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WILLIAM PENN HOTEL

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WILLIAM PENN HOTEL

PITTSBURGH, PENNSYLVANIA 15230

PAUL COHEN
General Chairman

W. M. PORTER
Secretary

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Current Practice In Water And Waste Water Filtration Technology

by E. J. TAGGART and E. B. MULL, Gulf Degremont, Inc., Liberty Corner, New Jersey

Years ago rapid sand filters replaced slow sand filters and with it came the 2 and 3 gallon rates that found their way into the design manuals and rules and regulations of engineers and public health authorities. Gradually other filter media were tried. Calcite, anthracite, carbon, gravel and even synthetic materials have been and continue to be used in granular pressure and gravity filters.

At first only a single granular medium was used, and it was found that small particles gave better quality but shorter filter runs than coarse particles when water was filtered at the same rate to the same terminal headloss. This was so for all types of media although it was recognized that there were differences between various types having the same effective size — differences like porosity, shape, specific gravity, hardness and electrical charge and potential. Furthermore because most of the removal of suspended material occurred at or near the surface at 2 and 3 gallon rates, the schmutzdecke which formed on the surface had to be broken up by higher backwash rates, and mud balls became a problem.

This led to the introduction of fixed and rotary surface washers to help break up the surface crust. Many times this only aggravated the problem as mudballs worked their way down into the bed leading to channeling during filtration and gravel upset or turnover during backwash.

Upsetting filter beds was a problem because the underdrain systems required a graded support bed (usually gravel) for the filter medium. With the improvement of underdrain systems the graded gravel was eliminated although it is still required with some underdrain systems in use today.

Current practice has changed past practices in many significant ways. Low filter rates have given way to high rates; the single filter medium is giving way to dual and multi-media beds; coarse medium is replacing fine medium especially in dual and multi-media beds where the media of differing specific gravity is coarse to fine in direction of flow.

These have led to deeper beds for high rates; the use of air in backwash procedures; upflow and even lateral flow filtration as well as the more prevalent downflow practice and have most of all led to a re-evaluation of our thinking in the design and operation of granular filters particularly with respect to the hydraulics of filtration and backwash. This paper will address itself to the latter.

We believe it would generally be agreed that filtration consists of three major phases whether it is a unit operation or a complete process. These are solids preparation, solids separation and solids elutriation.

Solids Preparation

A water or waste water to be filtered must be prepared or pretreated so that its electro-chemical characteristics make it truly filterable. In the present state of the art this is done by the addition of chemicals and/or polyelectrolytes prior to the filter. The control parameters of solids preparation are pH, turbidity and suspended solids.

Although turbidity is currently the most common parameter, it is not as accurate a one as suspended solids for the two are quite different. Turbidity is a light scattering phenomenon whereas suspended solids, a gravimetric determination, is a measure of mass. Although mass may consist of a lesser or greater number of particles without affecting its magnitude, turbidity is greatly affected by the number of particles. Consequently, although suspended solids may be constant, the turbidity could be variable. Perhaps a better parameter would be number and size of solids. Equipment is available to use this parameter, but in practical terms of cost-benefit pH is probably the best current parameter of solids preparation for filtration when it is related to filtration quality.

Optimum pH for good settling is not necessarily the optimum pH for good filterability. It has been shown that the zeta potential for good filterability is about 70 percent of the zeta potential for good settlling.[1] If this is true, it doesn't make any sense to try to get the lowest turbidity possible from a clarifier if the effluent is to be filtered in a properly designed filter because you will be using more chemical(s) than required, and the filter won't be as efficient as it could be. In other words, the filter will work better if there is carryover from the clarifier provided the dosage of chemical(s) gives the optimum pH for good filterability.

Solids Separation

After preparation, the water or wastewater is applied to the filter, and the solids are separated from the liquid. Again the most common control parameter is the turbidity of the filtrate, and again we are confronted with the same shortcoming.

Let us consider the hypothetical case where the same suspended solids in one instance consists of one million particles and in the other one hundred thousand particles. In either case let us assume the filter removed 99% of the suspended solids. Of the original million particles the filtrate will contain 10,000 particles and in the case of the original one hundred thousand particles, the filtrate will contain 1,000 particles — if all the particles in each case were of equal mass. Certainly the turbidity of each filtrate would be different even though the suspended solids removed were the same. Obviously, suspended soilds is the better parameter.

The mechanisms of solids-liquid separation in a granular filter are complicated. Small particles are agglomerated to form large particles and removed by collision, hindered settling, sedimentation and electrical neutralization. Small particles are removed by diffusion. In any event it appears that solids-liquid separation is done by electrochemical and physical forces.

Solids Elutriation

No matter how effectively a filter separates suspended solids from a liquid, it is of little value unless it can be cleaned by washing. Cleaning a dirty granular filter bed is done by backwashing with water in an upward direction expanding the bed so that the dirt which is lighter than the expanded granules can be removed from the bed and from the filter itself.

The purpose of backwashing is threefold:

1. It must loosen the dirt from the intersticies and surfaces of the granules;
2. move the dirt out of the bed to its surface;
3. and displace the dirt from the filter itself.

Air can be used with water to do this and is particularly advantageous in cleaning high rate in-depth filters where the dirt has penetrated the bed and is found throughout its depth.

The Hydraulics of Filtration

It has been common practice to operate filters at a constant rate throughout the filtration cycle to assure equal distribution to all filters and to limit the maximum rate of flow through each filter. The reason for these practices is not entirely clear although it has been said that this type of operation eliminates flow surges which would push the dirt through the bed into the effluent.

If we examine this premise, we find that it would be true if the filter bed consists of fine granules. Fine granules have more surface area than coarse granules; for example, 0.5 mm sand would have twice the surface area of 1.0 mm sand, and consequently is likely to be coated with more dirt. In addition, the interstial velocity through fine granules is higher than that through coarse granules and for the example given above would be four times greater. It follows that the shearing forces would also be greater in the fine bed and hence the dirt would be broken up and pushed further through the bed and into the effluent.

In the above examples the superficial velocity was the same in both cases while the interstial velocity was four times greater in the fine bed than that in the coarse bed. Since headloss is proportional to the square of the velocity, it can be seen that the shearing forces in the above examples were 16 times greater in the fine bed than in the coarse bed. Thus it can be understood why a coarse bed withstands shock loads better than a fine bed. More important however is the fact that this explains why the practice of operating filters at a constant rate and assuring that the flow was distributed equally to all units and limiting the maximum rate through each filter was adapted. These conditions were set by the environment created by the filter bed which consisted of a single medium fine to coarse in the direction of flow.

There are three characteristics of current filtration practice which abrogate the old rules of filter design and operation which called for constant rate, equal distribution and limiting the maximum rate. These are:

1. The use of coarse to fine media in the direction of flow.
2. The elimination of rate control.
3. The use of polyelectrolytes in pretreatment.

Coarse to Fine Media in the Direction of Flow

We have compared fine and coarse media as they affect the hydraulics of filtration and have seen that although fine granules have more surface area than coarse granules and the porosity of both are the same, the interstial velocity of flow varies directly with the square of the inverse ratio of the granule diameters and the headloss varies directly with the fourth power of the inverse ratio of their diameters.

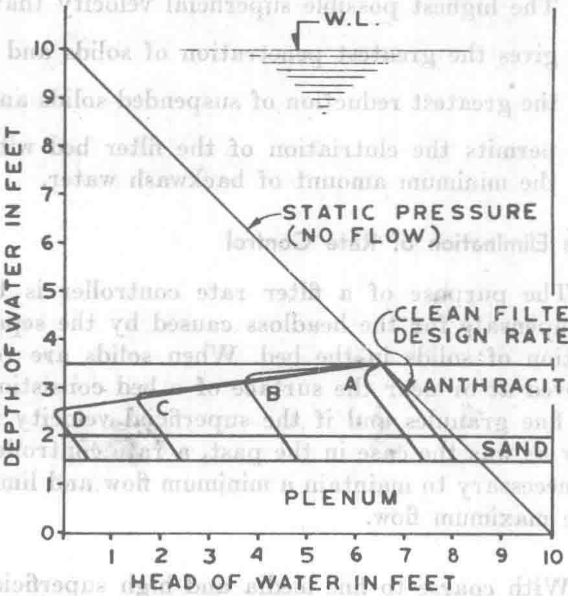
From this we can conclude that coarse granules would make a better filter bed than fine granules inasmuch as superficial velocities could be higher, penetration would be greater and more of the storage capacity of the filter bed would be used. If a coarse medium is placed on top of a fine medium so that the fine medium acts as a polishing layer and minimizes further penetration of dirt, we would have a dual bed. The coarse bed should be about 75 percent of the total bed depth since this is where the dirt should be removed and enough depth is left for the fine bed to polish the effluent and prevent breakthrough. When solids penetrate to the interface, there will be a noticeable increase in the rate of change of headloss across the bed. The interface also can be monitored by a turbidimeter to show penetration and the end of the run.

Filter effluent turbidimeters are commonly used along with headloss across the filter bed as control parameters for filter operation and performance. But as previously noted, turbidity does not tell you anything definitive about the suspended solids removed by the filter or in the effluent.

Headloss as a control parameter is of less value than turbidity. It doesn't tell you anything about solids separation in the bed. All it tells you is the pressure drop across the entire bed, and this doesn't indicate the degree of solids penetration and separation in the bed. Figure 1[2] shows a composite pressure profile through a dual media bed consisting of coarse granules on top of fine granules at different times in the run. For simplicity the condition is for a gravity filter, but we would get the same type of profile throughout the bed of a pressure filter.

The straight line at 45° angle is the pressure profile under static or no flow conditions. When the filter is put into operation with a clean bed, there is a small loss across the bed represented by the straight line immediately to the left of the static pressure line. The magnitude of this loss depends upon the flow rate and is measured by the horizontal distance between the static pressure line and the dynamic clean bed pressure line.

As solids separation occurs from the top of the



PRESSURE PROFILES THROUGH A DUAL BED FILTER
A—SHORTLY AFTER START OF RUN
B—NEAR MIDDLE OF RUN
C—NEAR END OF RUN
D—END OF RUN

FIGURE-1

bed down the porosity of the bed decreases at the top, the interstial velocity increases and the pressure drops. But below the depth where solids are being separated, the interstial velocity is less because the porosity is greater, and the pressure is also greater and its pressure line parallels the dynamic clean bed pressure line. Line "A" is the pressure profile early in the run.

If the superficial filter rate approaching the top of the bed is high enough, the separation of solids will occur deeper in the bed, and we will be getting the penetration required to use the storage capacity available. Lines "B", "C" and "D" are pressure profiles progressively later in the run. Note the greater penetration of solids throughout the run as indicated by the knee in the respective profiles. Note also that near the end of the run we have a negative head condition although the loss of head across the bed does not indicate it. Ideally the knee of the pressure profile at the end of the filter cycle would be at the interface of the dual bed and the maximum amount of the available head would have been used.

The important parameters of good filter operation are:

1. Proper preparation of the solids to be separated.

2. The highest possible superficial velocity that
3. gives the greatest penetration of solids and
4. the greatest reduction of suspended solids and
5. permits the elutriation of the filter bed with the minimum amount of backwash water.

The Elimination of Rate Control

The purpose of a filter rate controller is to compensate for the headloss caused by the separation of solids in the bed. When solids are removed at or near the surface of a bed consisting of fine granules and if the superficial velocity is low as was the case in the past, a rate controller is necessary to maintain a minimum flow and limit the maximum flow.

With coarse to fine media and high superficial velocities where penetration occurs throughout the bed, rate controllers are not necessary.[3] As solids are separated deep in the bed and the headloss increases, the flow through the filter gradually decreases. This is declining rate operation. In a properly designed filter battery this decline in flow rate in one filter is taken up by the other filters in the battery such that every filter has a natural superficial velocity determined by the condition of its bed. This is truly an example of the environment regulating itself.

The fact that the influent flow to a battery of filters is distributed naturally to all filters in accordance with the condition of the beds means that any filter at any time may have an increase in its superficial velocity because its bed is not as dirty as those of other filters in the battery. Thus declining rate operation really is variable declining rate filtration. Its distinguishing operating characteristics are:

1. No rate control.
2. The rate is established by the condition of its bed and
3. The condition of the beds of all the other operating filters in the battery because the influent header reflects these conditions.
4. The effluent quality will be better than that of a constant rate filter because the shearing forces will decline with the rate avoiding "leakage" of solids or a higher turbidity that would result in a constant rate filter.
5. Longer filter runs than that obtained in constant rate filters when operated to the same terminal headloss.
6. The operating level in a gravity filter is a direct reflection of its headloss.

Figure 2 is a typical illustration of a gravity filter designed for variable declining rate filtration. Figure 3 is a water treatment plant designed for variable declining rate filtration and consists

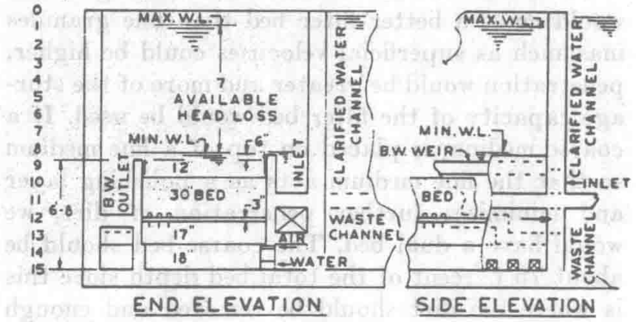


FIGURE-2
AQUAZUR FILTER FOR DECLINING RATE OPERATION

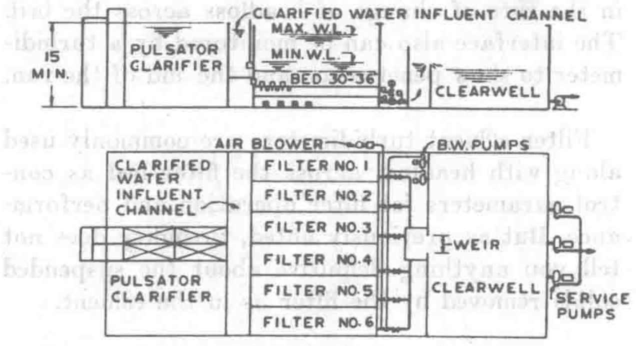


FIGURE-3
PULSATOR-AQUAZUR VARIABLE DECLINING RATE WATER TREATMENT PLANT

of clarifiers and filters with an above grade filtered water clearwell all built on one common foundation slab. Not only is construction simplified by variable declining rate design but maintenance is minimum as there are no rate controllers. In addition, the single effluent weir which is an integral part of the clearwell serves as a simple and inexpensive anti-drain device.

Variable declining rate operation is not really new because pressure filters have been operating that way for years. Because superficial filter rates have been so low, it hasn't been readily apparent but the fact that pressure filters do not normally have rate controllers is a significant clue.

Pressure filters don't really need rate controllers because the available head is high and headlosses of 5 to 10 psi are customary when operating at 2 and 3 gallon rates. These headlosses are two to four times those of gravity filters, and they could be even higher if plenty of cheap power is available.

With the advent of high rate, in-depth pressure filters, pressure drops are higher and beds much deeper because they are normally operated at superficial velocities from 10 to 20 gallons per minute per square foot. At such rates penetration of solids separated in the bed is great as is the need for variable declining rate operation if the quality of the filtrate is to be maintained and sustained.

With pressure filters, variable declining rate filtration requires at least three units. Two are operated and one is a standby. When a unit is taken out of service to be backwashed, the standby filter is put into service and the dirty filter backwashed with clean filtered water. The backwash water can be obtained from the effluent of the filters in operation or from filtered water storage. This decision depends upon process requirements and storage facilities and is usually made on an economics basis consistent with the ability of the system to produce a high quality product water dependably and consistently.

Figure 4 is a typical high rate, in-depth pressure filter. The horizontal pressure vessel offers several advantages over vertical units:

1. Lower headroom requirements.
2. They can be stacked to save floor space.
3. They can be shipped in one piece up to 44 feet in length.
4. They are compartmented which provides:
   a. in-depth filtration by series flow through two or three separate compartments;
   b. and less backwash water required which means smaller sewer pipes.

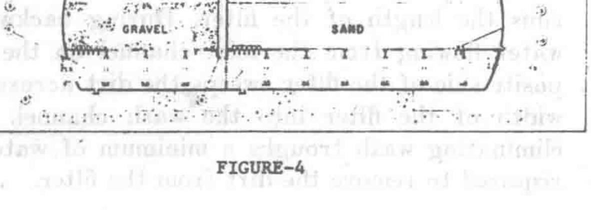


FIGURE-4

Using different types of media in the various compartments permits varying the area of the beds which maximizes the advantages of variable declining rate operation. For example, if the second compartment has a filter area twice that of the first compartment, the superficial velocity will be half that in the first compartment. This could be called the fixed variable rate component of a variable rate operation. They are not only compatible but desirable as well.

The Hydraulics of Backwash

Filter backwash is particularly important today because the high filter rates produce penetration in relatively deep beds and the job of cleaning is consequently more difficult. The concurrent use of air and water not only makes the job easier but it saves considerable amounts of backwash water.

As has been previously noted, the purpose of backwashing is threefold:

1. Loosen and release the dirt from the interstices and surfaces of the granules;
2. Move it to the surface of the bed, and
3. Displace the dirt from the filter itself.

In the United States this has been classically done by upflowing water which loosens the dirt, expands the bed and moves the dirt to the surface of the bed after which it is displaced from the filter and carried away in wash troughs. However, because of high rate, in-depth filtration, it has been found necessary to use air as well as water to get good cleaning, a practice which has been used in France and throughout the world for many years.

In filters designed for backwashing with water only, it was considered good practice to locate the bottom of the wash troughs a distance above the bed equal to 50 percent of the depth of the filter medium. The number of wash troughs was determined by limiting the horizontal travel of a particle to a maximum of about 3 feet.

50 percent expansion of the bed was considered to be good practice although experience has indicated it was rarely required to get good cleaning. Where it was required was when graded media was upset and had to be reclassified. This usually occurred when the backwash valve was opened too quickly.

Backwashing is the opposite of filtration. In filtration dirty water leaves the dirt in the bed and the dirty water is conditioned to separate the dirt efficiently. The media is selected to complement this objective and as it becomes clogged we must be careful not to allow the local or interstial velocities to get so high as to shear the dirt and push it into the effluent.

In backwashing clean water loosens and shears the dirt interstial velocities high enough to do this in order to move the dirt out of the bed and then displace it to the wash troughs. Actually the cleaning has to be done at the beginning of the backwash and it has to be done before the bed is fluidized because as the backwash rate increases, bed expansion increases and local, interstial velocities decrease. When the bed is fluidized, its granules are completely surrounded by water and the headloss remains constant as the gravity force of the granules and the upward force of the water are in equilibrium. Any additional increase in the superficial velocity of backwash water only expands the bed further with the possible loss of the finer granules and contributes absolutely nothing to the cleaning of the bed.

In many ways high backwash rates and high expansion are self-defeating with respect to cleaning of the bed. Typical backwash rates are almost double the fluidization rate so the only logical reason for them is to move the dirt out of the bed and out of the filter faster and hope that the bed has been properly cleaned before the fluidization rate was reached. The time available for cleaning is very short as the backwash rate is increased from zero to the fluidization rate. The bulk of the backwash time is for displacement.

The use of air and water concurrently does a better cleaning job and saves considerable water. Air alone is of no value whatsoever for it displaces water from the voids of the submerged bed causing it to collapse and compact. If the air rate is too high, it will mix the granules and the dirt in it. Air is a well-known mixer and is used for this purpose in mixed bed demineralizers and in chemical tanks and mixing basins. In waste treatment it also mixes in addition to furnishing oxygen for the bugs.

When used concurrently with water to backwash a filter, air is very effective. Tests have shown that air and water backwash expands a bed less than the same water backwash rate when used alone.[4] A possible explanation is that the air in the water inhibits the flow and results in lower interstial velocities than would occur with water alone. The local velocities are high enough however to shear the dirt, and the combination of air flotation and water displacement move the dirt out of the bed faster.

The low superficial water backwash rate when used concurrently with air does not visibly expand the bed but boiling effect can be seen at the surface. In an air and water backwash the water rate is less than the fluidization rate. This is extremely important for tests have shown that fluidization occurs with air and water at the same water rate that would fluidize the bed with water alone and has further shown that a dual media bed of coarse anthracite on fine or medium sand will completely mix within 5 seconds when fluidized with air and water. It is obvious then that fluidization is to be avoided when washing with air and water and the air should be terminated after the short period necessary to clean the bed. After the air is terminated, the water upflow rate is increased to move the dirt out of the bed and out of the filter, but it should not be increased to the fluidization rate. The only reason to increase the upward rinse water rate to or beyond the fluidization rate would be to get the dirt out of the filter faster.

With wash troughs located at an appreciable distance above the bed, this is understandable; however, it poses the danger that the lighter anthracite granules will be carried out of the filter by the higher water rate in the presence of escaping air globules. There is no need for upflow water rates high enough to fluidize the bed and there is no need for wash troughs.

Figure 2, a gravity filter designed for variable rate operation, has no wash troughs. It doesn't need any. The main purpose of wash troughs is to remove the released dirt from the filter after it has been moved to the top of the bed. Since they are located more than half the depth of the bed above its top, a great deal of water has to be wasted just to move the dirt into the troughs.

With wash troughs eliminated the wash water is collected over a weir into a backwash channel. The channel, located at a side wall of the filter, runs the length of the filter. During backwash, water flowing from the inlet channel on the opposite side of the filter sweeps the dirt across the width of the filter into the wash channel. By eliminating wash troughs a minimum of water is required to remove the dirt from the filter.

Current practice in water and waste filtration includes:

1. The use of coarse to fine media in the direction of flow.

2. The use of dual and multi-media of different specific gravities.
3. The use of high rates in both gravity and pressure filters.
4. The use of polyelectrolytes to condition both the filter influent and the bed.
5. The use of air and water in backwashing.
6. The elimination of wash troughs in gravity filters and the subsequent reduction of free board in both gravity and pressure filters.
7. The elimination of rate of flow controllers.
8. The incorporation of variable declining rate filtration in the design and operation of filters.

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PREPARED DISCUSSIONS

John L. Cleasby, Professor of Civil Engineering
Iowa State University, Ames, Iowa

Terry Dillman, Water Illinois Treatment Company
Rockford, Illinois

John L. Cleasby—

SUPPORT FOR VARIABLE DECLINING RATE FILTER DESIGN

I would like to commend Messers. Taggart and Mull for proposing the use of variable declining rate filters in water and waste water treatment. I have been a strong proponent of this system for some time and it is receiving increasing and adoption in the Western Hemisphere. I look forward to their promotion of the idea.

I have several points where I disagree with other concepts presented in the paper (which I'll enumerate later) but I would not want those disagreements to detract from my strong support for the use of the system of variable declining rate filtration for all new gravity filter plants and for some renovations of existing plants.

I feel the authors could have spent more time explaining the mode of operation of these filters, therefore, I will do so in the discussion.

Fig. 1a illustrates one possible arrangement for new plants designed for variable declining rate operation.

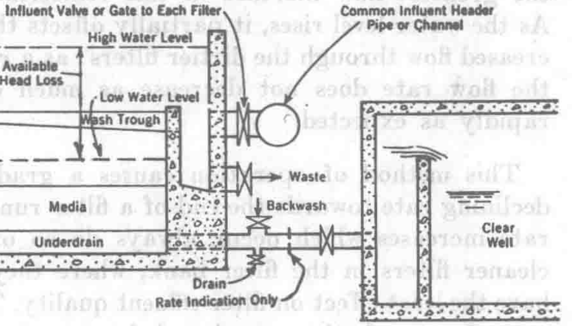


Figure 1a.

Variable Declining Rate Filtration—Typical filter and clear well arrangement.

The method of operation is as follows: Fig. 1b illustrates the typical water level variation and head loss variation observed with this mode of

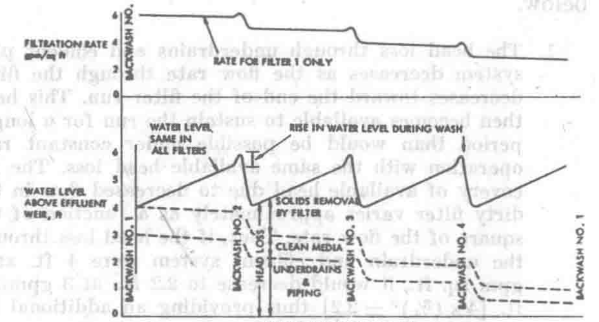


Figure 1b.

Variable Declining Rate Filtration—Filtration rate, head loss, and water level during one filter run in a plant having four filters.

operation. The filter influent enters below the low water level of the filters. The water level is essentially the same in all operating filters at all times. This is achieved by providing a relatively large influent header (pipe or channel) to serve all the filters and a relatively large influent valve or gate to each individual filter. Thus, head losses along the header or through the influent valve are small and do not restrict the flow to each filter. The header and influent valve will be able to deliver whatever flow each individual filter is taking at the moment.

All of the filters in the bank of filters served by the common influent header get dirty; thus the flow through the dirtiest filters tends to decrease the most rapidly. This causes the flow to redistribute itself automatically so the cleaner filters pick up the capacity lost by the dirtier filters. The water level rises slightly in the redistribution of flow to provide the additional head needed by the cleaner filters to pick up the decreased flow of the dirtier filters. The cleanest filter accepts the greatest flow increase in this redistribution. As the water level rises, it partially offsets the decreased flow through the dirtier filters; as a result, the flow rate does not decrease as much or as rapidly as expected.

This method of operation causes a gradually declining rate towards the end of a filter run. The rate increases which occur always do so on the cleaner filters in the filter bank, where they will have the least effect on filter effluent quality. These rate changes, both upward and downward, occur gradually and smoothly without any automatic control equipment. This is desirable because slow, smooth rate changes have less effect on filtrate quality than sudden changes.

The available head loss that has to be provided can be relatively small for the reasons discussed below.

1. The head loss through underdrains and effluent pipe system decreases as the flow rate through the filter decreases toward the end of the filter run. This head then becomes available to sustain the run for a longer period than would be possible under constant rate operation with the same available head loss. The recovery of available head due to decreased flow in the dirty filter varies approximately as a function of the square of the flow rate. Thus, if the head loss through the underdrain and effluent system were 4 ft. at 4 gpm/sq. ft., it would decrease to 2.2 ft., at 3 gpm/sq. ft. $[4 \times (3/4)^2 = 2.2]$ thus providing an additional 1.8 ft. of head for the continuation of the run on the dirtying filter.
2. The lost capacity of the dirtiest filters is accepted by all of the cleaner filters. Thus the rate increase on each filter is only very small; only a slight rise in water depth is required. Thus the water level rises very slowly until it reaches the high water level. At that time the filter with the longest hours is backwashed. When the backwashed filter is put in service, the level declines to an equilibrium level with that filter now at the highest rate in the bank of filters.

Variable declining rate operation could be adopted with little or no expense by hundreds of existing treatment plants whose controllers are not functioning properly or are causing excessive maintenance problems. Some plants have been designed for this method of operation. Others have been forced to do so due to inoperative rate controllers. However, despite the merits of this method, it has not received enough explanation or attention. This method should be seriously considered for all new gravity filter plants.

POINTS OF DISAGREEMENT WITH THE PAPER

I will merely list the points I would question or challenge if time permitted. I will not be able to present my supporting arguments in detail due to time limitations.

1. I do not agree that surface wash may aggravate mud ball problems. The value of surface wash in reducing mud ball problems has been well-established. However, I currently consider air-scour, properly designed and used, to be superior to surface wash.
2. I disagree with most aspects of the sections entitled "Solids Preparation" and "Solids Separation." Turbidity and suspended solids are both important in the filtrate, and pH is no valid indication of optimum coagulant dosage.
3. The second and third paragraphs of the section entitled "Hydraulics of Filtration" are erroneous. Average interstitial velocity is the same through small and large media if the porosity is the same. Surface area varies inversely with the square of the media diameter. Head loss in granular filters varies with the first power of the filtration rate (superficial velocity) since the flow has been shown to be in the laminar range. Therefore, the conclusions of this section are not valid.
4. The last half of the first paragraph under "Coarse to to Fine Media in Direction of Flow" is erroneous for the reasons sited under No. 3 above. The arguments negating turbidity are covered by response No. 2 above.
5. Item 5 under the section "Elimination of Rate Control" is not necessarily true. Run length and production per run are expected to be generally about the same as for constant rate filters. More operating experience with this system is needed before we can make such a positive statement
6. The discussion of pressure filters adds complication to the paper. Pressure filters operated at constant total pressure loss will be declining rate as head loss develops. However, when one filter is shut down, the others must pick up the load suddenly since there is no capability to change the amount of stored water in the filter housing. Thus, I do not like the use of the term "variable declining rate" for pressure filters because rate changes would tend to be abrupt and more detrimental to filtrate quality.
   Furthermore, the mechanisms of removal for pressure filters are the same as for gravity filters, and thus higher rates and higher terminal head losses may mean bad filtrate quality in some waters for either pressure or gravity filters.
7. The section entitled "The Hydraulics of Backwash" covers an area where current research is being conducted at Iowa State State University which may yield some definitive answers in the future. At this time, I can only raise some points of uncertainty.
   a. Air and water wash used together may result in media loss, especially coal. I currently favor air wash followed by water wash.
   b. Water washing below the point of fluidization may lead to accumulation of dirt in the filter and filter problems. I favor the water wash above the fluidization point with 20 to 25 percent bed expansion.
   c. If water washing achieves 20 to 25 percent bed expansion, then restratification occurs at each wash and mixing caused by the air scour is of no concern.
   d. I agree with the elimination of wash water gutters but do not feel the influent should be wasted during the wash, because it can be a substantial flow if filtration rates are high.
   e. Maximum hydraulic shear during backwashing occurs at a fluidized porosity of about 0.70, not below the point of fluidization as stated by the authors.

Terry Dillman—

While water filtration is one of the oldest unit operations, the design of filter equipment continues to be a mixture of art and science. That is, art being the continuance of things on the basis of experience, and science being the use of a complete theory. The proportion that science has taken in this mixture has steadily increased, but the art is still an important ingredient in design.

Experience indicates a number of factors to be of importance for the successful performance of filter equipment. The authors have ably illustrated these factors and the current practices of operating granular filters.

In their advice for solids preparation, the authors recommend that clarification be carried out only until the optimum pH for good filterability is obtained. While we can agree on the desirability of minimizing chemical feed, we wish to point out that carryover from a clarifier can cause instability of a water. In the case of a lime-soda ash softening plant, the instability of the water results in precipitation of calcium carbonate in the filter bed. This instable precipitate of calcium carbonate is catalized by the calcium carbonate already removed in the filter. The amount of after precipitation is practically nil at the beginning of a filter run, but soon reaches an equilibrium value that is constant throughout the run. After—precipitation in a bed is a significant load on a filter, as evidenced by short runs and unacceptable effluent quality.

It should be noted that the common granular materials used in a dua media filter are 0.4-0.5 millimeters sand and 0.85-0.9 millimeters anthracite. The anthracite, with a specfic gravity of approximately 1.5, must have twice the grain size of the sand, with a specific gravity of 2.65, to be lifted at the same backwash rate. If the size ratio at the interface of the sand and coal is greater than 3, there will be mixing at the interfacc during backwash. In order to take full advantage of the effectiveness of the sand below the anthracite, mixing must be minimized for avoidance of premature headloss or filter breakthrough. Because the freeboard is generally very limited, it is essential to change the backwash rate as the water temperature changes. This avoids loss of anthracite during backwash in cold weather and suspends all the sand during warm weather.

The authors state that with pressure filters the horizontal vessel offers several advantages over vertical units. We are in support of their claims but submit one serious disadvantage: Certain areas of the filter bed adjacent to the shell are inactive during filtration and backwashing.

It is significant to comment on the use of polyelectrolytes to condition either the filter influent or the filter bed. By coating a filter medium it is possible to reverse its surface charge (Zeta potential) from negative to positive. Since nearly all natural suspended solids in surface waters are negatively charged in the neutral pH range, the adsorption of suspended solids is improved. The more commonly used practice is to add a polyelectrolyte coagulant aid directly to the water entering a filter. The polyelectrolyte causes the floc particles to adhere to the filter media. This method is useful when controlling breakthru on difficult water. The necessity of an air-water scrub is dependent upon the polyelectrolyte used. Air-water requirements range from 0.15-5.5 SCFM/ft^2 and 6.0-8.0 gpm/ft^2 respectively. In most cases the water level is drained to a few inches above the filter media and the filter scrubbed for one minute. This is followed by the normal backwashing procedure.

The increasing demand for extreme clarity in municipal and industrial waters has placed a strong emphasis on the development of filtration technology. New concepts in filtration will improve performance and efficiency and lower the operating cost.

Hall Industrial Water Report

How much treatment is enough?

There's a story about a farmer who wrote to the USDA, "Please stop sending folders about better farming. I already know how to farm better than I do now."

Water treatment is something like that. You must balance the cost of completely controlling scale, corrosion, and other problems against a lesser treatment, with the possible damage to equipment and loss of production if the system breaks down or runs less efficiently.

You will find your Calgon representative an ideal man to work with on this delicate balance. With his overall view of water management problems and cost of treatments, he can help you arrive at the optimum program for your needs. Give him a call soon.

Red-water complaint bells were ringing

A suburban town had such a severe red-water problem in its distribution mains that the state water analyses showed dissolved iron, manganese, and corrosion from one end of the system to the other.

The local Calgon representative knew about the problem from experience—he lived in the town. After studying the problem, he convinced the waterworks manager to start feeding Calgon® TG-10 Inhibitor at 2 ppm. The manager's misgivings soon changed to enthusiasm as his complaint telephone actually stopped ringing after a week or so. For better feed solution stability, the town switched to Calgon C-39 Inhibitor. The red-water problem is now controlled with a feed rate of only 1.5 ppm. This type of problem can be controlled just as easily in industrial water mains.

Alum sours boiler... polymers sweeten it

Tube failures in a 600-psi boiler prompted an industrial plant to call for a Calgon study of the causes. The lab report showed the deposit in the tubes to be mostly analcite. Alum used for coagulating the lime-softened river water was spotted as the culprit.

Jar tests indicated that Cat-Floc® polymer could replace a large part of the alum, and a test run showed a dramatic reduction of alum in the effluent: from 1.0 ppm to 0.15 ppm.

The Cat-Floc program was started, backed up with Calgon Burolock® feed to the boiler to disperse the sludge and control deposits in the downcomer areas. Results: Boiler inspections in the last two years have shown the units to be completely free of deposits. No further tube failures have occurred. How sweet it is!

Instant measurement for corrosion rate

Calgon field personnel are equipped with the Corrator,* a portable instrument that provides on-the-spot readings on corrosion rate and pitting index of metals exposed to process or cooling water. This test is important. It reveals immediately if there is a dangerously high corrosion rate because of improperly controlled plant conditions.

The Corrator is another example of Calgon's investment in the latest diagnostic equipment to help customers spot and solve water-related problems.

*Registered trademark of Magna Corporation.

Continuous casting causes cooling crisis

A new continuous-casting plant used water-jacketed copper molds to handle molten steel, which ran at 1600-2000 F. Well water for cooling was recirculated through an 8,000-gpm tower with no chemical treatment.

Heavy scaling on the water side of the copper molds caused the molds to overheat and fail. After a week or two, the plant ran out of replacement molds. It made an emergency call to Calgon on Friday and asked for help in getting started again on Saturday.

The local Calgon water specialist borrowed a drum of Calgon® CL-70 Inhibitor, bought some battery acid from a chemical supplier and drove over to the plant on Saturday morning. He stayed all day to get the system running right, and made up a recommendation for regular continuing treatment which the grateful customer put into effect. One more crisis cooled off by Calgon.

Silt control ends air conditioner's midsummer slump

Two air conditioning systems serving a large pharmaceutical plant had an unfortunate habit: They would clog up every year in midsummer, requiring a shutdown for "rodding out." The once-through systems used well water containing 1.5 ppm of iron and 18 grains of hardness. A silt control product gave some improvement for two years, but head pressure still built up to 14 psi by the end of the summer—just barely under the automatic cutoff point.

With the introduction of a new type of silt control product, Calgon CL-75, the local Calgon representative had the right tool to overcome the conditions. By feeding a gallon of CL-75 into the systems once each day, he produced a drop from 12 psi to normal operating pressures of 9 and 6.5 for the two systems. This happened over a one-week period. The pressures have stayed right on target ever since. No midseason shutdown was needed, and surfaces were cleaner than ever before.

For more information on Calgon products and Hall Water Conditioning services for water management, call (412) 923-2345 or write: Consulting Dept., Calgon Corporation, Calgon Center, Pittsburgh, Pa. 15230.

Treatment Of A Highly Concentrated Industrial Waste

by JOSEPH SOMPEL, Stepan Chemical Company, Fieldsboro, New Jersey; BASIL G. LOUROS and RICHARD T. LYNCH, Calgon Corporation, a Subsidiary of Merck & Company, Inc., Pittsburgh, Pennsylvania

INTRODUCTION

Granular Activated carbon has been widely used to remove chemical organic compounds from industrial wastewater. Experience has shown that materials contributing to chemical oxygen demand (COD), biochemical oxygen demand (BOD), soluble organic carbon (SOC), total organic carbon (TOC), color and odor can be removed both effectively and economically. Generally, COD concentrations in industrial wastes are less than 2000 mg/l. This paper will show how granular activated carbon is being used to treat a waste stream containing COD in the range of 30,000 mg/l to 100,000 mg/l. This corresponds to TOC values in the range of 7000 mg/l to 30,000 mg/l.

History

The wastewater under discussion is a by-product of a Stepan Chemical Company plant located in Fieldsboro, New Jersey. This plant produces liquid detergent intermediates from a variety of chemicals, including xylene, ethyl alcohol, other linear alcohols and sulfuric acid. Both batch and continuous operations are conducted at the plant which functions 24 hours per day, seven days a week.

Plant wastewaters are collected at two locations. A small sump receives wastes from equipment washdowns, leaks, accidental spills and a few condensate drains in the main process building. The second location is an open ditch adjacent to the main building which collects water from chemical spills, drainage and storm water runoff. All wastes are combined in a main sump and then pumped to a three million gallon storage tank.

Total daily flow to the storage tank varies from 5,000 to 11,000 gallons depending upon weather conditions. Table 1 shows an average analysis of the combined waste. Temperatures of this water usually range between 100° and 140° Fahrenheit.

State Laws

At the point of discharge of the Stepan plant the New Jersey State law and Delaware River Basin Commission require 85 per cent BOD_5 removal or 100 mg/l BOD_5 whichever is less. In addition suspended solids must be removed and the pH controlled to be between 6.5 and 8.5. In general, discharges must not contain more than a negligible amount of debris, oil, scum or substances which produce color in the water.

TABLE 1

Wastewater Analyses

pH	8.0
Color (optical density at 500 m μ)	1.7
TOC (mg/l)	7600
COD	32000
Suspended Solids (mg/l)	150 to 650
BOD_5	6700
BOD (ultimate)	8500

The final treated water characteristics did not meet the requirements of the State of New Jersey and Delaware River Basin Commission. Laboratory studies conducted by Calgon Corporation indicated that the final BOD (5-day) after adsorption treatment was approximately 510 mg/l. Although this is a substantial reduction from the 8,500 mg/l BOD (ultimate), it does not meet the 100 ppm (BOD_5) requirement as set by the State of New Jersey.

It was found that the organic materials not being adsorbed by the granular carbon were low molecular weight methanol and ethanol. These chemicals are readily biodegradable and can be destroyed easily in this manner. It is anticipated that a considerable reduction in biochemical oxygen demand (BOD_5 and BOD ultimate) will take place due to biological activity on the activated carbon adsorbers after they have been running for a short period of time. This biological activity will convert a large amount of these small organics to a biological mass as well as destroy some of the carbonaceous materials to harmless Co_2 and water. The chlorination of the effluent from the carbon column will substantially oxidize the by-products from this biomass on the carbon. The resultant waste water will be low in BOD_5; hopefully, below 100 ppm.

Although there is no data in this report to substantiate the claim that biological activity on the carbon adsorbers will reduce BOD to meet State requirements, it is anticipated that this will hold true because of experience with the treatment of other wastes. There are countless reports available which show that biological activity does take place on granular activated carbon where readily biodegradable compounds are available. The most noted work has been done on municipal effluents where there is a large source of bacteria. However, this has also taken place on many industrial wastes, even those containing toxic organic materials. Data shown on Table 2 describes the effluent from the adsorption treatment facility.

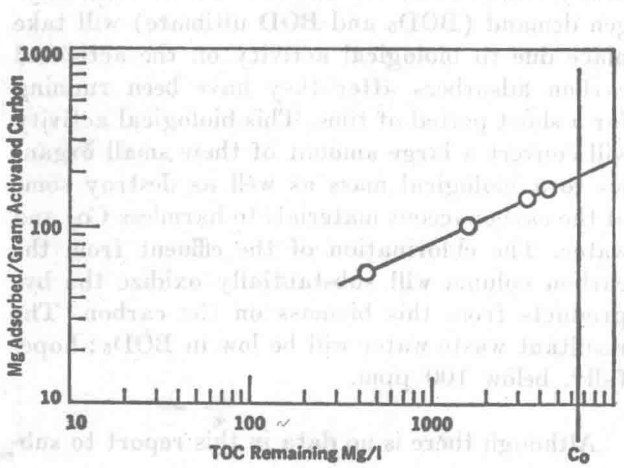
TABLE 2

Treated Effluent Characteristics

pH	8.0
TOC	400 mg/l
BOD_5	510 mg/l
BOD (ultimate)	620 mg/l
Suspended Solids	5 mg/l
Color (APHA)	< 5
Total Solids	1,665 mg/l
Total Dissolved Solids	1,620 mg/l
Oil and Grease	< 1 mg/l
Chloride	27 mg/l
Sulfate	720 mg/l
Sulfide	< 0.1 mg/l

The curve shown on Figure 1 indicates how the BOD (ultimate) value was developed for this waste effluent. The curve indicates that organic material passing through the graular carbon adsorption system is readily biodegradable. This further supports the fact that biological activity

Figure 1



if induced on the granular carbon adsorbers would probably reduce the BOD considerably. This accompanied by superchlorination would probably substantially reduce the BOD_5 value in the effluent and would possibly achieve an effluent of a quality which would be less than the 100 ppm BOD_5 requirement.

Treatment Methods

Three wastewater treatment approaches were examined from the standpoints of effectiveness and economics. Conventional biological processes were ruled out immediately because they were not amenable to the high organic concentrations in the wastewater. Incineration looked attractive but was eliminated on the basis of economics and the high concentration of inorganic salts. The third approach, adsorption with granular carbon was found to be both effective and economically acceptable.

Feasibility Studies

To determine feasibility of treatment with granular carbon, adsorption isotherm studies were conducted. An adsorption isotherm is a test in which varying weights of pulverized carbon are mixed with fixed volumes of wastewater samples for a fixed length of time. The amount of organic removal at the varying dosages gives an indication of the amount of carbon required to treat the waste to satisfy effluent requirements.

In the case of Stepan Chemical Company, Calgon's Filtrasorb 300 carbon was used for the isotherms. The tests showed that one gram of carbon was capable of removing 190 milligrams TOC. (Fig. 2). This corresponds to a carbon dosage of 417 lbs./1000 gallons.

Figure 2