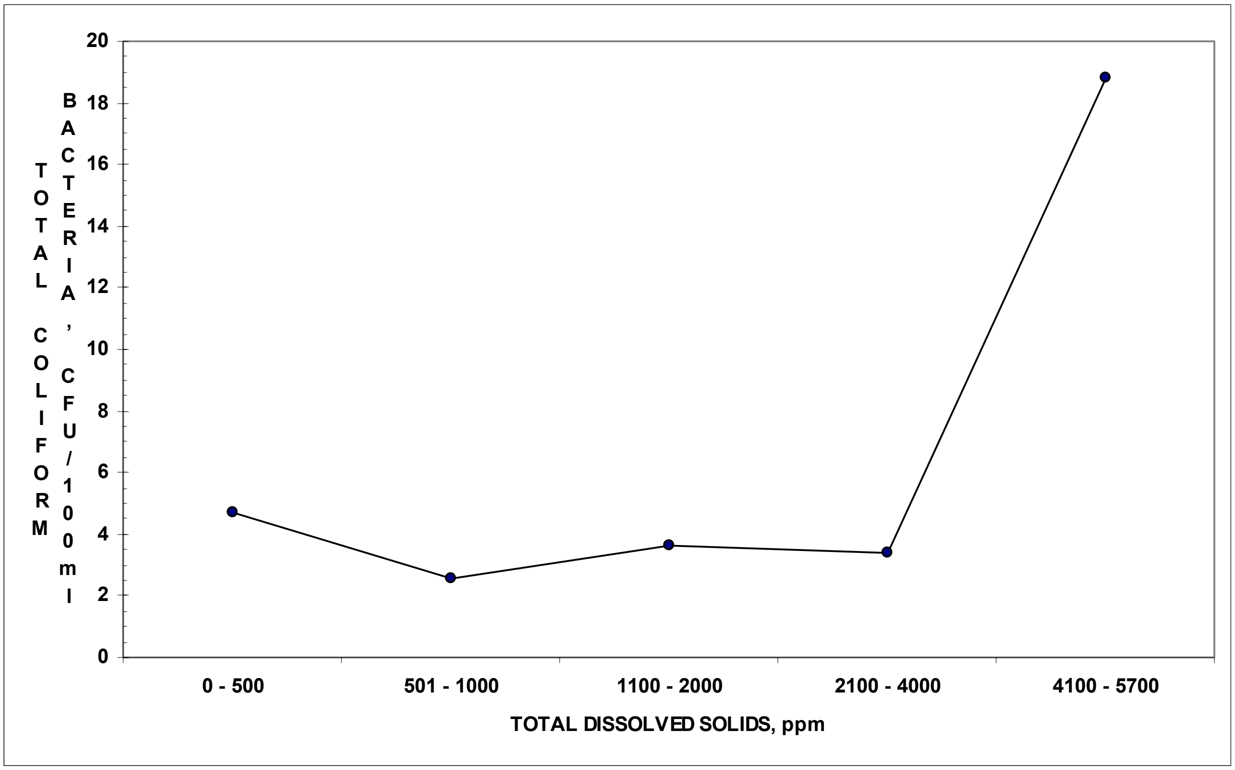

FIGURE 10: RELATIONSHIP BETWEEN TOTAL COLIFORM BACTERIA POPULATION AND WATER TEMPERATURE

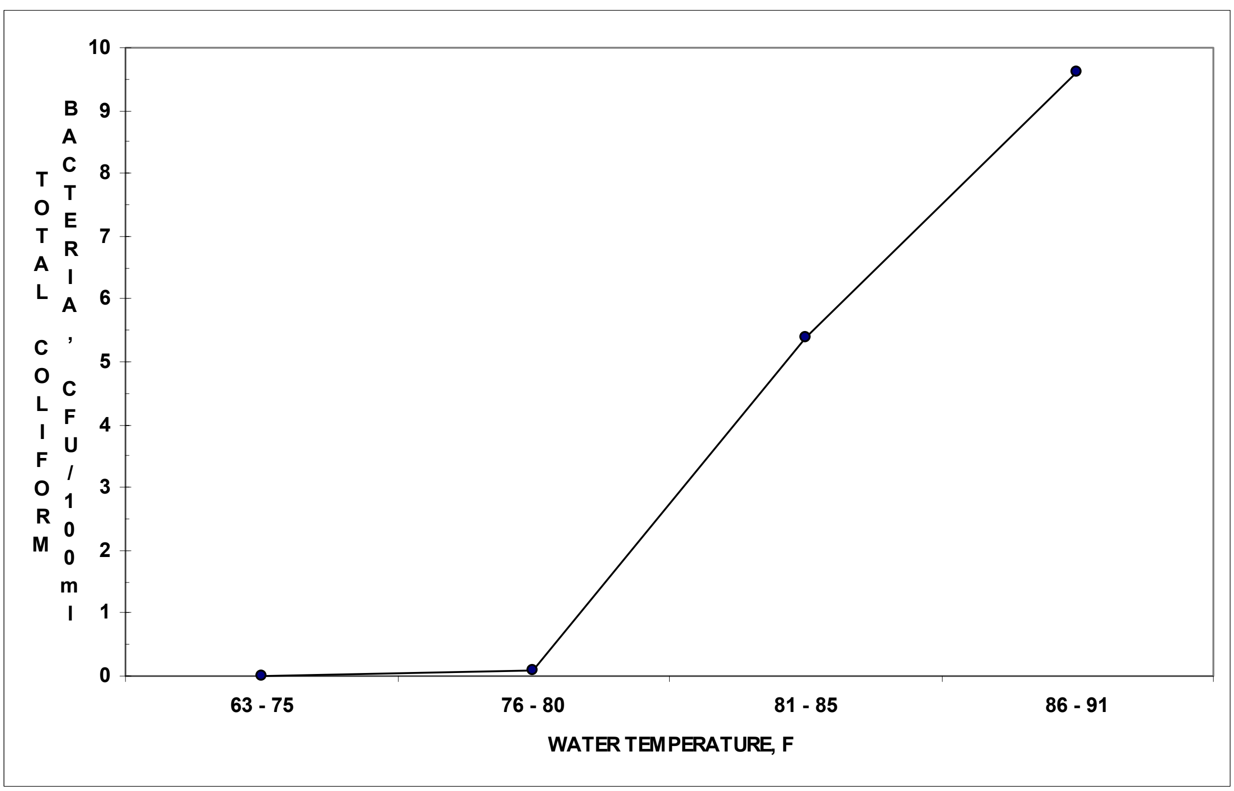

FIGURE 11: RELATIONSHIP BETWEEN NON-COLIFORM BACTERIA POPULATION AND WATER TEMPERATURE

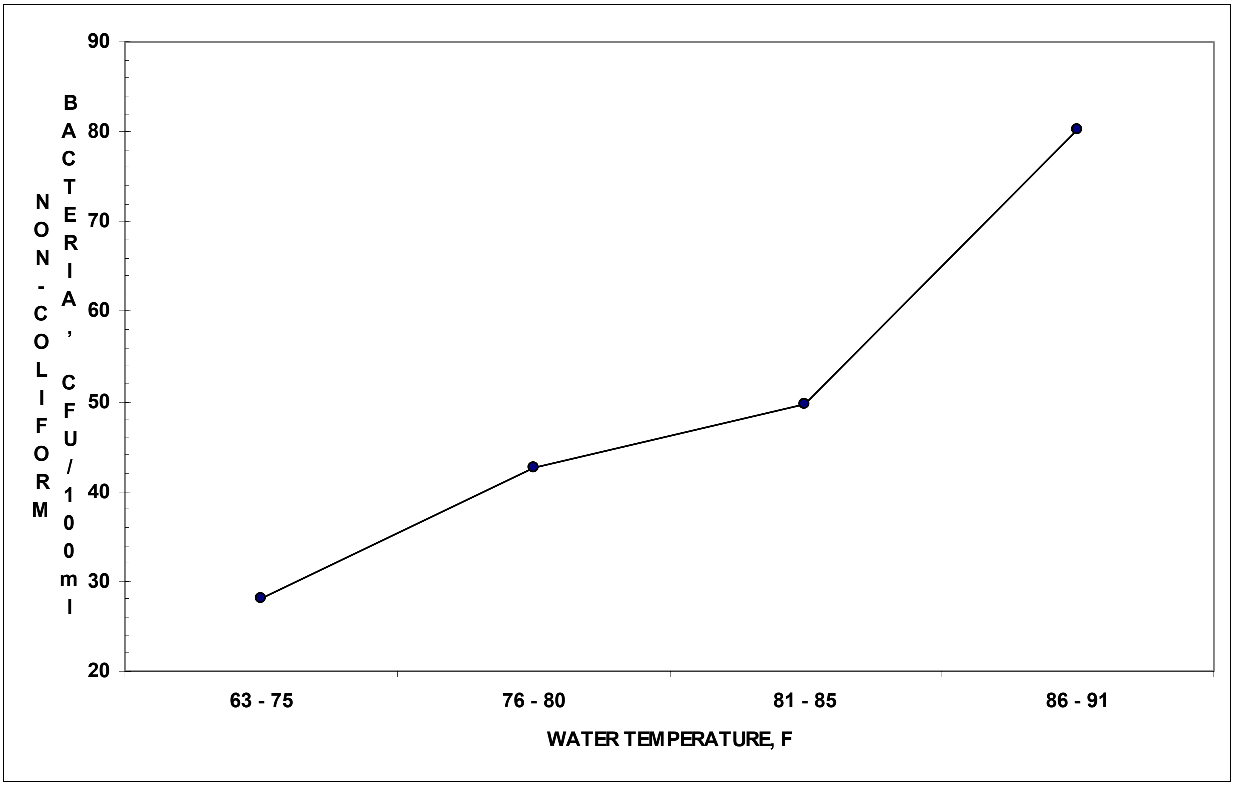

FIGURE 12: % OF POOLS DEEMED SATISFACTORY AND UNSATISFACTORY
FOR SWIMMING BY MODEL A CRITERIA (BACTERIA ONLY)

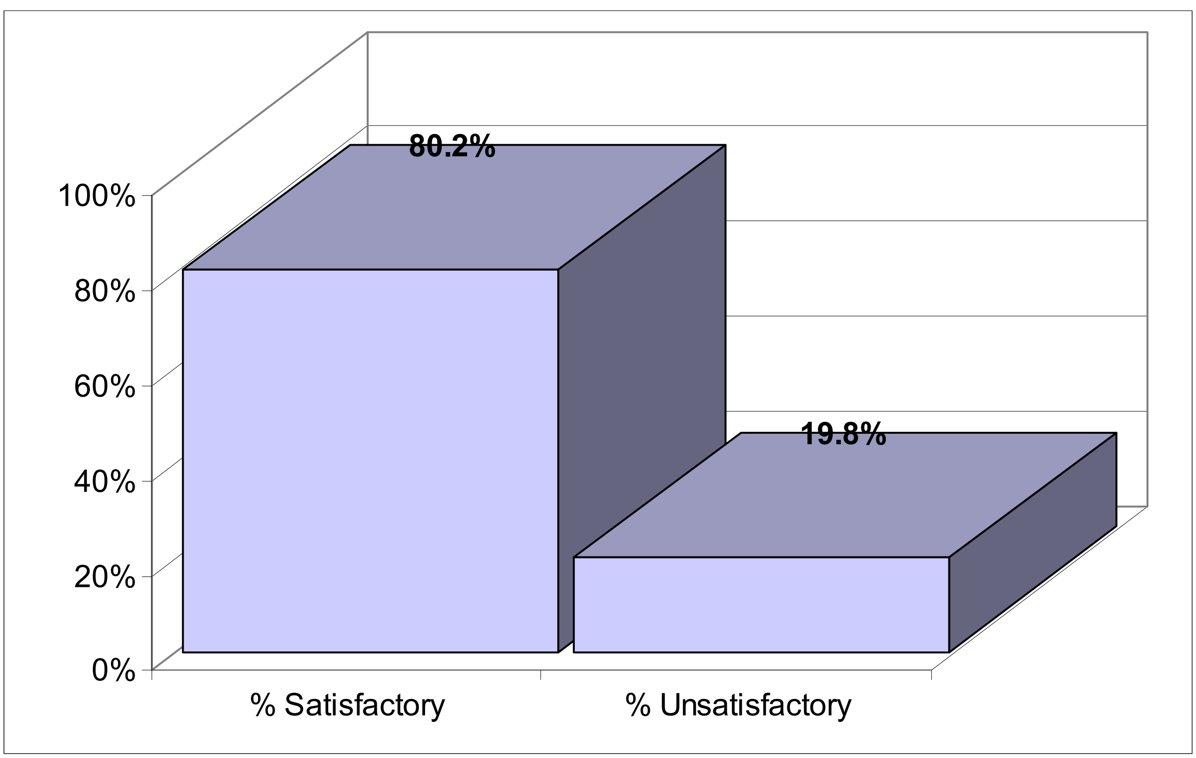

FIGURE 13: % OF POOLS DEEMED SATISFACTORY AND UNSATISFACTORY FOR SWIMMING BY MODEL B CRITERIA (FREE CHLORINE)

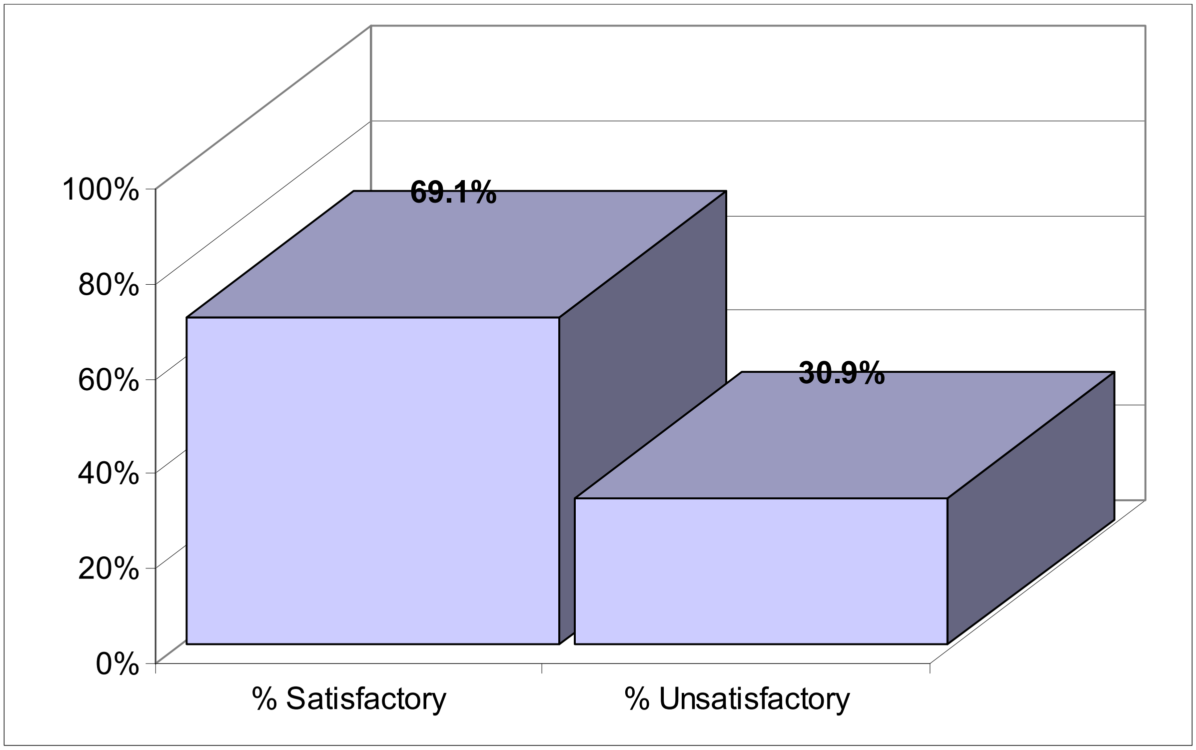

FIGURE 14: % OF POOLS DEEMED SATISFACTORY AND UNSATISFACTORY FOR SWIMMING BY MODEL C CRITERIA (BACTERIA AND FREE CHLORINE)

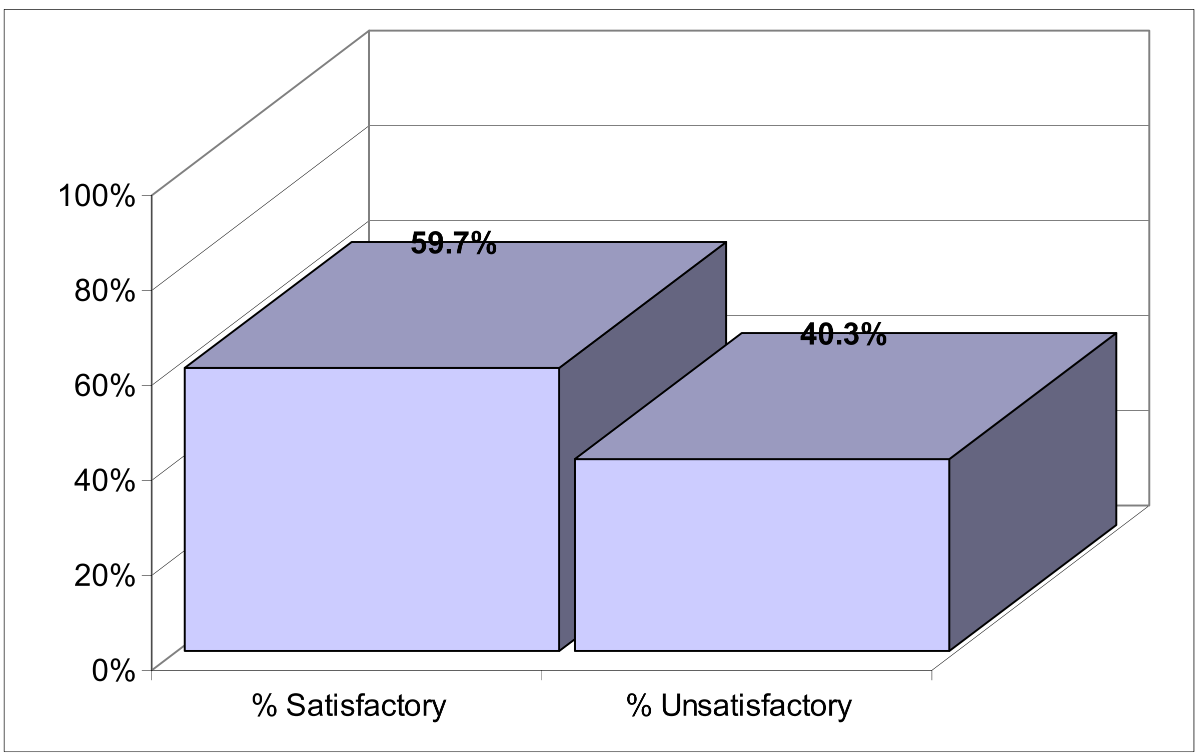

FIGURE 15: RELATIONSHIP BETWEEN HETEROTROPHIC AND TOTAL COLIFORM BACTERIA POPULATIONS

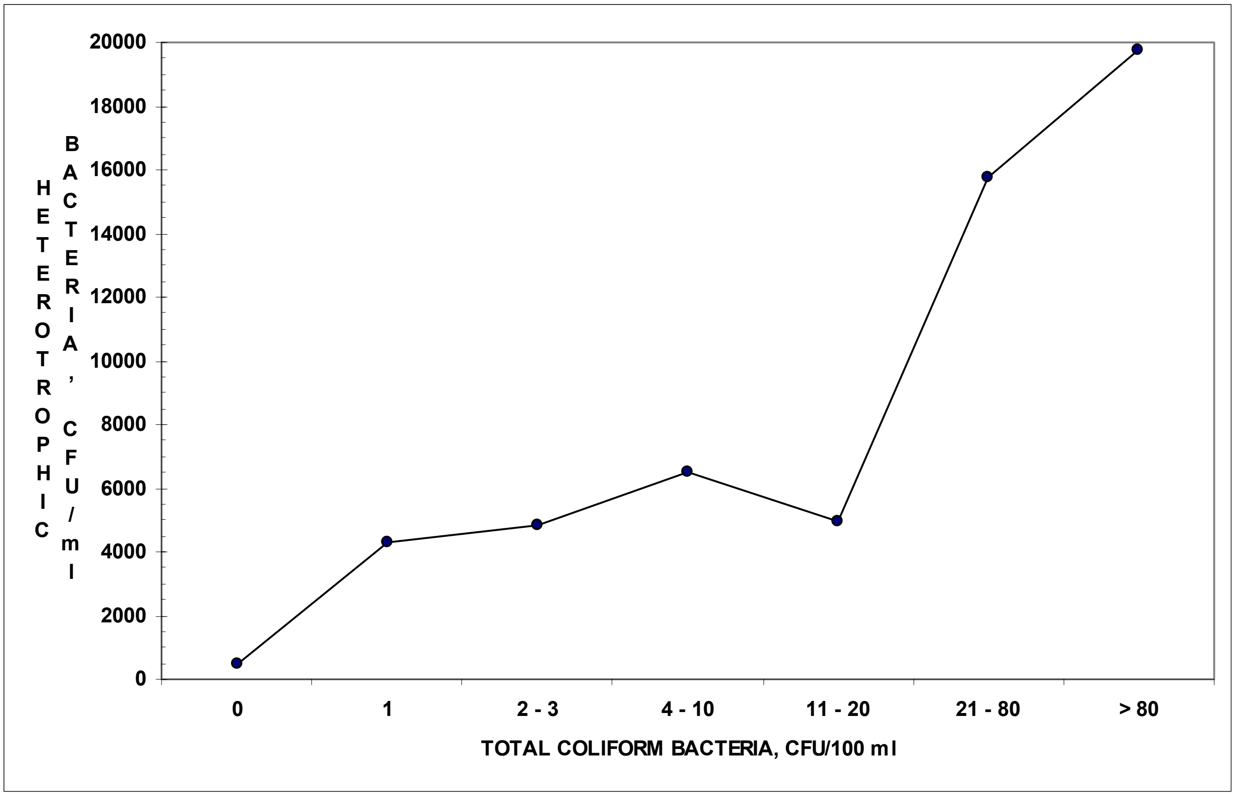

FIGURE 16: % OF POOLS DEEMED SATISFACTORY AND UNSATISFACTORY
FOR SWIMMING BY MODEL D CRITERIA (FREE CHLORINE AND PH)

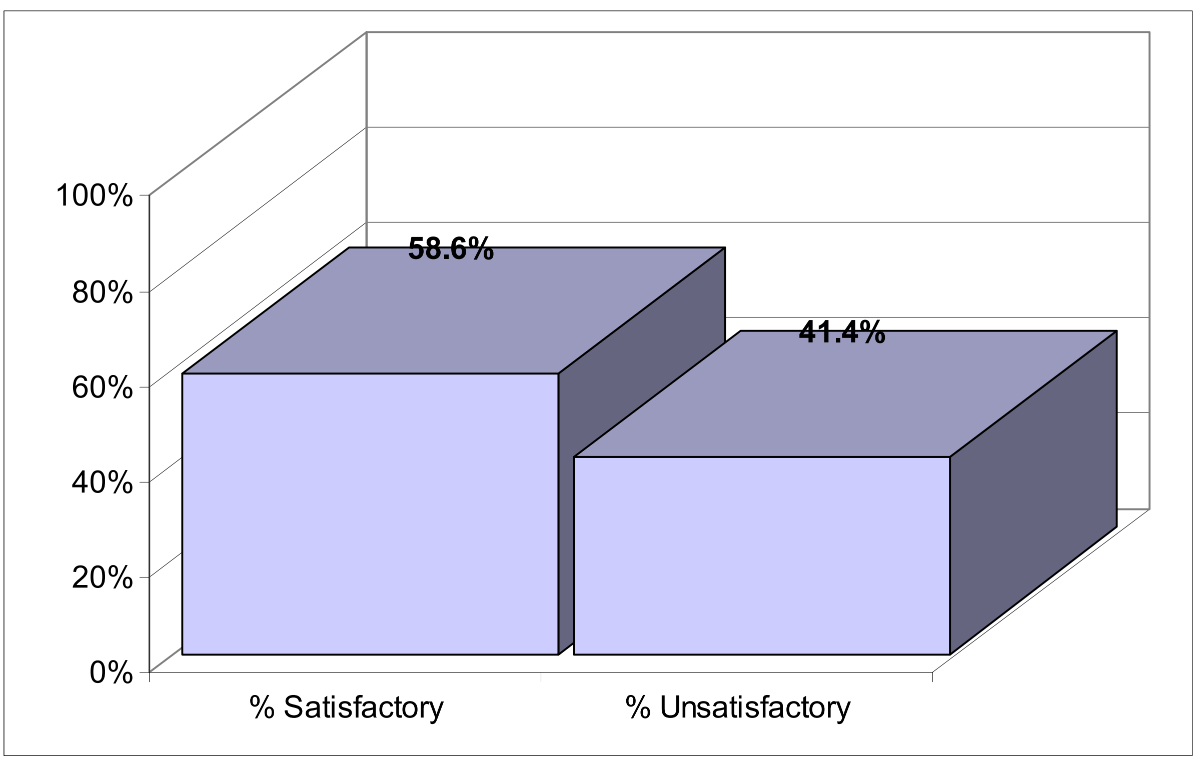

FIGURE 17: % OF POOLS DEEMED SATISFACTORY AND UNSATISFACTORY FOR SWIMMING BY MODEL E CRITERIA (1-5 FREE CHLORINE, PH AND CYANURIC ACID)

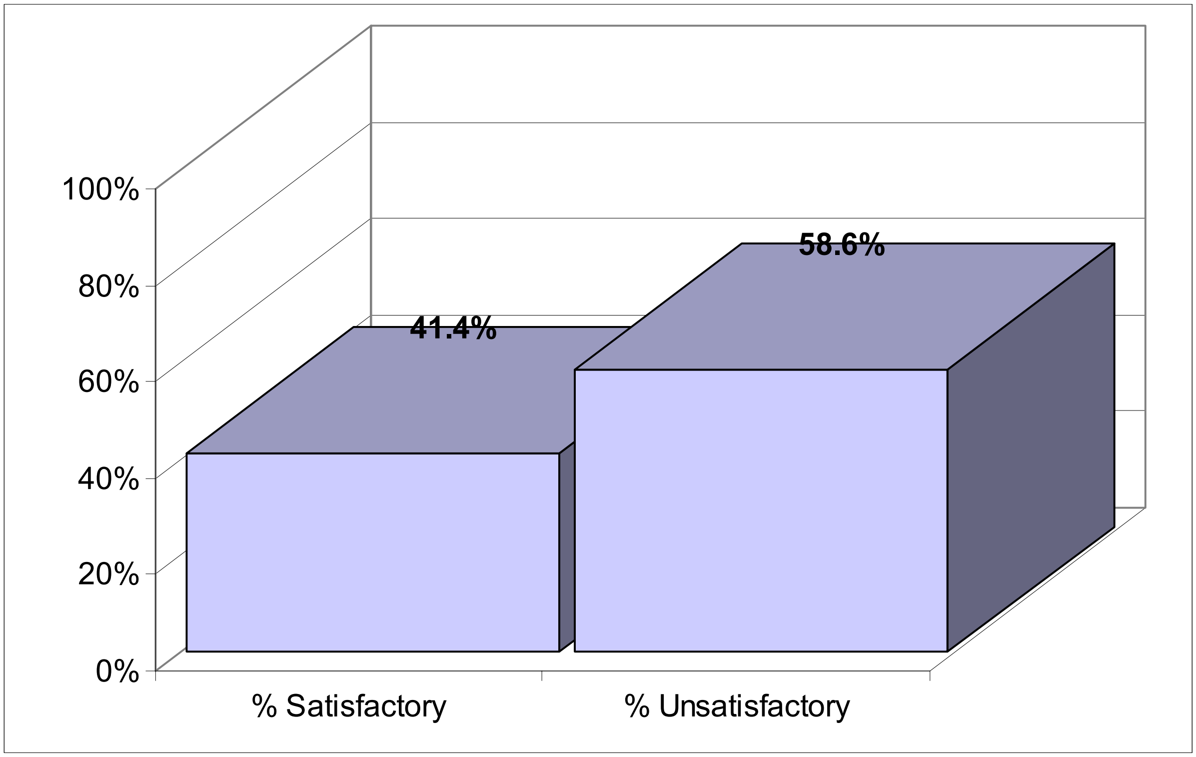

FIGURE 18: % OF POOLS DEEMED SATISFACTORY AND UNSATISFACTORY FOR SWIMMING BY MODEL F CRITERIA (1-3 FREE CHLORINE, PH AND CYANURIC ACID)

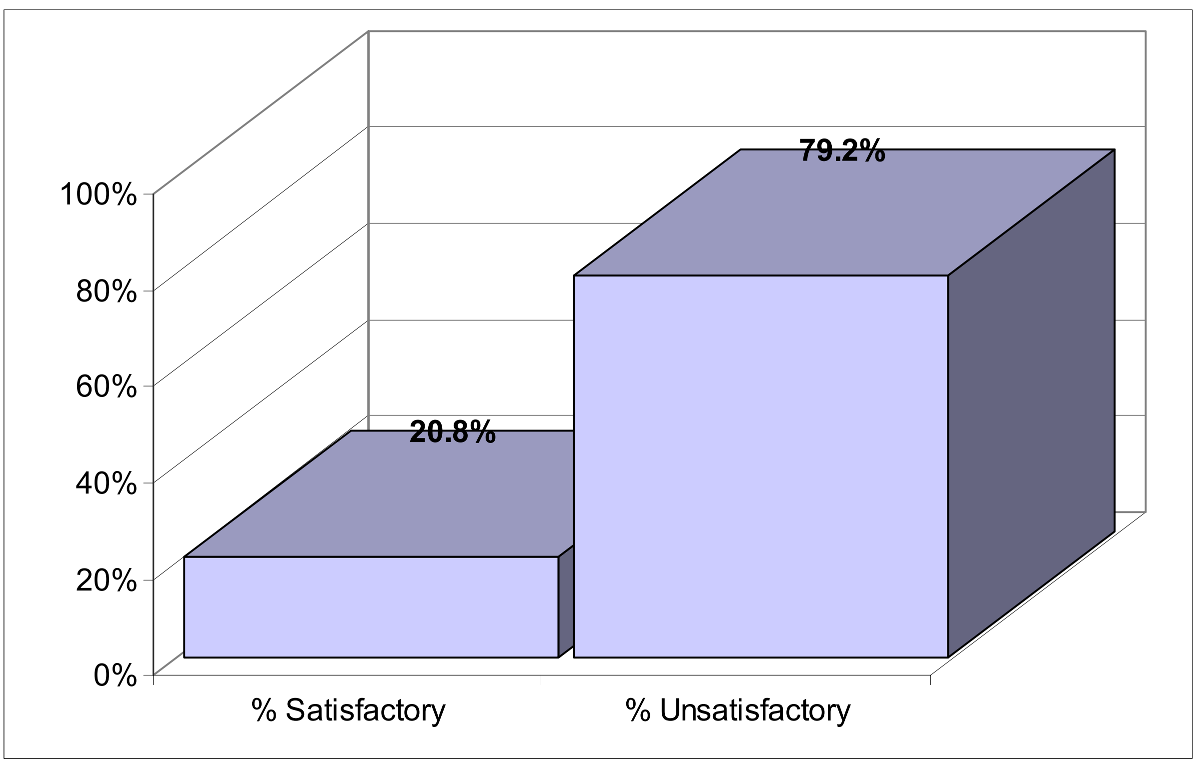

FIGURE 19: POOLS DEEMED SATISFACTORY FOR SWIMMING

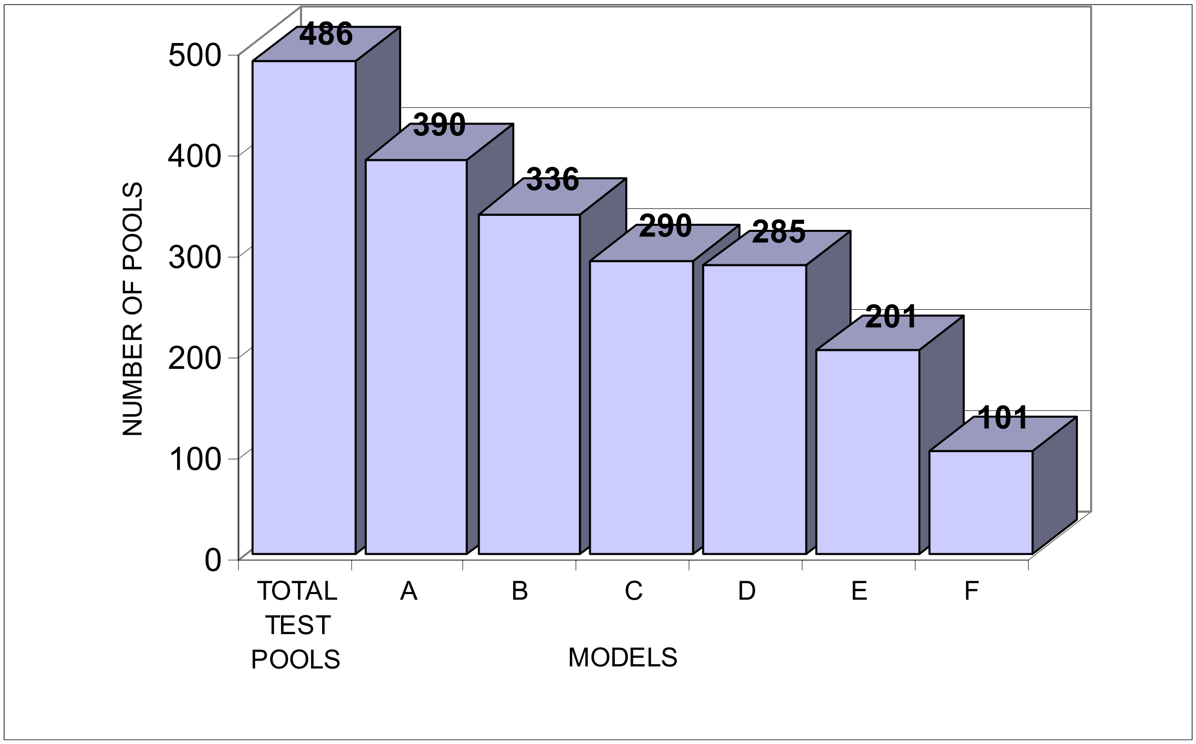

FIGURE 20: % BACTERIOLOGICALLY SATISFACTORY / UNSATISFACTORY POOLS IN POOLS DEEMED SATISFACTORY BY MODELS A – F

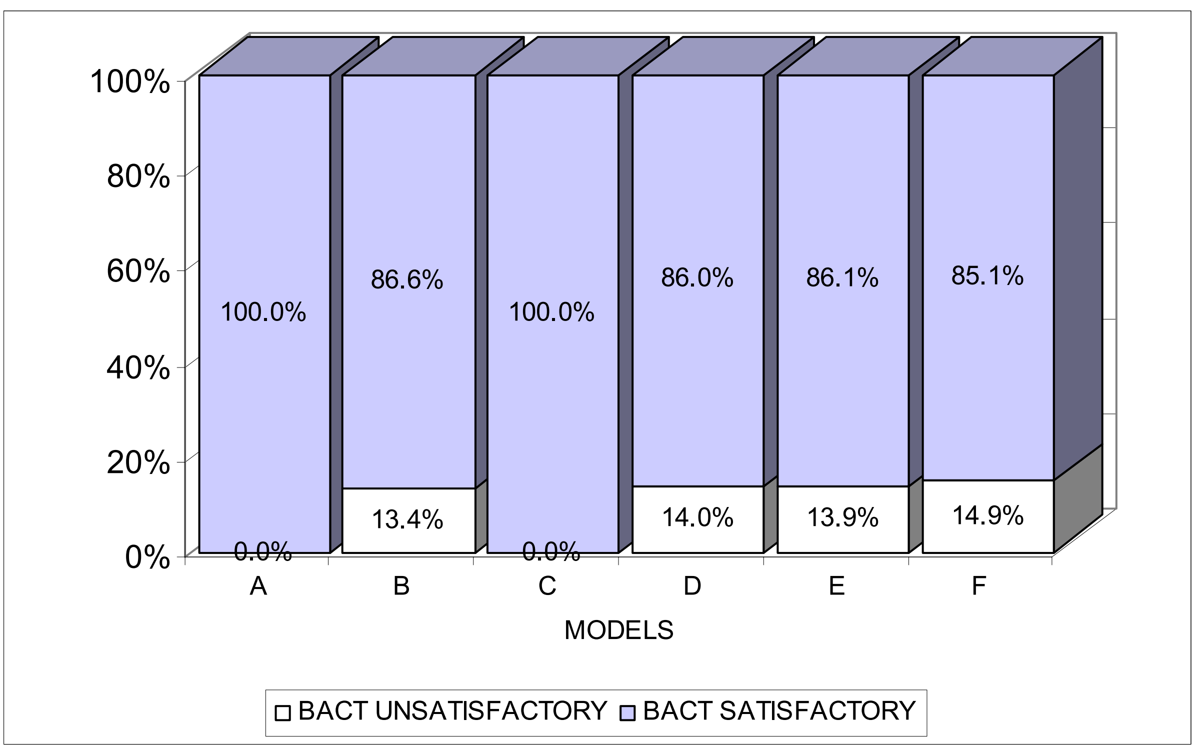

FIGURE 21: % OF TEST POOLS WITHOUT AND WITH ALGAE

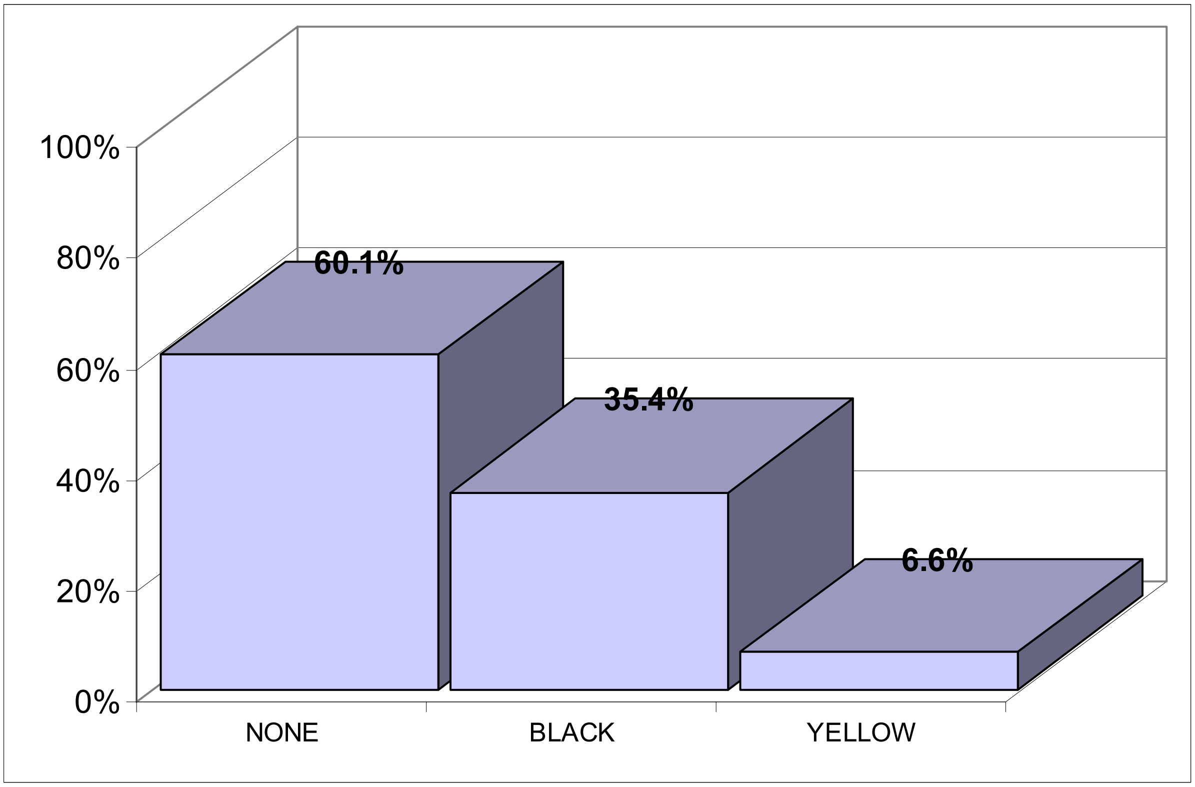

FIGURE 22 RELATIONSHIP BETWEEN BLACK ALGAE AND FREE CHLORINE

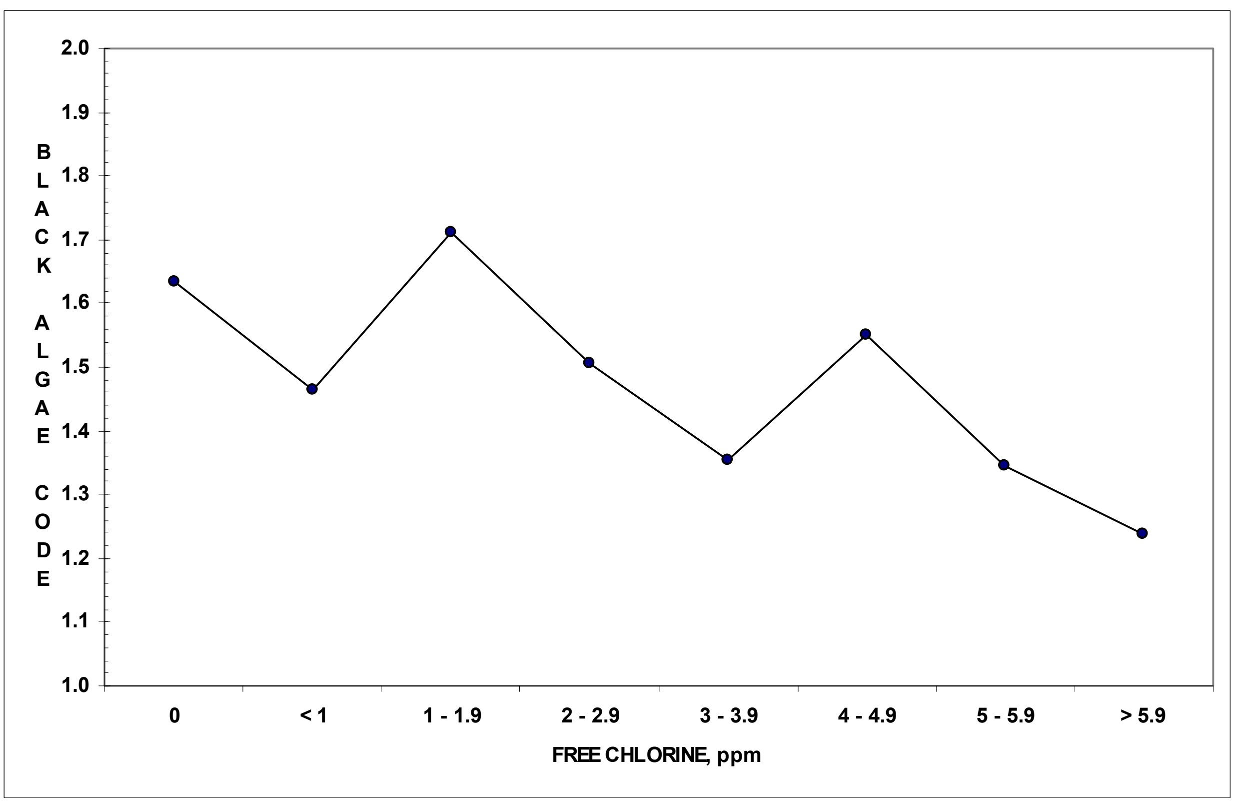

FIGURE 23 RELATIONSHIP BETWEEN YELLOW ALGAE AND FREE CHLORINE

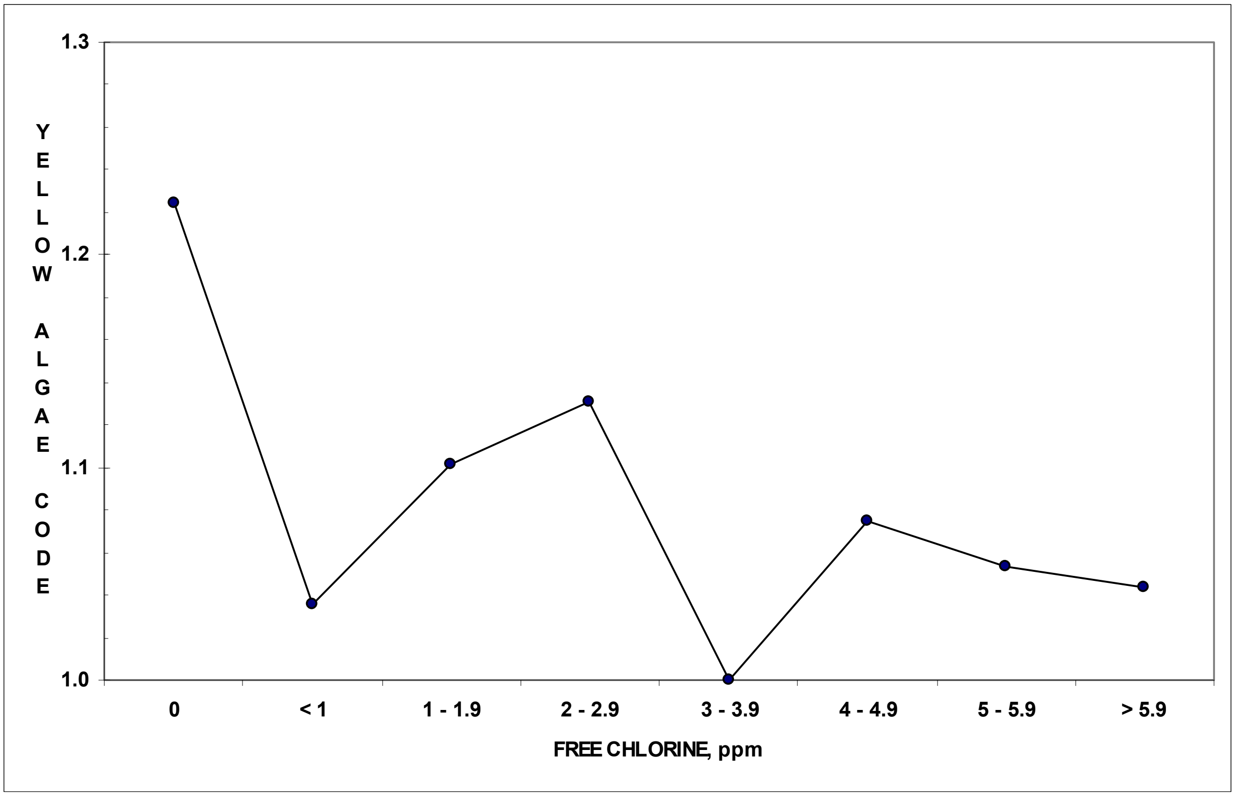

FIGURE 24: EFFECT OF FREE CHLORINE ON INCIDENCE OF ALGAE

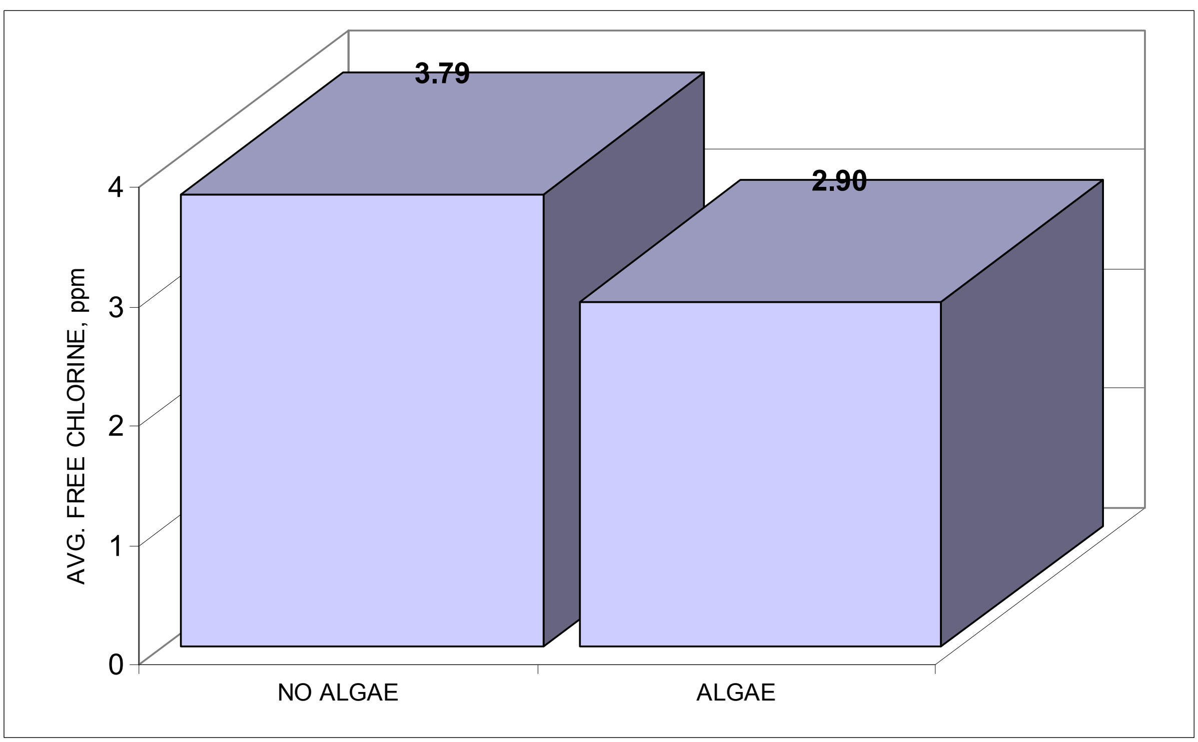

FIGURE 25: RATIO OF ALGAE / NO ALGAE POOLS IN POOLS DEEMED SATISFACTORY FOR SWIMMING BY MODELS A – F