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EVALUATION OF A PROTOTYPE AUTOMATED POND WATER TREATMENT UNIT

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Two automatic pond water filtration units were tested with performance evaluated by analysis of both raw and treated water samples. A large filter, three feet in diameter, was tested and provided water at just over two gpm per square foot. The small filter, with an area of one square foot, was tested at various flow rates, run lengths, and total operating times. Both units were upflow filters with flocculation taking place below the filter media.

The units effectively reduced turbidity as indicated by analysis of raw and purified water. High turbidity waters could not be effectively treated, and high flow rates gave unsatisfactory results. The filters had to be operated at or close to the design flow of one gpm per square foot. Correct alum dosages were important to insure a functional filter system. Maintenance of the system required periodic refilling of chemical solution tanks, backwashing of the filter, and replacement of filter media. These operations could easily be done in conjunction with a time clock regulation of the system.

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from a small pond or other impoundment. Waters in these impoundments are usually quite turbid and they must be filtered and purified. The problems faced in this treatment are somewhat different from those of a municipal water treatment plant. Slow, sand-filtration systems have been developed in recent years which make possible the utilization of surface water supplies for household use. However, these slow, sand filters call for construction and operation skills not usually possessed by the home operator.

It is not uncommon for small towns and communities in Oklahoma that use ground water for their water source to run out of water during dry periods in the summer. They then have to haul in water by tank trucks and severely ration this water. Most of these towns have surface waters in the immediate vicinity that could be used as emergency water if they had some way of treating these waters.

Experimental Equipment:

Large Filter - A three-foot diameter, seven foot tall aluminum tank was constructed. Aluminum sheeting (16 gauge) was utilized for the tank with support provided by steel bands. Raw water entered the bottom of the tank through PVC pipe which projected the diameter of the tank. Three-eighths inch holes were drilled to facilitate even distribution of the water. The holes ran in two parallel rows, one on each side of the pipe. The entire three foot pipe was perforated. Drainage was provided by a drain located on the side of the filter directly below the inlet line.

This filter was constructed with access to the filter media of prime interest. Therefore, the final product was a two-part structure. The bottom section housed the filter media while the top contained the filtered water.

The filter media chosen for this project was Filter-ag, a commercially manufactured non-hydrous aluminum silicate, which is a product of the Clack Corporation (Table I). The filter bed was six inches in depth.

TABLE I

PHYSICAL PROPERTIES OF FILTER-AG

Color - Light Gray to Near White
Density - 24-26 lbs/ft^3
Effective Size - .57 mm
Uniformity Coefficient - 1.66

A steel grid was constructed of a plate perforated with one inch diameter holes, over which one layer of 20 mesh screen and one layer of 50 mesh screen were placed. The filter media was supported by the grid. Four steel pipe legs held the grid in place.

Because of the light weight of the material a 50 mesh screen was also placed above the bed. The screen was held in place by a grid identical to its lower counterpart. Screening prevented uplifting of the bed and held the filter material in place.

A 1/2 hp pump supplied raw water to the system. The flow rate was adjusted as desired by a manually controlled gate valve.

Chemical feeder pumps were utilized to apply alum and chlorine to the water system. Both pumps operated with 30 gallon stock solution tanks. Alum was added first, followed by chlorine. Both chemicals were applied to the inlet pipe before reaching the actual filter tank. As the rapid "flash" mixing is an important part of the coagulation-flocculation process, it was felt the turbulence in the PVC pipe was an efficient method of accomplishing the rapid mix. The two pumps had adjustable rates enabling accurate metering of the stock solution.

A 3/4 hp pump removed water from the filter storage and placed it into a pressure tank which provided storage for 60 gallons of water ready for household use.

Water level control was provided by liquid level controls. As power to the feeder pumps was governed by the liquid control box, the entire system was automatic. The raw water pump operated until reaching a point near the top of the tank, when it closed down. When the level had risen to a point above the filtered water outlet, the pressure pump was activated. The pressure pump continued to work until the water level fell below the filtered water outlet, at which time the pressure pump shut down and the raw water pump was activated. The chemical feeder pumps operated in conjunction with the raw water pump.

Small Filter - The smaller filter, having a one by one foot cross section, was constructed of plexiglas. This enabled observation of the entire filtration procedure. A column of space 3.5 feet tall was allowed for coagulation and flocculation to occur. A six-inch filter bed was above the three and one half foot space, followed by a one foot storage area for filtered water. Unlike the three foot diameter filter, the small filter was designed to be used in conjunction with a storage tank of adequate capacity.

All components of the filter; drain plates, fittings and flow deflectors, were assembled first. Then three sides of the filter were glued together, all pieces placed inside and the fourth side was attached. All gluing was done by clamping pieces together and "welding" with Ethylene Dichloride cement. The glue was distributed with a hypodermic needle and syringe. The support screen for the filter media was also installed at that time.

Drainage was provided by two drains located on the side of the filter. Sloping plexiglas plates directed the drainage water and accumulated floc out the drains. The top sloping plate was designed to capture most of the settling floc, with deflectors to help keep the floc from settling on the lower plate. It was also hoped that velocities of incoming raw water would be deflected by the upper plate and not disturb captured floc. The lower plate completely covered the tank bottom and directed floc which had missed the top plate and had settled on the lower plate out the drain when the drain was opened.

Raw water flowed into the filter through a one-inch PVC pipe that extended across the one foot filter. Three-eighth inch holes were drilled in the pipe on two parallel rows which continued the length of the pipe.

The filter media was supported and contained by 50 mesh screening. The lower screen was supported by plexiglas bars while the upper screen was held in place by plexiglas strips secured around the perimeter. The supports had to be capable of holding the weight of the filter material and any water retained in the pore spaces when the filter was drained.

Analysis Equipment - A Hach floc tester was used for the jar tests to determine correct application rates of alum. A standard mercury thermometer was used in temperature determinations.

Conductivity was established with a Yellow Springs conductivity meter. Turbidity measurements and residual chlorine were determined with a Hach Turbidimeter and a Hach Spectrophotometer, respectively. The Seargent-Welch pH meter was used in pH measurements and in alkalinity determinations. Hardness was evaluated with chemical reagents from the Hach Laboratories, as was alkalinity and residual chlorine. Bicarbonate alkalinity was determined from phenolpthalein alkalinity and total alkalinity.

Procedure:

The two water filtration units were built as detailed in Figures 1 and 2. All construction was done at the Oklahoma State University Agricultural Engineering Laboratory.

All tests run on the filters, with one exception, were carried out in the soil and water research laboratory of the Agricultural Engineering Laboratory. The small filter was taken to the field once.

Figure 1. Three-foot diameter filtration unit.

Figure 2. One-foot square filtration unit.

It was felt that in a pond water situation, fluctuations in the turbidity would be very gradual, if any at all. Therefore, a constant turbidity approach to testing was used. The soil and water laboratory had a sump with a capacity of 225 cubic feet (1680 gallons). With the use of a 1/2 hp pump the water was continuously recirculated to maintain the desired turbidity. With the use of the sump, turbidities were easily altered either by the addition of soil or by the dilution of the existing water.

Raw water samples were taken from the sump and analyzed. The samples were taken in the center of the sump, between the outlet for the circulated water and the inlet for the raw water pump. Raw water was analyzed for turbidity, hardness, alkalinity, conductivity, pH, and temperature.

Raw water was pumped through the filters at varying rates and with different alum concentrations. The alum concentration used was dependent on the turbidity, pH of the water, and upon the time available for flocculation to occur. The latter was dependent on the rate of flow of the water. Alum concentrations were determined from jar test results.

Flow rates were computed using a known change in height of water in the filter, the cross-sectional area of the filter unit, and a stopwatch for timing the changes in height.

Filtered water was collected after the filter had been in operation long enough to stabilize. If a filter was started after it had been sitting dry, some time was necessary for the initial high turbidity to clear. With respect to the large filter, samples were generally taken after the pressure pump had operated three times. The small filter was generally stabilized after ten minutes of operation and samples were taken then and again thirty to forty minutes after operation. Turbidity, hardness, alkalinity, conductivity, pH, temperature, and chlorine residue were measured from these samples.

The effectiveness of the system was evaluated by the results obtained from the water tests. Turbidity was the quality with the noticeable change. All flow rates and alum concentrations were evaluated with turbidity change as the first consideration and the other parameters second.

Methods of water analysis came from the Standard Methods for the Examination of Water and Wastewater or the Hach Water Analysis Handbook or the value was read directly from an instrument. The Hach Water Analysis Handbook (1) follows the Standard Methods procedures and is approved by the American Water Works Association. Chlorine residual and hardness methods of analysis were from the Hach Handbook. Alkalinity determinations followed the method outlined in Standard Methods.(2) Turbidity, conductivity, and pH were read directly from the instruments in the laboratory. A mercury thermometer was used for the temperature measurements.

Results:

Large Filter - The filter was put into operation. Small leaks occurred and several applications of fiberglas merely slowed the leaks, it did not stop them. It was felt that the aluminum sheeting used in construction of the filter was too thin to withstand the normal handling necessary to work on the filter. Application of a small force caused indentations in the 16 gauge sheet metal which also affected the seams. It was decided to continue to operate the filter as the amount of water leaking was negligible when compared with the filter capacity.

Emphasis was placed on mechanical operations. The chief concern was to have both pumps, chemical feeders, and the liquid level control in good working condition. Because of this, turbidity was the only factor used to determine effectiveness of the system.

Three trials were made. Alum concentrations were determined by jar tests (Table II).

TABLE II

LARGE FILTER TEST RESULTS

Trial No.	Raw water (NTU)*	Finished Water (NTU)	Alum (ppm)	Flow Rate (gpm/ft^2)
1	47.5	1.5	50	2.26
2	47.5	2.0	75	2.26
3	13	1.4	50	2.26

*Nephelometer Turbidity Units.

Small Filter - The small filter was tested at flow rates from one to 5.89 gpm. In all of the filter runs, water samples were taken after the first ten minutes of operation. Allowing this time period before sampling let any initially cloudy water disburse. After thirty to forty minutes of operation, a second sample was taken and checked for turbidity only. In some instances tests were carried out for longer periods of time. This indicated performance of the filter with the passage of time.

The range of the parameters is given in Table III.

TABLE III

RANGE OF VALUES OF WATER PARAMETERS

Parameter	Raw Water	Filtered Water
Turbidity (NTU)	17 - 160	.2 - 120
pH	7.11 - 8.49	5.74 - 8.35
Conductivity (μmhos)	455 - 590	520 - 710
Hardness (mg/l as $CaCO_3$)	155 - 192	169 - 190
Phenolpthalein Alkalinity (mg/l as $CaCO_3$)	0 - 6	0
Bicarbonate Alkalinity (mg/l as $CaCO_3$)	127 - 276	27 - 226
Total Alkalinity (mg/l as $CaCO_3$)	127 - 276	27 - 226
Temperatures (°C)	19 - 28.2	21 - 29.4

Alum concentrations applied to the raw water ranged from 45 ppm to 450 ppm.

Filter media was changed when it appeared necessary due to poor filter performance. The filter media had great floc holding capacity. After a long operation period the gravity drain rate through the filter was considerably slower than when the filter was first placed into operation.

While the laboratory work provided adequate testing for the filter, an example of work in the field was desired. The Cole farm at Perkins, Oklahoma had a stock pond with high turbidity due to colloidal clay.

The filter was easily switched to a field experiment. A generator was necessary to provide power for the raw water pump and for the chemical feeder pump. Chlorine was not added as the spectrophotometer necessary for residue measurement was not available.

The alum created large floc particles but the filter was not capable of handling the water. Floc broke through the filter bed almost immediately and the filtered water was a slight improvement over the untreated water. While operating at 0.6 gpm the turbidity of the filtered water at ten minutes after the start of the run was 135 NTU. After twenty minutes of operation the turbidity was 195 NTU. Turbidity of the raw water was then measured and found to be approximately 4000 NTU.

An attempt was made to operate the filter under conditions similar to those encountered in a household.

A time clock was used to control the operation. For fifteen minutes every hour the raw water pump and alum feeder pump were operated. A one gpm flow rate was used and with fifteen minutes of operation every hour the filter provided 360 gal/day.

The valve controlling flow into the filter caused an unexpected problem. With the manual valve partially closed to provide a flow rate of approximately one gpm, the head added by the partially shut valve was too great for the pump to pick up speed. Installation of a solenoid valve operated by a time delay relay eliminated the problem. The relay opened the solenoid valve allowing twenty seconds of unobstructed flow before closing and permitting only the low flow rate.

Turbidity was the only parameter measured during the two tests. Both raw water turbidity and filtered water turbidity were measured.

The first test was started on September 19, 1978. The flow rate was 1.12 gallons per minute with an initial turbidity of 22 NTU. The filtered water had a turbidity of .75 NTU. Alum was applied at the rate of 50 ppm. On September 20 the filtered water had a turbidity of .8 NTU.

The sump was of a capacity such that it had to be refilled every two days. Upon filling on September 21, the addition of soil to increase the turbidity created a turbidity far exceeding 22 NTU, terminating the test run.

During flow periods the filter bed lifted 0.0625 to 0.125 inches due to clogging of pore spaces with floc. Therefore, the filter media was removed and replaced with clean material.

The second test was started September 27, 1978. The results are shown in Table IV.

TABLE IV

WEEK LONG FILTER TEST

Date	Raw Water Turbidity	Filtered Water Turbidity
9-27	30	.3
9-28	26	.17
9-29	42	.4
9-30	28	.2
10-1	--*	--*
10-2	27	.25
10-3	--*	--*
10-4	18	1.5
10-4	12	2.0
10-5	12	1.1

*Indicates data not taken.

Discussion:

Large Filter - At 2.26 gpm per square foot the filter provided water with a turbidity acceptable by the United States Public Health Service. All the mechanical components of the purification unit operated smoothly. The results indicated the filter worked.

The filter worked but was overdesigned for the single home water system. It was capable of producing water, at a one gpm per square foot flow rate, at just over seven gpm. Thus, the filter was much too large for one household but could be used as the purification unit for a group of residences. In addition to the capacity limitations the filter was too expensive for the individual household.

A raw water pump, water line to the filter, the power for the chemical feeder pumps are all the outside components necessary to put the filter in operation. The unit was designed as a portable system capable of being connected and functionable anywhere.

Small Filter - Optimum alum applications were determined from jar tests. Turbidity removal was dependent upon the amount of alum applied, to a point. The rate of alum resulting in the best turbidity control was contingent on the water when considering a constant flow rate. Application of a higher percentage of alum often did not give better water and sometimes appeared to result in a poorer quality water. Thus, the proper alum concentration was essential to the satisfactory operation of the filter.

Jar tests for waters tested indicated the most effective alum concentration to be 45 to 75 ppm. At the lower flow rates these alum concentrations sufficiently controlled turbidity. The higher flow rates--the two to five gpm range--sometimes required much higher alum concentrations to produce acceptable water than was indicated by the jar tests. Five to six gpm rates were unsatisfactory at any tested alum concentration.

An extreme amount of alum was necessary to treat water in the range of 150 to 160 NTU, even at low flow rates. A good quality of water was obtained by the application of the alum but the resulting pH of the water was low. Alum is slightly acidic and the large amounts applied in some cases resulted in slightly acidic water. The lowest pH recorded was 5.74. The World Health Organization recommends a pH limit of 7 to 8.5 but accepts a pH of 6.5 to 9.2. In all tests, except those in which chlorine was added, the alum lowered the pH of the water. When chlorine was applied (with the alum) at the rate of four ppm the resultant pH was lower than the original. With an application rate of eight ppm the ensuing pH was higher than the starting pH.

In addition to the low pH resulting from treating the high turbidity waters, very large quantities of floc were produced. In a long run floc would accumulate to make it necessary to backflush frequently for control of clogging of the filter media and especially the drain plate collection.. Thus, a pretreatment of the water would be necessary. A settling basin to reduce the solids in the raw water would probably be most efficient. Dependent upon the water, chemical treatment could be needed before the settling basin could be effective.

Conductivity of the raw water varied but after the application of alum and chlorine the resultant conductivity was always greater than the original conductivity.

From raw water to purified water there were very few differences in the hardness. Sometimes the resultant hardness was higher than the original and sometimes the consequent hardness was lower than the original hardness. There was no observed relationship between chemical applications and water hardness.

With the exception of those tests which involved chlorine, the alkalinity of the purified water was less than that of the raw water. A four ppm chlorine application caused the alkalinity of the purified water to drop in one situation and rise in another. Eight ppm of chlorine applied to the raw water caused an increase in alkalinity.

All runs were made during the summer resulting in warm water temperatures. In every case, the filtered water temperature was equal to or higher than the raw water temperature. The temperature rise was probably due to water surfaces in contact with the air, filter media, and filter sides as opposed to water in the sump. At lower temperatures viscosity of water increases and rate of settling of floc is decreased. To compensate for temperature drop, coagulant dosages were generally increased, which is what would have to be done with the upflow filters.

The first test with the time clock operating the system was discontinued after two days, due to unacceptable water. The poor water was a consequence of a higher turbidity raw water coupled with a floc loaded filter. The latter was felt to be the main factor involved in the poor operation. If the filter media had been in better condition (less accumulated floc) the filter would probably have recovered from the higher turbidity water.

The second test had good results. During the one week period the filtered water turbidity never exceeded two NTU. The values were well within the allowed limit of five NTU.

The filter was then backwashed and operated an additional day. The backwashing proved successful as the filtered water had a turbidity of 1.1 NTU.

The long term tests demonstrated the filter had the capability to adequately purify water. Chlorine was not used in the tests but with a few trials the proper chlorine dosage could be readily found and applied with the chemical feeder.

General

These systems were designed for a one gpm per square foot flow rate. At the design flow rate, the inclusion of a pump to pressurize the water and a storate tank would be necessary for a household system using the small filter.

Maintenance of the system required little time. The chemical stock solution concentration combined with the adjustable flow rate of the feeder pumps made replacement of the stock solutions infrequent. Thus, chemical solutions could be replaced when the filter was backwashed. At that time the chlorine residual could also be checked.

Conclusions:

1. Effectiveness of the filters was demonstrated by turbidity reduction.
2. High turbidity waters cannot be effectively treated and so require some form of pretreatment.

3. High flow rates gave unsatisfactory results. The filter must be operated at approximately one gpm per square foot. The filter output is directly proportional to size and so the desired capacity is insured by proper sizing of the unit. The low flow rate necessitates use of a storage reservoir.

4. The unit can be fully automated. Chemical stock solutions can be concentrated such that they need be refilled once a week. At the same time, the unit should be backflushed and chlorine residue checked.

5. No relationship was observed between necessary chemical treatments and raw water parameters.

6. Correct alum dosages, based on jar tests, were important to insure a functional filter system.

7. Frequency of replacement of the filter media was dependent on the amount of floc in the water.

8. Combined residual chlorine was found in the purified water. To obtain free residual chlorine the application rate of the chlorine must be increased.

REFERENCES

1. Hach Water Analysis Handbook. Ames, Iowa: Hach Chemical Co., 1977.
2. Standard Methods for the Examination of Water and Wastewater. 13th Edition. Washington, D.C.: American Public Health Association, 1971.