Trace Organic Compounds: What Goes In Must Come Out

Chemically enhanced high rate settling (CEHRS) shows promise in removing harmful compounds such as pharmaceuticals and consumer products from wastewater.

by Daniel Austria Jr.

A recent research project involved the pilot testing of a chemically enhanced high rate settling (CEHRS) process for removal of selected trace organic compounds (TOrCs). This article is a summary of those piloting efforts.

Increasing amounts of TOrCs at wastewater treatment plants (WWTPs) around the world is a phenomenon that has been occurring for some time now. Some examples of these compounds are consumer products (surfactants, caffeine), pharmaceuticals (drugs, hormones), pesticides (DEET), and volatile organics (flame retardants, household cleaning products). Many of these compounds are the result of every day human activities; this is especially true in developed consumer-based societies where environmentally conscious living has become secondary to keeping up with social status standards. These compounds can be harmful not only to humans but to the entire ecosystem. It is still not completely known how the compounds' presence will affect the environment long term, as current data is limited, but they are generally labeled a health risk by many experts. Research is continually being done to gauge the ability of water treatment technologies to remove such compounds from municipal water treatment plants (WTPs) and WWTPs.

Current literature demonstrates that generally the majority of TOrC removal at WWTPs can be attributed to the typical biological secondary treatment of an activated sludge process (ASP). With activated sludge, the WWTP can fine tune treatment by controlling the balance of new treatment organisms that grow to replace those that die and are wasted. A WWTP can operate a CEHRS process that utilizes "fresh" powdered activated carbon (PAC) and "used" PAC in a similar fashion. With proper PAC addition/recirculation/wasting, a WWTP can control the amount of time PAC is used/recycled to ensure full utilization of its adsorptive capacity. A system that can take full advantage of the inherent efficient adsorption capacity of PAC would potentially see significant removals of TOrCs.

Typical CEHRS Process Review

A general process overview of a CEHRS process (see Figure 1) is: raw water enters the CEHRS system in the first flash mix tank (coagulation tank). Here, chemical coagulant is added and thoroughly mixed to destabilize suspended solids and colloidal matter. The flow then enters the second tank (maturation tank) where flocculant aid polymer and microsand are added. In the maturation tank, relatively milder mixing provides ideal conditions for the formation of polymer bridges between the microsand and the destabilized suspended solids. The turbomix draft tube produces effective dynamic mixing to ensure that a very dense floc is formed; the fully formed ballasted flocs leave the maturation tank and enter the settling tank. It is here where ballasted flocs rapidly settle out and are collected to a center sludge pit. The sludge/microsand slurry is withdrawn from the collection pit using a centrifugal slurry pump where the slurry is then pumped to hydrocyclones for separation. The pumping energy is transferred from pump to hydrocyclone, which acts as a centrifuge causing chemical sludge to be separated from the higher density microsand. Once separated, the microsand is concentrated and discharged from the bottom of the

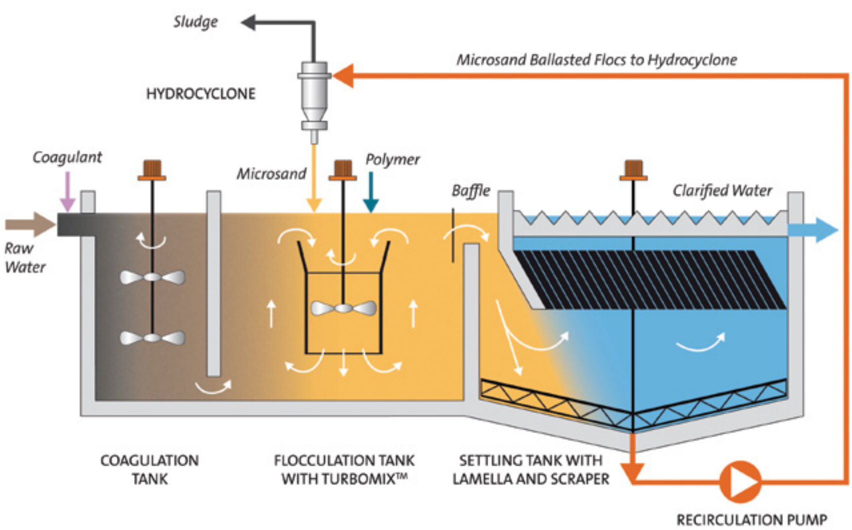

Figure 1: A CEHRS (ACTIFLO®) process schematic. (Image provided by Kruger Inc.)

hydrocyclone and re-injected into the CEHRC process for reuse. The lighter density sludge is discharged out of the top of the hydrocyclone.

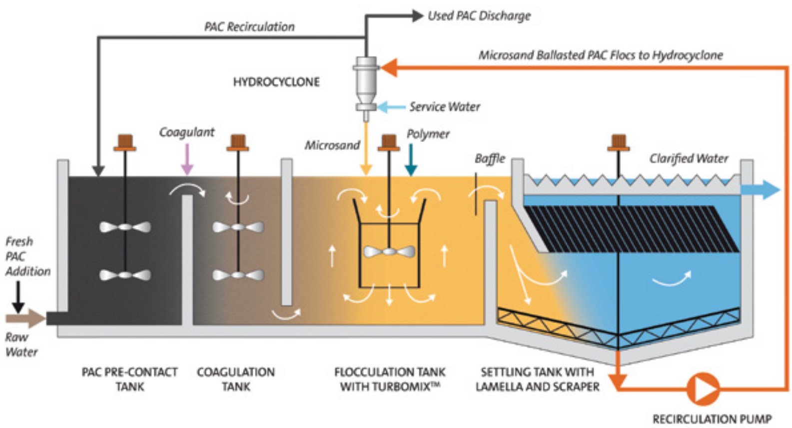

Figure 2: A CEHRS/PAC (ACTIFLO® CARB) process schematic. (Image provided by Kruger Inc.)

CEHRS + PAC Process Review

The CEHRS process can easily be combined with a PAC recycle/contact step to produce a process "offspring" that utilizes the high rate settling of the CEHRS process with the adsorption capabilities of PAC.

A general overview of this CEHRS/PAC process (see Figure 2) is: a PAC contact tank resides directly ahead of the CEHRS process. This tank allows for contact time of raw water with fresh and recycled PAC. A target solids concentration is maintained in this contact tank at a specific residence time. From here, the aforementioned CEHRS process steps occur; instead of the sludge/PAC slurry being wasted immediately, it is recycled back to the PAC contact tank. The PAC tank enables the process to exploit the well documented adsorption properties of PAC. Fresh PAC is added to the raw water stream as it flows into the contact tank with the recycled PAC/Sludge. Contact tank solids are wasted at a rate that keeps the entire solids balance within the CEHRS system in equilibrium and makes the most use of the PAC adsorption sites.

Pilot Program Review

Testing was completed in two phases to capture seasonal variations of test sites. Phase 1 occurred in April 2011 and Phase 2 during July/August 2011. A number of operating parameters were varied and monitored throughout the study although the most relevant parameters for discussion would be the fresh PAC doses and the removals of some TOrCs at those doses.

Wood-based PAC was used throughout the study after pre-pilot screening. The pre-screening demonstrated that the wood-based PAC provided for a good balance of performance and economic feasibility when compared to coconut-based PAC. Ten specific TOrCs were selected to be analyzed for removal efficiencies. These selected compounds in alpha order were: caffeine (stimulant/tracer), carbamazepine (anti-epileptic), diltiazem (anti-hypertensive), diphenhydramine (antihistamine), fluoxetine (anti-depressant), naproxen (anti-inflammatory), ofloxacin (antibiotic), sulfamethoxazole (antibiotic), triclosan (biocide), trimethoprim (antibiotic).

Pilot Testing Results

The summary of results can be seen in Table 1-2. This is a general view of what type of removals were achieved with regard to the 10 selected compounds.

Pilot Testing Conclusions

Overall, the average removal of all 10 compounds was nearly 70% at 10 mg/L fresh PAC dose and more than than 80% at 20 mg/L fresh PAC dose. These results generate a few conclusions from the testing:

- A CEHRS/PAC process is capable of removing TOrCs from a typical municipal WWTP stream
- Generally, a higher fresh PAC dose resulted in higher removal
- PAC dose may be optimized at a full-scale plant to balance expected performance and operating costs based on the above
- Some compounds were more easily removed than others, which indicates a compound's molecular make-up may drive its capacity to be removed from the waste stream

PARAMETER	RANGE	UNITS
Raw Water Flow	75 – 95	gpm
System Hydraulic Retention Time	27 – 34	min
Hydraulic Loading Rate	13 – 14	gpm/sf
Ferric Chloride Dose	1.5 – 5.7	mg/L as Fe
Flocculant Aid Polymer Dose (anionic type)	1.5 – 3.8	mg/L
Microsand Concentration in System	14 – 16	g/L

Table 1: CEHRS/PAC operational conditions. (Image provided by Kruger Inc.)

FRESH PAC DOSE	TRACE ORGANIC COMPOUND AVERAGE REMOVALS AT 10 & 20 mg/L PAC									
	Caffeine	Carbamazepine	Diltiazem	Diphenhydramine	Fluoxitine	Naproxen	Ofloxacin	Sulfamethoxazole	Triclosan	Trimethoprim
10 mg/L	44%	68%	89%	81%	52%	42%	69%	54%	90%	87%
20 mg/L	74%	88%	95%	92%	78%	67%	75%	75%	88%	97%

Table 2. CEHRS/PAC pilot TOrC average removals. (Image provided by Kruger Inc.)

The results of the piloting efforts that took place at the Milwaukee Metropolitan Sewerage District demonstrate that a CEHRS/PAC process provides municipal WWTPs with a viable option in removing TOrCs from their waste streams. This marks significant progress in the research to find economic ways to remove harmful compounds in public water/wastewater streams. Future research can now use the results from this pilot as a resource to make further gains in the TOrC removal arena. The health of the public and the overall ecosystem is at stake as more and more pollutants like TOrCs make their way into the human water supply. Knowing that resources to help eliminate the TOrC issue exist and will continue to grow, communities everywhere can now look to the future in a positive light. ■

Pilot Testing Team: Many thanks go to the pilot program team that executed the pilot testing. It was the collaborative efforts of the following organizations that made the pilot testing a success: The Water Environment Research Foundation (WERF), The Milwaukee Metropolitan Sewerage District (MMSD), Veolia Water Milwaukee (VWM), Veolia Water Solutions & Technologies (VWS), University of Wisconsin-Milwaukee (UWM), and Corollo Engineers.

Daniel M. Austria Jr. is an application engineer for the ACTIFLO Systems division of Kruger / A Veolia Water Solutions & Technologies Company. His experience has focused on process design, engineering, and operation of physical/chemical separation technologies. Prior experience includes working in the environmental department of a pulp/paper manufacturer for two years, and also participating in water and wastewater treatment system design and operation for 12 years. He has a bachelor of Science In Chemical Engineering from The University of Dayton, OH.