

Correlation Between Fluoride Ion Levels in Harnett County Drinking Water and Students' Dental Health

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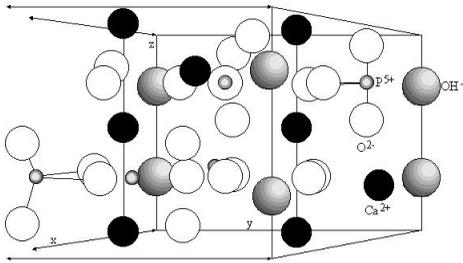
ABSTRACT

North Carolina ranks forty-fifth in the nation in total number of dentists per capita. With 0.45 dentists per 1000 residents, this value is dramatically lower than the national average of 63.6 dentists. Since dentists typically concentrate in urban areas, residents in rural counties such as Harnett have limited access to quality dental care. As a result, most rural US counties fluoridate their drinking water. However, studies indicate that the benefits of drinking fluoridated water may be outweighed by other sources of fluoride, such as toothpaste and mouth rinses. Elementary and high school students (n=383) in Harnett County were surveyed about their oral hygiene, including: participation in fluoride rinse programs, number of oral cavities, and brushing habits. Fluoride ion standards were prepared using sodium fluoride and Total Ionic Strength Adjustment Buffer (TISAB). Household water fluoride levels were sampled and measured using a fluoride ion selective electrode (ISE), and the resulting fluoride levels were determined using a calibration curve of the standards. Results indicate no correlation between fluoride levels in public drinking water and number of cavities in these students. Also, there was no significant difference in the number of cavities regardless of participation in the school's fluoride rinse program.

INTRODUCTION

Since the early twentieth century water has been publically fluoridated; however, its widespread use was not put in place until the 1950s.¹ Public fluoridation of water in America is believed to play a vital role in the maintenance of dental health, which is especially important to rural communities, such as Harnett County, that have less access to dental healthcare.¹⁻² Fluoride acts on the enamel, which is primarily composed of a molecule known as hydroxyapatite.¹ Figure 1 is an x-ray crystallograph of this molecule that shows its

3D structure. Normally, hydroxide ions can degrade over time when protons (such as those found in sugars) bind, and water molecules are formed.³ Fluoride, however, acts on the enamel by trading places with hydroxide ions, located on the outer edges of the molecule. Therefore, when fluoride builds up on the enamel the formation of water molecules does not occur as often. In other words, fluoride forms a protective barrier on the tooth's enamel. It is predicted that individuals who drink county fluoridated water (as opposed to bottled water or well water) will have better dental



Crystal Structure of Calcium Hydroxyapatite Powders Synthesized in SEF at 37°C (Hexagonal, $P6_3/m$, $a = 9.4125$, $c = 6.8765$ Å)

Figure 1- Crystal Structure of Calcium Hydroxyapatite

health, thus yielding fewer cavities.¹

With only 0.45 dentists per 1000 residents, Harnett County ranks as a prime example of a target rural community for the use of public water fluoridation.^{2,4} The effects of fluoridation in the rural county of Harnett have never previously been studied in detail. This project initially began as a survey that was sent home to the parents of students grades K, 3rd, and 5th. The survey was completed by 146 students. Due to the fact that dental health has many contributing factors, students were asked questions regarding their brushing habits, type of water consumed, frequency of dental cleanings, and more.⁵ In addition to drinking county water, it was predicted that students who have healthy dental habits, such as regular tooth brushing and dental cleanings, will have fewer cavities than their classmates who do not drink county water or have healthy dental habits.

Elementary school students in Harnett County and across the state also have access to a weekly fluoride rinse program. Since this is a program that costs North Carolina about five dollars per year per child, or roughly \$376,805, according to an e-mail from Bonnie Johnson who is a public health dental hygienist in North Carolina,⁶ its effectiveness was included in this study.

Furthermore, in order to rule out the contributing factor of genetic makeup and its effect on dental health, the study looked

at a potential correlation between a child's parent cavity history and the child's incidence of oral cavities. It is predicted that students whose parents have a greater number of cavities are also likely to have a greater number of cavities.

Economic trends were also studied. According to the 2010 United States Census, the average annual household income for Harnett County was \$35,105.⁷ Additionally, 17% of children ages 18 and under in Harnett County live below the poverty line.⁷ Because of the low access to dental health in Harnett County mentioned previously, it is predicted that students who live in low income households are also at greater risk for cavity formation. This too masks the effects of the consumption of household fluorinated drinking water.

The average fluoride ion concentration (in ppm) was also determined from the student's home water samples in order to determine if the average met the recommended U.S. Public Health Service level of 0.7-1.2 ppm.^{1,5} According to the 2009 Harnett County Water Quality Drinking Report, the fluoride level in drinking water was found to be 0.66 ppm;⁸ however, a representative of the Harnett County Regional Water Treatment Plant ascertained that the

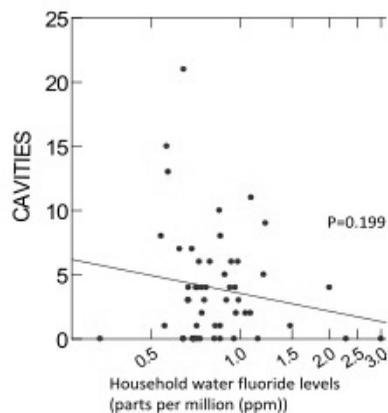


Figure 2- Household Fluoride Ion Concentrations for Harnett County Middle/High School Students and Total Number of Cavities for Each Student

average level of fluoride in drinking water is 1.00ppm.⁹ As a cost effective measure and in response to the rising levels of fluoride available to children via toothpastes, mouth rinses, and fluoride supplements, the US Department of Health and Human Services (HHS) has recently announced that the recommended level of fluoride be changed from the current range of “0.7-1.2ppm” to a single value of 0.7ppm.¹⁰ The HHS believes that this lowered fluoridation level will be cost saving yet high enough to maintain oral health among the population.¹⁰ Since this topic is of great interest to a rural area such as Harnett, it was important for the fluoride levels in the drinking water to be analyzed in this study.

Several of the trends in the initial survey were not as expected, which was assumed to be due to small sample size. For example, there was no definite correlation between either the school fluoride rinse program or the consumption of county water on dental health. Therefore, the survey was extended to middle and high school students, as well as modification of the wording of a few of the questions for clarification purposes (Figure 3). Additionally, the surveys were coupled to individual water samples from the student’s home water supply, which were tested for their fluoride content. In this manner, the exact concentration of fluoride in the student’s water could be compared to the student’s dental health,

creating a more direct correlation.

Based off the surveys alone, the consumption of county drinking water was not shown to have a correlation with dental health despite the fact that the average fluoride ion concentration level was near the recommended 1.00ppm level recommended by the ADA.¹ This was an unexpected result; however, it further confirmed the earlier results from the first set of surveys. Additionally, students who participated in the fluoride rinse program were not shown to have an improvement in dental health. Students who were from low income families, as indicated by their participation in the free/reduced lunch program, were shown to have a greater number of cavities, as expected. Furthermore, this study proved that students whose parents had an increased number of cavities were more likely to have increased cavities.

MATERIALS AND METHODS

Surveys were distributed to an elementary school in Harnett County to all kindergarten, third, and fifth grade teachers to be distributed to the parents of the students. The middle and high school surveys were sent to one of each school type in the county to the science teachers to be completed by their students. (All surveys available from the author or faculty mentor.)

In addition to the survey, the middle and high school students were given a sample collection bottle (disposable plastic scintillation vial) with a bottle number that matched the student’s survey number. Teachers were asked to instruct the students to collect water from drinking water in the home, ideally the kitchen, and to rinse the water through the vial prior to filling the vial thoroughly. Rinsing a collection vial prior to its use is most important when using glassware; however, it is also advised for sampling plastics as well.¹¹ Also, uniformly instructing students to collect samples from the drinking water faucet of the home

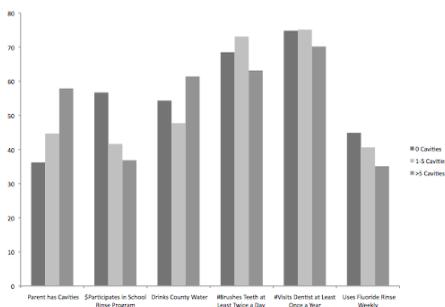


Figure 3- Oral Hygiene Habits of School Aged Students (K-12) by Percentage

helped ensure validity of this research. For example, if students collected samples from a faucet in their home not used for drinking, such as the bathroom sink, the results would not be as applicable as that of the kitchen sink, and this could introduce some sample bias.

Several acceptable methods are plausible for measuring fluoride in water samples;¹² however, the following method using an Accumet® fluoride combination ion selective electrode (ISE) was employed due to its cost effectiveness and the fact that the department had access to fluoride ISEs, as opposed to other equipment, such as an anion chromatograph. Furthermore, the limit of detection of a fluoride ISE is on a range of 10^{-6} M to 1 M.¹³ The lower limit of detection was an acceptable concentration, due to the fact that the fluoride samples were expected to have a concentration of about 1.0 ppm based on previous studies of Campbell University's water conducted earlier over the course of the project.

Seven sodium fluoride standards of known fluoride ion concentration, ranging in even increments from 1.5×10^{-5} M to 1×10^{-6} M were prepared in Total Ionic Strength Adjustment Buffer (TISAB), and the mV reading of the standards was measured using a fluoride ISE. A calibration curve of the standards was created by plotting the log of the fluoride ion concentration versus the mV reading. Water samples were prepared by diluting the sample in a 10 mL volumetric flask up to a 20% (w/v) solution in TISAB. The mV reading of the samples was measured using a fluoride ISE. A calibration curve of the standards was plotted, and, the NaF concentration of the samples was interpolated from the graph.

Samples were re-calibrated on a daily basis prior to measuring test samples, or every two hours if samples were tested over greater than a two hour range in a single day. This calibration procedure follows that of the manufacturer of the fluoride ISE,

and ensures standard "drift" does not skew the results.¹⁴ Furthermore, the manufacturer indicates that a slope of -54 to -60 mV indicates "correct electrode operation."¹⁴ In order to ensure proper function of the electrode, the slope was checked daily when the calibration was performed to ensure that it fell within the accepted range.

The data from the samples collected from the students, as well as the survey results were tabulated in an Excel spreadsheet, and Systat software was used to analyze results. To determine if two numerical variables were correlated, a Pearson Correlation test was used. A linear regression line was applied to each correlation to test for significance. To test for significant differences across categories, a Studentized T-test was used (for two categories), or an ANOVA was used (for more than two categories). An alpha = 0.05 (95% confidence interval) was used to determine significant differences between categories.

DISCUSSION OF RESULTS

Excluding well water samples, the average fluoride concentration in Harnett County was found to be 0.999 ppm with a standard deviation of 0.52 ppm (N=91); this value is within range of the suggested daily intake of 1.00 ppm set by the ADA. Our study aimed to analyze if the fluoride levels in the drinking water were significant enough to reduce cavities among the students surveyed. Figure 2 shows a Pearson Correlation for number of dental cavities and household fluoride ion levels. As shown in the graph, most of the fluoride ion levels center around the 0.7-1.2 ppm range; however, there are a few outliers that may be due to student sample collection error. The R^2 value of the regression was found to be 3.3, which means that only 3.3% of the variation in cavities can be explained by the household water levels. Furthermore, the P-value (slope of the line) is not less than 0.5; therefore, fluoride levels

in the student's homes are not correlated to number of cavities.

A total of 381 surveys were completed by school age students in grades K-12, 146 of which were completed by students in grades K-5. As observed in Figure 3, there is a direct linear correlation between students who brush their teeth regularly, visit the dentist regularly, and use a fluoride rinse weekly (aside from the fluoride rinse program at school). These results are as predicted; however, this graph only serves the purpose of showing some trends in student's habits and cavity numbers. ANOVA tests were performed to determine if these trends were statistically significant.

Figure 3 does not clearly indicate a trend between participation in the fluoride rinse program at school and a lowered incidence of cavities; therefore, an ANOVA was performed, and the use of the fluoride rinse program was not shown to have a significant difference in reducing cavities. Figure 4 compares the responses of middle and high school students to their participation in the fluoride rinse program and their proclaimed number of dental cavities. Although it can be determined from Figure 4 that the fluoride rinse program did lower cavities among those surveyed, the ANOVA test yielded a P-value of greater than 0.05; therefore, the two groups, cavities and participation in the fluoride rinse program, are not different from one another.

The correlation between student's household income level and dental health was also observed in this study. It is expected that students from lower income households will have a greater incidence of cavities due to a lack of exposure to quality dental care. Household income level was analyzed by student's participation in the free/reduced lunch program, which is set-up for students who are categorized as being from low income homes. As apparent in Figure 5, low income students have a higher cavity incidence than non low

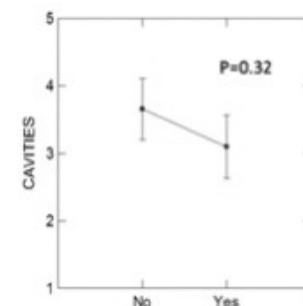


Figure 4- Number of Dental Cavities of Middle/High School Students Who Did and Did Not Participate in the Fluoride Rinse Program While in Elementary School

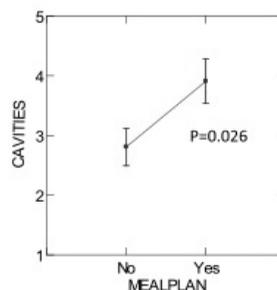


Figure 5- Number of Dental Cavities for Harnett County Middle/High School Students and Their Household Income Level

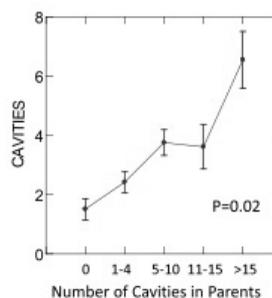


Figure 6- Number of Dental Cavities for Harnett County School-Aged Students and Parents

income students. The ANOVA test yielded a P-value of 0.026, which means that the two groups, cavities and income level, are not different from one another.

This trend is similar to that of parent's history of cavities and students incidence of cavities. Students whose parents had greater than 15 cavities were found to have significantly more cavities than that of

their fellow classmates. Figure 6 shows the ANOVA for this category, in which the y-axis indicates the student's number of cavities. The error bars for the two groups do not overlap (the P-value is less than 0.05); therefore, there are significant differences in cavities across the parent cavity category.

CONCLUSIONS

This multi-layer study was successful in analyzing many factors contributing to the dental health of school aged students in Harnett County, yet there is still much work to be done. Although the fluoride ion levels in Harnett County have been shown to meet the recommended guidelines for good dental health, the consumption of the drinking water is not shown to have an impact on cavity levels. Many factors that could mask the true effects of drinking county water, such as diet, amount of water consumed daily, and the onset of cavities, were not analyzed in this study. Therefore, we still do not have a good grasp on the true effects of drinking water on Harnett County school student's dental health.

This needs to be taken into consideration when conducting future work on this project because the HHS's suggestion to lower the recommended fluoride ion concentration necessary for good dental health from 1.00ppm (Harnett County) to 0.7 ppm would mean a possibility for a significant reduction in daily fluoride consumption for these students. This is of special interest to the rural county of Harnett. This study has suggested that the low income students in Harnett County do indeed have a higher incidence of cavities than that of their peers. Thus, the reduction of fluoride ion concentration in the drinking water could mean these students would potentially develop even poorer dental health.

The study has also suggested that the fluoride rinse program in Harnett County is ineffective. A careful look needs to be taken at how the fluoride rinse program is

being administered to the students. It is a fact that this program costs the school system a significant amount of money each year, and if it is being used improperly, coupled with the fact that it has been shown to be ineffective, then the money spent is to no avail. Furthermore, the study suggested that students whose parents have a greater incidence of cavities are likely to also have more cavities than that of their peers. With this knowledge, it would be suggested to put in place a program to monitor these students dental health in order to reduce their risk of cavity development.

Fluoride consumption in drinking water and the incidence of cavities in school aged children has many contributing factors. However, with the knowledge gained from this study, its results could be used to help modify practices in rural counties similar to Harnett, and also help educators and county leaders make important decisions about water treatment with fluoride, as well as school dental programs. Through this study, fluoridation of drinking water has been shown to play a role in reducing the incidence of cavities, but this in itself will not make a change; parents, educators, and students need to be informed about the effects their diet and dental health habits play on their dental health so that student's dental health can improve county-wide.

Future research would include some revisions to the procedure, as well as a change in the surveying process and questions asked, in order to gain more accurate and pertinent results. For additional samples collected, samples will be stored in a controlled refrigeration environment. The laboratory used during this project is now equipped with a refrigerator, but was not at the time of the experimentation. Furthermore, additional studies would look at factors not studied in this project, such as that of race, dietary habits, and outstanding dental issues. Race and "history of dental problems" were asked of the

participants in this survey; however, there was such little feedback to these questions that their results were not useful to include in this paper. For example, many students wrote down several races in the blank “indicate your race,” did not answer the question at all, or wrote an erroneous race, such as “brown.” Also, many students did not answer the very last question regarding history of dental problems. These factors, as well as that of dietary habit would be good to study in the future in order to obtain a better grasp on the issues surrounding cavity numbers in school aged children.

Another issue that would need to be addressed is that of self-reported cavity numbers. With a limited budget for this project, the simplest and cheapest way to obtain an indication of a student’s dental health, as related to cavity numbers, was to simply have the students self-report the number of cavities the student had in his/her lifetime. This of course could have led to an issue of under-reporting values, but also, it is possible that some students could have never visited a dentist and would not have a way of knowing how many cavities he/she had. This issue could be addressed by gaining access to a student’s dental record, which would take a great deal of time and may bring some legal question into

consideration, or by having a dental exam conducted on each student to be surveyed, which would increase the cost of the project itself.

ACKNOWLEDGEMENTS

We would like to thank the Campbell University Department of Chemistry and Physics as well as the Campbell University College of Pharmacy and Health Sciences for lab space and resources. We would also like to thank Dr. F. Serio, Associate Dean of Clinical Affairs of the East Carolina University Dental School, for his assistance.

We would like to thank student interns Jacob Bartlett (Harnett Central High School) and DeVante Monds (Triton High School). Other acknowledgements include Harnett County Schools, The Burroughs Wellcome Fund, Dr. J. Bartlett (C.U. Biology), Dean Mark Hammond and the Faculty of the College of Arts and Sciences at Campbell University, Mrs. Brandy Coker (Boone Trail Elementary School), and Mrs. Emily Bloom (C.U. Pharmacy).

All surveys available upon request from the student author or faculty mentor.

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