Removal of Endocrine Disrupting Compounds in Water Reclamation Processes

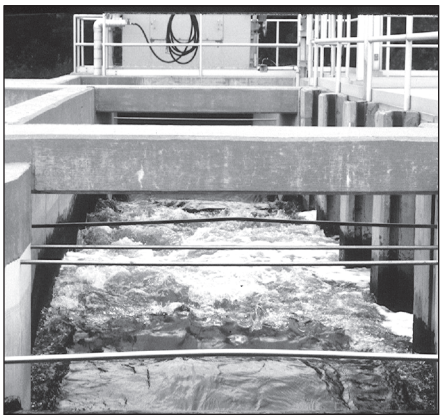
Endocrine disrupting compounds (EDCs) include thousands of compounds that have the potential to interact with components of the endocrine system, altering the natural action of the hormone. This disruption can occur by several mechanisms such as: mimicking the hormone at a receptor (receptor agonist); blocking a hormone's normal action (receptor antagonist); or altering its synthesis, degradation, or elimination.

It is not known whether observed variations of EDC concentrations and activities are a result of single unit processes, operational parameters, or sequences of processes used during water reclamation. Conventional wastewater treatment facilities are not specifically designed to remove EDCs, and the degree with which they are removed during primary and secondary treatment varies. There is also a need to assess the removal of endocrine disrupting activity during advanced unit operations such as activated carbon, membrane treatment, UV disinfection, and soil-aquifer treatment.

This study evaluated analytical tools for quantifying EDCs in wastewater matrices. The research team assessed conventional water reclamation treatment trains to determine their ability to reduce concentrations of EDCs and biological activity. The study also evaluated the ability of advanced treatment processes to reduce biological activity and determined the degree to which operational parameters influence the final effluent concentrations of EDCs and biological activity.

Operational Processes During Treatment

Field investigations at water reclamation facilities in six states allowed investigators a look at regional variations and the removal efficiencies of individual processes in a variety of different processes. Hydraulic corresponding composite samples were collected for individual unit operations. Secondary treatment was represented by activated sludge systems with hydraulic retention time (HRT) and solid retention time (SRT).



The ability to link physiological effects with molecular endpoints will prove invaluable to understanding the effect of treated effluents on aquatic life.

A full-scale membrane bioreactor was examined as well as three pilot-scale membrane bioreactors. Disinfection processes were represented by chlorination and UV-disinfection. Laboratory investigations explored adsorption of EDCs onto powdered-activated carbon using spiked wastewater samples and testing of representative target compounds during treatment with high-pressure membranes under various operational conditions. The team conducted soil-columns studies to simulate soil-aquifer treatment under different flow and redox conditions. Results were verified through full-scale studies at two water reuse field sites.

Approaches to Removal of EDCs

The researchers found a very strong relationship for the two estrogenic bioassays and gas chromatography-negative chemical ionization-mass spectrometry (GC-NCI-MS) results. These results indicat-

BENEFITS

- Finds that secondary treatment can provide substantial removal of endocrine disrupting compounds and activities.
- Determines that two estrogenic bioassays agree reasonably well with chemical analyses, indicating that chemical contribution to estrogenic activity is well defined.
- Determines that EDC load and removal to a plant correlate with biochemical oxygen demand (BOD) load and removal.

RELATED PRODUCTS

Assessment of the Occurrence and Ecological Significance of Endocrine Disrupting Chemicals in Watersheds (99EC03)

Analytical Method for Endocrine Disruptors in Sewage Sludge (02HHE1CO)

EDCs and Implications for Wastewater Treatment (04WEM6)

Online Methods for Evaluating the Safety of Reclaimed Water (01HHE4a)

Moving Towards an Innovative DNA Array Technology for Detection of Pharmaceutics in Reclaimed Water (01HHE21T)

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ed that all three analytical techniques are likely acceptable approaches with which to study the removal of estrogenic compounds and biological activity during wastewater treatment. Results for raw wastewater samples through GC-NCI-MS and high-performance liquid chromatography enzyme-linked immunosorbent assay varied significantly, but were in general agreement for treated wastewater samples. The androgen assays indicated higher levels of activity in the primary-treated effluent than could be explained by the concentrations of testosterone, although the sensitivity of the androgen receptor-transfected yeast assay was too poor to assess activity in secondary-treated wastewater.

In exploring the removal across conventional secondary treatment, it was found that secondary treatment can provide substantial removal of EDCs and biological activities. The removal appears most variable for estrone, nonylphenol, and 4-tert-octylphenol. These compounds represent metabolites or degradation products and, therefore, have the potential to be formed during activated sludge treatment. Although the combination of estrogenic compounds was well related to estrogenic activity, testosterone alone was not able to explain all the androgen activity in primary effluents. Other naturally occurring metabolites of testosterone (e.g., androsterone, 4-androstenedione, and 5α-androstanedione) would likely need to be quantified to find a better relationship.

Findings relating removal of EDCs with treatment parameters suggest that the estrogenic activity in the influent is strongly correlated with the biochemical oxygen demand (BOD) load coming into a plant. Removal of biological activity correlated well with BOD removal, and high removal of individual EDCs and biological activity was achieved at SRTs exceeding 2 days. In the range of SRTs studied, no significant improvement in removal was observed between 2 and 10 days of SRT. A clear relationship was also lacking between removal and HRT. However, one facility with the longest HRT employing nitrification/denitrification and biological phosphorus removal achieved the highest removal of EDCs among all the plants.

Advanced treatment processes such as activated carbon, high-pressure membranes, and soil-aquifer treatment represent viable barriers to further remove EDCs and biological activities. Only small amounts of activated carbon (10 mg/L) were required to remove steroid hormones to below detection limits and significantly reduce phenolic compounds. Integrated membrane systems employing microfiltration followed by reverse osmosis removed EDCs and biological activity to no detection levels. Subsurface treatment, such as soil-aquifer treatment leading to groundwater recharge, reduced both EDCs and biological activities after very short travel times to below detection limits. These findings suggest that subsurface treatment is a strong barrier in removing biological activity from reclaimed water.

Summary

Biodegradation is the main removal mechanism for EDCs and biological activity; sorption to biosolids is also important. Return flows from biosolids handling facilities (supernatent returns) can contribute significantly do the incoming load of EDCs to a wastewater treatment facility, suggesting that biosolid treatment is only partially successful in removing EDCs adsorbed onto biosolids. Future research needs to address the efficacy of different biosolids treatment processes as well as the fate and transport of EDCs adsorbed onto land-applied biosolids.

The estrogenic *in vitro* bioassays proved to be robust tools for following changes in activity during wastewater treatment, and were generally consistent with chemical measurements. Future work, however, could focus on the development of more sensitive *in vitro* tools for androgenic and thyroid active compounds. The ability to link physiological effects (e.g., intersex fish) with molecular endpoints, such as gene expression changes, will likely prove invaluable to better understanding the effect of treated effluents on aquatic life. Gene expression changes can occur with very short exposures, greatly reducing the expense of these studies. Gene array technology, where thousands of gene expression changes can be monitored in one experiment, show great promise in the development of molecular biomarkers indicating exposures to EDC.

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