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Studies of Effectiveness of Commercial Home Treatment Systems

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Technical Completion Report Research Project G-829-09

Arkansas Water Resources Research Center
University of Arkansas
Fayetteville, Arkansas 72701

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A B S T R A C T

STUDIES OF EFFECTIVENESS OF COMMERCIAL HOME TREATMENT SYSTEMS

Eleven home water systems were tested representing six different types of filtering systems. Tests were made for Sulfates, Nitrates, Phosphate, Iron and Escherichia coli and Enterobacter aerogenes before and after passing through a home treatment system. All of the systems removed iron adequately but had little effect on the removal of nitrates, phosphates, sulfates or control of pH.

Since none of the ground waters was contaminated by coliforms, nothing was established regarding the effectiveness of bacterial removal by these systems.

William W. Trigg and Raymond D. Couser

Completion Report to the United States Department of the Interior, Washington, D.C. September, 1984.

KEYWORDS -- Pollution, Contamination (bacterial, fecal), Coliforms, Lactose fermenters, Escherichia coli, Enterobacter aerogenes, Chemical contamination.

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INTRODUCTION

One of the major problems with selection of an appropriate home water treatment system for individual home use is the variety of types of systems and the variations in water properties (especially pH). An individual home owner in most areas can only contact a water conditioning dealer who rarely has the technical ability to evaluate a best system and who sometimes is only interested in making a sale of his most expensive unit. This research project measured the chemical and bacterial contents of raw water and water samples treated by commercially installed water conditioners. The objective of this project was to establish the relative effectiveness of water conditioning systems as installed in home service.

A. Purpose and Objectives

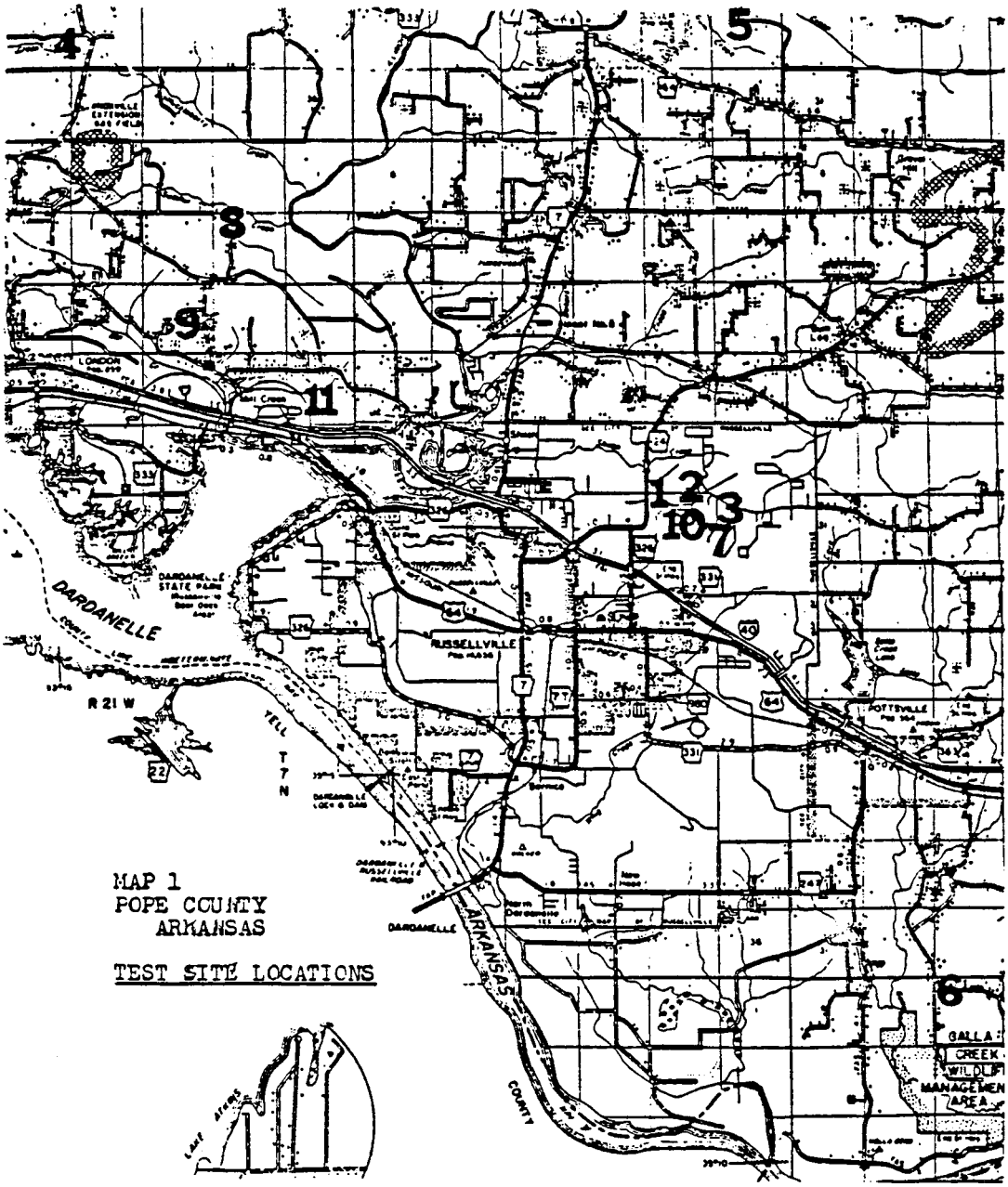
The purpose of this research was to analyze water samples from private wells to determine the effectiveness of various treatment systems. The objective was to establish a reference base from which recommendations of filter types could be made based on chemical and biological performance.

B. Related Research or Activities

None.

METHODS AND PROCEDURES

Eleven private well systems were selected (see Map 1) for this study. The selections were based on a variety of locations and a variety of filter types (see Table 1). At each site, sample



MAP 1
POPE COUNTY
ARKANSAS

TEST SITE LOCATIONS

taps were installed, where needed, immediately before and after the filter system. Samples were taken during the months of October, November and December of 1983 and January, March, April and June of 1984.

Table 1.

NAME	LOCATION	FILTER TYPE
Couser	1	Ion exchange
Hefley	2	Sand filter
Martin	3	Ion exchange
McDaniel	4	Ion exchange
Myer	5	Sand filter and charcoal
Patterson	6	Ion exchange and NaOCl chlorination
Shelton	7	$KMnO_4$
Simmons	8	Ion exchange
Smith	9	$KMnO_4$
Talbert	10	$KMnO_4$
Trigg	11	Ion exchange and Neutralizer

Samples were obtained using autoclaved food canning jars with rubber seal rings to insure sterility. In the laboratory the samples were first analyzed biologically to reduce the risk of contamination. The Standard Analysis of Water consists of three parts: presumptive, confirmed and completed. The presumptive part consists of a series of lactose broth Durham tubes into which a specific volume of test water is added. Ten milliliters of water is added to each of three tubes containing double strength lactose broth. One milliliter of the same water sample is added to three

single strength lactose broth tubes and one-tenth milliliter of the same sample is added to three single strength lactose broth tubes. Gas production in any of the tubes constitutes a positive presumptive test. The number of bacteria presumed to be in 100 milliliters of the sample is determined by utilizing a Most Probable Number table.

The water in any tube in which gas was formed is considered unsafe. Confirmation of gram-negative lactose fermenters necessitates the innoculation of an appropriate medium with a sample of the positive lactose broth culture. Since non-coliform bacteria, e.g., Clostridium perfringens, produce gas, the confirmed part of the analysis will not only select against this and other gram-positive organisms but will allow for the differentiation of the coliforms Escherichia coli and Enterobacter aerogenes. For the confirmed part, Levine's EMB agar was used.

Coliform colonies from the Confirmed test are then transferred to a tube of lactose broth and a nutrient agar slant. A gram-reaction slide is then made from each of these slants and lactose tubes.

The chemical analyses consisted of the determination of pH and the concentrations of sulfates, phosphates, nitrates and iron.

Hydrogen ion concentration was determined using a pH meter standardized with pH 7.0 buffer.

Nitrate was determined using the cadmium reduction method and reading at 543 nanometers. A standard nitrate solution of 10 ppm

was used as a reference.

Phosphate was determined using the ascorbic acid method and reading at 700 nanometers. A standard phosphate solution of 1 ppm was used as a reference.

Sulfate was determined using the barium chloride turbidimetric method and reading at 450 nanometers. A standard sulfate solution of 50 ppm was used as reference.

All measurements were made on a Bausch and Lomb Spectronic 20 with standard Bausch and Lomb cuvettes.

CHEMICAL PROCEDURES:

pH Determination:

Hydrogen ion concentration was determined as pH using a Sargent Welch model RB pH meter. The meter was calibrated using pH 7.0 ±.02 buffer solution freshly prepared from pHydrion buffer powder (a mixture of sodium and potassium phosphates). Individual samples were analyzed with the calibrated pH meter washing the electrode between each determination and drying the electrode before insertion into samples. Readings were recorded upon stabilization of the meter's indicator.

Nitrate Determination:

Nitrate ion concentration was determined using the Cadmium Reduction Method. In this procedure, 25 ml amounts (via class A glassware) were treated with one NitraVer V Nitrate Reagent Powder pillow (a mixture of metalic cadmium and gentistic acid; a product

of Hach Chemical Company). The mixture was shaken vigorously for one minute and read spectrophometrically after at least 5 minutes and no more than 15 minutes. A Bausch and Lomb Spectronic 20 spectrophotometer was used for all measurements. The instrument was warmed-up, 0%T set according to directions, and 100%T set using untreated sample. Readings were made at 500 nanometers using standard Bausch & Lomb cells. A standard solution of 10.0 ± 0.1 ppm nitrate nitrogen was identically treated with each group of samples and used as a reference. Calculations were made using Beer's Law:

$$(A_{unk})\ (\text{concentration}_{unk}) = (A_{ref})\ (\text{concentration}_{ref})$$

Phosphate Determination:

Phosphate ion concentration was determined using the Ascorbic Acid Method. In this procedure, 25 ml amounts (via class A glassware) were treated with one PhosVer III Phosphate Reagent Powder Pillow (a mixture of ascorbic acid, antimony potassium tartrate and ammonium molybdate, a product of Hach Chemical Company). The mixture was shaken immediately and read spectrophometrically after at least 2 minutes and no more than 10 minutes. A Bausch and Lomb Spectronic 20 spectrophotometer fitted with appropriate red filter and red-sensitive photocell was used for all measurements. The instrument was warmed up, 0%T set according to directions, and 100%T set using untreated sample. Readings were made at 700 nanometers using standard Bausch and Lomb cells. A standard solution of 1.0 ppm phosphate was identically treated with each group of samples and used as a

reference. Calculations were made using Beer's Law:

$$(A_{unk})\ (\text{concentration}_{unk}) = (A_{ref})\ (\text{concentration}_{ref})$$

Sulfate Determination:

Sulfate ion concentration was determined using the Turbidimetric Method. In this procedure, 25 ml amounts (via class A glassware) were treated with one SulfaVer IV Sulfate Reagent Powder Pillow (a mixture of barium chloride and conditioning reagent, a product of Hach Chemical Company). The mixture was shaken immediately and read spectrophometrically after at least 5 minutes and no more than 10 minutes. A Bausch and Lomb Spectronic 20 spectrophotometer was used for all measurements. The instrument was warmed up, 0%T set according to directions, and 100%T set using untreated sample. Readings were made at 450 nanometers using standard Bausch and Lomb cells. A standard solution of 50.0 ± 0.5 ppm sulfate was identically treated with each group of samples and used as a reference. Calculations were made using Beer's Law:

$$(A_{unk})\ (\text{concentration}_{unk}) = (A_{ref})\ (\text{concentration}_{ref})$$

Iron Determination:

Total iron ion concentration was determined using the 1,10-Phenanthroline Method. In this procedure, 25 ml amounts (via class A glassware) were treated with one FerroVer Iron Reagent Powder Pillow (a pre-measured amount of 1,10-phenanthroline, a product of Hach Chemical Company). The mixture was shaken immediately and read spectrophometrically after at least 3 minutes and no more than 30

minutes. A Bausch and Lomb Spectronic 20 spectrophotometer was used for all measurements. The instrument was warmed up, 0%T set according to directions, and 100%T set using untreated sample. Readings were made at 510 nanometers using standard Bausch and Lomb cells. A standard solution of 1.0 ppm iron was identically treated with each group of samples and used as a reference. Calculations were made using Beer's Law:

$$(A_{unk})\ (\text{concentration}_{unk}) = (A_{ref})\ (\text{concentration}_{ref})$$

BACTERIAL ANALYSIS:

It is an established fact that some of the waters in this area are contaminated with bacteria and certain chemicals. The bacterial investigation dealt with determining whether or not coliform bacteria Escherichia coli and/or Enterobacter aerogenes were present in the water supply and if so, to what extent the filter system would remove these bacteria. Selection of water to be tested was based on the homeowner's suspicion (fear) of pollution, the location of the home (and water source), and the type of filter employed. Suspected pollution was our first criterion of selection.

Samples were taken almost monthly over the grant period and each sample was tested for coliforms employing the techniques for the standard bacterial analysis of water. As stated in the original proposal, our intent was to measure the chemical and bacterial content of raw water and these same water samples treated by commercially installed water conditioners.

As defined in "Standard Methods for the Examination of Water and Wastewater" the coliform groups include all of the aerobic and faculatative anaerobic, Gram negative, non-spore-forming rod-shaped bacteria which ferment lactose with gas formation within 48 hours. The list of coliform will not be included except for Escherichia coli and Enterobacter aerogenes which are considered to be the prime pollution indicators. These organisms can be identified and a distinction made between the two by the techniques mentioned previously. Typical E. coli and closely related strains are of fecal origin while E. aerogenes and its close relatives are not of direct fecal origin.

The standard bacterial analysis of water consists of a presumptive, a confirmed, and the completed phase. The presumptive phase "assumes" the water to be contaminated. In essence, the presumptive phase involves the innoculation of lactose broth Durham tubes for the determination of gas production. Tubes in which gas is produced are considered positive. Innoculum from these tubes is transferred to an Eosin Methylene Blue agar plate. This is a differential medium on which colonies of E. coli are small and flat with a metallic sheen while colonies of E. aerogenes are larger, more raised and without a metallic sheen. In the completed phase, colonies of E. coli are transferred to tubes of lactose broth and an agar slant. The tubes are checked for gas and the slant colonies are subjected to the IMVIC series of tests and a Gram stain is made.

None of the samples were positive for coliforms either in the filtered water or the raw water. The determination of fecal contami-

nation was the thrust of our investigation and no attempt was made to determine if other forms of micro-organisms were present.

PRINCIPLE FINDINGS AND SIGNIFICANCE

All water samples were collected in sterilized containers and delivered as soon after collecting as possible. As soon as the samples arrived they were tested for coliforms by the Standard Bacterial Analysis of Water. No coliforms were detected in any of the water samples. In fact, there were no lactose fermenters of any kind in any of the samples as evidenced by the fact that no gas appeared in any of the Durham tubes. Therefore, no conclusions can be made as to the effectiveness of the home water filters tested to remove coliform bacteria.

These units have little or no effect on pH and have little effect on nitrate removal.

Generally speaking, the units have little effect on phosphate removal. There was, however, an exception where phosphate was added to the filtered water. This increase is unexplained at this time but might be due to the regeneration process which could be adding phosphates to the water. These units have little effect on sulfate removal.

CONCLUSIONS

These units are designed primarily for the removal of iron which is done effectively by all systems. These results indicate that any of the systems will effectively remove iron in concentra-

tions below 3 ppm and a sand and ion exchange combination appears needed at higher concentrations.

LITERATURE CITED

None.

Table 2.

	pH Results						
	Oct. 83	Nov. 83	Dec. 83	Jan. 84	Mar. 84	Apr. 84	Jun. 84
Couser Before Filter	6.8	6.2	6.4	8.0	6.3	7.0	6.4
Couser After Filter	6.5	6.2	6.2	6.5	6.3	6.9	7.0
Hefley Before Filter	7.3	6.5	6.3	6.6	7.0	7.2	6.1
Hefley After Filter	7.2	6.6	6.2	6.5	7.2	7.2	6.1
Martin Before Filter	7.2	6.6	6.9	7.5	6.6	5.4	7.0
Martin After Filter	7.6	6.5	6.6	7.2	5.8	5.5	6.5
McDaniel Before Filter	7.4	8.0	6.2	7.5	6.5	5.6	6.5
McDaniel After Filter	7.5	6.8	6.0	7.3	6.7	6.0	7.0
Myer Before Filter	7.2	7.4	na	6.7	5.7	5.4	6.3
Myer After Filter	7.6	7.5	na	6.5	6.1	6.5	6.9
Patterson Before Filter	6.8	6.0	na	6.9	7.0	7.5	7.7
Patterson After Filter	6.8	7.1	na	6.9	6.5	8.0	8.3
Shelton Before Filter	7.5	6.7	na	7.5	7.5	7.0	6.6
Shelton After Filter	7.4	6.7	na	7.3	7.5	7.0	7.0
Simmons Before Filter	na	6.5	na	7.0	6.4	6.5	6.7
Simmons After Filter	na	6.6	na	6.8	6.3	6.5	7.4
Smith Before Filter	7.1	6.1	na	na	6.5	6.4	6.3
Smith After Filter	7.1	6.4	na	na	7.0	7.3	6.4
Talbert Before Filter	9.1	6.2	6.3	6.8	6.5	5.8	na
Talbert After Filter	7.1	6.0	6.0	6.5	6.2	6.0	na
Trigg Before Filter	8.0	8.0	na	6.9	6.9	5.6	7.3
Trigg After Filter	8.0	7.5	na	6.6	6.9	5.6	6.9

na = no sample available

Table 3.

Nitrate Results

	Oct. 83	Nov. 83	Dec. 83	Jan. 84	Mar. 84	Apr. 84	Jun. 84
	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Couser Before Filter	.83	bd	bd	3.1	bd	bd	bd
Couser After Filter	.83	bd	bd	2.3	bd	bd	bd
Hefley Before Filter	3.3	.07	bd	bd	bd	bd	bd
Hefley After Filter	1.7	.03	bd	bd	bd	bd	bd
Martin Before Filter	2.4	bd	bd	bd	bd	bd	bd
Martin After Filter	.85	bd	bd	bd	bd	bd	bd
McDaniel Before Filter	3.1	1.3	bd	6.0	bd	bd	bd
McDaniel After Filter	1.6	.03	bd	2.3	bd	bd	bd
Myer Before Filter	3.9	bd	na	5.4	bd	bd	bd
Myer After Filter	1.6	bd	na	1.5	bd	bd	bd
Patterson Before Filter	1.7	bd	na	24.6	bd	bd	2.1
Patterson After Filter	1.7	bd	na	8.5	bd	bd	2.1
Shelton Before Filter	3.9	.04	na	bd	bd	bd	bd
Shelton After Filter	2.3	.03	na	bd	bd	bd	bd
Simmons Before Filter	na	bd	na	5.4	bd	bd	bd
Simmons After Filter	na	bd	na	1.5	bd	bd	bd
Smith Before Filter	1.9	.05	na	na	bd	bd	bd
Smith After Filter	1.5	.04	na	na	bd	bd	bd
Talbert Before Filter	1.7	.07	bd	5.4	bd	bd	na
Talbert After Filter	1.7	.03	bd	2.3	bd	bd	na
Trigg Before Filter	1.3	bd	na	bd	bd	bd	bd
Trigg After Filter	1.3	bd	na	bd	bd	bd	bd

na = no sample available
bd = below detection limit

Table 4.

Phosphate Results

	Oct. 83	Nov. 83	Dec. 83	Jan. 84	Mar. 84	Apr. 84	Jun. 84
	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Couser Before Filter	.10	bd	.50	.26	.56	.22	.41
Couser After Filter	.25	.50	.60	.44	.12	.43	.68
Hefley Before Filter	.30	1.0	.50	.35	.94	.35	.41
Hefley After Filter	.20	bd	.30	.31	.27	.22	.27
Martin Before Filter	.40	bd	.40	bd	.05	.78	.19
Martin After Filter	.20	.50	.30	bd	.06	.57	.19
McDaniel Before Filter	.50	bd	1.5	.30	.22	.26	.36
McDaniel After Filter	1.9	1.7	2.6	1.7	.59	1.9	2.2
Myer Before Filter	.50	.50	na	.59	.91	.30	.36
Myer After Filter	.30	.30	na	.19	.65	.30	.50
Patterson Before Filter	.20	bd	na	.33	1.3	.48	.23
Patterson After Filter	.20	bd	na	.67	.26	.48	.29
Shelton Before Filter	.40	bd	na	bd	1.1	.43	.26
Shelton After Filter	.20	bd	na	bd	.26	.30	.32
Simmons Before Filter	na	.50	na	.20	.44	.26	.38
Simmons After Filter	na	.60	na	.74	.39	.61	.76
Smith Before Filter	.40	bd	na	na	.07	1.0	.27
Smith After Filter	.30	bd	na	na	.28	.39	.32
Talbert Before Filter	.20	bd	.50	.28	.15	.26	na
Talbert After Filter	.40	bd	.40	.22	.12	.22	na
Trigg Before Filter	.10	bd	na	.41	.47	.22	.20
Trigg After Filter	.20	bd	na	.33	.52	.22	.20

na = no sample available
bd = below detection limit

Table 5.

Sulfate Results

	Oct. 83	Nov. 83	Dec. 83	Jan. 84	Mar. 84	Apr. 84	Jun. 84
	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Couser Before Filter	27	35	112	65	67	71	44
Couser After Filter	25	20	112	68	67	69	45
Hefley Before Filter	4	bd	17	14	17	12	8
Hefley After Filter	3	bd	12	11	13	8	7
Martin Before Filter	3	12	bd	bd	1	2	bd
Martin After Filter	1	1	bd	bd	1	1	1
McDaniel Before Filter	3	bd	5	12	4	3	2
McDaniel After Filter	3	bd	2	6	3	.1	1
Myer Before Filter	5	bd	na	7	6	3	2
Myer After Filter	1	bd	na	1	.4	1	2
Patterson Before Filter	146	166	na	244	178	178	175
Patterson After Filter	146	166	na	244	178	178	175
Shelton Before Filter	3	7	na	bd	4	3	3
Shelton After Filter	2	8	na	bd	1	3	.1
Simmons Before Filter	na	bd	na	42	11	11	5
Simmons After Filter	na	bd	na	46	15	12	9
Smith Before Filter	42	59	na	na	68	39	13
Smith After Filter	36	54	na	na	66	36	16
Talbert Before Filter	27	31	60	49	54	45	na
Talbert After Filter	27	34	52	33	52	38	na
Trigg Before Filter	3	2	na	bd	.4	1	1
Trigg After Filter	2	8	na	bd	bd	bd	1

na = no sample available
bd = below detection limit