
TECHNICAL MEMORANDUM

TO: C. GRABHAM (WQ)
FROM: TIMOTHY C. MCFETRIDGE, P.E.
SENIOR ENVIRONMENTAL ENGINEER
SUBJECT: TREATMENT OF STEROLS & STANOLS
DATE: 12/20/10
CC: J. WIGAL (WQ)

At your request, I have reviewed the *Compilation of Information on Treatment Options for Sterols and Stanols* (Attachment A). I thought that the information was complete, and I agree with the findings that retrofitting existing sewage treatment works to obtain higher removal efficiencies for sterols and stanols would be a disproportionate response to the environmental threat of these compounds in effluent.

However, it may be helpful to think about a few things that were not presented in the subject memo. For example, the reader may want to refer to Bruce Hope's 10/25/10 technical memo *Aquatic Toxicity of Sterols & Stanols* to know what sterols and stanols are chemically, and where they come from. Also, consider the following:

- In Bruce Hope's technical memo it states that the compounds "degrade in conditions found in...sewage treatment plants". Upon further inquiry Bruce explained that cholesterol is reduced to coprostanol by enteric bacteria in the gut of mammals. Once in the environment, particularly an aerobic one, coprostanol can be converted by microbial action to epicoprostanol. Absent bacterial action coprostanol is "resistant to change." In other words, cholesterol and coprostanol resist being degraded when they are in anoxic sediment. Cholesterol can be oxidized by free radicals in the air and is also degraded and assimilated by various species of bacteria.
- Bruce's technical memo stated that "coprostanol is typically associated with particulate matter". If this is the case, a logical conclusion might be that sewage treatment plants should remove 85 – 95% of the compound.¹ Typical influent sewage is around 200 – 300 mg/l TSS and effluent is typically less than 30 mg/l and commonly less than 10 mg/l in a properly operated activated sludge plant.
- The *Summary of Removal Efficiency Research* by WA Dept of Ecology stated that pH changes can increase removals for some pharmaceuticals. Does this imply intentional changes in pH, or that associated with biological nutrient removal and the loss of alkalinity during that process? The replacement alkalinity in a plant that denitrifies would again change pH. Could

¹ During treatment, activated sludge and UV disinfection both remove 85% of cholesterol and 97% of coprostanol from wastewater (USEPA, 2010).

this change in pH further the removal of these compounds, or is the reduction in pH the primary mechanism?

Again, I found the *Compilation of Information on Treatment Options for Sterols and Stanols* (Attachment A) to be to the point and I agree with the findings, however, my work in the design review of treatment systems has not involved the potential removal of these compounds. My three thoughts above are something to think about. I'm not proposing that you change the summary. Also, consider that historically speaking, the removal of BOD, TSS, and bacteria (e.coli, fecal/total coliform) has relied on cholesterol and coprostanol as indicator organisms – i.e. if their removal efficiencies are high, unwanted pollutants (of which there are 100s if not 1000s) are likely removed. This assumption is likely true for many pollutants, maybe even most pollutants, but certainly not all of them.

The presence of sterols and stanols in domestic sewage, and the potential for them to result in negative impacts to the water environment leads to the question: "How can we remove them from the wastewater prior to it being discharged to state waters?" Treatment technology such as reverse/direct osmosis would be effective in the removal of the compounds, however, this technology is extremely costly up front and very energy intensive to operate. Membrane bioreactors may be effective and are somewhat less costly than RO, but to retrofit an existing large AS plant to an MBR would be prohibitively expensive. It appears that the alternative most likely to be effective in terms of cost is to merely remove the discharge from surface water and instead irrigate the water on land. Many municipalities will not have the ability to implement such projects. For major sewage treatment plants, hundreds of acres would be required.

In summary, it appears that the existing sewage treatment infrastructure does in fact remove sterols and stanols at a relatively high level of efficiency. In addition, as the level of efficiency in the removal of TSS increases, so does the removal of sterols and stanols, meaning that well operated plants can do a better job in removing them as opposed to poorly operated ones. In my opinion, retrofitting existing sewage treatment works to obtain higher removal efficiencies for sterols and stanols would not be economical. Such funding would be better invested in other types of infrastructure.

Call if you have any questions.

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Compilation of Information on Treatment Options for Sterols and Stanols November 17, 2010

Contact: Cheryl Grabham

Treatment Options for Sterols and Stanols

Summary compiled by Karen Whisler, Oregon DEQ, October 2010

During treatment, activated sludge and UV disinfection both remove 85% of cholesterol and 97% of coprostanol from wastewater (USEPA, 2010). There is some indication (Jones et.al, 2007; and Abeggien et.al, 2009), although not a lot of data, to suggest that certain treatment processes may reduce sterols and stanols better than others (i.e., aeration, longer sludge retention times, ozonation, and powdered activated carbon adsorption).

A study by Jones et.al concludes that the use of advanced treatment to remove organic micropollutants (which include human steroids) can result in an increase in energy consumption (and CO₂ emissions), sludge disposal costs, and capital expense that, based on the available information, does not justify the benefit in reductions gained.

Technical Considerations Regarding Management of Sterols and Stanols

Summary compiled by Dr. Bruce Hope, Oregon DEQ, October 2010

Coprostanol constitutes about 60% of the total sterol pool in human feces and about 40% of the total sterols identified in raw sewage. Its concentration is unaffected by various treatments such as chlorination or aeration of overlying water. However, coprostanol and cholestanol degrade under the conditions found in aerobic wastewater treatment plants, in treatment effluent, and in seawater but are known to be refractory² in anoxic sediments (Snyder et al., 2003). For example, coprostanol's biodegradation half-life drops from >400 d under aerobic conditions to ≈1 d under aerobic conditions (Barber and Writer, 1998). Coprostanol is typically associated with particulate matter and becomes quickly incorporated into the sediments due to its lipophilic nature ($\log K_{OC} \approx 5$ (Barber and Writer, 1998)). Studies of sediments from freshwater systems have shown that once coprostanol and cholestanol are buried in anaerobic sediments, they are persistent.

Summary of Removal Efficiency Research by WA Dept of Ecology

Excerpt from: Lubliner, et al., 2010.

Several studies have evaluated removal efficiency of PPCPs by different treatment processes (Snyder et al., 2007; Miege et al., 2008). These include reverse osmosis, ozonation, membrane bioreactors, constructed wetlands, and riverbank filtration (Snyder et al., 2007; Drury et al., 2006; Kimura et al., 2005; Barber et al., 2006; Heberer et al., 2004, respectively).

None of the processes evaluated has been found to remove 100% of all PPCPs. Some treatment processes effectively reduce some pharmaceuticals down to very low levels, while other pharmaceuticals

² Refractory means "resistant to change." In other words, cholesterol and coprostanol resist being degraded when they are in anoxic sediment.

remain resilient to removal by conventional secondary or tertiary wastewater treatment. PPCPs resistant to treatment include, but are not limited to, carbamazepine, fluoxetine, clofibric acid, mefenamic acid, phenazone, diclofenac, and dimethylaminophenazone (Kinney et al., 2006a; Kimura et al., 2005; Miege et al., 2008; Rounds et al., 2009; Ternes, 1998).

Researchers at the Cemagref Water Quality and Pollution Control Research Unit in France have compiled a database from 113 international research papers on the occurrence and removal of PPCPs from WWTPs (Miège et al., 2008). Data collection included types of processes, operating conditions, influent and effluent data, mixed liquor in the biological reactor, volume of the reactor, retention times, and other physical characteristics. The Cemagref database found that only 32 PPCP chemicals comprise 80% of the data in their database.

Some studies have shown that operating the WWTP with a longer solids retention time (SRT), which allows for a longer biological contact time, will increase PPCP removal rates. Retention time is often longer for WWTPs that operate biological nutrient removal. Also, pH changes within the treatment system may increase the rate of antibiotic removals (Holtz, 2006). The Cemagref database allowed researchers to calculate removal efficiencies based on data from 24-hour flow proportional composites samples. Operating conditions were cited as playing a large role in PPCP removal. In fact, processes with nitrogen treatment and high hydraulic retention time (HRT) of >12 hours, and high SRT of >10 days, were found to be more efficient in removing PPCPs than processes without nitrogen treatment. The most effective processes were biological treatment (50-90%) such as conventional activated sludge with nitrogen treatment and with membrane bioreactors combined with nitrogen treatment (Miège et al., 2008).

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