BACTERIA COLONIZING POINT-OF-USE, GRANULAR ACTIVATED CARBON FILTERS AND THEIR RELATIONSHIP TO HUMAN HEALTH

BY

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ABSTRACT

An epidemiological study on the health effects associated with bacteria found in granular activated carbon (GAC) point-of-use filters was conducted by the Department of Epidemiology and Public Health, Yale School of Medicine. The study population consisted of Navy families that lived in off-base Navy housing in Groton, Connecticut. Two types of filters were used during the study. The first type was a filter that attached at the end of the kitchen faucet. Participating families used a filter with either a cartridge containing granular activated carbon or a blank cartridge. The second type of filter was a dual cartridge bypass filter that had its own faucet at the kitchen sink. Bacterial data and health data were collected during monthly visits to the subjects' homes. All water samples were analyzed for heterotrophic bacteria using two media. The carbon filters eluted significantly higher densities of bacteria than unfiltered water (tap water or water from the blank cartridge). Of the two media used for heterotrophic bacterial analyses, R2A recovered significantly more bacteria than did the standard plate count agar. Mean Standard Plate counts from the faucet carbon filters and the bypass filters were 689 and 1049 per ml respectively compared to 198 and 53 per ml for blank filter effluents and the tap water respectively. The R2A medium yielded roughly twice these levels for each of the four categories of waters. Bacterial isolates from a random sample of homes with carbon filters were identified. The majority of the bacteria belonged to the Flavobacterium and Pseudomonas genera. In particular, the bypass bacteria were primarily *P. stutzeri*. All families were monitored for grastrointestinal and dermatologic symptoms. Despite the high bacterial densities there were no differences in gastrointestinal illness or dermatologic illnesses between the control group (blank faucet filter) and the two test groups (carbon faucet filter and bypass carbon filter). An exposure analysis estimated an average daily intake of 10^6 organisms per day per person for carbon filter users.

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SECTION 1

INTRODUCTION

There has been an increased awareness of the chemicals contained in drinking water. Many of these chemicals affect the aesthetic properties of water such as taste, color and odor. Other chemicals such as trihalomethanes and other volatile organics may be potentially harmful. It is estimated that only one half of one percent of water produced by a municipal water treatment facility is actually used for cooking and drinking (Regunathan, et al., 1983). Some water consumers wish that this small fraction of potable water could meet more stringent requirements for chemical contamination whether for health effects or aesthetic effects. In some communities the water quality can be more effectively controlled at the point of use than at the central treatment plant. Many taste, color and odor complaints are due to microbial regrowth, corrosion products in the water main and by-products of chlorination. These events occur after leaving the treatment plant. In many households, the installation of point-of-use (POU) treatment devices are used to provide specially treated water for drinking and cooking purposes.

Many different kinds of POU devices are available for consumer use. The most commonly used devices contain granular activated carbon (GAC). Filters with GAC remove common tastes and odors, some turbidity, chlorine, and many organic contaminants. Charcoal has been used for water purification for centuries. The need for higher adsorptive capacities led to the development of activated carbon in the early 1900's. Activation provides the carbon with a high degree of porosity and an associated high surface area. The high surface area renders activated carbon an excellent adsorbent for a wide range of chemicals. This high surface area also provides an excellent surface for biomass attachment and a favorable environment for the growth of microscopic organisms (Rice and Robson, 1982). Several papers have reported the colonization and subsequent discharge of higher densities of bacteria in laboratory studies on GAC filters (Geldreich et al., 1985, Brewer and Carmichael, 1979, Bell, et al., 1984). The effects of such growth have been reported as both advantageous (Rice and Robson, 1982) and disadvantageous (Wallis, Stagg and Melnick, 1974). Of special concern is the health hazard that may be created if pathogenic organisms adhere to and grow on carbon surfaces. This concern was categorized succinctly by Dufour (1985) into five questions:

1. What are the possible health risk concerns?
2. What bacteria are associated with granular activated carbon?
3. What are the origins of these health risk concerns?
4. Are there reasons to question the health risk concerns?
5. How can the assumed health risks be verified?

The types of health risks of concern are related to the use of water from POU-GAC filters. The primary use of water from POU-GAC filters is for drinking and culinary purposes. It follows that the primary health concern would be gastrointestinal infections associated with bacteria in water from GAC-POU filters. A secondary use of water from POU filters would be for handwashing (contact) and hence there is a secondary risk of dermatologic infections associated with the bacteria discharged from GAC-POU filters. To better understand the health concerns, the second question: "What are the bacteria associated with activated carbon filters?" must be asked.

The types of bacteria associated with granular activated carbon are diverse and depend on three factors; 1) the types of bacteria found in the influent water; 2) the ability of a species of bacteria to attach to GAC; and 3) the ability of a species, once attached, to multiply in the carbon media and slough off in sufficient densities to be detected in the filter effluent. One study by Geldreich and coworkers (1985) reported that four out of seven tested species including Pseudomonas aeruginosa readily colonized GAC filters in the laboratory. Other studies report that many of the bacteria that colonize in GAC filters are native to aquatic environments and normally are not considered to be pathogenic. This leads to the third question: "What are the origins of the health risk concerns?"

A majority of the concerns arise out of the types of bacteria that cause nosocomial (hospital acquired) infections. Many bacteria found in potable water have been found in increasing numbers as causes of nosocomial infections (Karnad, et al. 1985). A secondary concern arises over the higher densities of these bacteria eluted from the GAC filters. Geldreich and coworkers reported densities of heterotrophic bacteria exceeded 1000 cfu per ml. An 8 ounce glass of water (237 ml) would contain approximately 2×10^5 organism. Since little is known about infective doses for the majority of heterotrophic bacteria, the high densities suggest a dose may be sufficiently high enough to cause disease. However, this poses the fourth question: "Are there reasons to question the health concern?"

The few studies done on the effect of ingesting high densities reported contrary data (Dufour, 1985). Two bacteria, Klebsiella pneumoniae and Pseudomonas aeruginosa both of which were shown to colonize GAC filters in laboratory studies (Geldreich, et al., 1985) were used in human feeding experiments. Doses of up to 10^8 organisms showed no illnesses in the human volunteers. Both of these organisms are common causes of nosocomial infections but healthy volunteers did not develop gastrointestinal infection when challenged.

While there is evidence to suggest that bacteria associated with GAC filters do not cause disease, the overall question of a health effect is still a concern. There are two major reasons for this continued concern. The first is the diverse nature of bacteria found in distribution systems and hence able to colonize GAC filters. Little is known about these organisms and what if any effect they would have on people who may be exposed to higher densities of these bacteria. The second reason is that these filters will be used in a wide variety of homes where the spectrum of people exposed will range from infants to senior citizens. Previous studies on gastrointestinal illnesses have focused on families with young children (Cabelli, 1982; Monto and Koopman, 1980). It is believed this age group is most susceptible to gastrointestinal infections. This leads to the last and final question: "How can the assumed health risks be identified?"

One way to answer the question would be to conduct an epidemiological study on the use of POU-GAC filters and relate it to illnesses in the user populations. The objective of this study was to do just that, namely conduct an epidemiological study which would evaluate the health effects, if any, of bacteria from a distribution system that colonized POU-GAC filters. In the years of 1984 to 1986, a study on the health effects of higher bacterial densities in effluent waters from POU-GAC filters was conducted by the Department of Epidemiology and Public Health, Yale School of Medicine under the terms of a cooperative contract with the Health Effects Research Laboratory, U.S. Environmental Protection Agency.

SECTION 2

CONCLUSIONS

1. Point-of-use granular activated carbon filters (by-pass and faucet) are colonized by heterotrophic bacteria from the water supply distribution system. Once colonized, the filters discharge significantly higher densities of heterorophic bacteria than unfiltered tap water.

2. Exposure to these higher densities of heterotrophic bacteria (over 1000 cfu per 1.0 ml) did not cause an increase in acute symptomatology (gastrointestinal and dermatologic) as compared with those people who were exposed only to unfiltered water.

3. Gastrointestinal infections reported to a physician by study participants were not associated with bacteria colonizing GAC filters.

SECTION 3

MATERIALS AND METHODS

A. MICROBIOLOGY

Sample Collection

Two water samples were collected from each house during the initial visit by one of the field investigators. The first sample, approximately 100 milliliters in volume, was collected from the cold water faucet in the kitchen after the water had run for about two minutes. After the faucet filter or bypass filter had been installed, a second 100 milliliter sample of the filtered water was collected. This second sample was collected as soon as the effluent from the filter was clear of all air or any minute carbon particles. All homes, i.e. both test and control residences, were sampled at least once per month. At that time, two water samples were collected. The procedure in collecting these two samples was as follows:

1. the mouth of the discharge orifice for unfiltered water was wiped with a prep swab saturated with 70% isopropyl alcohol and allowed to dry thoroughly; the faucet was turned on and the first 50 milliliters were discarded and the next 100 milliliters were collected in a sterile bottle which contained sodium thiosulphate.

2. the discharge orifice for filtered water was treated the same as above and a sample collected as outlined.

Bacterial Analysis

Two media were used on all water samples to measure the total heterotrophic bacterial count. The first was a Standard Plate Count Agar(Difco) (APHA, 1981) and the second was a media called R2A (Difco) developed by the U.S. Environmental Protection Agency (Reasoner, 1985) that is being evaluated currently as a possible replacement for the SPC medium.

With the exception of samples collected on Sunday nights, all samples were plated on the same day of collection. The Sunday samples were done on Monday morning after being stored at 4°C. Plates (R2A and SPC) were predryed at room temperature to allow the plating of 1.0 milliliter onto the agar. All "A" samples (unfiltered tap water) had 1.0 milliliter of water examined on R2A and 1.0 milliliter on SPC plates. The "B" samples (filtered water) were either diluted 10 fold or 100 fold in sodium phosphate buffer (pH=7.2). From these final dilutions a 1 ml and a 0.1 ml aliquot were plated in duplicate on R2A and SPC media.

The SPC plates were incubated at 35^{o}C for five days and the R2A plates were incubated at 22^{o}C for five days. Although Standard Methods (1982) recommends a three day incubation period, Reasoner and workers (1985) reported increased recoveries on both SPC and R2A with extended incubation. Space and time constraint in the laboratory allowed a five day incubation.

Identification of Isolates

A random sample of households with POU-GAC filters was chosen to have their bacterial isolates identified. Representatives of each colony with similar morphology were picked from "A" and "B" samples and were streaked for isolation on a modified R2A agar that contained an additional 1% dextrose. This modified R2A medium was found to be superior to SPC and plain R2A media in laboratory passage of isolates.

The isolated colonies were Gram stained and all Gram negative organisms were inoculated into glucose oxidative fermentation tubes. These tubes were incubated at 30^{o}C for 21 days. This extended procedure was recommended for water bacterial isolates (Spino, 1985). All oxidative positive and nonreactive isolates were further identified using API, NFT strips. All fermentative isolates were speciated using API 20E identification strips. These identification strips were further supplemented with motility and oxidase testing. Motility was tested using MIO medium (Difco) and the isolates were incubated at room temperature for 48 hours.

Flushing Experiments

A series of flushing experiments were done to determine the effect of flushing the filter on heterotrophic bacterial counts in filter effluent. The faucet filter studies were conducted in the laboratory on a faucet filter containing carbon catridge attached to the laboratory sink. For one week prior to the experiment the filter was run for five minutes twice a day to seed the filter. The bypass filter used for the flushing experiments was one of the filters installed in the subjects home. The subject was asked not to use the filter in the previous twelve hours prior to our visit. A series of 250 ml (faucet filter) or 500 ml (bypass filter) sample bottles containing sodium thiosulfate were filled subsequently with filter effluent. Samples were then plated on R2A agar only and incubated at 22^{o} for five days.

B. FILTERS

Faucet Filter

The faucet filter used was a Pollenex WP-100 GAC water filter. This filter is listed by the National Sanitation Foundation (NSF) for Taste and Odor Reduction under standard No. 42 which is for "Aesthetic Effects". The Pollenex filter was attached at the end of the kitchen faucet. The faucet filter households were divided into test and control groups. The test group had a filter cartridge with carbon and the control group had an empty cartridge. A schematic flow diagram of the unit is shown in Figure 1. The carbon cartridge contained approximately 50g.

Bypass Filter

The second type of POU filter was an Everpure QC4-THM dual cartridge bypass filter. This filter has a NSF listing under Standard 42 and an additional listing for Turbidity Reduction, Cyst Reduction and Total THM Reduction under Standard 53 which is for" Health Effects". This filter was installed under the sink with its own faucet in the upper right corner of the sink (Figure 2). The amount of GAC in the first cartridge was approximately 500g, while the second cartridge included about 100g of Powdered Activated Carbon.

Installation

The Polenex faucet filters were installed by research personnel during the initial visit to the subjects' house. All filters were painted with a number in a hidden place on the filter. This number identified whether the cartridge was a blank or a test cartridge. After the installation, the subjects were given a small demonstration on proper use of the filter, such as using the switch to get filtered or unfiltered water. This information was also summarized on a paper given to them.

The Everpure bypass filters were installed by a licensed plumber. After the plumber had completed the installation, the use of the filter was demonstrated by a member of the research team and an explanation was given on how water could be turned off in the case of any water leaks.

Maintenance

The faucet filters were changed every three to four months. At the time of the change, the entire unit was changed so that the subject would not know whether they were getting a filter with a carbon or a blank cartridge. In most cases filters were changed from carbons to blanks and blanks to carbons. On occasion filters would break or leak and filters would have to be repaired before the next monthly visit.

The bypass filters required very little maintenance. The filter cartridges were changed when the flow became impeded or subjects complained of taste problems. Approximately five sets of cartridges were changed during the study. The cartridges were changed by the researcher during the monthly visit.

C. EPIDEMIOLOGY AND STUDY SITE

City of Groton Water Supply

The present source of Groton's water supply is predominantly derived from the Great Brook watershed and a portion of the Billings Avery watershed. The mouth of Great Brook empties into the Poquonamock River and its source is located in the southerly portion of the Town of Ledyard. This watershed is 15.9 square miles in area and develops a surface water supply which has been estimated to have a safe daily yield of 12.1 million gallons per day.

The City of Groton's Filtration Plant, where the water is treated, consists of three units; the original built in 1939, has four, one-half million gallons per day filter beds; an addition built in 1950 has four one million gallons per day filter beds; and an addition built in 1961 having three, two million gallons per day filter beds, which results in a total of twelve million gallons per day nominal capacity rating of the plant. In 1971, one of the two million gallon per day sand filter beds was rebuilt utilizing a mixed filter media of ilmenite and anthracite, which has doubled the capacity to four million gallons and has increased the nominal rating of the plant to fourteen million gallons per day. The current daily usage averages 11.18 million gallons per day. In 1986, the City of Groton, Department of Utilities reported an average free chlorine residual of 1.1 ppm at the filtration plant and 0.9 ppm in the Navy housing area distribution sites. Their quarterly heterotrophic bacteria plate counts in the plant effluent averaged <1 per ml. There were four distribution sampling locations in the study area. These locations averaged <1 cfu per ml. (Report furnished by City of Groton, Department of Utilities.)

Description of Subjects

The pool of subjects used in this study was taken from families who resided in off base U.S. Navy housing in Groton, Connecticut. This population was chosen because 1) they all had the same water supply; 2) they had access to free medical care and; 3) the majority of housing residents are families with children under the age of ten.

From a Navy housing mailing list, with over 5000 addresses, 800 families were initially selected randomly to receive the first questionnaire asking them to participate in the study.

From the pool of returned questionnaires, people were selected for the study if 1) they indicated they wished to participate on the questionnaire and 2) they had a personal rotation date that exceeded the length of the study. These people were contacted by phone and an appointment was scheduled to install a filter in their home. Six months after the start of the study, the bypass filter was added to the study. An additional 700 questionnaires were sent out to solicit additional families. These households were selected based on the criteria described above.

<u>Questionnaires</u>

The first questionnaire was a general survey on how residents of the house felt about the taste, odor and color of their water. Additional questions were asked about hot water, dishwashers and the use of any water treatment devices. The final section asked questions on demographics, personal rotation date and willingness to participate in the study. This questionnaire was accompanied by an information letter stating the purpose and requirements of the study (See Appendix A for letter and questionnaire).

At the first installation visit all subjects were asked to read and sign a consent form (Appendix A). The use of the health diary was explained to them. In this study, the effect of bacteria associated with carbon filters and their impact on health was measured in terms of acute symptomatology. The health diary used was a revised diary used previously in EPA sponsored studies. The diary method is a variation on self-administered questionnaires. Self-administered questionnaires were preferred for many reasons. The first is that this avoids problems of interviewer error. Secondly, since information on all household members was collected, the self-administered questionnaire allowed time to ascertain the status of all household members. Most importantly, self-administered questionnaires have been shown to collect information more accurately (Cannell and Fowler, 1963). The diary consisted of a list of gastrointestinal and dermatological symptoms. The severity of the symptoms was measured in terms of affect on subjects daily living such as did they stay home or in bed and did they seek medical care. If they sought medical care they were questioned subsequently to determine what the diagnosis was. This diary was exchanged for a new one at the monthly visit and the symptoms, if any, were reviewed by the researcher with an adult member of the house. This supplemental interviewing is recommended for self-administered questionnaires (Moser and Kalton, 1972).

<u>Marketing Survey</u>

Questions were submitted by both filter manufacturers to be included at the bottom of the monthly diary. Questions concerning taste, odor and color reduction were asked of both Pollenex and Everpure filter users. In addition, Everpure had questions that related to the design and function of their filter. The results of the marketing questions used are summarized in the Appendix B.

Filter Use Survey

At the end of the study an exit survey on use of filters and amount of filtered water consumed by subjects was done. The adult member of the household present at the last monthly visit was interviewed concerning the intake of water by all members of the household (See Appendix A).

Human Investigation Committee

All questionnaires, health diaries, consent forms, information letters, went to the Yale University Human Investigation Committee (HIC) before use for clearance and approval. No questionnaire was used until an HIC approval was received.

D. MEDICAL CLINIC VISITS AND CLINICAL LABORATORY PROCEDURES

The health survey approach to establishing an association between the microbial quality of GAC filtered water and illness in water consumers was supplemented by examining the direct relationship between bacteria isolated from patients who visited a physician because of a gastrointestinal illness and bacteria colonizing the GAC filter used by the study participant. This direct approach was implemented in the following manner. The medical clinic records of all individuals participating in the study were flagged so that (1) the examining physician would be aware that the patient was a study participant and (2) a bacterial work-up on the patient's specimen would be requested if the diagnosis indicated a possible bacterial etiology. Any bacterial isolates from patient specimens were to be preserved for further laboratory examination. The participants were requested at the beginning of the study to consult a clinic physician if they experienced severe gastrointestinal illness or skin infections. In addition, the participants were requested to notify the study coordinator if they consulted a physician so that a follow-up investigation could be conducted to determine how the illness was diagnosed and if a clinical specimen was obtained. In the event that a bacterial isolate was obtained from a clinical specimen, it was to be characterized biochemically and identified to the species level if possible. Subsequent to the identification of the clinical bacterial isolate, the GAC in the filter serving the patient would be removed from the filter housing and examined for the presence of a bacterial isolate identical to the patient isolate. Although the finding of a bacterial strain in a GAC filter that is similar or identical to one isolated from a patient using the filter is not unequivocal evidence of cause and effect it does present a fairly strong indication that the filter may have been the source of the causative organism.

SECTION 4

RESULTS AND DISCUSSION

A. MICROBIOLOGY

Approximately 1800 paired samples were collected over the seventeen month duration of the study. This does not include approximately 220 pairs of filter effluent and tap samples collected during the installation visit to the homes. There were four sample categories. The first category was the tap water sample collected from each home on every monthly visit. The remaining three categories were filter effluent samples. The water samples collected from faucet filters were either from filters containing a cartridge with granular activated carbon (GAC) or from filters containing a cartridge that was empty. The fourth category of water samples came from the bypass GAC filters. The total number of samples analyzed for each group is summarized in Table 1.

Geometric means and standard deviations of bacterial counts of the filters at installation are summarized in Table 2. The majority of the carbon filters (bypass and faucet) eluted no (<1 cfu/ml) bacteria upon installation indicating lack of contamination of carbon filters during manufacturing or installation. The blank cartridges may have been somewhat colonized but since these were empty cartridges some of the bacteria may have been from the tap. The tap sample at installation is different from the tap samples collected in subsequent months in that the water ran for two minutes before collection during the installation sampling compared to the specific procedure used during the rest of the study period as outlined in Section 3. Initially the number of blank filters installed was smaller because the blank filters were added to the study two months after the study began.

The overall geometric mean and standard deviation of bacterial counts are given in Table 3. There were two heterotrophic bacteria media used on each sample, R2A and Standard Plate Count (SPC). In each of the four sample types the R2A medium detected more heterotrophic bacteria than did the SPC. This increased detection was statistically significant ($p<.05$, paired t-test). The bacterial densities were different for each of the four types of water samples. As expected, the highest densities of bacteria were found in the two carbon containing filters. The bypass filter discharged the highest densities of bacteria. The lowest densities from a filter were discharged by the blank filter. The higher densities found in the bypass filter versus the facuet filter may be due to a higher amount of carbon found in the bypass filter, hence providing more surface area. An analysis of variance was performed on the four water categories and their bacterial densities and each of the category mean densities of bacteria was significantly different from each other.

Each of the two carbon filters had significantly higher bacterial densities in their study effluent samples than the installation samples. However, the overall geometric study mean of bacterial densities in blank fil ter effluent was not statistically different from those found upon installation. The mean for blank filters was higher indicating a possible colonization of bacteria on the walls of the blank cartridges, but these cartridges had a certain density of bacteria associated with them at installation.

The bacterial densities were grouped together by calendar month. A geometric mean for each month was calculated for each of the four categories and plotted. The graphs illustrate the magnitude of the differences between the tap water and bypass filters (Figure 3), the tap water and carbon faucet filters (Figure 4) and the tap water and blank faucet filters (Figure 5). The graphs also pointed out seasonal trends and the influence of ambient temperature on bacterial densities. To illustrate this association better, the average monthly raw water temperature at the Groton water filtration plant was plotted along with bacterial densities for each of the water sample categories. Graphically, there were temperature trends associated with the tap water samples (see Figure 6), the carbon faucet filter (see Figure 7) and the blank faucet filter water samples (see Figure 3). The fluctuation in bacterial densities eluted from bypass filters (see Figure 9) were not as great. Statistically all bacterial mean densities in the four water sample categories were highly correlated with water temperature (Table 4). This correlation was true for bacterial densities whether measured by R2A or SPC agar.

Paired water samples (tap and filter) from either bypass or faucet carbon filter households were randomly chosen for bacterial species identification. A total of six faucet filter households and nine bypass filter households were examined. The identification of bacterial isolates was performed on both the tap water and filter effluent samples. The results of the tap/carbon faucet water samples are in Table 5. The majority of the identifiable isolates were Flavobacterium or Pseudomonas. In comparison to the bypass filters (Table 6), the tap/carbon faucet pairs seem to be more diverse. The most notable feature of the bypass filters was the predominance of Pseudomonas stutzeri. This organism was predominant in seven out of nine bypass filter effluents examined. The table notes the number of isolates that subsequently did not grow or grew very slowly in the laboratory. These isolates were not identified. One such isolate was a small coral pigmented isolate that routinely took up to 15-21 days to grow at room temperature. Repeated passage of this isolate did not change its growth rate.

B. EPIDEMIOLOGY

The study period for each of the filter groups was slightly different. The faucet filter portion of the study began with installations in February and March of 1985 and continued until June of 1986 (approximately 15 months). In this time period the average length of an individual household participation was six months. The bypass filter study began with installations in June of 1985 and continued until August of 1986 (approximately 13 months). The average length of participation of an individual household with a bypass filter was seven months. This difference is due partly to the different drop out rates. In general the drop out rate for bypass filters was much less. This is partly due to the tighter screening of subjects and the emphasis upon the cost of filter installation. Another explanation for the two differences is that households in the faucet filter study often dropped out after receiving a blank. These families complained that they liked a carbon filter and would not participate if they did not have a carbon filter unit. This was despite the fact that the researchers never confirmed whether a household had a blank or carbon filter.

The number of person-years for the study by sex and filter groups is presented in Table 7. The number of person-years for each filter group by age group may be found in Table 8. The sex and age distributions for each filter group were similar. Approximately 40% of the persons in each filter group classified by age were in the highly susceptible population (less than 10 years of age).

There are two kinds of error which may occur in analyzing data from an epidemiological study. The first error, called the Type I error, consists in declaring that the difference in population studied is real when in fact no difference exists. This is often called the alpha significant level and is typically set at .05 or smaller.

The second type of error, called Type II, consists of failing to declare populations significantly different when in fact they are different. To control for a Type II error the power of a test is determined. The power of a test is denoted as 1-beta, where beta is the probability of failing to detect a specified difference as being statistically significant.

The smallest number of person-years was observed in the blank filter group. This group had 180 person-years. With this as a limiting factor, an example of the smallest proportional difference that could be detected with an alpha = .05 and power = 95 is .20-.05 or a proportional difference of .15 between two groups. However, the proportional difference significantly detected is dependent also on the magnitude of the proportions and the number of comparisons being made. In Table 9, the incident density per person-year is given for each of the symptoms. There were no statistically significant differences detected between the three study groups for any of the symptoms. The sample size was sufficiently large enough to detect any statistically significant differences.

A stratified analysis of the combined gastrointestinal symptoms was done. The incident density or proportion with symptoms stratified by age and sex for each filter group is in Table 10. The stratified data did not show any significant differences between study groups for gastrointestinal illnesses. There was a trend for the highest disease proportion to be found in the under six years of age groups. This was not unexpected as studies have reported higher gastrointestinal symptom rates in preschool children (Monto and Koopman, 1982).

In examining sex differences there did not appear to be any differences between study groups. However, within each study group there were three statistically significant differences detected between males and females. Two of these occurred in the by-pass group and one was in the blank filter group. This difference entailed a significantly higher gastrointestinal rate in females over males in the adult age group. There were two phenomena in the population to explain this difference. First many of the adult female subjects became pregnant during the course of the study. This would increase the level of gastrointestinal symptoms. Secondly, this study was carried out on many families where the male adult typically was gone (out to sea) for many months during the study. Hence, the adult male typically would appear healthy when in reality he was absent. The other group that showed significant differences was the by-pass <6 years group. In this group the females reported a higher incidence of gastrointestinal illness than males. Explanations for this phenomena would be speculation.

C. CLINICAL FINDINGS

A total of 3333 symptomatic illnesses were reported during the course of the study. Two-hundred and sixty-nine of the illnesses were considered by the study participants to be severe enough that they consulted a physician. Forty-two percent of the patients who were seen by a physician were less than six years of age, 10% were ages 6 through 10 years, 6% were ages 11 through 18 years and individuals over the age of 18 comprised 36% of this group. A follow-up investigation of all reported physician visits revealed that none of the patient illnesses were diagnosed as having a bacterial etiology and, therefore, clinical specimens were not collected for laboratory work-up. The nonoccurrence of illnesses or infections that might be attributable to bacteria associated with GAC filters indicates that the ingestion or use of GAC filtered water was not a risk factor for disease in the populations examined in this study.

D. EXPOSURE

In order to estimate an actual exposure level, all households remaining in the study by May of 1986 were interviewed as to consumption of filtered water and filter use habits. A single person (usually the mother) was interviewed by a Yale researcher for members of her family and their drinking water habits. A series of questions were then asked about how water is taken from the filter and how they used filtered water. The categories of use for filtered water is summarized in Table 11. For cold drinks, the majority of both filter users reported using filtered water almost exclusively. The two filter groups reported different use patterns for each of the remaining categories. The by-pass filter users reported using filtered water for hot drinks (98%), cooking (88%) and ice cubes (88%). This was compared to faucet filter users that reported 62% for cooking, 58% for hot drinks and 83% for ice cubes. Some of these differences can possibly be explained by filter design or filter flow. A further report on likes, dislikes and other consumer type questions is in the marketing report attached hereto (Appendix B).

The subjects were then asked how they collected water for use from their filter. The collection process was slightly different for each filter group (Table 12). The by-pass filter, which has its own faucet, were divided between "immediately" or "after a few seconds". The faucet filter group let the filter run a few seconds (62%) or longer (21%). The slight difference in use pattern may have had an effect on the possible dose received. The faucet filter exhibited a flushing phenomena of reduction in effluent heterotrophic bacterial densities after approximately 1.25 liters of water were withdrawn (Table 13). This was in contrast to the by-pass filters which showed equivalent reduction in bacterial cell densities after three liters.

The final question analyzed in order to estimate exposure was amount of water consumed daily. The amount of filtered water used by subjects is summarized in Table 14. The distribution for each of the ounce categories were slightly different for each filter group. The by-pass filter group consumed slightly higher volumes of water than did the faucet filter group. This was further evidenced by comparing the mean ounce consumption reported by the by-pass households (31.5 ounces per person) with the mean reported by the faucet filter households (26.4 ounces per person). If the ounces are converted to milliliters, an estimate of the number of organisms ingested on daily basis can be made. The average milliliters consumed per day is multiplied plied by the geometric mean for the carbon filters to estimate an average heterotrophic bacterial density per day. The results are as follows:

BY-PASS FILTER

31.5 oz/day/person x 29.57 ml/oz x 2000 org/ml = 1.9×10^6 organisms/day

CARBON FAUCET FILTER

26.4 oz/day/person x 29.57 ml/oz x 1000 org/ml = 7.8×10^5 organisms/day

The estimated average daily intake for the subjects who used GAC-POU filters was approximately 10^6 organisms per day.

E. DISCUSSION

The colonization of filters was not unexpected as many laboratory studies reported on colonization of GAC filters by bacteria (Geldreich, et al., 1985; Bell, et al., 1983). The magnitude of colonization and the variation in filter effluent bacterial densities due to filter type and temperature was new. Of particular interest was the high incidence of colonization of the by-pass filters by Pseudomonas stutzeri. There appears to be no apparent reason for such high incidence of this organism in these filters.

In general, the primary genus colonizing both types of POU-GAC filters was Pseudomonas. Pseudomonas aeruginosa has been implicated in many water contact diseases such as hot tub folliculitis and swimmer's ear (Calderon and Mood, 1982). In this study, there was only one isolation of P. aeruginosa. The majority were other pseudomonads such as P. diminuta and P. stutzeri.

The second most common bacterial colonizer was the genus Flavobacterium. This geneus, like the non-P. aeruginosa pseudomonads, is a common soil organism and is often found in drinking water. A literature search indicated that this genus has not been associated with outbreaks of gastrointestinal or dermatologic disease. The amplification of their densities by POU-GAC filters did not result in any increased health risk in our study.

The gastrointestinal rate in all categories was higher generally than what has been reported in other studies (Monto and Koopman, 1980). However there was no significant difference between the group that had unfiltered water versus the group that had carbon filtered water. Tests on the statistical power of the data analysis indicates a sufficient sample size to detect a difference. Other reasons for no health effects associated with consumption of water containing high density of bacteria relate to either the organism, the exposure or the host.

Considering the ubiquitous nature of the organisms that colonized the POU-GAC filters, it may well be that these organisms just do not cause infections or disease in man. The exposure route often determines whether an organism causes disease or not. In this study the primary route of exposure was the gastrointestinal or dermatologic route. It may be that these bacteria do not lead to diseases in man by these routes of exposure due to host barriers such as stomach acid and normal flora of skin and intestinal tract.

Finally the lack of a health effect may center on the host. It is well documented that Legionella, a common soil and aquatic organism, only causes Legionnaires' Disease when it comes into contact with an immunocompromised population. The organisms found on POU-GAC filters may only be of concern to a very select small population considered to be immunocompromised. This study does not address the problems that may be experienced by an immunocompromised population. Furthermore, this study does not address other exposure routes such as respiratory. There are GAC water treatment devices that filter the entire house water supply. These filters are called point-of-entry because they are installed at the point where water enters the house. The extent of colonization of the whole house filters by bacteria has not been reported in the literature. If one assumes some colonization of point-of-entry filters, there is a potential for total body exposure to bacteria via shower generated aerosols. Hence, the question of health effects associated with bacterial colonization of granular activated carbon filter still needs to be addressed with point-of-entry water filters.

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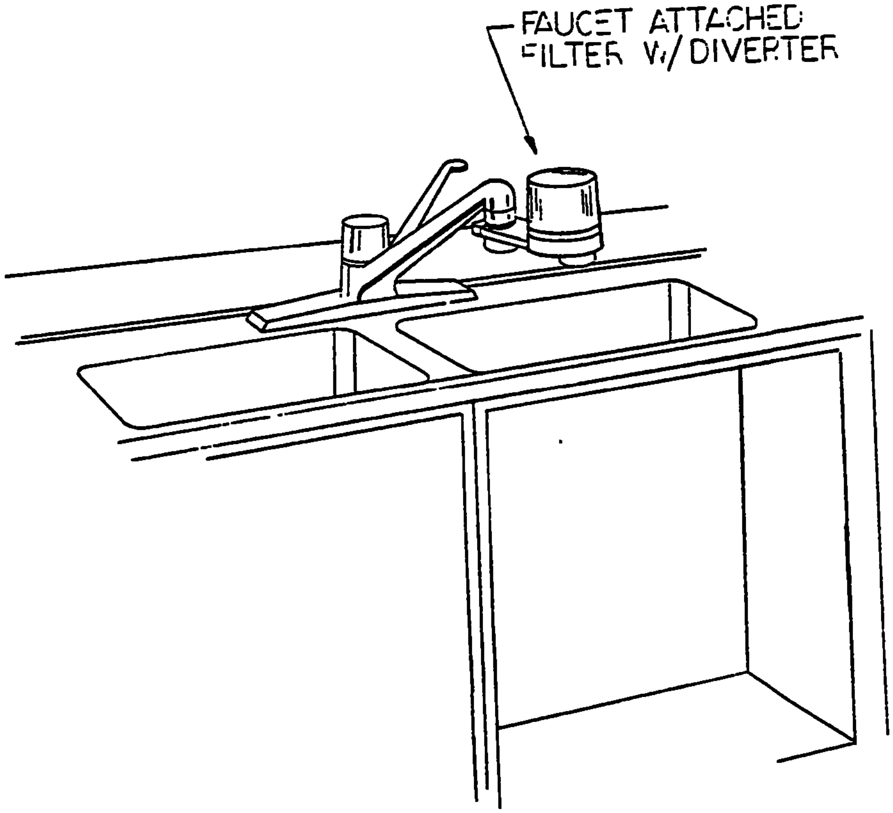

Figure 1. Schematic diagram of faucet filter as it is installed (courtesy of P. Regunathan).

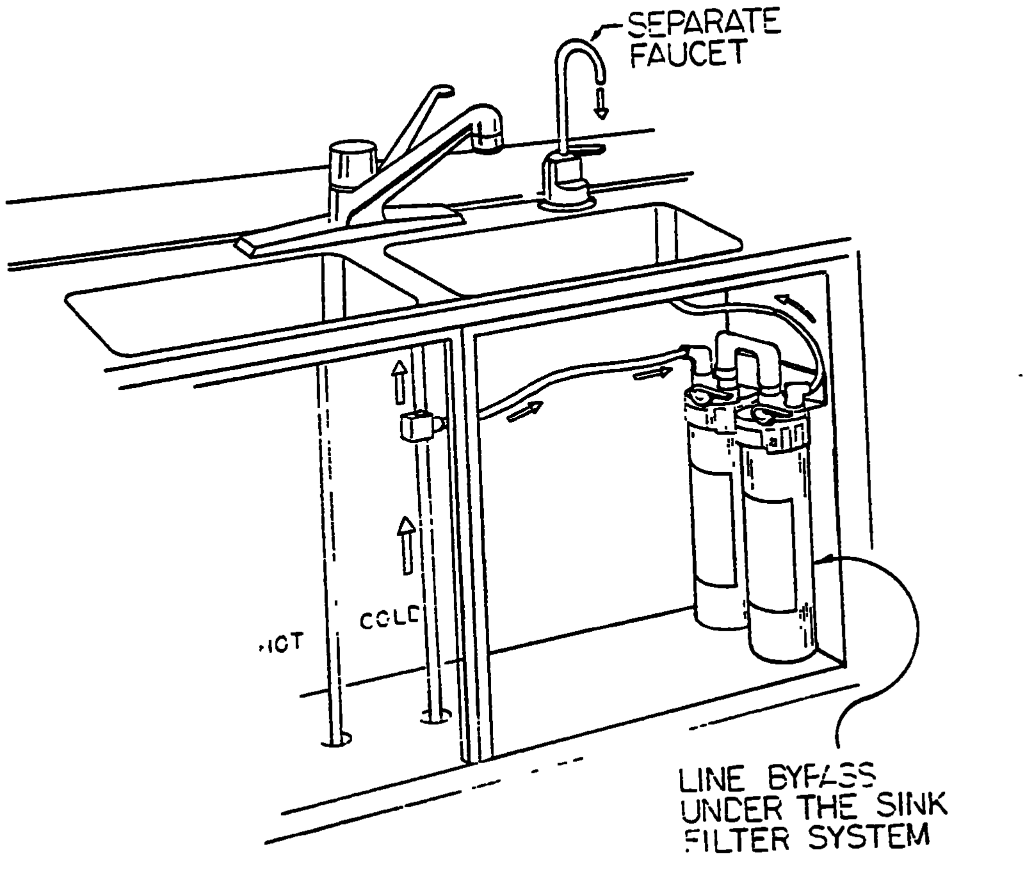

Figure 2. Schematic diagram of bypass filter as it is installed (courtesy of P. Regunathan).

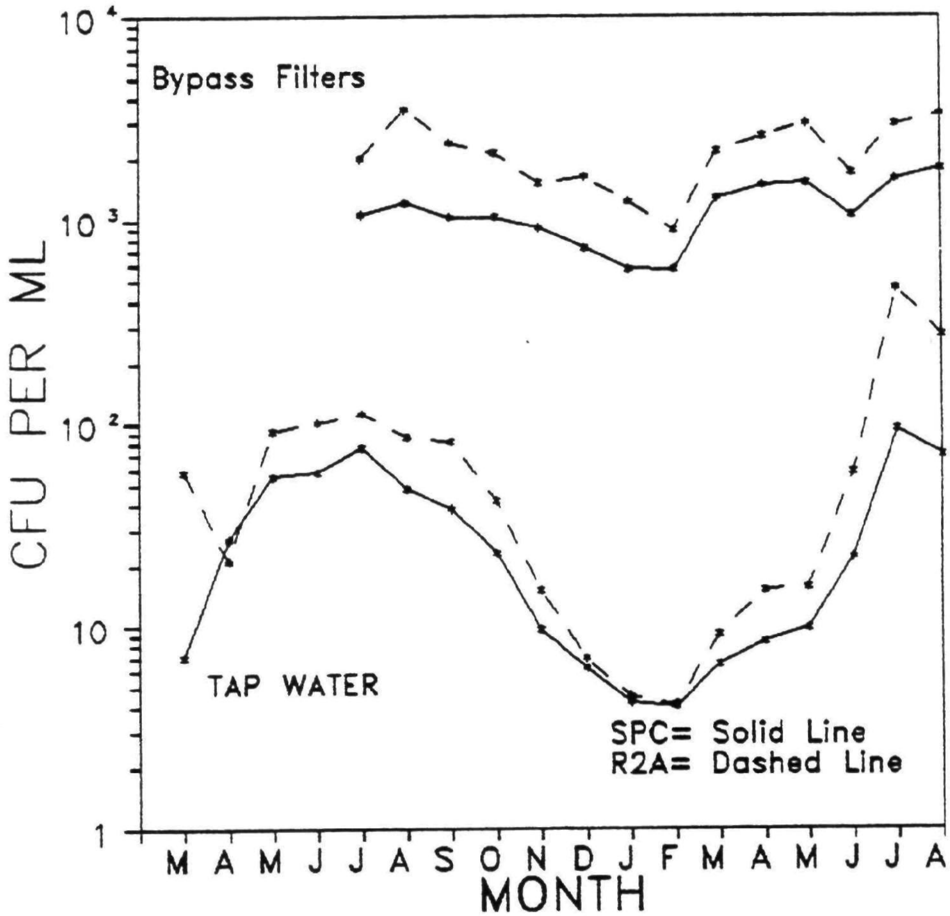

Figure 3. Heterotrophic bacterial densities as measured by standard plate count agar and R2A agar by month for tap water and bypass carbon filters.

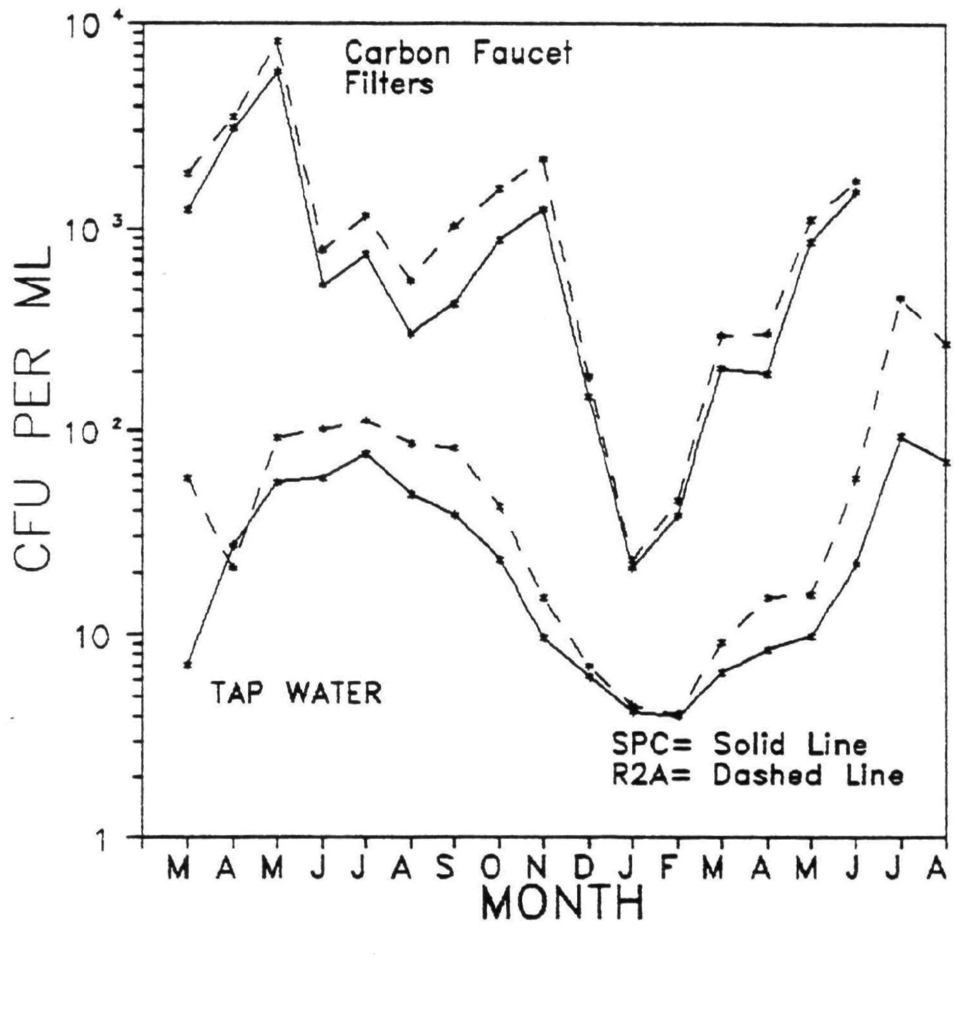

Figure 4. Heterotrophic bacterial densities in tap water and carbon faucet filters as measured by standard plate count agar and R2A agar by month.

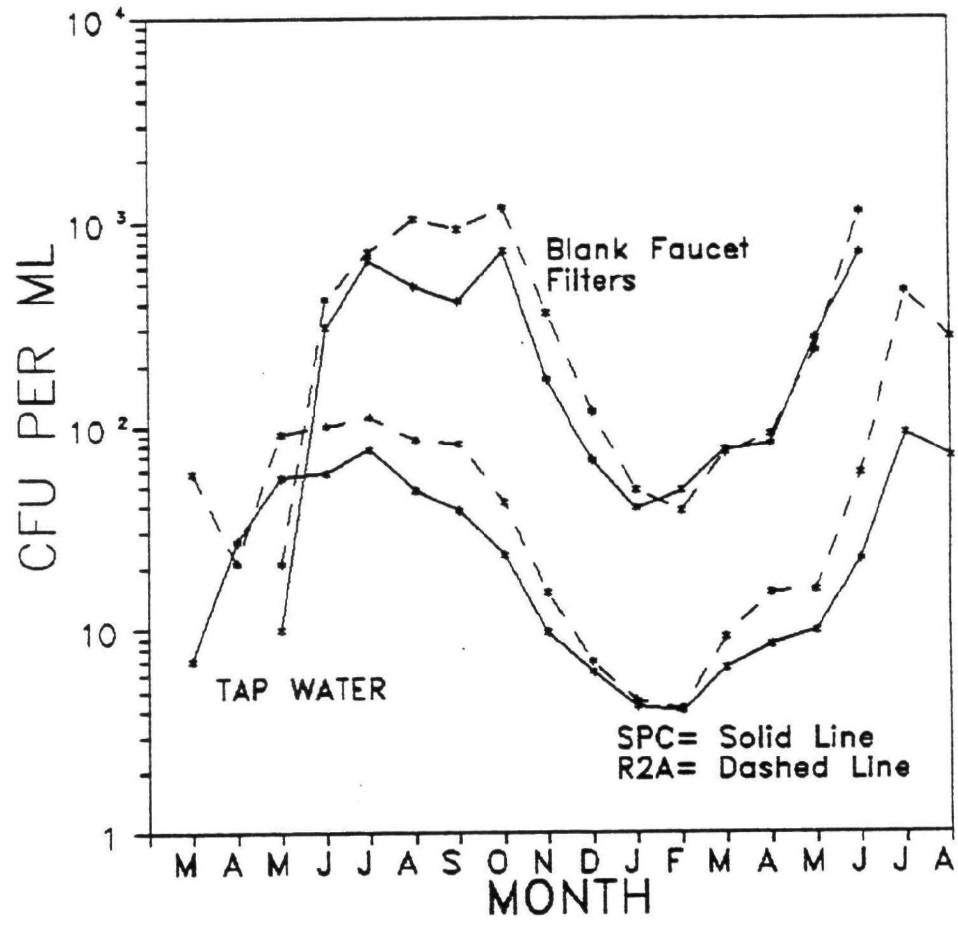

Figure 5. Heterotrophic bacterial densities in tap water and blank faucet filters as measured by standard plate count agar and R2A agar by month.

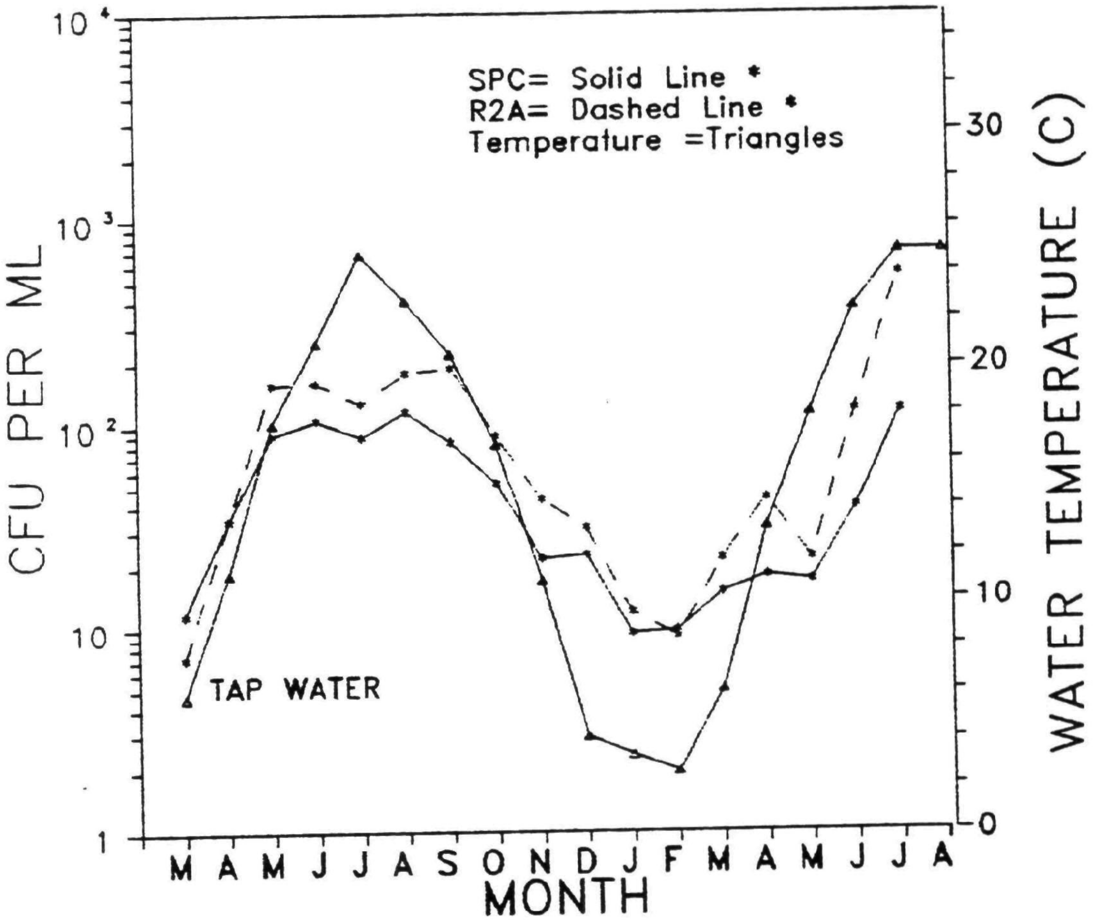

Figure 6. Heterotrophic bacterial densities in tap water and water temperature by month.

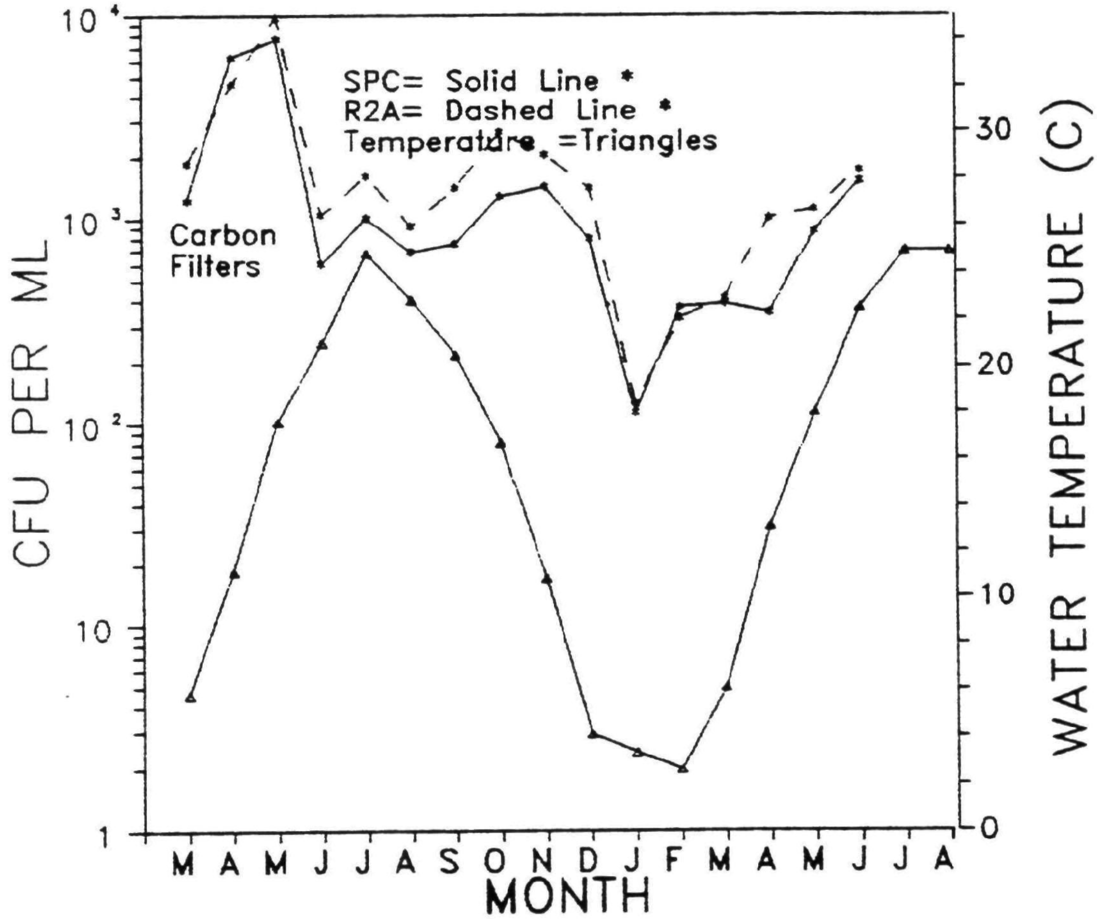

Figure 7. Heterotrophic bacterial densities in carbon faucet filters and water temperature by month.

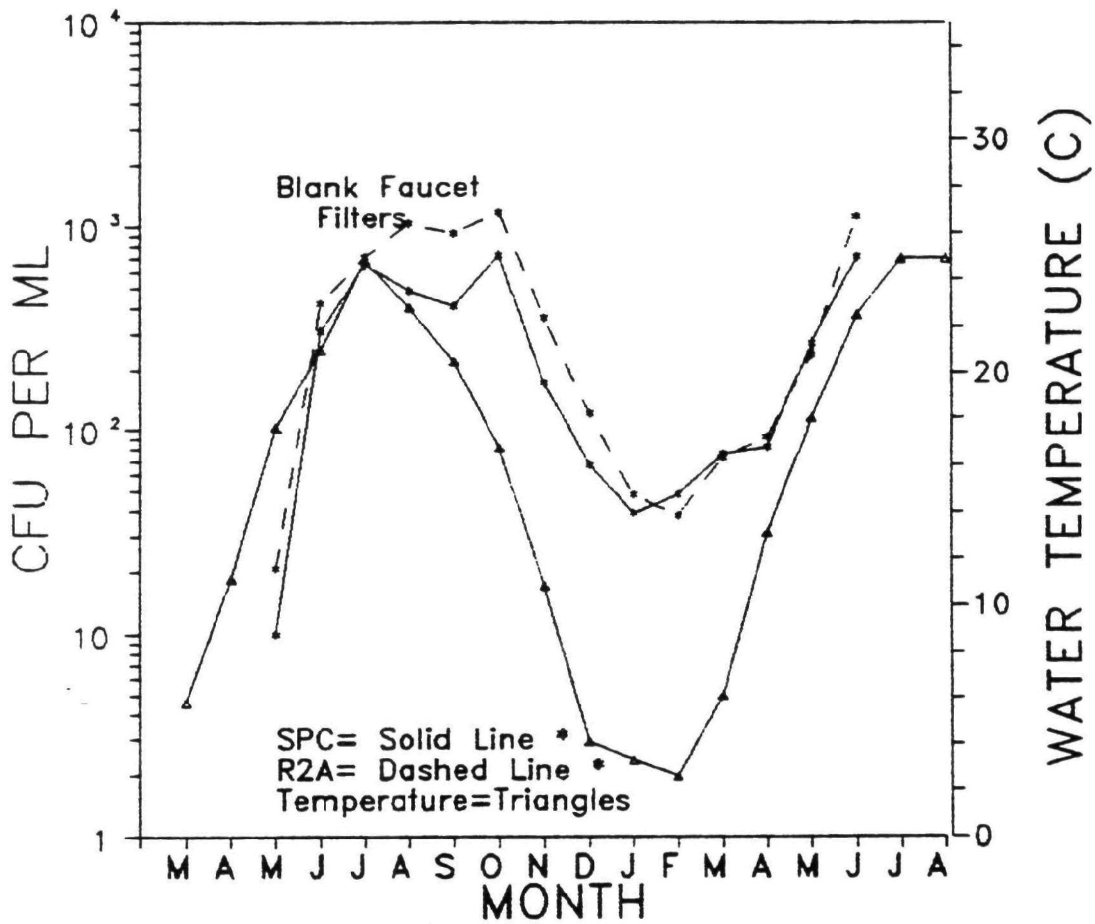

Figure 8. Heterotrophic bacterial densities in blank faucet filters and water temperature by month.

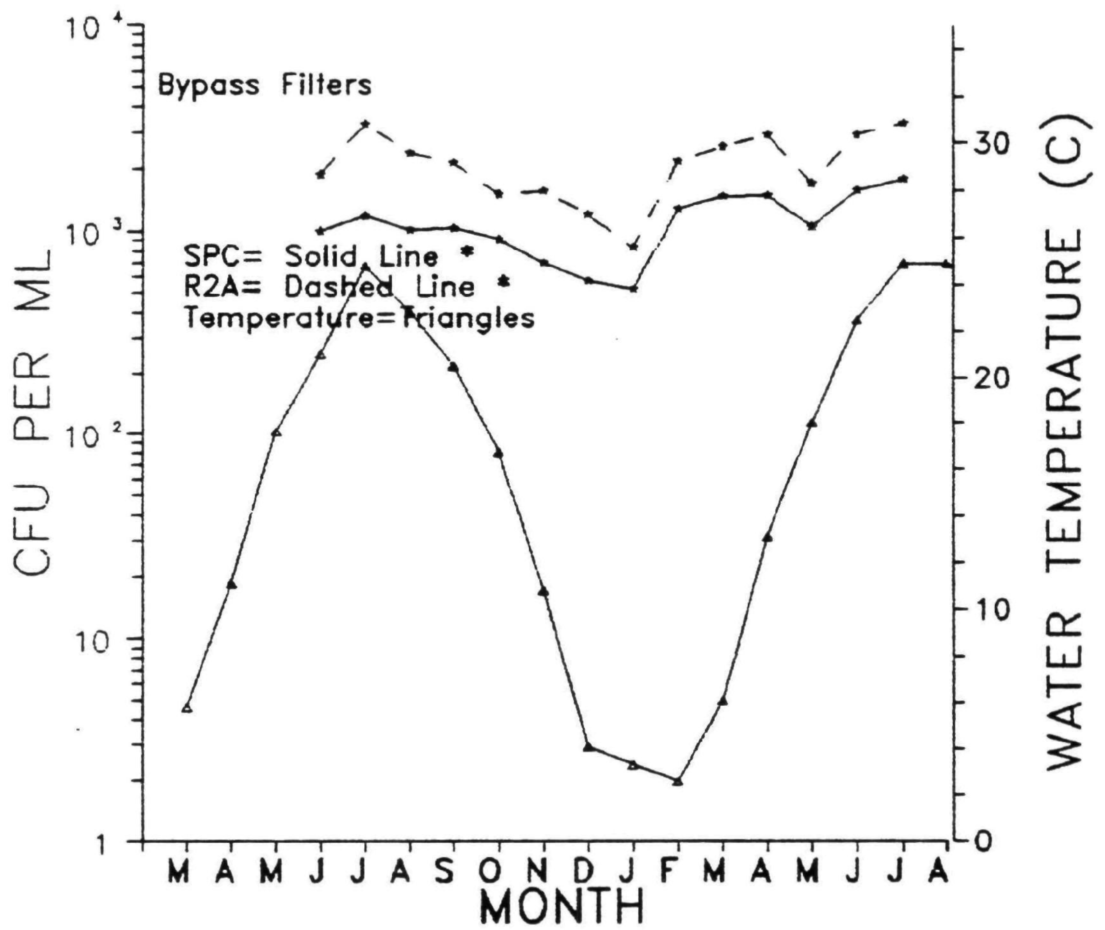

Figure 9. Heterotrophic bacterial densities in bypass carbon filters and water temperature by month.

Table 1. Number of water sample types collected over a 17 month period (1985-1986).

Sample	N
Bypass Filter	722
Carbon Faucet Filter	559
Blank Faucet Filter	486
Tap	1766
Total	3533

Table 2. Geometric mean and standard deviations of heterotrophic bacterial densities from installation water samples.

	MEDIA			
	SPC[1]		R2A[2]	
Sample	Mean	STD	Mean	STD
Bypass Filter (62)	0.2	34	0.4	41
Carbon Faucet Filter (110)	6	5	9	6
Blank Faucet Filter (43)	85	9	98	7
Tap Water (215)	6	17	11	20

[1]35°C, five days.
[2]22°C, five days.

Table 3. Geometric means and standard deviations of heterotrophic bacterial densities discharged from two granular activated carbon filters, blank filters and tap water as measured by Standard Plate Count agar and R2A agar.

	MEDIA			
	SPC[1]		R2A[2]	
Sample	Mean	STD	Mean	STD
Bypass filter	1049	5	2042	4
Faucet filter	689	16	1035	17
Blank filter	198	17	289	19
Tap Water	53	12	92	13

[1]35°C, five days.
[2]22°C, five days.

Table 4. Correlation coefficient of water temperature with bacterial densities from bypass filters, carbon and blank faucet filter and tap water using Standard Plate Count and R2A agar.

	MEDIA	
Water Sample	SPC[1]	R2A[2]
	(Correlation coefficient for water temperature)	
Bypass filter	.617	.663
Carbon faucet filter	.743	.761
Blank faucet filter	.931	.883
Tap water	.923	.956

[1]35°C, five days.
[2]22°C, five days.

Table 5. Types of bacteria isolated from tap and carbon faucet filter water samples from six homes.

	Number of Isolates		
Organism	Tap Only	Filter Only	Both
Alcaligenes spp.	1	1	0
Acinetobacter spp.	1	0	2
Actinobacillus spp.	1	0	0
Flavobacterium spp.	2	0	5
Pseudomonas spp.	1	0	1
Pseudomonas aeruginosa	0	1	0
Pseudomonas diminuta	0	1	0
Pseudomonas fluorescens	0	1	0
Pseudomonas paucimoblis	0	1	0
Pseudomonas vesicularis	1	1	2
Not identified	12	7	

Table 6. Types of bacteria isolated from tap and bypass carbon filter water samples from 9 homes.

	Number of Isolates		
Organism	Tap Only	Filter Only	Both
Acinetobacter spp.	1	1	0
Flavobacterium spp.	3	3	1
Pseudomonas spp.	2	2	0
Pseudomonas diminuta	1	0	0
Pseudomonas paucimoblis	1	1	1
Pseudomonas stutzeri	0	7	0
Pseudomonas vesicularis	1	3	1
Yeast	1	0	0
Not identifiable	12	8	

Table 7. Person years of surveillance for each filter group in the point-of-use study by sex (1985-1986).

	Filter Group person years - (%)		
Sex	Bypass	Faucet Carbon	Faucet Blank
Male	116.5 (50.6)	117.8 (51.4)	94.6 (52.0)
Female	113.8 (49.4)	111.8 (48.6)	87.3 (48.0)
Total	230.3 (100.0)	229.6 (100.0)	181.9 (100.0)

Table 8. Person years of surveillance for each filter group in the point-of-use study by age group (1985-1986).

	Filter Group person years - (%)		
Age	Bypass	Faucet Carbon	Faucet Blank
<6 years	59.0 (25.6)	43.1 (18.1)	43.1 (23.9)
6 to 10 years	34.8 (15.1)	43.8 (19.0)	32.4 (17.9)
11 to 18 years	15.3 (6.7)	24.2 (10.5)	15.9 (8.8)
>18 years	121.2 (52.6)	120.2 (52.0)	89.3 (49.4)
Total	230.3 (100.0)	231.3 (100.0)	180.7 (100.0)

Table 9. Symptom rate in the point-of-use filter study per person year by filter group (1985-1986).

	Filter Group person years - (%)		
Sex	Bypass	Faucet Carbon[1]	Faucet Blank
Vomiting	.38	.43	.41
Nausea	.54	.61	.61
Diarrhea	.72	.90	.93
Fever	.67	.56	.78
Body aches	.55	.55	.70
Neck pain	.17	.19	.28
Skin rash	.16	.15	.13
Infected wound	.01	.03	.03

[1]No signifcant difference between the three study groups for any of the symptoms.

Table 10. Incident density of gastrointestinal illnesses in each study group by age and sex.

	Age Group (per person year)			
Group	<6 years	6-10 years	11-18 years	>18 years
Bypass				
Female	2.8*	1.2	0.7	1.9*
Male	1.8*	1.4	0.6	0.6*
Carbon faucet				
Female	2.3	1.4	1.3	1.6
Male	2.3	1.6	1.2	1.0
Blank faucet				
Female	1.9	1.7	1.2	1.5*
Male	2.5	1.7	1.3	0.8*

*Rate statistically higher in females than males.

Table 11. Percentages of reported uses of GAC filtered water by filter type.

Use	Bypass	Faucet
Cooking	88%	62%
Hot Drinks	98%	58%
Cold Drinks	98%	100%
Ice Cubes	88%	83%

Table 12. Percentages of how water was collected by subjects from a filter by filter type.

Procedure	Bypass	Faucet
Immediately	41%	17%
After a Few Seconds	40%	62%
Run a Long Time	19%	21%
Total	100%	100%

Table 13. Densities of heterotrophic bacteria discharged with volume flow from bypass and faucet point-of-use granular activated carbon filter.

Faucet filter		Bypass filter	
Bacteria (cfu/ml)	Volume (ml)	Bacteria (cfu/ml)	Volume (ml)
382	250	412	500
231	500	247	1000
217	750	175	1500
143	1000	150	2000
78	1250	133	2500
40	1500	93	3000
44	1750	78	3500
46	2000	54	4000
40	2250	51	4500
22	2500	53	5000

Table 14. Consumption of filtered water by point-of-use filter type.

Ounces[1]	Bypass	Faucet
16 oz or less	35%	47%
17-32 oz	34%	29%
33-64 oz	27%	22%
>64	4%	2%
Total	100%	100%
Mean	31.5 ounces	26.4 ounces

[1]Ounces per person per day.

APPENDIX A

QUESTIONNAIRES AND HEALTH DIARY

Yale University

SCHOOL OF MEDICINE

Department of Epidemiology and Public Health

P.O. Box 3333
60 College Street
New Haven, Connecticut 06510

Dear Resident:

The Department of Epidemiology and Public Health, Yale School of Medicine, is conducting a study on point-of-use granulated activated carbon filters. These filters are used in homes at the kitchen sink to filter water used for drinking, cooking and handwashing. These filters remove many water impurities as well as improve taste and odor problems. We are interested in determining if these filters do improve the quality of the water and if there is an improvement in health associated with better water quality. We have received permission from the Navy base authorities to conduct this study on residents of Navy housing.

Your household has been randomly selected for the first part of the study. Attached is a questionnaire on basic background information and water use. If you wish to participate in the second part of the study, please indicate so on the questionnaire. The second part of the study will require the following:

1) Completion on a monthly basis of a health diary for the household;
2) Notify researchers at Yale if any of the listed symptoms require medical care;
3) Allow a researcher from Yale on a monthly basis to collect a water sample for analysis when a member of the household notifies us as in #2; and
4) Allow Yale researchers with trained personnel at no cost to the subjects, to install a filter at the kitchen sink.

The study will be conducted from February 1985 to November 1985. Not every family will participate for the entire period as households will be phased in and phased out of the study. For every family that completes the study a $10.00 donation will be made to the Navy Relief Fund. If you think you would like to participate but need more information please indicate so on the questionnaire or call us as indicated. Even if you do not wish to participate further please fill out the questionnaire and return it in the self-addressed stamped envelope. Thank you for your time and cooperation.

Sincerely,

Rebecca L. Calderon

Rebecca L. Calderon
Dept. of Epidemiology & Public Health
Yale School of Medicine

YALE SURVEY

Please fill in the blank or circle your answer.

1. Which of the following best describes how your water tastes:
   a. Acceptable taste all the time
   b. Acceptable taste most of the time.
   c. Unacceptable taste most of the time.
   d. Unacceptable taste all the time.
   e. No opinion

2. Which best describes the amount of odor in your water:
   a. Never has an odor
   b. Occasionally has an odor
   c. Has a constant odor
   d. No opinion

3. Which best describes the color and/or turbidity in your water:
   a. Never has any turbidity and/or color
   b. Occasionally has turbidity and/or color
   c. Is constantly turbid and/or colored.
   d. No opinion

4. Do you have a dishwashing appliance in use in your home? YES NO

5. Are there any of the following water treatment devices being used in your home?

a.	Water softener	YES	NO	DON'T KNOW
b.	Faucet filter	YES	NO	DON'T KNOW
c.	Iron removal filter	YES	NO	DON'T KNOW

   d. OTHER (specify)______________________________

6. What type of water heater is used in your home?
   a. Electric
   b. Gas
   c. Oil
   d. OTHER (specify)______________________________

7. What is the temperature of the hotwater in your house?____________________
   (If you don't know, leave it blank)

   Is there a storage tank with your hotwater heater? YES NO DON'T KNOW

8. Which of the following materials is your kitchen sink made of:

   PORCELAIN STAINLESS STEEL

   Is there a sprayer/hose apparatus on the kitchen sink? YES NO

9. Which best describes your home?
   a. A mobile home or trailer
   b. A one bedroom house
   c. A two bedroom house
   d. A three bedroom house
   e. A four bedroom house
   f. Other (specify)________________

10. How many persons are there living in your household? __________

11. How many persons are there who are:
    a. Less than 2 years old ____________
    b. 2-5 years old________________
    c. 6-10 years old________________
    d. 11-15 years old________________
    e. 16-21 years old________________
    f. greater than 21 years old__________

12. Does everyone in your household use the Navy clinic and/or hospital for minor health problems such as cold, diarrhea, fever or rash?

    YES NO

    If NO, how many members of your household would seek care some place else for such minor health problems?________________

13. What is the Personnel Rotation Date for the active duty member of the household?

    (If more than one active duty member in the household, use the earliest PRD)

    ____

If you think your family would like to participate in the second part of the study, (please see accompany letter) please fill in your name and address.

NAME____

ADDRESS_____________________________________

____

If you have any questions please fill in the phone number and a convenient calling time and we will contact you.

NUMBER______________________________

TIME________________________________

Or if you wish, you can call us at 1-785-2881, 9:00 am to 5:00 pm, Monday - Friday.

Please return this questionnaire in the postage paid envelope.

CONSENT FOR PARTICIPATION IN A RESEARCH PROJECT
YALE UNIVERSITY SCHOOL OF MEDICINE - YALE NEW HAVEN HOSPITAL

You and your family are invited to participate in a study on the improvement to health and quality of drinking water by use of residential point-of-use granulated activated carbon filters. These filters are used to remove some impurities and to improve odor and taste problems. You have been chosen for this study because you live in housing provided by the U.S. Navy.

In this study each home will have a filter installed at the kitchen sink. One half of the homes will receive a filter without carbon, and the other half will have filters with carbon. The homes with carbon in their filters will be selected at random (by the luck of the draw). These homes will change over the course of the study so that every home during the study will have carbon in their filter. This is a blind study so it should not be apparent to you at anytime whether you have a filter with carbon or without carbon. The study will last for up to nine months during which time we will ask you to keep a monthly diary on intestinal and skin ailments occurring in all members of the household. In addition, we would like to arrange for monthly visits to collect water samples for analysis and to insure proper maintenance of the filters. This may require up to 30 minutes of your time every month, including water sampling and questionnaire answering.

If you or any member of the household should experience one of the above classes of illnesses and have decided that medical care is needed, we ask that you immediately let us know. We would like to collect additional water samples for analysis.

This study may be of no direct benefit to you individually, but will improve our knowledge of whether use of water filters improve the quality of drinking water and the health of people who use them. You will not be paid for participation, but all filters, their maintenance and water testing will be provided for free during the study. In addition, for every family that fully participate in the study, a $10.00 donation will be made to the Navy Relief Fund in their name.

In all records of the study you will be identified by a number and your name will be known only to the researchers and the Navy clinic/hospital. Your name will not be used in any scientific reports of the study. There will be complete confidentiality of all records.

You are free to choose not to participate. Due to expense and effort of installing filters, we ask that you try to commit to participating for the duration of the study. If for some reason you can not complete the study or must withdraw or choose not to participate, it will not adversely affect your relationship with Yale or the Navy.

We have used some technical terms in this form. Please feel free to ask about anything you don't understand and to consider this research and the consent form carefully before you agree to participate.

Authorization: I have read this form and decided that ______________________
(name of head of household)
will participate in the project described above. Its general purposes, the particulars of involvement and possible hazards and inconveniences have been explained to my satisfaction. My signature also indicates that I have received a copy of this consent form.

____
Signature

____
Relationship (self, parent, etc)

____
Date

____
Signature of Person Obtaining Consent

If you have further questions about this project or your rights as a research subject or if you have a research related problem, please contact the project director, Rebecca L. Calderon, 785-2831, Department of Epidemiology and Public Health, Yale School of Medicine, New Haven, Ct. 06510.

THIS FORM IS NOT VALID UNLESS THE FOLLOWING BOX HAS BEEN COMPLETED IN THE HIC OFFICE.

THIS FORM IS VALID ONLY UNTIL

5-21-86 (date).

HIC PROTOCOL # 3356

INITIALED: MA

YALE HEALTH SURVEY

This is page one of the health diary which we are asking you to keep over the duration of the study. Notice that the second page is the actual diary of health symptoms. Every month a water sample will be collected and at that time we will collect your health diary for the past month and will give you a new second page for the ensuing month. At the end of your participation in the study we will collect the front page. The front page is to assign everyone in the household a number for identification and to collect basic information. Be sure to keep everyone's number the same throughout the study. For convenience, we suggest you place your diary in a prominent place such as the refrigerator door or family bulletin board.

Please review the list of symptoms on the next page. Note that we are interested in only when these symptoms occur and their duration. Please check or fill in only the boxes that apply. If you or a member of your household decide to seek medical help for any of the symptoms we ask that you call us immediately. We may want to collect a water sample. To call New Haven, dial 0 and then dail our number 785-2881. Wait for either a tone or an operator to ask you for your number. The number for the study is 620-185-8977-9916. If you have trouble getting through, call us collect. When you or any member of the household vist the doctor, be sure to tell him/her that you are a study participant.

PERSON	#1	#2	#3	#4	#5	#6
FIRST NAME (optional)						
DATE OF BIRTH						
SEX						

PAGE 2 FAMILY ID________________ MONTH_____________

PERSON NUMBER														
DATE OF ONSET OF SYMPTOMS														
SYMPTOMS A. Vomiting or throwing up														
B. Nausea or feeling nauseous														
C. Diarrhea or loose bowels														
D. Fever (state temperature)														
E. Body aches														
F. Neck pain														
G. Rash														
H. Infected wound (location e.g. knee)														
How long did the symptoms last? (in days)														
Did the person stay home?														
Did the person stay in bed?														
Did the person seek medical help?														
Where did you go for medical help?														
Navy hospital/clinic?														
Private physician?														
Other?														

At the end of the month, please answer the following questions?

Please rank the benefits the system provides in order of importance to you and your family. (1 = most important; 6 = least important)

_____ Taste and odor removal

_____ Improved clarity and color of water

_____ Health benefits of cyst and asbestos removal

_____ Health benefits of organic chemical removal

_____ Appliance protection provided by lime-scale inhibition

_____ Chlorine removal

HOW TO USE YOUR POLLENEX PURE WATER "99"

FOR CLEAR, CLEAN FILTERED WATER MOVE SWITCH TOWARD YOU. IMPORTANT: RUN WATER THROUGH THE REPLACEABLE FILTER FOR TEN SECONDS BEFORE FIRST USE OF DAY. WHEN FIRST USING A NEW FILTER CARTRIDGE FLUSH FOR SEVERAL MINUTES. FOR REGULAR UNFILTERED TAP WATER MOVE SWITCH AWAY FROM YOU.

The Pure Water "99" Water Filter is designed to restrict the water flow. The slower the water flows through the Activated Charcoal bed, the more "contact time" there is, allowing for better adsorption of chemical contaminants. Filter has a rated service flow of .5 gallons per minute; a minimum operating pressure of 10 PSIG and maximum operating pressure of 125 PSIG. For greater filtration, you may wish to slow down the water to allow even more "contact time" than provided by the built-in flow restrictor. Do not run hot water through the filter.

We will replace the filter every three months. Do not attempt to take the filter apart. If it is not working properly, you can remove the entire unit from the faucet. If you call us we will replace the filter.

As part of the final stage of this study we would like to ask a few questions on how you use your filter and the filtered water. Can we take a few moments of your time to ask the questions.

ID ______________

1. Did you use filtered water for any of the following:

   a) Cooking YES NO

   b) Drinking
      Boiled YES NO

      Not Boiled YES NO

   c) Making Ice Cubes YES NO

2. Which of the following best represent how you collect water from the filter:

   a) Take the water as it immediately comes out of the filter

   b) Let the filter run a few seconds and then collect the water

   c) Let the filter run MORE than a few seconds before collecting the water

3. For each of the people in the house how many 8 oz. glasses of filtered water would you estimate they drink every day? Do NOT include water that has been cooked, e.g., coffee, tea, formula.

Person	Glasses

Thank you for your participation in the study.

APPENDIX B

MARKETING REPORT

INTRODUCTION

This is a summary report compiled for the manufacturers who participated in the Yale GAC point-of-use filter study. This report is comprised of two parts. The first is the results of questions sent to potential study participants. These questions mainly pertain to the subjects perception of their water quality. The second part of this report concerns the results of questions asked of study participants about their filter.

PART 1

The initial pre-study questionnaires included questions that would help us evaluate people's opinions regarding the general present quality of their drinking water before entering the study. The total number persons included in the evaluation of the pre-study questionnaires was 343.

We asked their opinion on the following:

1) how the water tastes
2) the amount of odor in their water and
3) the occurrence of color and/or turbidity in their water

With respect to taste27.7% found their water acceptable all the time and 57.4% found it acceptable most of the time. Much smaller proportions of the population found the water unacceptable most of the time (8.5%) and unacceptable all of the time (5.5%). Only 0.9% of the polled population had no opinion at all regarding the tasteof their drinking water.

The majority of respondents (45.8%) found that the water never had an odor, while 42.9% found that it occasionally had an odor.

Again, smaller percentage comprised the remaining categories of those who felt their water had a constant odor (5.2%) and those who had no opinion about drinking water odor (6.1%).

Only 9.3% of the population were of the opinion that their water had color and/or turbidity constantly. A small percentage (3.5%) had no opinion regarding this issue, while 50.7% felt they occasionally experienced color and/or turbidity in their drinking water. The remaining 36.5% felt that their water never had color or turbidity.

We also inquired about the use of water softeners, faucet filters and iron filters in the subjects' homes. Of the three devices the most prevalent one was a faucet filter (8.2%). This was followed by a water softener (1.2%) and an iron filter (0.6%).

An overwhelming majority answered no to whether or not a treatment device was being used in their home; faucet filter (81%) an iron removal filter (81.9%) and a water softener (85.7%). A small percentage (13.1%) did not know whether or not their house had a water softener. Approximately ten percent (10.2%) did not know if there was a faucet filter being used and another 17% were not aware of whether or not an iron removal filter had been installed in their house. This is not surprising since the participants do not own their homes and are not responsible for its maintenance.

For convenience the results have been summarized below in table form.

Table 1. Results of pre-study questionnaire.

Question: Which of the following best describes how your water _____?

TASTE (N=343)

27.7%	Acceptable all the time
57.4%	Acceptable most of the time
8.5%	Unacceptable most of the time
5.5%	Unacceptable all the time
0.9%	No opinion

ODOR (N=343)

45.8%	Never had an odor
42.9%	Occasionally has an odor
5.2%	Has a constant odor
6.1%	No opinion

COLOR (N=343)

36.5%	Never has color
50.7%	Occasionally has color
9.3%	Has a constant color problem
3.5%	No opinion

Question: Are there any of the following water treatment devices being used in your home?

WATER SOFTENER (N=343)

1.2%	Yes
85.7%	No
13.1%	Don't know

FAUCET FILTER (N=343)

8.2%	Yes
81.0%	No
10.8%	Don't know

IRON FILTER (N=343)

0.6%	Yes
81.9%	No
17.6%	Don't know

PART II

With regard to actual use of POLLENEX faucet filters, statistics were compiled on subject responses to marketing questions placed at the bottom of each health diary. The questions were provided by Associated Mills, the filter manufacturer. After some modifications by the Yale research team for use in the diaries, the questions were approved by the Human Investigations Committee at Yale University. Each month for 6 months, the families were given a set of questions.

The first set of questions asked the following: DID THE ODOR, TASTE, OR COLOR CHANGE IN THE LAST MONTH? A yes/no response was provided with the exception of the first month (of filter use) which asked to clarify the change as to better or worse.

The results in Table 2 reflect percents of subject response and is broken down on a monthly basis. We've delineated the two filter types as well as the response with respect to ODOR, TASTE, COLOR, and NO ANSWER.

Those with carbons seemed to respond to odor and color with no change, 70.8% and 67.4%, respectively. As you can see 55.6% of those with blanks thought the change in odor was for the better, while a larger majority s aw no change in color (77.7%). It seems that more of the participants noticed a change for the better with regards to taste: 65.6% for carbons, while those with blanks were nearly evenly split between better and no change in taste: 52.9% to 47.0%.

There is a large discrepency between filter types in the percentage of people who did not respond: 18.3% for carbons, 45.7% for blanks. And yet when you look at the next two months, the blanks have a zero, non-respondent percentage.

Month 2 yields a generally higher no change response for all three elements in both groups. Those with blanks may have caught on because their response to change in odor plummeted to 0% in the yes category.

Month 3 holds similar percentages for those with carbons with the exception that the ratio of yes to no is closer to 1:4 than 1:3. The blanks responded to both odor and taste with 100% no change and did not answer the color portion.

The second set of questions were aimed at evaluating two things:

1) DID THE FILTER PERFORM AS EXPECTED?
2) WOULD THE SUBJECTS HAVE BOUGHT A FILTER PRIOR TO THE STUDY?

Before looking at the statistics, it's important to note that generally, for months 1-3, people had the same filter type. Month 4-6, the filter type should have been switched. By month 4, the time of the switch, people had an "expectation" because they had become familiar with the filter and its previous performance. This may be reflected (Table 3) in the increase in the positive response category for the carbons for months 4-6. The positive responses for the blank filters also increased for months 4-6.

Those with blanks tended to have less of an expectation. This is reflected in the higher percentages in their "no expectations" responses.

Evaluation of the second question is not an easy task. In

Table 2.
FAUCET FILTER AESTHETICS

% Of Subject Responses to Marketing Questions

First Set: Did the Odor, Taste, or Color Change in the Last Month?

	Month 1					Month 2				Month 3			
	Carbon			Blank		Carbon		Blank		Carbon		Blank	
	Better	Worse	No Change	Better	No Change	Yes	No	Yes	No	Yes	No	Yes	No
Odor	28.1	1.1	70.8	55.6	9.0	23.3	76.7	0	100%	22	78%	0	100%
Taste	65.6	1.1	33.3	52.9	47.0	35.2	64.8	33.3	66.7	24.4	75.6	0	100%
Color	31.5	1.1	67.4	22.2	77.7	24.7	75.3	33.3	66.7	17.1	82.9	0	0
No Answer		18.3%		45.7%		20.6%		0%		14.6%		0%	

Table 3.

Subject Responses to Marketing Question

Second Set

		Month 1&2		Month 3		Month 4		Month 5		Month 6	
		Carbon	Blank	Carbon	Blank	Carbon	Blank	Carbon	Blank	Carbon	Blank
Did the water filter perform as expected?	Yes	50%	15.4%	46.5	42.9	64.5	44.1	82.8	36.6	54.3	50.0
	No	0	27.0	11.6	28.6	8.3	23.5	2.8	20.0	5.7	27.3
No Expectations		-	7.7	9.3	28.6	13.2	-	1.1	13.3	11.4	13.6
Would you have bought a filter before the study?	Yes	20%	23.1	9.3	28.6	9.9	-	8.3	10.0	22.9	9.1
	No	30	15.4	53.5	-	44.6	41.2	55.6	40.0	37.1	50.0
No Expectations		-	11.5	9.3	28.6	16.5	8.8	16.7	20.0	11.4	31.8
No Answer		50%	46.2%	30.2%	14.3	21.5	41.2	19.4	30.0	28.6	9.1

month to month collections there were people who were "true converts" and loved their filters and then there were those who found the "inconvenience" almost too demanding. These preferences may be reflected in the evaluation of whether people would have purchased a water filter prior to the study.

It appears that more people would not have bought a filter previously. For both groups the response is variable across the 6 months, but generally we can see an increase in those persons who would not have purchased a filter. Perhaps prolonged use of an "inconvenient" water device has lead some subjects to vote "no".

The final question was "How could the water filter be improved?". There were 42 individual suggestions given into three categories. The first and most common suggestion concerned the space the filter occupied. Many suggested making it smaller, attaching it someplace else, or designing it so it wasn't so "bulky". The second category of suggestions concerned durability. Many people said it leaked at the connection to the sink, the switches leaked and that the filter was not durable enough to attach the dishwasher to it. The third category concerned the actual mechanics of the filter. That is to say people felt they should be able to run not water through it and that the filter was too slow. A few subjects did comment that they were satisfied with the filter and had no suggestions.

At the end of the faucet filter study, the majority of subjects kept their POLLENEX filter.

PART II

With regard to actual use of the Everpure by-pass filters, statistics were compiled on subject responses to marketing questions placed at the bottom of each health diary. The questions were provided by Everpure, Inc., the filter manufacturer. After some modifications by the Yale research team for use in the diaries, the questions were approved by the Human Investigations Committee at Yale University. Each month for 6 months, the families were given a set of questions. The results are given by question.

1. During the past month, has there been any change in odor, taste or color of your drinking water?

ODOR (N=60)

67% Did not detect a change in odor
33% Did notice a change in odor

For those that detected a change in odor, 95% indicated that the odor of the water was better. Only 5% (one person) thought that the odor was worse.

TASTE (N=60)

40% Did not detect a change in taste
58% Did detect a change in taste
2% Did not answer the question

For the families that detected a change in taste 97% thought that the water tasted better. Only 3% indicated that the water tasted worse.

COLOR (N=60)

72% Did not detect a change in color
27% Did detect a change in color
2% Did not answer the question

For those that detected a change in color, 88% indicated that the color of the water had improved. Only 13% thought that the color was worse.

QUESTION 2

Do you feel that your water filter has performed as you expected?

(N=62)
84% Yes
5% No
11% No expectations

QUESTION 3

Would you have bought a water filter before the study?

(N=62)

19% Yes
53% No
27% Don't know

QUESTION 4

How could the water filter you have now be improved?

*Note: Some people supplied more than one answer. There were 21 responses.

57% Faster water flow/more pressure
14% longer neck on faucet
10% connect it to the main faucet
10% filter hot water
5% keep sprayer
5% colder water through filter
5% make it taste as good as norelco clean water machine
5% faucet switch is rough on bottom; should not be sharp

QUESTION 5

What single feature/benefit do you like about your under-counter drinking water system?

*Note: Some people supplied more than one answer. There were 60 answers.

42% improved taste
13% convenient
8% takes up little space/not bulky
7% filter hidden out of sight
7% on/off valve easy to use
7% pure water
3% use of portable dishwasher without disconnecting filter
3% clearer water
2% double filter system
2% cold water
2% better water
2% easy to keep clean
2% separate spigot
2% chemical removal
2% drink more water
2% better odor

QUESTION 6

Is there something you do not like about it?

(N=60)

22% Yes
78% No

If yes, what is it? (N=13)

*Note: Some people supplied more than one answer.

46% slow water flow
31% loss of sprayer hose
15% faucet small
8% no hot filter water

8% not attached to main faucet

8% bland taste

QUESTION 7

How could the water filter system be improved?

*Note: Some people supplied more than one answer. There were 26 answers.

54% increase water flow/pressure
19% increase height and extension of faucet
12% improve taste
8% keep sprayer hose
4% attach to main faucet
4% prevent leaking of cartridges
4% colder water through filter
4% filter hot water

QUESTION B

Please rank the benefits the system provides in order of importance to you and your family. (1=most important; 6=least important)

-------Taste and odor removal

-------Improved clarity and color of water

-------Health benefits of cyst and asbestos removal

-------Health benefits of organic chemical removal

-------Appliance protection provided by lime-scale inhibition

-------Chlorine removal

Not all respondents answered this question in the same manner. For example, some ranked the benefits from most important to least important, while others ranked the importance of each benefit.

The responses were analyzed in three different ways: 1) Numerical means for each benefit; 2) the frequency that each benefit was ranked 1 or 2; and 3) the frequency that each benefit was ranked 5 or 6.

#1 NUMERICAL MEANS

	Numerical Means
Taste and odor removal	2.0
Organic chemical removal	2.0
Cyst and asbestos removal	2.3
Chlorine removal	3.2
Improved clarity and color	3.7
Appliance protection	4.4

The lower the mean, the more important the benefit.

#2 Percentage that benefit was ranked 1 or 2 - Most important

Organic chemical removal	72%
Taste and odor removal	67%
Cyst and asbestos removal	35%
Improved clarity and color	20%

#3 Percentage that benefit was ranked 5 or 6 - Least important

Taste and odor removal	5%
Organic chemical removal	6%
Cyst and asbestos removal	17%
Chlorine removal	23%
Improved clarity and color	44%
Appliance protection	61%

The three different analyses indicate that taste and odor removal, organic chemical removal and cyst and asbestos removal are of equal importance to the filter users. Chlorine removal is less important followed by improved clarity and color, and finally, appliance protection.

QUESTION 9

Did you formerly buy bottled drinking water?

(N=56)

14% Yes
86% No
4% No answer

If no, did you ever consider doing so?

54% Yes
43% No
2% No answer

QUESTION 10

Are you aware of the difference between a water softener and a drinking water system? (N=56)

52% Yes
46% No
2% No answer

If Yes, in your opinion, what is the major benefit each provides?

Water softener

Improves cleaning
Whiter laundry; better for skin
Healthier bathing and washing
Less soap and detergent
Clean clothes
Not sure
Better for skin
Use less soap
Provides elements and mineral to soften water
Adds salts; less soap; no mineral build up

Removes hardness

Removes minerals for better cleaning, laundry

Softer water

Reduced mineral content

Better for washing

Washing

Hard water to soft, removing lime deposits

Conserves soap used, prevents scum

Better for washing

Filters out impurities and water is not so hard on skin, clothes, etc.

Drinking water system

removes odor; improves taste

tastes and feels better

better taste; cleaner water

tastes and looks better

better drinking water

healthier

clean pipes; good drinking water

convenience

filters out chemicals and parasites

better water

healthier water; better taste

removes elements to purify

removes organic and inorganic impurities, improves taste and smell

removes impurities

purifies water; removes chlorine

less minerals

remove minerals, contaminants, particles; cleaner, better taste and smell

cleaner and healthier water

improves taste; removes impurities

taste

taste, purity

purity for drinking

health benefits from chemical removal

better tasting; purer water

improved taste