WATER QUALITY IN THE PUBLIC DISTRIBUTION
SYSTEMS OF THE VIRGIN ISLANDS

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ABSTRACT

The public distribution systems of the Virgin Islands were first installed in 1949 through the mid-1950's. The cast iron pipes which comprise the system are subject to severe corrosion. Though the systems have undergone several major repairs, questions have arisen about the quality of the water being distributed as a direct result of a typhoid epidemic at a public housing complex on St. Croix in which potable water was the suspected carrier. These fears are understandable in as much as the systems can become contaminated by several different pathways. A study of the distribution systems of all three islands was conducted. The principal findings were that with the exception of iron, probably due to residual rust in the lines, all systems easily met the U.S. E.P.A. physical and chemical parameters for drinking water. The real threat to public health however is due to inadequate or improper chlorination. Without proper chlorination, then the outbreak of some other water borne enteric disease is highly likely.

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INTRODUCTION

The public distribution systems of the Virgin Islands were first installed in 1949 through the mid-1950's. The system on St. Croix serves an area of 14 square miles with 3,000 connections; in St. Thomas it serves 2 square miles with 2,150 connections; and, on St. John 0.3 square miles are served through 10 connections. The necessary pressure in the systems on St. Thomas and St. John is maintained by pumping while the St.Croix system is mainly a gravity operation. Maintenance of the distribution lines is difficult. Through the years these systems have undergone several major repairs due to corrosive soils and the presence of most of the lines in areas in close proximity to sea water.

Water in the public distribution systems in the Virgin Islands can most readily become contaminated due to leakage into the lines, cross connections, siphonage during periods of negative pressure, and insufficient disinfection. Several questions have been raised by the public concerning the quality of the water being distributed. In 1985 this was particularly a concern when 66 cases of typhoid were diagnosed and confirmed at a housing complex in St. Croix. Water from the public distribution system was the suspected carrier.

The immediate benefit of the project is obvious. Analysis of water at several points in the distribution systems

will assist in the identification of areas where water contamination is more likely to occur. This has been hindered in the past when analysis with any similarity was performed on an emergency basis and often by groups with particular self-interests.

This investigation is especially timely in that the distribution system in St. Thomas is currently undergoing major renovations. This project provides both before and after looks at contamination in this system. The investigation provides information that can be be used in planning similar renovations on the St. John and St. Croix systems. Determination of quality profiles of the St. Thomas distribution system will also develop baseline data for monitoring the integrity of the system. For these reasons there is a need for a comprehensive systematic survey of water quality in the public distribution systems of the Virgin Islands.

MATERIALS AND METHODS

Site Selection

To help identify the sample point locations, a map of the potable water distribution system was obtained, then with the aid of the Department of Conservation and Cutural Affairs personnel responsible for monitoring the quality of water in the distribution systems, field trips were made to locate useable sample points.

In St. Thomas, there are four main lines which constitute the distribution system (Figure 1). From these main lines extend the laterals which serves the homes and businesses. The heart of the water supply system is a 2.5 million gallon per day desalination facility located at Krum Bay, St. Thomas. The desalinated water is pumped first to storage tanks, enters into filter tanks,then passes through a chlorination chamber. From the chamber it enters directly into the distribution system.

The first main line is a ten inch line laid in 1975, which travels from Krum Bay west to the University of the Virgin Islands. The second main line is a six inch line laid in 1950 that runs east from Krum Bay along Harwood Highway and Main Street. This is the line which was being relaid with new eight inch Ductile steel, to replace the original cast
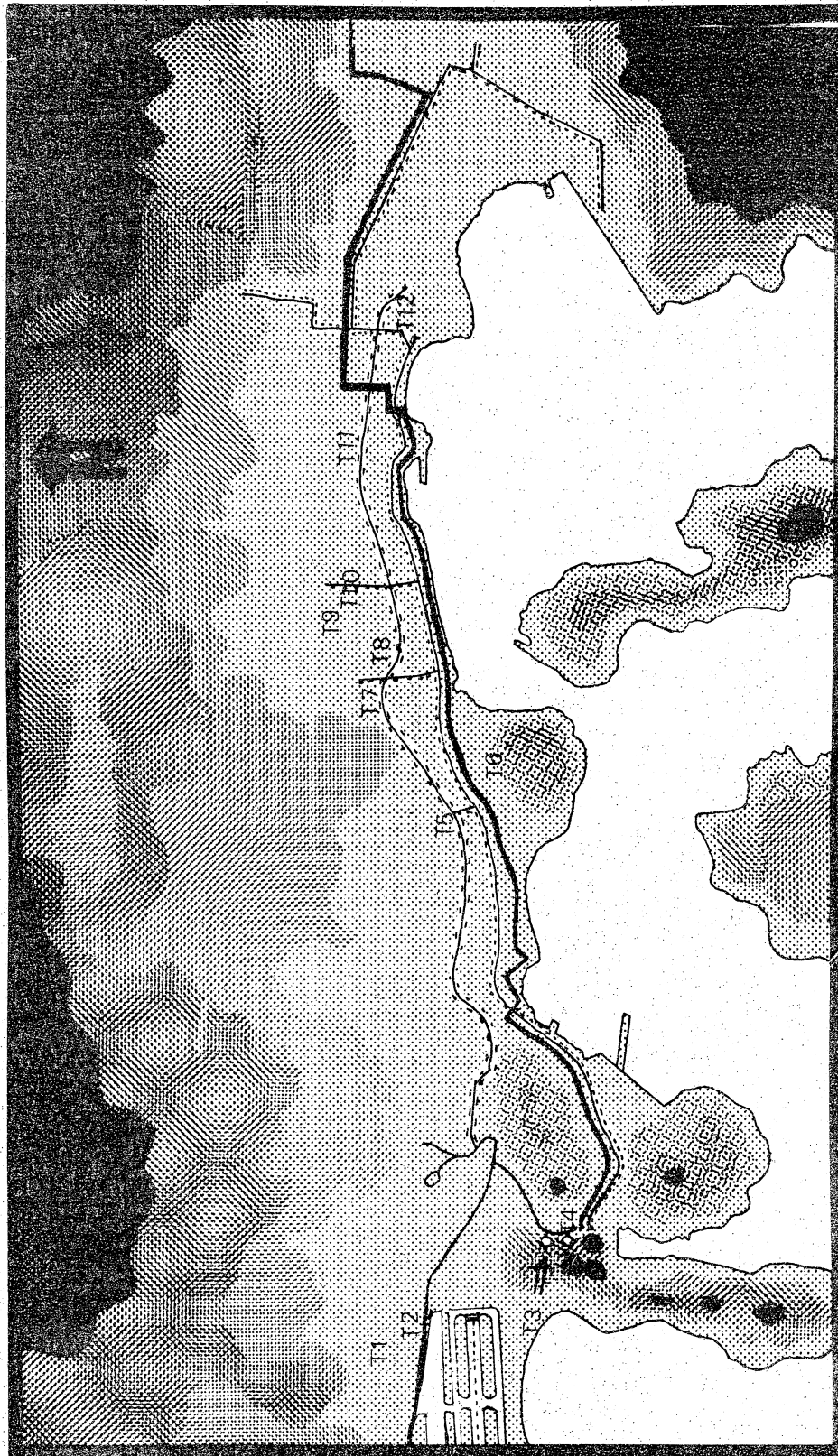
Figure 1. St. Thomas Water Distribution System

iron pipe. The third main line is a ten inch line laid in 1963 which services the French Town fishmarket, continues under the waterfront apron, services the main fire station, and branches into a dead end at the Boy Scouts of America Headquarters. The other branch of this line runs north, then east as far as Oswald Harris Court. The fourth and final main line is a 24 inch line laid in 1976 which runs directly to a storage tank at the top of Raphune Hill. This tank feeds the Estate Tutu area to the east. At the time of this study there was no water flowing in this line which is activated only as needed. The other three lines are in continuous use.

Sampling points which would provide samples that were truely representative of the overall water quality of the entire distribution system were selected. Samples were taken from the three active main lines, and from branches and laterals originating off the main lines. Samples were obtained as far away from the source as possible as well as the source itself. Nine sampling points were selected on the "old" distribution system and three on the "new" system. Of that twelve, two were controls. One was directly from Filter Tank #1, the "positive" control, and the other was from a tap at the Public Works Department Motorpool, a point right after the water has been chlorinated, and the "negative" control.

Going west, samples were taken from the Kirwan Terrace Fire Department, which is about 50 ft. off of the main line,

and also at a tap at the Kirwan Terrace housing project maintenance building. Going east, three samples were pulled directly off of the new line on Harwood Highway and Main Street. Three other samples were pulled from laterals off of this main line. One sample was taken each of the three from standpipes in the Savan area of Charlotte Amalie. From the third main line, also going east, two samples were taken, one at the French Town fishmarket, and the second at the Boy Scouts of America Headquarters.

One of the problems encountered was locating points directly off of the distribution system. In many cases, a desirable point would be eliminated because the water would first flow into a cistern which also stored roof top harvested rain water which made the sample not representative of the water quality in the lines.

During this initial phase of locating sample points, when a point was found that met the criterion of a) coming off the distribution system b) not first entering a cistern c) being in an appropriate area, a sample was then collected for rough bacteriological background data. Total coliform, fecal coliform, and fecal streptococcus analysis were run from each acceptable point to determine if dilutions would have to be made once regular sampling began. Also free and total residual chlorine levels were taken at this time.

A similar trip was made to the island of St. John. The St. John distribution system is very small being about 0.3 of a mile long. Only three sampling points were selected. They were the main storage tank at the southern end of the system, the Agricultural Station, just north of the midpoint, and the Office of the Administrator, which is the northern most accessable point. Sampling sites are shown in Figure 2.

St. Croix was also sampled. However, due to time limitations, only two mass sampling efforts could be done. During the initial visit, fifteen samples were collected. These were taken from points extending from the Pearl B. Larsen School east of Christiansted, to La Grange which is west of Frederiksted. At each sample point free and total residual chlorine levels were made and a sample collected, stored, and returned to St. Thomas for total coliform, fecal coliform, and fecal streptococcus analysis, with each sample being run in duplicate. The second visit involved the same fifteen sample points, the same analysis, but also included pH, temperature and conductivity measurements. In Figure 3, sampling points are shown.

Collection Procedures

Samples were collected in accordance to Standard Methods for the Examination of Water and Wastewater and Microbiological Methods for Monitoring the Environment.
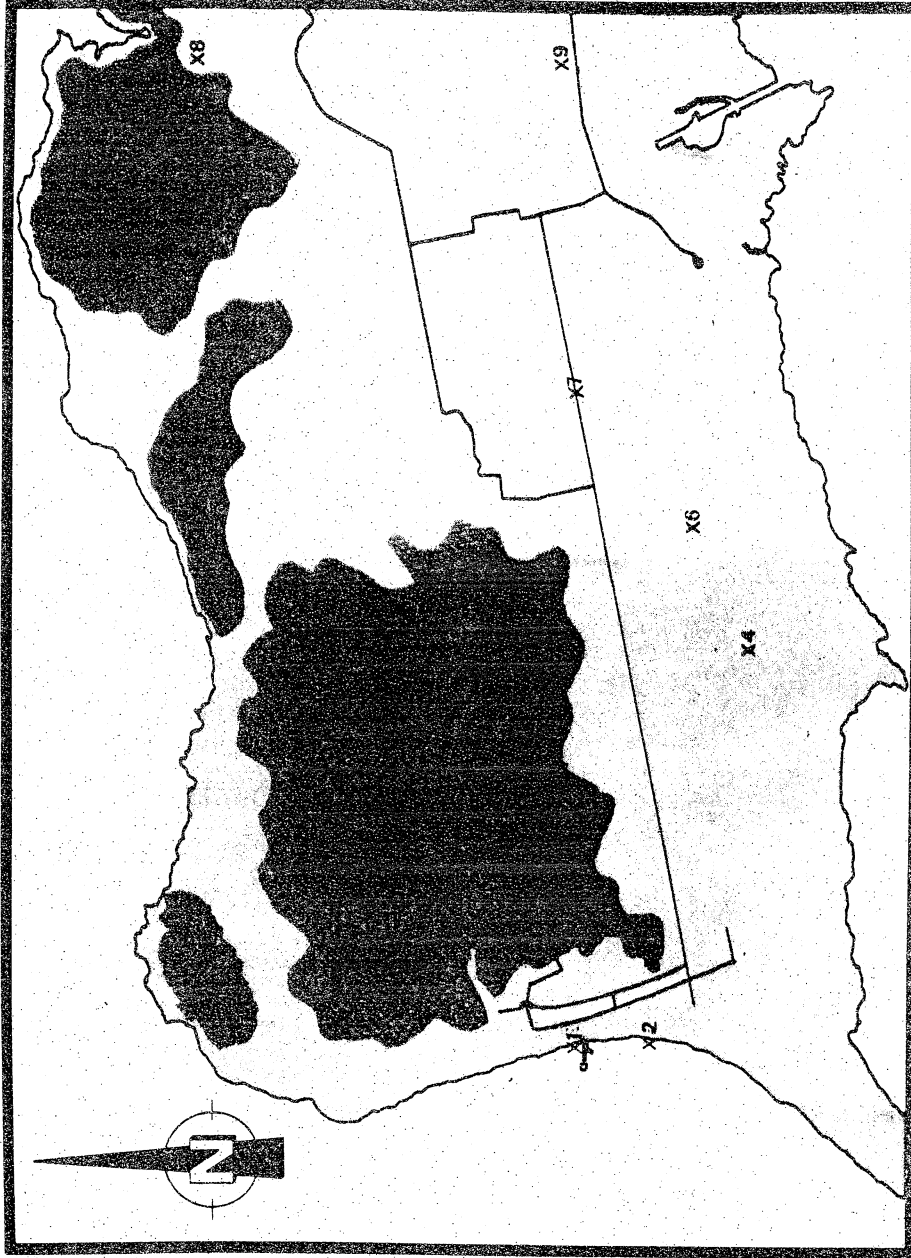
Figure 2a. St. Croix Water Distribution System
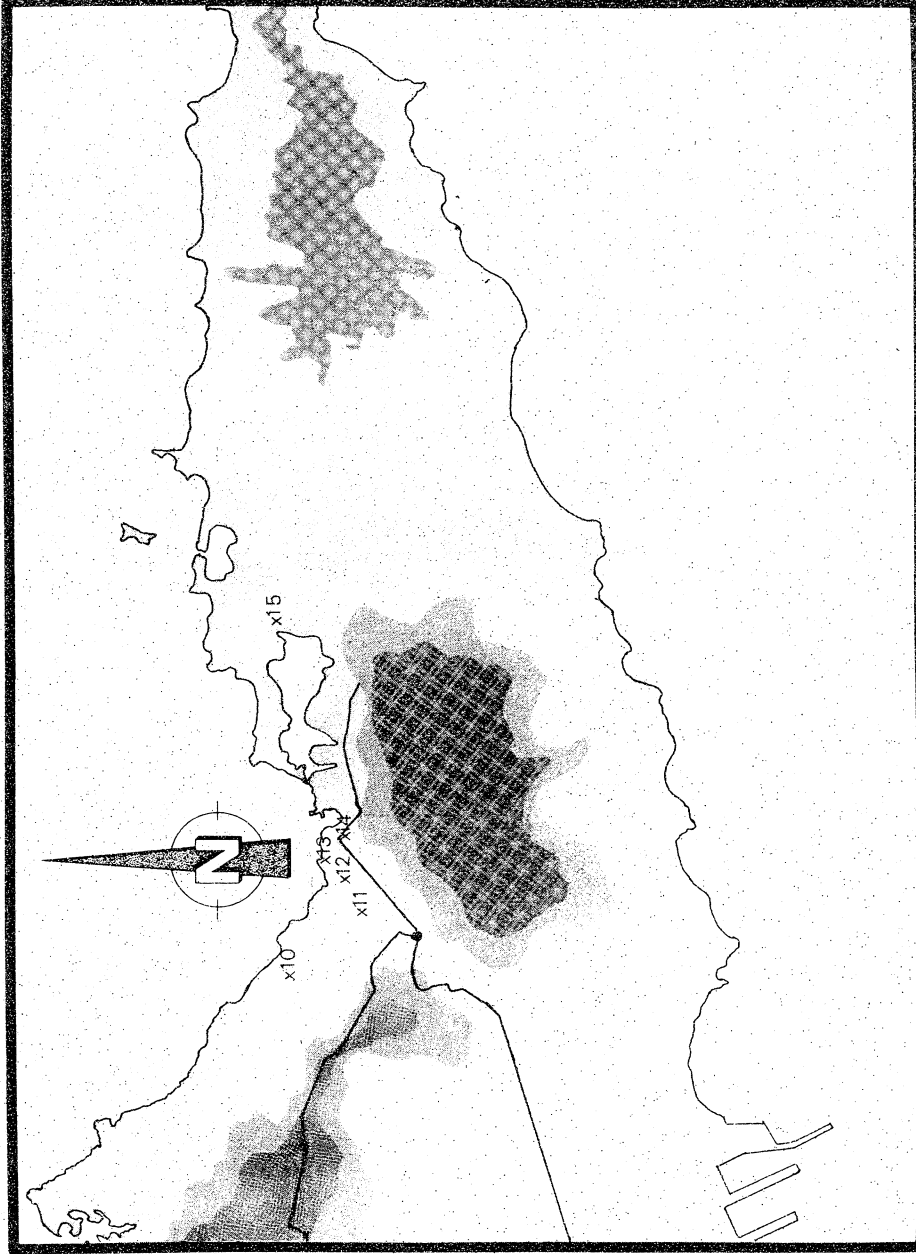
Figure 2b. St. Croix Water Distribution System
(Continued)
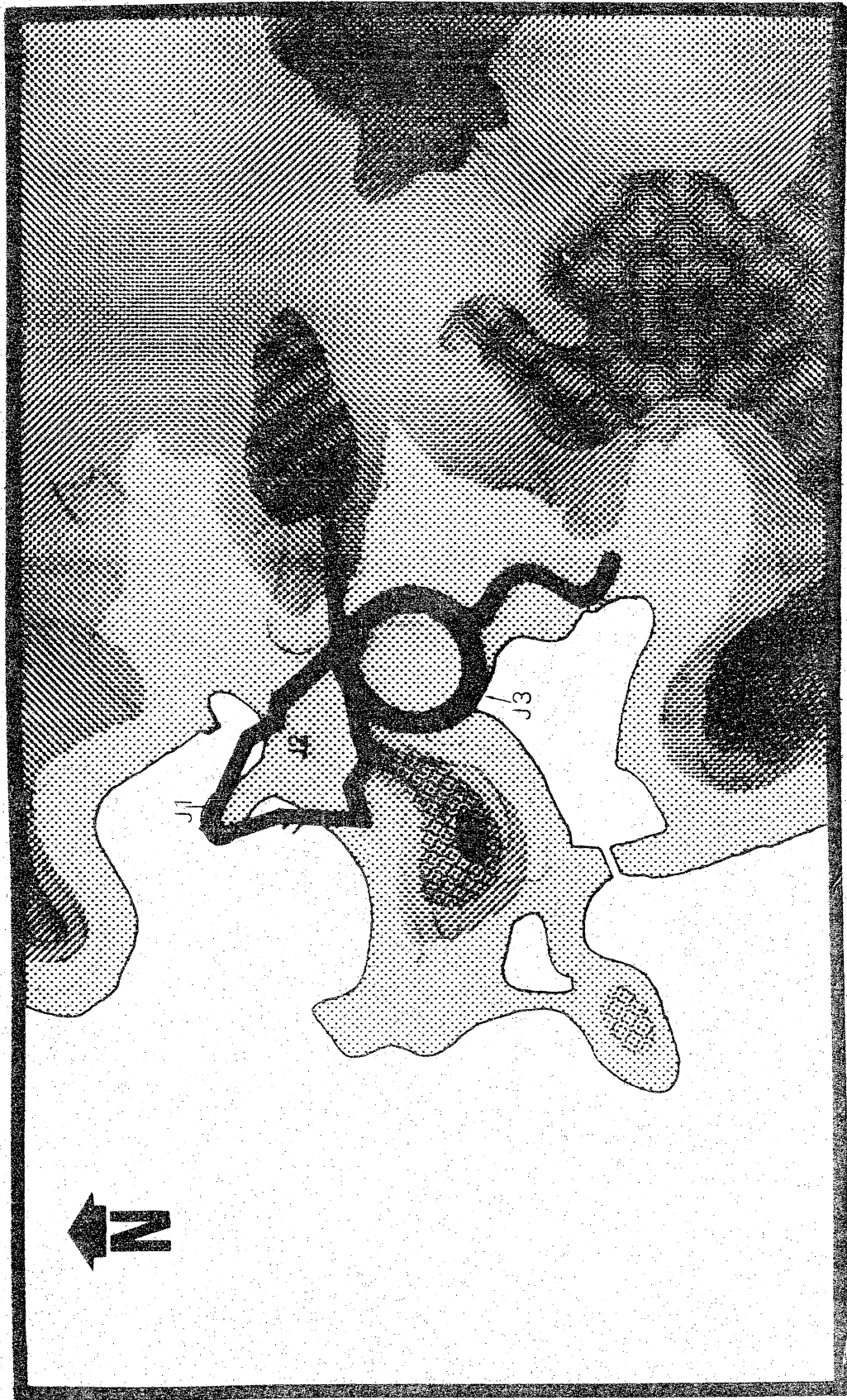
Figure 3. St. John Water Distribution System

All chemical samples were collected in clean, thoroughly washed and rinsed borosilicate glass bottles and preserved with either H_2SO_4 or HNO_3 to a pH less than two depending on the analysis to be done. The one exception was the sample for silica which was collected separately in a clean, thoroughly washed and rinsed polypropylene bottle.

The microbiological samples were all collected in one liter borosilicate glass bottles with ground glass stoppers. Prior to collection 0.8 mL of a 10% solution of sodium thiosulfate was added to each one liter bottle (giving a final concentration of 0.1 mL per 125 mL of sample) and the bottle was autoclaved.

Once in the field, all the collection taps were flushed for at least three minutes before the samples were collected. Once collected, the samples were immediately rushed back to the laboratory. All microbiological analyses were begun within four hours of the time of collection.

Chemistry and Physical Analyses

The chemical parameters examined were temperature, free and total residual chlorine, apparent color, dissolved oxygen, turbidity, pH, conductivity, total solids, nitrate, calcium, chloride, iron, silica, sodium, and magnesium.

Temperature was taken using a celsius degree thermometer.

Free and total residual chlorine readings were done using the N,N-diethyl-p-phenylenediamine (DPD) colorimetric method. Color was done as apparent color using a spectophotometric method.

Dissolved oxygen was measured using the azide modification of the Winkler titration method. Chloride was analyzed by the mercuric nitrate titration method.

Turbidity was measured by nephelometric using the HF. DRT 100 (HF instrument Co., Fredona, NY).

pH was done using the potentiometric system. We used two pH meters in this study the Hach 19,000 (Hach Chemical Co., Loveland, CO) and the Markson 90 (Markson Instruments, San Diego, CA) with sealed combination electrodes. Conductivity was run using a Markson 15/16 conductivity meter (Markson Instruments).

Total solids were run by evaporating enough sample at 103-105° C so that there was a minimum difference of 5 mg between the initial weight and the final weight. The amount of total solids were then calculated using the formula:

$$\text{mg total solids/L} = \frac{(A-B) \times 1000}{\text{Sample volume, ml}}$$

where A = Final weight (dish + residue in mg)

B = Initial weight (dish in mg)

Magnesium, sodium, calcium and total iron were analyzed by atomic absorption. With calcium the EDTA titrimetric

method was used; with total iron the 1.10 phenanthroline method using spectrophotometry was used.

Nitrates and silicates both were done by using the Hach DR-3 spectrophotometer (Hach Chemical Co.) which is part of the Hach DREL-5 Field Laboratory Kit. Nitrates were analyzed by the cadmium reduction method and silicone by the heteropoly blue method.

Except for those analyses that used specific instruments such as atomic absorption, temperature, conductivity, pH, residual chlorine, turbidity and total solids, all other analyses were done using the Hach DREL-5 Field Laboratory Kit. While all of these Hach kits used prepackaged "powder pillows" all the analyses are based on methods found in Standard Methods for the Examination of Water and Wastewater.

Microbiological Analyses

The microbiological parameters examined were as stated before, total coliform, fecal coliform, fecal streptococcus and standard plate count - heterotrophic plate count. All are standard tests in determining water quality. In addition, because of the typhoid outbreak on St. Croix in 1985, attempts were made to isolate Salmonella spp. from each sample.

These five tests taken collectively yield information about the quality of the water, and whether adequate disinfection is occurring, or if not, whether it might be prudent

to use other tests in conjunction with the standard analyses to insure a safe supply of drinking water. As will be seen, all tests used are those in use throughout most water quality and public health laboratories. The one exception is our procedure for the qualitative isolation of Salmonella sero-types. Even here the procedure is but a modification of two existing methodologies combined into one, and this is nothing more than an extension of the total coliform procedure. This is important because with minimal additional training and supplies, the procedure could be readily incorporated into the analysis of all major problem supplies. In addition, it has the potential for rapid, wide, acceptance because - with the exception of the procedure - the methodologies are well known and universally accepted.

The total coliform has been the indicator organism of choice for determining the bacteriological quality of drinking water since 1914. The reason is it most closely approximates the ideal indicator organisms. In recent years however, the standard total coliform analysis has come under increasingly heavy scrutiny because it has been extensively reported in the literature that in many instances stressed coliforms fail to be detected. Indeed, stressed or injured total coliforms have become the rule rather than the excep-tion, and now many researchers have proposed either new procedures, or new media, whereby these stressed or injured

coliforms can be detected. It is not the intent of this paper however to use either new procedures, or new media, which are still in the experimental phases of testing; rather it is the intent to use established methodologies to determine the suitability of the water.

The two universally accepted techniques for the quantitative isolation of total coliforms are the Most Probable Number (MPN) technique and the Membrane Filtration (MF) technique. The MPN technique is based upon the statistical probability of finding X number of total coliforms if Y number of tubes are positive for the production of acid and gas in both lauryl tryptose broth, and brilliant green bile 2%. The primary use of this technique involves those samples which tend to have either high turbidities, toxicity, or considered to be chlorinated effluents. The major drawbacks to this procedure are:

1) The results are statistical values and not a direct count.

2) The procedure tends to yield higher percentages of both false positives, and false negatives than does the MF technique.

3) It is both more costly and time consuming than the MF method.

4) It requires much more space to do an equivalent number of samples compared to the MF method.

The MF technique is the preferred method because:

1) It yields a quantitative direct count of the total coliforms present.

2) It yields fewer false positives and fewer false negatives.

3) It is rapid and relatively inexpensive.

4) It takes up very little space to do a lot of samples.

In as much as the samples being analyzed were not either highly turbid, toxic or chlorinated effluents and for the reasons stated above, all samples were processed by the MF technique.

The total coliform group includes all the aerobic and facultative anaerobic, gram negative non-spore forming rod-shaped bacteria that ferment lactose in 24-48 hours at 35*C. It includes the genera Escherichia coli, Citrobacter, Enterobacter, and Klebsiella. In performing the total coliform analysis all samples were run in duplicate. Each replicate involved filtering a 100 ml volume of water through a 0.45 mm type HA filter (Millipore Corp., Bedford, MA), and then placing the filter on m-Endo agar (Difco, Detroit, MI) which was contained in 50x9 mm pre-sterilized plastic, disposable petri dishes with tight fitting lids (Gelman, Ann Arbor, MI). These plates were then incubated at 35°C $\pm$ 0.5°C for 24 hours. At the end of the 24 hour incubation period the plates were examined and the typical golden green metallic sheen colored colonies were counted. These typical colonies were then subjected to verification. All colonies (or a maximum of ten typical colonies) were randomly picked and placed in single strength lauryl tryptose broth (Difco)

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and single strength brilliant green bile 2% (Difco) and incubated at 35°C ± 0.5°C for up to 48 hours. All samples which showed production of acid and gas in both media were considered to be positive for the presence of coliforms. In the event only the lauryl tryptose broth tube was positive, a new tube of brilliant green bile 2% was innoculated from the positive tube and then incubated for up to 48 hours at 35°C ± 0.5°C. If after this period of time the brilliant green bile 2% tube was still negative for the production of acid and gas, the colony was then listed as negative for the presence of total coliforms.

If no typical colonies were seen then up to five non-typical or atypical red colonies were picked and subjected to the same verification procedure. The final reported colony count was adjusted accordingly.

Analyses for fecal coliform were also run. Fecal coliform are part of the total coliform group but these gram negative, non-spore forming rods which ferment lactose can grow at the elevated temperature of 44.5°C ± 0.2°C with the production of acid and gas in 24 hours and are frequently used as indicators of sewage treatment plant efficiency. Alternatively, they can be used to indicate contamination from human sources. The primary fecal coliform is Escherichia coli which is almost solely associated with man. Their presence in potable water would indicate a supply that

may have been contaminated by sewage seeping into the lines, or by back siphonage from a cross connection. Because sewage seepage and /or cross connection are thought to exist, the fecal coliform analysis was run.

Like the total coliform, fecal coliform can be analyzed by either MPN or MF methodologies. The MF procedure was again chosen, and again for the same basic reasons. Again all samples were run as duplicates. Each replicate consisted of filtering a 100 mL volume of water through a 0.7um type HC filter (Millipore Corp.) as has been recommended for fecal coliform analysis, and then placing the filter on m-FC agar (Difco) to which Rosolic Acid has been added. The plates were then incubated at $44.5°C \pm 0.2°C$ for 24 hours in a Blue M waterbath. At the end of the 24 hour incubation period, all typical blue colonies were counted. These blue colonies were then submitted to verification procedures. All, or up to a maximum of ten, blue colonies were verified. The colonies were first picked, and then inoculated into lauryl tryptose broth (Difco) and incubated at $35°C \pm 0.5°C$ for up to 48 hours. All positive tubes which showed the production of acid and gas within that period were then transferred into EC broth (Difco) and incubated at $44.5°C \pm 0.2°C$ for 24 hours. All tubes which showed the production of and gas at the end of that period were counted as verified fecal coliforms. The final reported count was then adjusted accordingly.

The fecal streptococcus group are defined as those gram positive cocci belonging to the Lancefield's groups D and Q. The normal habitat of the fecal streptococcus is the intestinal tract of man and other warm blooded animals. These organisms too are good indicators of fecal pollution. However unlike the fecal coliform, which comes primarily from man, fecal streptococci come primarily from animals. When the fecal coliform count is compared to the fecal streptococcus count, a ratio is established. This ratio can then be used to determine whether the source of the pollution is primarily from man enhanced sources - such as sewage - or from animal sources - such as runoff from animal feed lots or whether it might be a mixture of both.

As was the case with both the total coliform and the fecal coliform, the fecal streptococcus can be analyzed for by either the MPN or MF techniques. Also, as were the cases for both the total coliform, and fecal coliform, the fecal streptococcus were analyzed by the MF technique for the same reasons as the total coliform and fecal coliform.

As in the previous cases, each sample was run as a duplicate, each replicate consisted of filtering 100ml of sample through a 0.45 um Type HA filter (Millipore) which was then placed on KF streptococcus Agar (Difco) to which one milliliter of a sterile 1% solution of TTC (2,3,5 Triphenyl-

tetrazolium chloride) was added for each 100 mL of sterile medium. The plates were then incubated at $35°C \pm 0.5°C$ for 48 hours.

In an additional experiment, another exact set of duplicate plates using only loose fitting lids were run. They too were incubated at $35°C \pm 0.5°C$, but this time under a CO_2 atmosphere of 5-10% CO_2 (Marion Scientific). This experiment was run to see if CO_2 incubation would significantly increase the recovery of fecal streptococcus. It is known that many Streptococci grow better under CO_2.

In both cases, after the 48 hour incubation period, the plates were examined and counted. Only the pink to dark red colonies were counted. Up to ten colonies were then picked and subjected to verification. The verification procedure consisted of picking the pink to dark red colony to brain heart infusion agar (Difco) slants and to brain heart infusion broth (Difco). After 24-48 hours of incubation at $35°C \pm 0.5°C$ the culture was tested for catalase activity. A loopful of the growth from the brain heart infusion agar slant was transferred to a clean slide and a few drops of 3% hydrogen peroxide (H_2O_2) were added to the smear. If a positive reaction occurred (presence of bubbles) the tube was discarded as a non-streptococcal species. If a negative test was recorded, a loopful from the brain heart infusion broth culture was transferred to fresh brain heart infusion broth

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and also to a tube of brain heart infusion broth plus 40% bile.

These tubes were then incubated at 44.5°C $\pm$ 0.2°C and 35°C $\pm$ 0.5°C respectively. Growth in both tubes within 48 hours was considered positive verification. Like the total coliforms and fecal coliforms, the final fecal streptococcus count was adjusted accordingly.

The standard plate count tells something about the overall treatment efficiency of whatever process is being used. While there are no current regulations in regards to the total number of organisms per milliliter of sample, the limit of 500/mL or less has been suggested as a bench mark figure. However this figure of 500/mL is based upon growth on a nutrient rich medium called plate count agar. In January of 1985 a new medium was reported in the literature which yields significantly higher counts (Reasoner and Geldreich, 1985). The new medium instead of being a nutrient rich medium is a minimal nutrient agar called R2A. This medium has rapidly gained acceptance in the field of Environmental Microbiology because less than one year after its formula was published, it became commercially available. The standard plate count has recently been changed to the heterotrophic plate count in the 16th edition of <u>Standard Methods</u> <u>for the Examination of Water and Wastewater</u>. Due to the flux in this area, both media were used and run in parallel. For

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purposes of this report the standard plate count will refer to those results obtained using plate count agar. The heterotrophic plate count will refer to those results obtained using R2A. With both media, three dilutions were run on each sample, and each dilution was run in duplicate.

The standard plate count using plate count agar (Difco) can be obtained by using a pour plate technique, or a spread plate technique. It does not readily lend itself to a membrane filtration (MF) technique.

The pour plate technique has several disadvantages that prevent the recovery of the maximum number of organisms by whatever methodology for determination of total bacteria. The major drawbacks are the user of tempered medium which may cause heat-shock to stressed bacteria, and the use of a nutritionally rich medium - such as plate count agar - which may likewise cause shock to starved bacteria.

The spread plate technique has two major advantages. The primary advantage is to eliminate the heat-shock caused by the use of tempered agar. The other major advantage is that all the colonies are on the surface of the agar where they can be readily seen and counted, and can be easily distinguished from particulates and air bubbles. The one major disadvantage lies in the fact that only relatively small volumes (0.1 - 1.0 ml) of samples can be used with this procedure depending on the absorbancy of the agar. In spite

of this drawback, it was felt that the advantages outweighed the disadvantages and the spread plate technique was chosen.

The heterotrophic plate count using R2A can be used as a pour plate, spread plate, or as a membrane filter (MF) method. While it has been reported that the spread plate technique gives better results than either the pour plate or MF techniques, it suffers from the threat of "carry-off" when using the glass rod or "hockey stick", and also from spreaders on plates which are not perfectly dry. The disadvantage of using a pour plate was seen, so while counts may not reach the theoretical maximum with the MF method, nonetheless, the MF method was chosen for the reasons that it is relatively fast and inexpensive while still yielding very good results.

The dilutions we used with both media were 1 ml, 0.1 ml and 0.01 mL . Later on when it became obvious that the heterotrophic plate counts we were seeing were higher than the standard plate counts at the same dilutions, the 1 ml dilution was dropped and a 0.001 mL dilution added. The plate count agar was incubated at 35°C $\pm$ 0.5°C for 48 hours, while the R2A was incubated at 30°C $\pm$ 0.5°C for seven days. After the appropriate incubation period, all the plates were counted. The standard plate count plates (100 x 15mm plates) were counted with the aid of a Quebec Darkfield colony counter. The heterotrophic plate count plates (50 x 9 mm)

were counted with the aid of a 10-15 X binocular microscope.

As has been stated earlier, an attempt was also made to isolate _Salmonella_ _spp._ from each potable water sample. This was a direct response to the 66 cases of typhoid reported on St. Croix in 1985, in which the potable water supply was thought to be involved. The procedure is a modification of one listed in _Standard_ _Methods_ _for_ _the_ _Examination_ _of_ _Water_ _and_ _Wastewater._ The procedure followed is an extension of the total coliform procedure. After the 24 hour incubation, all total coliform plates were examined for typical and atypical total coliforms. A count of the typical green metallic sheen colonies was made, and up to ten colonies were then picked for verification. In the event no typical colonies were seen, up to five atypical red colonies were picked and verified to ensure that no false negatives were missed. At this point the membrane filter was aseptically removed from the m-Endo agar, and transferred to a clean, sterile, empty 50 x 9 mm petri dish. To the petri dish which now holds the membrane filter, 10 mL of medium is added. The medium consists of m-tetrathionate broth base (Difco) to which has been added a 2% iodine solution, 1:50,000 brilliant green dye and 3 mg of 1-cystine per liter of the tetrathionate broth base. The plate was then gently agitated, and loopfuls of the media streaked out in duplicate on bismuth sulfite agar (Difco), brilliant green agar (Difco) and XLD agar (Difco).

These plates were designated as TT1 (Tetrathionate) at 0 hours. The tetrathionate cultures, brilliant green agar, and XLD agar plates were then incubated for 24 hours. The bismuth sulfite agar plates however were incubated at 35°C ± 0.5°C for a total of 48 hours.

After the 24 hour incubation period, the TT1 cultures were removed, and 1 ml was aseptically transferred to a tube containing new tetrathionate broth. This tube was then designated as TT2. Plates of bismuth sulfite, brilliant green, and XLD were again streaked in duplicate, at 0, 24, and 48 hours. These plates then bore the designations TT2/0, TT2/24, or TT2/48.

After the appropriate incubation time (24 hours for the brilliant green agar and XLD agar plates, and 48 hours for the bismuth sulfite agar plates) the plates were examined for both typical and atypical colonies.

An agar slant is created by pipetting a given volume of a molten agar into a test tube and tilting the test tube at an angle to create an oblique surface upon which organisms can grow. All slants will have two parts: The agar surface (air/agar interface) and the butt (solid agar/anaerobic zone) located at the bottom of the test tube.

Two types of colonies on the bismuth sulfite plates were picked to nutrient agar (Difco) slants. One of these colonies were the black and brownish-black colonies which were

surrounded by a brownish-black zone exhibiting a metallic sheen. The other type of colonies picked were the flat or slightly raised green ones. The media, plate and colony color were recorded on each slant.

On the brilliant green agar plates, pink-white opaque colonies surrounded by brilliant red media or any red colonies were picked to nutrient agar slants. On the XLD agar slants, red colonies, or red colonies with black centers were picked to nutrient agar slants. As before, media, plate and colony color were recorded on each slant.

All nutrient agar slants were then incubated for 24 hours at $35\,°C \pm 0.5\,°C$ for 24 hours. After the 24 hour period a loopful of the organism was streaked out on MacConkey agar (Difco). Non-lactose fermenting organisms (those that appear as colorless and translucent) were then picked to triple sugar iron agar (TSIA) slants (Difco). Those TSIA slants that gave an alkaline surface and an acid or, acid and gas butt along with the production of hydrogen sulfide (H_2S) were then submitted to the oxidase test, phenylalanine test, urease test and ONPG test. If the reactions for these four test were all negative, the culture was then inoculated into an API-20E strip. (Analytab Products Inc.) All strips which coded out as Salmonella were then reported out to the appropriate authorities as PRESUMPTIVE for the presence of Salmonella spp. with a culture submitted to public health for confirmation.

RESULTS AND CONCLUSIONS

The results of the chemical and physical analyses for St. Thomas and St. John are summarized in Tables 1 and 2 while the microbiological results are summarized in Tables 3 and 4. The findings for St. Croix are presented in Tables 5 and 6. In Tables 1, 3 and 5 the data is presented chronologically while in Tables 2, 4 and 6 the data is listed according to site. The Federal quality standards for drinking water are listed in Table 7.

All water samples taken fell well within the limits set for color, dissolved oxygen, turbidity, pH, conductivity, solids, nitrates, calcium, chlorides, silica, sodium, and magnesium in drinking water. Iron did not fall within drinking water limits. This is not suprising given the condition of the distribution system. Thus except for iron, from the chemical standpoint, water distributed by public pipelines in the Virgin Islands apparently easily meets the Federal water quality standards for drinking water.

The failings of the drinking water program lies not in the chemical realm, but rather in the microbiological realm. The microbiological problems stem from the almost total lack of free residual chlorine in the potable water distribution lines. This is of major concern because it is the free residual chlorine which acts to check the spread of disease

Table 1. Chronological Results of Chemical and
Physical Analyses for St. Thomas and St. John

SAMPLE SITE	DATE	FREE Cl- mg/l	TOTAL Cl- mg/l	TEMP C	pH	D.O mg/l	COLOR	TURB NTU	COND mhos/cm3	TOTAL SOLIDS mg/l	NO3 mg/l	Cl mg/l	Si mg/l	Na mg/l	Mg mg/l	Fe mg/l	Ca mg/l
T4	APR 21	<0.2	0.4	36.5	6.6	N/A	~13	0.19	69	18	<.44	57.75	N/A	11.32	1.22	N/A	N/A
T3	APR 21	ND	<0.2	38	6.8	N/A	5	0.21	75	17	<.44	49.5	N/A	11.38	1.03	N/A	N/A
T6	APR 21	ND	<0.2	36.5	6.9	N/A	6	0.2	81	N/A	<.44	57.75	N/A	11.32	1.43	N/A	N/A
T2	APR 28	ND	<0.2	31	9.8	N/A		0.2	105	59.44	<.44	90.75	N/A	11.28	0.65	N/A	N/A
T1	APR 28	ND	<0.2	30	8.7	N/A	~15	0.25	70	50	0.44	41.25	N/A	8.36	0.5	N/A	N/A
T10	APR 28	ND	<0.2	35	7.1	N/A	10	0.21	90	31.67	<.44	66	N/A	11.04	1.35	N/A	N/A
T9	MAY 6	ND	<0.2	33	6.8	N/A	17	0.52	95	47	<.44	49.5	0.05	12.82	1.62	N/A	N/A
T8	MAY 6	ND	<0.2	33	6.8	N/A	17	0.52	95	47	<.44	49.5	0.05	12.82	1.62	N/A	N/A
T12	MAY 6	ND	<0.2	33	7.1	N/A	15	0.69	95	47	<.44	49.5	0.08	12.48	1.96	N/A	N/A
T5	MAY 13	<0.2	0.2	36	6.1	N/A	3	0.22	55	48	13.2	28.05	0.05	6.56	1.55	0.28	1.7
T7	MAY 13	ND	0.2	35	5.2	N/A	3	0.21	45	21	0.44	24.75	0.04	6.1	1.53	0.16	1.7
T11	MAY 13	ND	0.2	35	5.6	N/A	5	0.21	50	15	0.44	33	0.04	6.74	1.73	0.21	1.7
J1	MAY 19	ND	<0.2	27	7.2	N/A	10	0.34	190	14	<.44	49.5	3.2	16.82	8.08	0.12	2.4
J2	MAY 19	ND	0.2	30	7.4	N/A	9	0.26	140	12	1.23	371.25	.39	301.6	43.63	0.05	6.8
J3	MAY 19	ND	ND	31	7.4	N/A	17	0.33	80	N/A	0.44	181.5	22.3	42.2	17.14	0.13	3.4
T4	MAY 27	0.4	0.4	35	5.9	7.4	11	0.24	32	N/A	<.44	16	0.05	10.9	1.59	1.36	4.5
T3	MAY 27	ND	<0.2	37	6.0	4.3	N/A	0.21	33	N/A	<.44	10	0.05	10.96	1.48	1.3	3.2
T6	MAY 27	ND	<0.2	35	5.7	7.6	11	0.24	30	N/A	<.44	16	0.05	11.46	1.6	1.44	4
T2	JUN 2	ND	<0.2	28	6.8	7	N/A	0.2	60	N/A	<.44	11	0.28	11.5	1.52	1.39	7.3
T10	JUN 2	0.2	0.2	35	6.6	8.2	N/A	0.2	340	N/A	<.44	11	0.05	9.62	1.54	1.61	1.6
T1	JUN 2	ND	0.2	33	6.4	10.5	N/A	0.19	360	3	<.44	12	0.04	10.18	1.46	1.35	4.9
T9	JUN 9	ND	<0.2	32	6.5	8	40	0.85	54	50	<.44	20	0.08	18.6	7.48	0.54	11
T8	JUN 9	ND	<0.2	35	6.1	6.4	10	0.35	51	12	<.44	30	0.09	17.8	6.3	13	7.5
T12	JUN 9	ND	ND	32	6.0	6	14	0.24	51	N/A	<.44	20	0.05	9.2	1.1	1.7	1.9
T5	JUN 17	ND	0.2	37	6.4	7.8	18	0.28	81	57	<.44	20	0.05	19.1	6.3	1	3.3
T7	JUN 17	<0.2	0.2	35	6.9	6.3	18	0.26	80	43	<.44	18	0.05	19	6	1.6	0
T11	JUN 17	<0.2	0.2	36	6.6	7.5	15	0.26	82	34	0.44	21	0.08	13.3	2.4	2.2	0
J1	JUN 23	3.0	1.5	30	7.6	8.5	N/A	0.2	78	481	0.55	11.5	18	65.5	31.5	0.77	38.3
J2	JUN 23	0.6	0.6	32	7.7	6.7	N/A	0.2	84	507	0.66	118	20	70.3	35.7	0.94	38.2
J3	JUN 23	0.8	0.8	34	7.7	6	N/A	0.2	86	477	0.88	120	19	85	40.4	0.44	47.9

SYMBOLS: [~] APPROXIMATELY   [ND] NOT DETECTED   [N/A] NOT AVAILABLE   [<] LESS THAN   CHRCTJ

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Table 2. Results of Chemical and Physical Analyses for St. Thomas and St. John Grouped According to Site

SAMPLE SITE	DATE	FREE Cl- mg/l	TOTAL Cl- mg/l	TEMP C	pH	D.O. mg/l	COLOR	TURB NTU	COND mhos/cm3	TOTAL SOLIDS mg/l	NO3 mg/l	Cl mg/l	Si mg/l	Na mg/l	Mg mg/l	Fe mg/l	Ca mg/l
T1	APR 28	ND	<0.2	30	8.7	10.5	~15	0.25	70	50	0.44	41.25	0.04	8.36	0.5	1.35	4.9
T1	JUN 2	ND	0.2	33	6.4			0.19	360	3	<.44	12		10.18	1.46		
T2	APR 28	ND	<0.2	31	9.8	7		0.2	105	59.44	<.44	90.75	0.28	11.28	0.65	1.39	7.3
T2	JUN 2	ND	<0.2	28	6.8			0.2	60	N/A	<.44	11		11.5	1.52		
T3	APR 21	ND	<0.2	38	6.8	4.3	5	0.21	75	17	<.44	49.5	0.05	11.38	1.03	1.3	3.2
T3	MAY 27	ND	<0.2	37	6.0			0.21	33	N/A	<.44	10		10.96	1.48		
T4	APR 21	<0.2	0.4	36.5	6.6	7.4	~13	0.19	69	18	<.44	57.75	0.05	11.32	1.22	1.36	4.5
T4	MAY 27	0.4	0.4	35	5.9		11	0.24	32	N/A	<.44	16		10.9	1.59		
T5	MAY 13	<0.2	0.2	36	6.1	7.8	3	0.22	55	48	13.2	28.05	0.05	6.56	1.55	0.28	1.7
T5	JUN 17	ND	0.2	37	6.4		18	0.28	81	57	<.44	20	0.05	19.1	6.3	1	3.3
T6	APR 21	ND	<0.2	36.5	6.9	7.6	6	0.2	81	N/A	<.44	57.75	0.05	11.32	1.43	1.44	4
T6	MAY 27	ND	<0.2	35	5.7		11	0.24	30		<.44	16		11.46	1.6		
T7	MAY 13	ND	0.2	35	5.2	6.3	3	0.21	45	21	0.44	24.75	0.04	6.1	1.53	0.16	1.7
T7	JUN 17	<0.2	0.2	35	6.9		18	0.26	80	43	<.44	18	0.05	19	6	1.6	0
T8	MAY 6	ND	<0.2	33	6.8	6.4	17	0.52	95	47	<.44	49.5	0.05	12.82	1.62	13	7.5
T8	JUN 9	ND	<0.2	35	6.1		10	0.35	51	12	<.44	30	0.09	17.8	6.3		
T9	MAY 6	ND	<0.2	33	6.8	8	17	0.52	95	47	<.44	49.5	0.05	12.82	1.62	0.54	11
T9	JUN 9	ND	<0.2	35	6.5		40	0.85	54	50	<.44	20	0.08	18.6	7.48		
T10	APR 28	ND	<0.2	35	7.1	8.2	10	0.21	90	31.67	<.44	66	0.05	11.04	1.35	1.61	1.6
T10	JUN 2	0.2	0.2	35	6.6			0.2	340	N/A	<.44	11		9.62	1.54		
T11	MAY 13	ND	0.2	35	5.6	7.5	5	0.21	50	15	0.44	33	0.04	6.74	1.73	0.21	1.7
T11	JUN 17	<0.2	0.2	36	6.6		15	0.26	82	34	0.44	21	0.08	13.3	2.4	2.2	0
T12	MAY 6	ND	<0.2	33	7.1	6	15	0.69	95	47	<.44	49.5	0.08	12.48	1.96	1.7	1.9
T12	JUN 9	ND	ND	32	6.0		14	0.24	51	N/A	<.44	20	0.05	9.2	1.1		
J1	MAY 19	ND	<0.2	27	7.2	8.5	10	0.34	190	14	<.44	49.5	3.2	16.82	8.08	0.12	2.4
J1	JUN 23	3	1.5	30	7.6			0.2	78	481	0.55	11.5	18	65.5	31.5	0.77	38.3
J2	MAY 19	ND	0.2	30	7.4	6.7	9	0.26	140	12	1.23	371.25	39	301.6	43.63	0.05	6.8
J2	JUN 23	0.6	0.6	32	7.7			0.2	84	507	0.66	118	20	70.3	35.7	0.94	38.2
J3	MAY 19	ND	ND	31	7.4	6	17	0.33	80	N/A	0.44	181.5	22.3	42.2	17.14	0.13	3.4
J3	JUN 23	0.8	0.8	34	7.7			0.2	86	477	0.88	120	19	85	40.4	0.44	47.9

SYMBOLS: [~] APPROXIMATELY [ND] NOT DETECTED [N/A] NOT AVAILABLE [<] LESS THAN   CHEMPTJ

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Table 3. Chronological Results of Microbiological
Analyses for St. Thomas and St. John

SAMPLE SITE	DATE	FREE Cl- mg/l	TOTAL COLIFORM /100 ml	NON-LACTOSE /100 ml	FECAL COLIFORM /100 ml	FECAL STREPT. /100 ml	STANDARD PLATE COUNT /ml	HETRO. PLATE COUNT /ml	SALMONELLA sp.	NOTES
T3	APR 21	ND	0	24	0	0	23,000	20,000,000	- -	
T4	APR 21	<0.2	0	0	0	0	5,300	120	- -	
T6	APR 21	ND	0	0	0	0	3,600	35,000	- -	BROKEN LINE
T1	APR 28	ND	252	TNTC	73	423	2,000	TNTC	- -	
T2	APR 28	ND	0	1	0	0	5,300	140,000	- -	
T10	APR 28	ND	0	18	0	0	51,000	91,000	-	
T8	MAY 6	ND	179	89	0	0	32,000	29,000	- -	
T9	MAY 6	ND	77	75	0	1	1,000	40,000	- -	
T12	MAY 6	ND	184	328	1	1	32,000	40,000	-	
T5	MAY 13	<0.2	0	3	0	0	4	7,100	- -	
T7	MAY 13	ND	0	5	0	1	100	17,000	- -	
T11	MAY 13	ND	0	8	0	0	130	37,000	-	
J1	MAY 19	ND	51	>1000	6	82	43,000	49,000	+ +	
J2	MAY 19	ND	1	>600	1	0	810	1,000	+	
J3	MAY 19	ND	1	>600	2	11	2,000	410	-	
T3	MAY 27	ND	0	19	0	0	5,300	TNTC	- -	
T4	MAY 27	0.4	0	3	0	0	N/A	N/A	- -	
T6	MAY 27	ND	12	120	1	1	22,000	TNTC	-	
T1	JUN 2	ND	0	410	0	0	N/A	540	- -	
T2	JUN 2	ND	1	39	2	0	N/A	51,000	- -	
T10	JUN 2	0.2	0	1	1	0	N/A	59	-	
T8	JUN 9	ND	1	19	1	4	74,000	240,000	- -	
T9	JUN 9	ND	0	30	2	3	66,000	610,000	- -	
T12	JUN 9	ND	2	4	0	0	520	75,000	-	
T5	JUN 17	ND	33	1	0	1	10	130	- -	
T7	JUN 17	<0.2	2	0	0	0	50	1,200	- -	
T11	JUN 17	<0.2	0	0	0	0	<10	90	-	
J1	JUN 23	3	0	5	0	0	<10	140	- -	
J2	JUN 23	0.6	1	0	0	0	10	160	- -	
J3	JUN 23	0.8	0	2	0	0	90	60	-	

SYMBOLS:

[<] LESS THAN   [ND] NOT DETECTED   [TNTC] TOO NUMEROUS TO COUNT

[>] GREATER THAN   [+] PRESENT   [-] ABSENT   chrmt]

Table 4. Results of Microbiological Analyses for St. Thomas and St. John Grouped According to Site

SAMPLE SITE	DATE	FREE Cl– mg/l	TOTAL COLIFORM /100 ml	NON-LACTOSE /100 ml	FECAL COLIFORM /100 ml	FECAL STREPT. /100 ml	STANDARD PLATE COUNT /ml	HETRO. PLATE COUNT /ml	SALMONELLA SP.
T1	APR 28	ND	252	TNTC	73	423	2,000	TNTC	–
T1	JUN 2	ND	0	410	0	0	N/A	540	
T2	APR 28	ND	0	1	0	0	5,300	140,000	–
T2	JUN 2	ND	1	39	2	0	N/A	51,000	–
T3	APR 21	ND	0	24	0	0	23,000	20,000,000	–
T3	MAY 27	ND	0	19	0	0	5,300	TNTC	–
T4	APR 21	<0.2	0	0	0	0	5,300	120	–
T4	MAY 27	0.4	0	3	0	0	N/A	TNTC	–
T5	MAY 13	<0.2	0	3	0	0	4	7100	–
T5	JUN 17	ND	33	1	0	1	10	130	–
T6	APR 21	ND	0	0	0	0	3,600	35,000	–
T6	MAY 27	ND	12	120	1	1	22,000	TNTC	–
T7	MAY 13	ND	0	5	0	1	100	17,000	–
T7	JUN 17	<0.2	2	0	0	0	50	1,200	–
T8	MAY 2	ND	179	89	0	0	32,000	29,000	–
T8	JUN 9	ND	1	19	1	4	74,000	240,000	–
T9	MAY 6	ND	77	75	0	1	1,000	40,000	–
T9	JUN 9	ND	0	30	2	3	66,000	610,000	–
T10	APR 28	ND	0	18	0	0	51,000	91,000	–
T10	JUN 2	0.2	0	1	1	0	ND	59	–
T11	MAY 13	ND	0	8	0	0	130	37,000	–
T11	JUN 17	<0.2	0	0	0	0	<10	90	–
T12	MAY 6	ND	184	328	1	1	32,000	40,000	–
T12	JUN 9	ND	2	4	0	0	520	75,000	–
J1	MAY 19	ND	51	>1000	6	82	43,000	49,000	+
J1	JUN 17	3	0	5	0	0	<10	140	–
J2	MAY 19	ND	1	>600	1	0	810	1,000	+
J2	JUN 23	0.6	1	0	0	0	10	160	–
J3	5/19/86	ND	1	>600	2	11	2,000	410	–
J3	6/23/86	0.8	0	2	0	0	90	60	–

SYMBOLS: [ND] NOT DETECTED   [TNTC] TOO NUMEROUS TO COUNT

[<] LESS THAN   [>] GREATER THAN   [+] PRESENT   [-] ABSENT   pmtj

Table 5. Chronological Results of Microbiological and
Physical Analyses for St. Croix

SAMPLE SITE	DATE	TEMP C	pH	COND mhos/cm3	FREE Cl- mg/1	TOTAL Cl- mg/1	TOTAL COLIFORM /100 ml	NON-LACTOSE /100 ml	FECAL COLIFROM /100 ml	FECAL STREPT. /100 ml
X1	APR 15				ND	<0.2	0	0	0	0
X2	APR 15				ND	<0.2	1	3	0	0
X3	APR 15				ND	ND	0	0	0	0
X4	APR 15				ND	<0.2	0	22	0	0
X5	APR 15				ND	<0.2	0	2	0	2
X6	APR 15				<0.2	0.2	0	2	0	0
X7	APR 15				0.2	0.4	0	0	0	0
X8	APR 15				ND	ND	20	200	0	4
X9	APR 15				0.4	0.4	0	1	0	1
X10	APR 15				1.0	1.5	2	17	0	6
X11	APR 15				0.6	1.0	0	13	10	0
X12	APR 15				ND	<0.2	0	3	0	0
X13	APR 15				ND	<0.2	0	5	0	0
X14	APR 15				ND	<0.2	0	26	0	8
X15	APR 15				ND	ND	0	8	0	0
X1	JUN 30	30	7.6	190	ND	ND	16	16	0	0
X2	JUN 30	33	9.7	130	ND	ND	0	0	0	0
X3	JUN 30	33	9.5	140	ND	ND	5	3	0	0
X4	JUN 30	35	7.1	84	ND	ND	143	10	0	1
X5	JUN 30	30	7.6	74	ND	ND	1	1	0	0
X6	JUN 30	36	7.6	81	ND	ND	20	3	0	1
X7	JUN 30	35	6.5	73	ND	ND	2	20	0	1
X8	JUN 30	32	10.7	230	ND	ND	0	0	0	0
X9	JUN 30	34	8.1	70	ND	ND	269	11	1	1
X10	JUN 30	36	6.8	130	<0.2	<0.2	0	0	0	1
X11	JUN 30	32	6.0	66	ND	<0.2	142	7	0	1
X12	JUN 30	29	6.2	68	ND	ND	183	11	0	15
X13	JUN 30	29	6.9	70	ND	ND	4	73	0	4
X14	JUN 30	30	8.4	20	ND	ND	3	219	0	0
X15	JUN 30	31	9.6	81	ND	ND	336	6	0	1

SYMBOLS: [ND] NOT DETECTED   [<] LESS THAN   chrmx

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Table 6. Results of Microbiological and Physical Analyses for St. Croix Grouped According to Site

SAMPLE SITE	DATE	TEMP C	pH	COND mhos/cm3	FREE Cl- mg/1	TOTAL Cl- /100 ml	TOTAL COLIFORM /100 ml	NON-LACTOSE /100 ml	FECAL COLIFORM /100 ml	FECAL STREP. per/100 ml
X1	APR 15	30	7.6	190	ND	<0.2	0	0	0	0
X1	JUN 30				ND	ND	16	16	0	0
X2	APR 15	33	9.7	130	ND	<0.2	1	3	0	0
X2	JUN 30				ND	ND	0	0	0	0
X3	APR 15	33	9.5	140	ND	ND	0	0	0	0
X3	JUN 30				ND	ND	5	3	0	0
X4	APR 15	35	7.1	84	ND	<0.2	0	22	0	0
X4	JUN 30				ND	ND	143	10	0	1
X5	APR 15	30	7.6	74	ND	<0.2	0	2	0	2
X5	JUN 30				ND	ND	1	1	0	0
X6	APR 15	36	7.6	81	<0.2	0.2	0	2	0	0
X6	JUN 30				ND	ND	20	3	0	1
X7	APR 15	35	6.5	73	0.2	0.4	0	0	0	0
X7	JUN 30				ND	ND	2	20	0	1
X8	APR 15	32	10.7	230	ND	ND	20	200	0	4
X8	JUN 30				ND	ND	0	0	0	0
X9	APR 15	34	8.1	70	0.4	0.4	0	1	0	1
X9	JUN 30				ND	ND	269	11	1	1
X10	APR 15	36	6.8	130	1.0	1.5	2	17	0	6
X10	JUN 30				<0.2	<0.2	0	0	0	1
X11	APR 15	32	6.0	66	0.6	1.0	0	13	1	0
X11	JUN 30				ND	<0.2	142	7	0	1
X12	APR 15	29	6.2	68	ND	<0.2	0	3	0	0
X12	JUN 30				ND	ND	183	11	0	15
X13	APR 15	29	6.9	70	ND	<0.2	0	5	0	0
X13	JUN 30				ND	ND	4	73	0	4
X14	APR 15	30	8.4	20	ND	<0.2	0	26	0	8
X14	JUN 30				ND	ND	3	219	0	0
X15	APR 15	31	9.6	81	ND	ND	0	8	0	0
X15	JUN 30				ND	ND	336	6	0	1

SYMBOLS: [ND] NOT DETECTED   [<] LESS THAN

pmx

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Table 7. U.S. E.P.A. Physical-Chemical Standards for Drinking Water

	Maximum legal concentration
Free Residual Chlorine	0.2 mg/L
Color	15 color units
Dissolved Oxygen	3 mg/L
Turbidity	1 NTU
pH	6.5 - 8.5 ph units
Conductivity	50 μMHOS
Total Dissolved Solids	500 mg/L
Nitrate	10 mg/L
Calcium	250 mg/L
Magnesium	100 mg/L
Sodium	250 mg/L
Chlorides	250 mg/L
Iron	0.3 mg/L
Silica	UNK

causing organisms. It has been shown that without free residual chlorine, the risk of having a viable pathogen present is increased significantly. (Kutcha, J. M. et. al. 1983; Burke, V., et. al. 1984; Keswick, B. H., et. al. 1985; Geldreich, E. E., et. al. 1978; Craun, G. F. et. al. 1978; McCabe, L. J. 1978; Natural Resources Council 1977; American Public Health Association 1985). The fact that almost without exception all the samples taken showed standard plate counts in excess of 500 total organisms per milliliter proves beyond a doubt that there is inadequate disinfection occuring throughout the distribution lines, even though the majority of the samples were negative for the presence of the standard total coliform and fecal coliform bacteria. Since it appears that there is inadequate disinfection occurring in the lines, it is no real surprise when on occasion, a total coliform or two is found. Nor was it surprising to find after a lateral line to one of the local housing projects had broken in two places, that the numbers of total coliform, fecal coliform, and fecal streptococcus, had increased significantly and that once the line was fixed the numbers dropped back to normal levels.

The value of the total coliform analysis has been shown time and time again (McFeters,G. A. et. al. 1978; Craun, G. F. 1978; Allen, M. J. and Geldreich, E. E. 1978; National

Research Council 1977; American Public Health Association 1985; Bolt, T. L. 1973; LeChevallier, M. W. et. al. 1983; McFeters, G. A. et. al. 1986) even though questions have arisen about its use as the sole source in determining water quality. This study supports its validation. In short, if total coliforms are found in any significant numbers other potential pathogens might be found. This study also supports the conclusions found in other studies which suggest that if total coliforms are absent, the water is safe to drink when in reality it is not. Both situations were poignantly realized during the investigation of the St. John potable water lines: At the main storage tank no free residual chlorine was detected, thus it was not surprising to find a total coliform count of 51 with more than 1000 other non-lactose fermenting organisms present, a fecal coliform count of six, a streptococcal count of 91, and a standard plate count of 4300. Again, it was also not a great surprise given these numbers to end up isolating a Salmonella species.

Less than a quarter mile away at the Agricultural Station another sample was taken. Here, after a total coliform count of one in the presence of around 700 other non-lactose fermenting organisms, a fecal coliform count of one, a fecal streptococcol count of 34, and a standard plate count of 810 was obtained. While contaminated, it is not overly so in comparison to other samples. From this point it was very surprising to isolate a Salmonella species.

Taken from individual standpoints, assuming that the samples had not been taken together, but alone, and that had microbial analysis been limited to the standard total coliform analysis alone to determine the suitability of the water for drinking purposes, the main storage tank which showed 51 total coliforms would have failed to pass acceptable levels. Contrastly, the other sample taken at the Agricultural Station which showed only one total coliform would have met existing minimal water quality standards when in fact a health hazard was present.

Several conclusions can be drawn from this study. The basic conclusions are:

1) If no free residual chlorine levels are found assume the probability of finding high numbers of non-lactose fermenting organisms to be high, thus do a standard plate count.

2) Just because a water supply shows only one total coliform, or no total coliform, and the amount of background growth (the non-lactose fermenting organisms) is high and there is an absence of any free residual chlorine, then the supply should not be assumed safe.

3) Montlhy analysis for fecal coliform and fecal streptococcus should be performed in addition to the total coliform and standard plate count if the lack of the free residual chlorine levels are found on a continuous basis from any given point. Alternatively, both analyses should be performed as part of the check sample if the previous sample showed more than one total coliform.

4) If the sample showed unusually high numbers of total coliforms - more than 16 - and an unusually high standard plate count - greater than 1000 - then in addition to the total coliform, fecal coliform, fecal streptococcus, and standard plate count, do an analysis for Salmonella.

The key to assuming a safe supply of drinking water is to insure that there is an adequate amount of free residual chlorine available in the lines at all times for disinfection purposes.

If free residual chlorine levels cannot either be maintained or assured on a continous basis, then the alternative is to more closely monitor the bacteriological quality of that water. But this would both be more costly and time consuming. Only in these ways can we be relatively certain that the water supply is safe to drink.

From an unbiased point of view it would be a lot easier to properly chlorinate the supply in the first place, and if necessary install supplemental automatic chlorine injectors throughout the distribution network to prevent over chlorination in one particular area or under chlorination in another.

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