

Practical application of foam fractionation treatment of low quality water
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TREATMENT OF LOW QUALITY WATER

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STUDY RATIONALE

The foaming technique has found extensive use for organic, ion, and colloid separations from liquid systems. When used to remove an ion or a colloid, a specific surface-active agent of opposite charge to the particle being removed is added to the solution and floated to the surface of the suspension by gas bubbles. The ion or colloid is adsorbed at the bubble interfaces and collected within the froth formed at the surface of the container. The froth, with the contaminant or concentrated material (depending upon the process and its use) is physically separated at this point and further processed or discharged to waste. The clarified bottom liquid is therefore suitable for other uses. In the water supply field, the bottom liquid is the important product that is to be recovered and used for consumptive purposes.

Much research has been performed on the theory and applications of various adsorptive bubble separation methods. These studies are well documented in the literature for various industries and applications which might take advantage of the method. It was not the intent of this work to amplify the findings of other research. The project was undertaken in an attempt to scale-up laboratory experiments previously performed at this Institute. No extension of theory, new processes, or revolutionary findings were attempted.

The original laboratory research (1) indicated that a foaming process might have some benefits in the treatment of low quality groundwaters for the remote villages located throughout the state. High iron concentrations in these groundwaters plague nearly all Alaskan areas within the permafrost and tundra regions. These same regions also encompass the greatest part of the native population

and can be truly classified as depressed areas. With few exceptions the communities (or villages, as they prefer to be called) have populations less than 300, a subsistence or partial subsistence economy, and no technically trained individuals. Excess lime treatment, on a batch basis, has been used with some success in some villages (2). However, the large quantities of chemicals necessary for such treatment, coupled with the excessive freight costs to deliver these chemicals to regions served solely by aircraft, leave much to be desired.

The above combination of circumstances usually obviates the more conventional methods of water purification. The more important water treatment plant characteristics for these villages are simple equipment, effective light weight chemicals, and minimum operation necessary to insure a safe and potable water. The ideal situation would consist of simple equipment fabrication completely made from materials available in these villages.

Although it appears crude in this day and age, a batch system for the majority of the locations in question is entirely suitable. Present sanitation facilities are nil, water being obtained from surface sources, either in the liquid or frozen state. Few, if any, homes have plumbing, and distribution systems are many years away at most locations. A simple structure housing a batch treatment plant, where the residents of the village can come on a daily basis to acquire their water, would be a great improvement over the existing situation.

Another process requirement is the type of chemical used, lime additions often negated by the fact that raw water quality changes,

thus changing the required dose. Seldom is anyone available at the site to make the analyses needed to adjust the dosage. Also, it has often been found that when untrained people use lime, if the proper dose is, for instance, one cup of lime per drum of water, they feel that two cups will create a better water. Obviously, the finished water could be very poor if such a practice were followed. Therefore, if chemical treatment must be used in the villages, it would be ideal if a chemical could be found that would not adversely affect the water if an excess were added, recognizing, of course, that this practice would be uneconomic.

The foam fractionation technique was thought to be the answer to many of the problems described above. The surfactant ethylhexadecyldimethylammonium bromide (EHDA-Br) is very light weight when purchased as a powder, and the freight would be minimal. An excess dose of the chemical might create a great deal of foam, but it would not have the tendency to produce an unpotable water if too much were applied. Lastly, it was hoped that the equipment necessary for such a treatment facility could be fabricated with locally available materials, the possible exception being the air compressor and the diffusers.

With the basic laboratory studies showing signs of promise, it was decided to construct and study a plant using the simplest of the foam techniques: bubble aeration with surfactant addition. It is realized that more sophisticated processes utilizing reflux, recycle, etc. would be more efficient, but such processes would obviate the simplicity sought for the remote Alaskan installations.

FIELD TEST UNIT

Common to all villages, regardless of remoteness, is the 55 gallon drum. The basic fractionation column was constructed by welding three such drums together to form a column 98.5 inches tall and 22 inches in diameter. The total volume of the column was 165 gallons. Sampling ports, an air inlet port, and a drain were installed as depicted in Figure 1.

All fittings were installed flush with the inside of the tank. Raw water was introduced by a hose hung over the top of the column. The aeration devices used were of two types. The one first used was a piece of 5/8 inch copper tubing, shaped in a semi-circle, which had 1/32 inch holes drilled at one inch intervals along its total length of two feet. The second type were carborundum stones which were used for the last few experiments. Water from a 45 foot well, driven through 35 feet of permafrost, was used as the test water during all the work reported herein. Some of the chemical and physical properties are reported in Table 1.

TABLE 1

Properties of the Raw Water Used In All Experiments

Raw Water Temperature	1 - 3°C
Iron	25 - 35 mg/l
Hardness	Greater than 500 mg/l as CaCO ₃
Turbidity	25 JTU
Organics, as tannin	Greater than 5 mg/l
pH	6.5

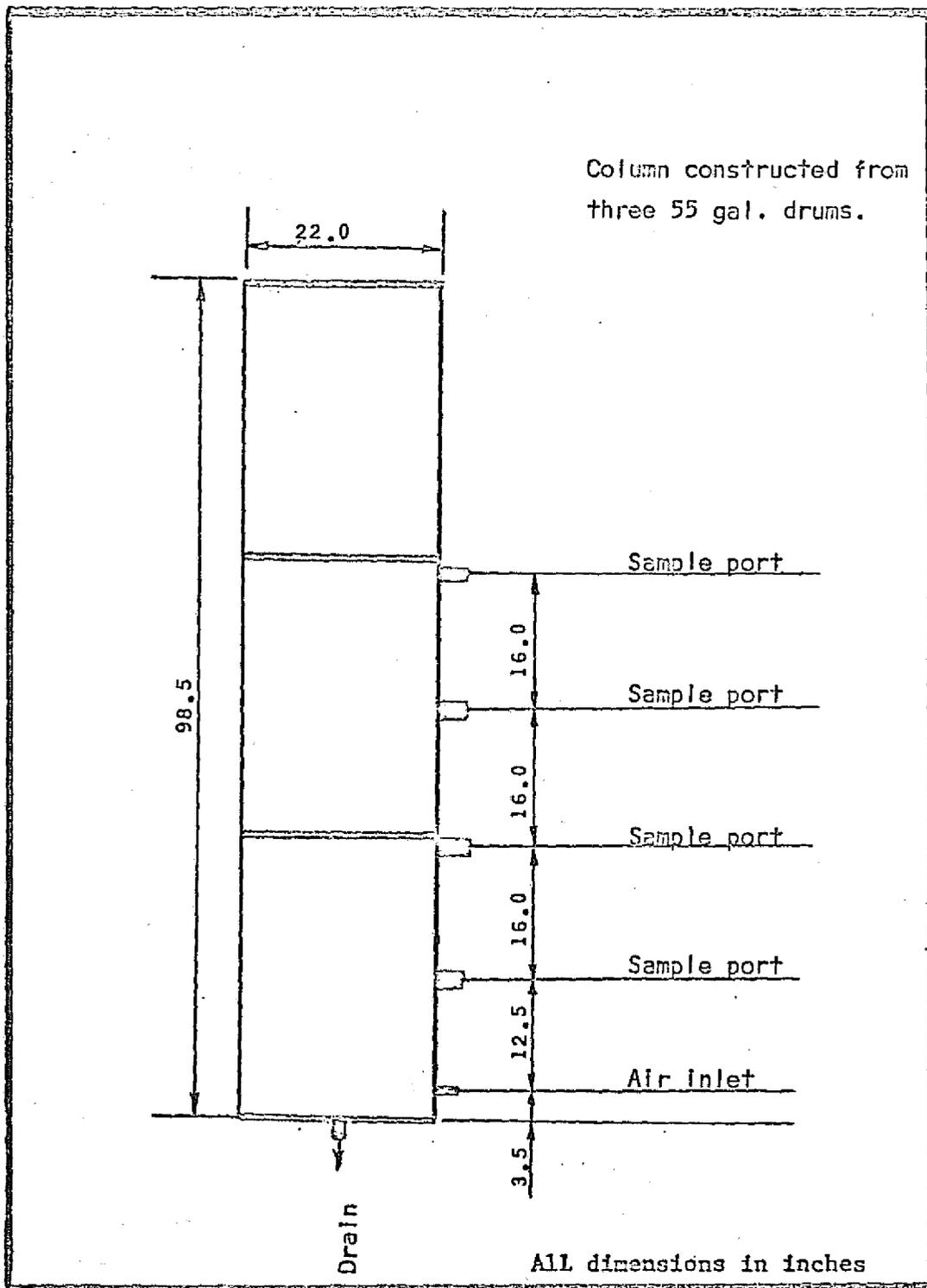


FIGURE I: Prototype Field Test Unit

Although by no means the poorest quality water to be found in the state, a good term for this particular water might well be "typically poor." Iron concentrations in excess of 100 mg/l are not uncommon (2, 3). The same raw water was used also in the majority of the laboratory studies.

The system was operated in such a manner as to best simulate a field situation. Wherever possible the field runs took advantage of the findings of the laboratory results. For instance, it was deemed best to add the surfactant incrementally rather than in one batch. Initial studies used the EHDA-Br concentrations found to be most effective in the laboratory. These were varied to determine their effect upon removal rates. The efficiency of the process was measured by the percent iron removed.

FINDINGS

The results of the field tests were completely negative and the original idea of treating low quality groundwater by this process has been abandoned. Table II summarizes the results of 14 of the 22 runs made during the study. Those runs not reported experienced difficulties of one sort or another which prevented their completion.

In order to claim any effectiveness for iron removal of the concentrations used in this study, in excess of 98 percent efficiency must be realized. It requires but a cursory review of the results to realize that the proposed process is inadequate.

EHDA-Br was added in four equal increments on all reported tests. Each increment was added after maximum foaming had taken place in the previous increment. Samples for analytical testing

TABLE II

Results of Field Trials

Run	Volume Raw Water, gal	EHDA-Br Added mg/l	Initial Fe, mg/l	Final Fe, mg/l	% Fe Removal	Initial Water Temp. °C	Water Age Hrs.	Aerator
1	50	55.5	22.4	21.4	4.5	4.5	0	Tube
2	50	120.0	24.4	23.7	2.9	5.0	0	"
3	110	37.6	22.6	22.0	2.6	5.2	0	"
4	50	103.0	29.4	29.4	0	11.5	12	"
5	150	112.0	33.8	20.8	38.6	15.0	60	"
6	50	120.0	26.2	22.2	15.3	5.6	0	"
7	50	120.0	29.0	27.9	3.8	23.3	36	"
8	50	1200.0	27.3	23.2	15.0	10.0	2	"
9	50	435.0	26.2	21.8	16.8	17.0	14	"
10	160	120.0	25.4	25.0	1.6	9.0	3	"
11	50	120.0	30.8	25.6	16.9	9.0	0	Stones
12	50	240.0	20.4	7.8	61.9	16.0	15	"
13	50	240.0	22.9	20.9	8.7	15.0	15	"
14	160	56.5	27.0	22.1	18.2	11.3	12	"

were withdrawn from the column at various sampling ports during and after each run. Results showed little significant variation as a function of the depth from which they were withdrawn, indicating good mixing of the tank contents.

The results indicate that water temperature, or some function of it, is the primary cause for the poor results. Low water temperatures were also indicated as somewhat detrimental in the laboratory studies. The hypothesis is the interference was not a function of the foaming process itself, but of the oxidation step occurring immediately prior to or during the foaming. A more complete discussion is presented in the above mentioned report (1). These conclusions may help to clarify the erratic and very poor results presented in this report.

In discussing the effect of the water temperature, a comment should be made as to how the "initial temperature" column of Table II was determined. For values less than 5.0°C the experiment was started immediately after the column was filled with water. The time that the water was out of the subsurface aquifer varied from 30 minutes to 1.5 hours depending upon quantity used, available pumping rates, and other users on the same system. For those values greater than 5.0°C the water was warmed by ambient conditions. The rate of heating was variable, depending upon the weather conditions and the time of day the column was filled. For instance, if the column was filled in the morning of a hot sunny day, the heating rate would be at a maximum compared to the situation when the column was filled in the late afternoon of a cool cloudy day. Significantly different results were obtained when the same experiment was conducted under various water warming rates (i.e. runs 12 & 13).

It is thought that the variations were a function of the temperature and rate at which the iron was oxidized. Any firm conclusions on such a theory were beyond the scope of this project. Extensive physical chemical studies performed under rigidly controlled conditions would be needed to adequately describe this particular water.

Additional difficulties with this system relate to the removal of the foam generated in the process. Only when the tank was completely full (165 gallons) could the foam be easily and continuously removed manually by scraping it from the surface with a straight board. The column width was too great to take advantage of a vacuum system at all intermediate depths. If better results were obtained with the full column it would be, of course, a simple matter to reduce the column cross-sectional area immediately above the water surface, thereby allowing more efficient foam removal by a vacuum method. It is not felt that these difficulties were responsible to any degree for the poor results reported.

Refinements on the process were obvious in many cases. However, each addition merely complicates the unit and makes it less suitable for its intended use. Sufficient data were obtained to be able to make conclusions on the project.

CONCLUSIONS

These experiments must be considered entirely negative. Future refinements on the process would be warranted only if greater skilled personnel and a sound economic basis should develop for these remote areas of Alaska. If this should transpire, reverse osmosis, electrophoresis, and other more advanced processes would compete in the application. Therefore, for a simple process using local materials

and labor to the maximum degree, foam fractionation does not appear to be the solution to Alaska's water treatment problems.

Controlled heating of the water throughout the year appears to be prerequisite to good operation. This is both uneconomic and impractical for a village facility. This factor alone obviates the process usefulness at the latitudes in question. The apparent sensitivity to iron oxidization rates, probably being a function of temperature, is another factor which would complicate the process efficacy in any remote installation.

REFERENCES

1. Murphy, R. Sage, "Treatment of Low Quality Water by Foam Fractionation," Report No. IWR-5, Institute of Water Resources, University of Alaska, February, 1968, pp. 12.
2. Benson, B.E., "Treatment for High Iron Content In Remote Alaskan Water Supplies," Jour. Amer. Water Works Assn., 58:1356, Oct., 1966.
3. Unpublished data, Institute of Water Resources, University of Alaska.