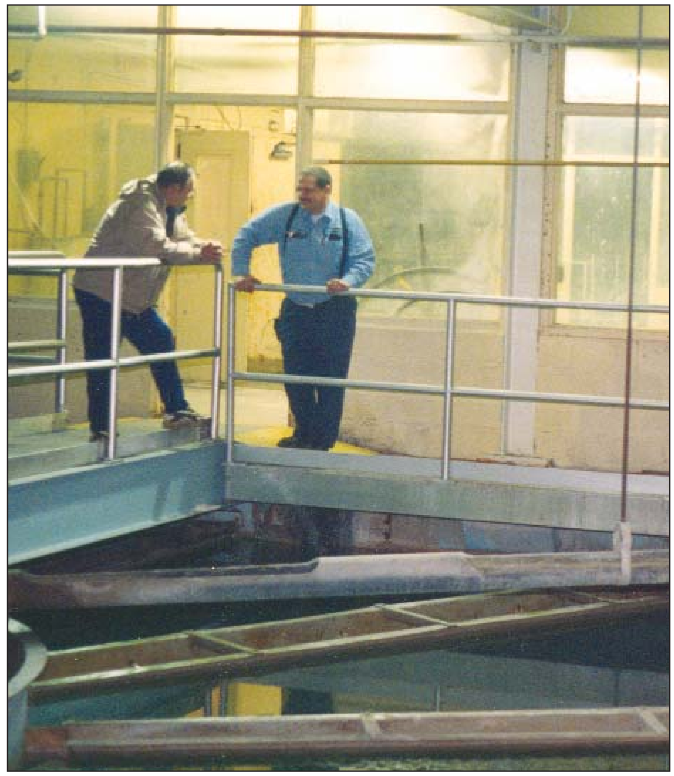
# Water Quality Improves by Recycling Settled Sludge

by John C. McLane



Retired chief operator Don Russell (left) and Fort Madison superintendent Norman Dodson at the upflow clarifier where the recycled sludge and the lime slurry are added through the suspended top pipe.

Many operators wear two hats: one as a water treatment plant operator, the other as a wastewater treatment plant operator. Likewise, many processes used in a wastewater plant can be adopted to benefit drinking water operations.

Wastewater operators are responsible for the biological processes of an activated sludge plant, where, at the beginning of the treatment process, settled activated seed sludge is inoculated in incoming raw sewage flow to kick-start the growth of bioreducing organisms in the sewage.

This same process of recirculation works equally well in the flocculation and coagulation processes of drinking water treatment. Recycling fresh settled chemical floc back to the incoming raw water flow initiates formation of good-quality chemical floc with exceptionally good solids and impurities removal and settling and filtering characteristics, particularly during cold-water seasons. This practice also provides many labor and cost-savings advantages.

## Midwestern Weather Woes

In 1994, I was hired as the superintendent of a 3.5-mgd water treatment plant in Fort Madison, Iowa. The plant's source is 70 percent surface water and 30 percent groundwater. The two different water sources have different chemistries and were being treated separately through coagulation, flocculation, and settling. Lime slurry was (and still is) used as the primary coagulant for solids removal in the surface water and for softening the groundwater. Each flow required a different pH for accomplishing the individual treatment goal. The flows were then combined for recarbonation, filtration, fluoride adjustment, and disinfection.

The plant experienced normal, rapid, and drastic raw surface water fluctuations during spring snow melt and periodic episodes of rain runoff. During these episodes, the surface water turbidity would jump from its normal 4–40 ntu to 1,500–3,000 ntu within a few hours. The high turbidity levels could persist for up to 20 days before returning to normal levels. The high raw water turbidity would carry over through the clarifiers and filters, and we'd have periods when finished water turbidity approached or exceeded the 1.0 ntu maximum contaminant level (MCL).

In contrast, another seasonal problem we faced was low-turbidity cold water. When temperatures reach freezing or below, surface water is difficult to treat because

- the cold temperatures slow the necessary chemical reactions,
- floc settling deteriorates because of the increased density of water below 4° C, and
- raw water turbidity often drops to 2 to 6 ntu. When the surface supply source freezes over, the ice cover eliminates the mixing effects of winds, waves, and tributary flows, so the frozen source water becomes quiescent and clear. When this happens, the water is "too clean" to form good-quality floc, which meant that during cold weather, our finished water turbidity periodically approached or exceeded the 1.0-ntu MCL.

*continued on page 16*

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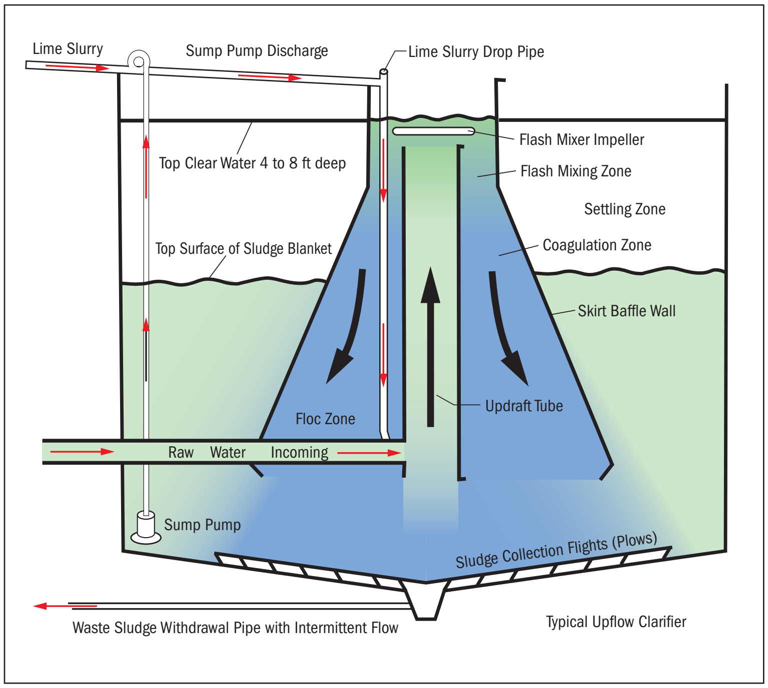
# Settled Sludge (from page 15)




**Schematic of sludge recycling process.**

We decided we needed to change our standard operating procedures if we wanted to bring the finished water turbidity down as low as reasonably possible and stay well within required standards, providing the very best finished water quality that we could.

The plant uses ferric sulfate to boost the floc's settling characteristics. However, the use of jar testing to determine proper chemical dosages of the primary flocculant, ferric sulfate, and cationic polymers had been discontinued sometime earlier. Chemical dosages were determined by trial-and-error — or just plain guessing — which left much room for error and caused marginally substandard finished water quality. This put the utility on the brink of intervention status by the state primacy agency.

Thus, our first steps for improvement were

- the reintroduction of proper jar testing techniques,
- the proper and effective interpretation of jar test results, and
- the proper application of the correct chemical dosages.

We determined that the process of sampling, testing, and controlling chemical feed rates for the two treatment trains — groundwater softening and surface water solids removal — was too labor intensive. The separate treatment trains made it difficult for the operators to properly control the chemistry of the two source waters. All too frequently, the wrong chemical feed rates were introduced because operators didn't have or take the time to monitor both sources. This resulted in decreased process efficiencies, corresponding plant upsets, and the rapid deterioration of final effluent quality.

By not using the correct or optimum chemical feed rates, good quality floc would not form and settle out. Clarifier effluent turbidity would increase from the normal 7–10 ntu to 30+ ntu. Excess solids would carry over to overload and pass through the filters, resulting in filter effluent exceeding the 1.0 ntu MCL. This would also cause rapid filter plugging and reduce filter run times from the usual 30 to 50 hours to short runs of only a few hours. Ultimately, the result would be emergency plant shutdowns, public notifications, and boil orders.

To correct these problems, we combined the groundwater and surface water flows just before they entered the coagulation–flocculation process, producing one combined raw water flow with a consistent chemistry that was less prone to rapid changes. This simplified the required lab work, minimizing human errors, and decreased the operator's workload. Then, having trained the operators to jar test and simplified the laboratory and chemical feeding duties, we were ready to take the next step.

### Adding Dirt

During the cold winter months when turbidity is low, some of my colleagues at other treatment plants theorized that we could add "dirt" — usually bentonite clay powder — to the raw water in an effort to increase turbidity, thus fostering better floc formation and greater turbidity removal to keep the finished water turbidity within specified limits. I had my own experience with bentonite and wasn't convinced that was the way to go.

A decade earlier, when I was working at the InterState Water Co. in Danville, Ill., we tried using bentonite, but were not pleased with the results. The bentonite was too difficult to mix into solution with the available equipment, and it was a burden on our budget. So we tried to recycle the muddy sludge from the bottom of the settling tank, reasoning that because this sludge was already wet and settled, it possessed good settling characteristics. And, it was free.

However, we didn't have the right equipment to make the process work effectively — our boat-mounted sludge pump was too unwieldy — so we abandoned the effort.

Later, I read about a plant-scale pilot study done in 1982 where settled sludge was used to enhance turbidity removal in secondary coagulation–flocculation tanks; the study confirmed my earlier thoughts about the possibilities of using recycled sludge. Fort Madison would be a good place to transfer the technology to a real-world application.

| | Before Sludge Recirculation | After Sludge Recirculation |
|---|---|---|
| Clarifier Effluent | 25–70+ ntu | 3.0 +/– 0.2 ntu (> 90% reduction) |
| Filter Effluent (maximum) | > 2.0 ntu | < 0.19 ntu (> 90% reduction) |
| Maximum Daily Effluent, Annual Average | 0.42 ntu | 0.0347 ntu (> 90% reduction) |

**Table 1. Benefits of switching to a recycled sludge process, based on constant raw water turbidity of 2–4 ntu for raw frozen surface water and 300–3,000 ntu for surface water affected by heavy rainfall or snowmelt.**

We determined that the settled sludge could be recycled by introducing it into the incoming combined raw water flow before the coagulation–flocculation process. Our first recycling attempt, using the existing equipment and plumbing, provided only an intermittent sludge return to the flow entering the flash mix and flocculation zone, because the sludge pump was only activated when the sludge pit was full.

We added pipes and valves so some of the settled sludge was recyled directly to the raw water pipes, but the sludge return was still intermittent. However, an increase in solids concentration was visible in the mixing zone, and we could readily measure and observe a marked reduction of the clarifier effluent turbidity. From a range of 10–30 ntu, the effluent had dropped to 5–7 ntu.

We could also see that intermittent recirculation was not enough. We needed constant recirculation.

### Tapping the Bottom Sludge

For our next effort, we installed an inexpensive 3,000-gph submersible sump pump, with its intake near the bottom of the settling zone, out of the path of the sludge collection equipment. We reasoned the best-quality sludge was that which had settled the fastest, and it would be at the bottom of the settling tank. The bottom sludge would be the most dense and concentrated. Sludge from a higher elevation in the tank would probably be less dense, and its settling characteristics would probably not be as good.

The sump pump discharged its flow into the lime slurry trough, mixed with the lime slurry, and was introduced into the incoming raw water flow just prior to entering the flash-mixing zone. The results of this modification were no less than spectacular.

It has now been more than seven years since we began recirculating the sludge. The process has proved extremely successful, yielding results far better and more numerous than we had hoped for or anticipated.

High raw water turbidity still carries over through the clarifier effluent and the filter effluent. But those fluctuations were greatly reduced after recirculation of the recycled floc was implemented. The undesirable fluctuations in our finished water caused by heavy rainfall or snowmelt and cold water have all been corrected, and the finished water turbidity is now far below the MCL. Our efforts to improve procedures and processes paid off.

### Water Quality Benefits

Since we began recycling the sludge, we have routinely experienced low clarifier effluent turbidity. Originally, the effluent turbidity from the sedimentation basin was in the 30–50 ntu range; now it consistently stays at 3.0 ntu (+/– 0.4 ntu).

During our trial phase, we did bring the clarifier effluent down to 1.0 ntu by adding extra primary coagulant and ferric sulfate and various cationic, anionic, and nonionic polymers at a significant cost per mil gal. However, we found that the floc produced would readily pass through the filters, with the resulting filter effluent registering 0.3–0.5 ntu.

We realized that the filter effluent we were getting with the 3.0 ntu clarifier effluent was far superior — a fairly steady 0.022 ntu (+/– 0.005). The Maximum Day Annual Average filter effluent for the past four years has been 0.0347 (+/– 0.002) ntu. The resultant process efficiencies and higher-quality finished water also means lower disinfectant by-products and fewer water quality problems of other kinds.

Filter runs originally were 30 to 50 hours during normal operating conditions. Now, they are 150 to 200+ hours, with few interruptions. The reduction in backwash water usage alone has saved the utility $46,000 annually. In Iowa, we are not allowed to recycle backwash water because of the concern that recycled backwash might result in a concentration of protozoa, such as *Giardia* and *Cryptosporidium*, reentering the filtration process.

Coliform and heterotrophic plate

*continued on page 18*

# Settled Sludge (from page 17)

count (HPC) analyses have been performed regularly during sludge recycling; almost no bacteria at all has been evident from the top of the filters and clearwell effluent, and the HPC is extremely low — far less than 10/mL. Prior to sludge recycling, HPC results were routinely >100,000/mL. Tests conducted monthly at more than 60 locations in the distribution system are also consistently well below the USEPA standard of >500 colonies/mL.

Prior to sludge recirculation, we received 30+ taste-and-odor complaints per week. Now we only receive a couple such complaints a year, and these are usually traced to some cause other than the drinking water.

Disinfection is more stable and consistent, primarily because of the much lower finished water turbidity and lower organic loading onto the filters. As a result, the total trihalomethanes and haleoacetic acid levels have been lowered to one third of the new MCLs. Chlorine demand and usage are also reduced. With this decreased disinfectant usage, distribution system chlorine residuals are much easier to manage throughout the year.

*It has now been more than seven years since we began recirculating the sludge. The process has proved extremely successful, yielding results far better and more numerous than anticipated.*

### Financial Benefits

We've also reduced the cost of new lime usage by 17 percent. Previously, because of the lack of bonding between the lime and the floc, lime would deposit on tank and pipe walls, mechanical equipment, and filter media; it took a jackhammer to remove it, and frequent media replacement was required. Now, the small amount of lime that does attach to the walls is much softer and can be removed by a fire hose and backwashing at flow rates of 15 to 20 gpm/ft$^2$ of filter area, without air scouring — another major cost savings.

The filter media have shown no signs of deterioration; there has been no increase of lime deposits plating the media, and the media no longer concentrate in concrete-like layers or mudballs. The filter media do not require replacement at all and may have an indefinite effective, useful life, which saves us a substantial amount, because previously the annual budget for media replacement was $40,000–$80,000.

Plant operations are less labor intensive now for our operators. Operators don't have to make emergency chemical feed-rate adjustments triggered by rapid, large fluctuations in raw water turbidity from rain runoff or snowmelt. Sludge recycling significantly buffers these fluctuations. Because the operators are now proficient at the practice, we've also cut back on routine jar testing — practicing it only when there are sudden changes in the raw surface water quality, when there are major seasonal temperature changes, or whenever the routine daily process chemistry tests indicate that the water quality diverges from the optimum operating control parameters.

We have found no disadvantages or drawbacks to implementing the sludge recycling process modification, which is now employed year-round, not just during the cold-water season.