Ocean Wastewater Discharge in the State of California
Report and Inventory Prepared by Heal the Ocean

February 2010

http://www.healtheocean.org/

Additional References, Summaries, and Sources

Water Reclamation and Contaminants of Emerging Concern

i. **Pesticides**
ii. **Alkylphenols and Alkylphenol Ethoxylates (APEs) and Bisphenol A (BPA)**
iii. **Polybrominated Diphenyl Ethers (PBDEs)**
iv. **Steroids and Hormones**
v. **Pharmaceuticals and Personal Care Products (PPCPs)**
vi. **Perfluorinated Compounds (PFCs)**

Water Reclamation and Contaminants of Emerging Concern

Brooks, Bryan, et al., Water quality of effluent-dominated ecosystems: ecotoxicological, hydrological, and management considerations, Hydrobiologia (2006) 556:365–379.

Abstract: In arid and semi-arid regions of the southwestern United States and other parts of the world, flows of historically ephemeral streams are now perennially dominated by municipal and/or industrial effluent discharges, particularly in urbanized watersheds. Because effluent-dominated and dependent water bodies have previously received limited scientific study, we reviewed select contemporary topics associated with water quality of ephemeral streams receiving effluent flows. Our findings indicate that these ecosystems present numerous challenges to aquatic scientists and water resources managers, including: 1) appropriate ecosystems or upstream conditions used reference sites in biomonitoring are difficult to locate or do not exist; 2) water quality criteria, particularly for metals, are dramatically influenced by unique site-specific stream and land use conditions; 3) effluent-dominated streams represent worse-case scenarios for evaluating and predicting aquatic responses to emerging contaminants (e.g., pharmaceuticals and personal care products); 4) low-flow and drought conditions often preclude effective biomonitoring and water quality interpretation, or skew ambient assessment results; 5) chemical-physical water quality parameters (e.g., dissolved oxygen, conductivity, temperature) are dramatically altered by effluent and stormwater characteristics; and 6) beneficial reuse of reclaimed effluent waters potentially conflict with sustainability of ecological integrity.
http://www.springerlink.com/content/y03v744pr00xm470/

Centers for Occupational and Environmental Health, University of California, Green Chemistry: Cornerstone to a Sustainable California

"As a consequence of long-standing weaknesses in federal policy, the health and environmental effects of the great majority of some 80,000 industrial chemicals in commercial use in the U.S. are largely unknown. This condition has produced a flawed market in which buyers, from individual consumers to the largest companies in California, lack the information they need to choose the least hazardous chemicals and products."
http://coeh.berkeley.edu/greenchemistry/briefing/

California Department of Toxic Substances web page accessed 10_15_09

"The U.S. currently has more than 85,000 chemicals in commerce. There are approximately 2,500 “high production volume” (HPV) chemicals, which are manufactured at a rate of more than one million pounds annually, with nearly 45 percent of these HPV chemicals lacking adequate toxicological studies conducted to evaluate their health effects on humans and wildlife. Further, about 2,000 new chemicals are introduced into commerce annually in the U.S., at a rate of seven new chemicals a day."
http://www.dtsc.ca.gov/AssessingRisk/EmergingContaminants.cfm

Emerging Pollutants of Concern: A Survey of State Activities and Future Needs. Special Project of State/EPA Water Quality Standards Workgroup – led by Deb Smith, CA Regional Water Quality Control Board-Los Angeles, January (2008).

The broad issue of emerging chemicals has been a growing concern in recent years. At the 2006 Annual Meeting of the Association of State and Interstate Water Pollution Control Administrators (ASIWPCA), the issue of emerging chemicals in water was noted as a priority by both the Monitoring, Standards and Assessment, and Research Task Forces. This issue has also been the subject of a series of three Monitoring, Standards and Assessment Task Force conference calls convened over the last year by Deb Smith (CA) and Scott Stoner (NY)....
http://www.asiwpca.org/home/docs/EmergingChemsSurvey.pdf

EPA Calls for Chemical Law Reform, More Responsibility on Companies, GreenerDesign, online report, 1 Oct. 2009.

"The U.S. Environmental Protection Agency (EPA) is calling for changes to the country's chemical management law, and has released a list of principles it and the Obama Administration hope Congress follows as it reviews the law. The EPA has also announced six chemicals it plans to prioritize for analysis and regulation."
http://www.greenerdesign.com/news/2009/10/01/epa-calls-chemical-law-reform-more-responsibility-companies

Gullick, Richard, et al. A Utility Approach for Assessing Compounds of Potential, Concern. Presentation to AWWA Sustainable Water Resources Conference, Reno, Nevada, Feb. 11, 2008.

Useful references to studies, database, and USGS websites and publications on contaminants of potential concern (and CEC).
http://www.awwa.org/files/Resources/Waterwiser/references/PDFs/sustainable2008_mon1-6.pdf

HPV Chemical Hazard Data Availability Study, 1998, EPA website (accessed October 2009).

Of the 3,000 chemicals that the US imports or produces at more than 1 million lbs/yr, a new EPA analysis finds that 43% of these high production volume chemicals have no testing data on basic toxicity and only seven percent have a full set of basic test data. This lack of test data compromises the public's right to know about the chemicals that are found in their environment, their homes, their workplace, and the products that they buy. Industry must do more to ensure that basic information is available on every high-production chemical they manufacture.
http://www.epa.gov/HPV/pubs/general/hazchem.htm

Integrated Risk Information System, National Center for Environmental Assessment, US EPA.

Health assessment information on a chemical substance is included in IRIS only after a comprehensive review of chronic toxicity data by U.S. EPA health scientists from several Program Offices and the Office of Research and Development. The summaries presented in Sections I and II represent a consensus reached in the review process. Background information and explanations of the methods used to derive the values given in IRIS are provided in the Background Documents.
http://www.epa.gov/iris/index.html

Literature Review of Organic Chemicals of Emerging Environmental Concern in Use in Auckland. Auckland Regional Council. Technical Report No. 028, December 2008.

"This report reviews the environmental hazard of organic chemicals in products of dayto-day use that are manufactured or consumed in high-volume. It covers, among others; plastics; resins and plastic additives (plasticisers, flame retardants); pharmaceuticals and personal care products (eg, disinfectants, antibiotics, fragrances, sunscreens, drugs, natural and synthetic hormones); detergents and other cleaning agents; various petroleum products, pesticides and biocides (eg, weed killers, fumigants, wood preservatives, antifouling agents); and compounds derived from wastewater and drinking water treatment, landfill or incineration."
http://www.arc.govt.nz/albany/fms/main/Documents/Plans/Technical%20publications/Technical%20reports/150/TR2008028%20%20Literature%20Review%20of%20Organic%20Chemicals%20of%20Emerging%20Environmental%20Concern%20in%20Use%20in%20Auckland.pdf

Mohammad A. Mottaleb, et al., Gas chromatography–mass spectrometry screening methods for select UV filters, synthetic musks, alkylphenols, an antimicrobial agent, and an insect repellent in fish, Journal of Chromatography A, 1216 (2009) 815–823.

Partial abstract: Two screening methods have been developed for simultaneous determination of ten extensively used personal care products (PCPs) and two alkylphenol surfactants in fish. The methods consisted of extraction, clean-up, derivatization and analysis by gas chromatography–mass spectrometry with selected ion monitoring (GC–SIM–MS) or gas chromatography–tandem mass spectrometry (GC–MS/MS) techniques. Among solvents tested to assess recovery of target compounds from 1-g tissue homogenates, acetone was selected as optimal for extracting compounds with dissimilar physicochemical properties from fish tissue. Initial experiments confirmed that GC–SIM–MS could be applied for analysis of lean fillet tissue (<1% lipid) without gel-permeation chromatography (GPC), and this approach was applied to assess the presence of target analytes in fish fillets collected from a regional effluent-dominated stream in Texas, USA. Benzophenone, galaxolide, tonalide, and triclosan were detected in 11 of 11 environmental samples at concentrations ranging from; 37 to 90, 234 to 970, 26 to 97, and 17 to 31 ng/g, respectively.
http://www.sciencedirect.com/science

Ng, Hoover. Setting California's Drinking Water Quality Standards, Water Replenishment District of Southern California.

To ensure the safety of drinking water, the providers of tap water are required by the government to take samples regularly and test them for a multitude of compounds to make sure they meet drinking water quality standards. But what exactly are drinking water quality standards? Who sets them and how are they established? Drinking water quality standards in California are established by the Federal government under the Environmental Protection Agency (USEPA) and the California Department of Public Health (CDPH). Any compounds found in water may be considered a contaminant for possible regulation. However, most contaminants do not present any health concern. For a contaminant to be assigned a drinking water quality standard, the following criteria have to be reviewed and met:
http://www.wrd.org/water_quality/drinking-water-standards-california.php

Occurrence of Contaminants of Emerging Concern in Wastewater from Nine POTWs August 2009, United States Environmental Protection Agency, EPA-821-R-09-009.

The primary objective of EPA's Nine POTW Study (the Study) was to investigate the occurrence of Contaminants of Emerging Concern (CECs) in untreated and fully treated wastewater at publicly owned treatment works (POTWs). EPA also initially investigated the occurrence of conventional, non-conventional, and toxic pollutants, including many of the pollutants in EPA's 1982 "50-POTW Study" (EPA, 1982). For the first four POTWs in this Study, EPA selected facilities that treated industrial discharges because POTWs receiving significant volumes of discharges from pharmaceutical or other manufacturing facilities might be expected to receive a significant quantity and variety of CECs.
http://www.epa.gov/waterscience/ppcp/studies/9potwstudy.pdf

Rhodes T., Constituents of Emerging Concern: An Overview. Water Environment Foundation, Proceedings of the Water Environment Federation, WEFTEC 2006: Session 11 through Session 20, pp. 1460-1467(8). Ingenta Connect website (accessed December 2009).

"Emerging constituents of concern have been with us from the beginning of the environmental era 45 years ago. They were behind the 1974 Safe Drinking Water Act. They are behind our struggle with disinfection byproducts. They were behind the development of the 129 (126) priority pollutants. They were behind RCRA and the Superfund. Now they are "emerging" as endocrine disruptors, pharmaceuticals, personal care products, persistent organic pollutants, etc...." PLUS table: "Several Emerging Chemicals and their Approximate Behavior" with indication of their biodegradability.
http://www.ingentaconnect.com/content/wef/wefproc/2006/00002006/00000012/art00055

Roh, Hyungkeun, et al. Biodegradation potential of wastewater micropollutants by ammonia-oxidizing bacteria. Chemosphere, Volume 77, Issue 8, November 2009, Pages 1084-1089.

This study examined the biodegradation potential of three wastewater micropollutants (triclosan, bisphenol A, and ibuprofen) by Nitrosomonas europaea and mixed ammonia-oxidizing bacteria in nitrifying activated sludge. N. europaea could degrade triclosan and bisphenol A, but not ibuprofen. The degradation was observed only in the absence of allylthiourea (an inhibitor for ammonia monooxygenase (AMO)), suggesting that AMO might be responsible for triclosan and bisphenol A degradation. Competitive inhibition among ammonia, triclosan, and bisphenol A was observed. Inactivation of N. europaea was observed after degrading a mixture of triclosan and bisphenol A. The inactivation might be due to product toxicity and/or antimicrobial effect of triclosan; however, the causes of the inactivation were not determined.
http://www.sciencedirect.com/

SCCWCRP Project: Contaminants of Emerging Concern in Coastal Waters, Sediment, and Biota

"Background and Objectives: Recent studies have documented toxicity in sediments in bays, as well as evidence of endocrine disruption in Southern California marine fish. Efforts to find the chemicals causing these effects have been largely inconclusive, since in situ data on contaminants of emerging concern (CECs) remain scarce. Due to the sheer numbers of different CECs, focused investigations are needed on the occurrence of suspected toxicants, in order to determine how widespread these contaminants are in the coastal environment. This project will characterize the occurrence of brominated flame retardants, industrial, commercial and personal care products and current use pesticides throughout the region."
http://www.sccwrp.org/view.php?id=275

Zhang, J., et al. 2008. Emerging Contaminants: Fate during wastewater treatment and water reclamation processes. Journal of Environmental Engineering, 134(6):433-442.

Although the fate of these compounds during conventional wastewater treatment is somewhat uncertain, the hydrophobic character of known estrogenic compounds in wastewater suggests that they will associate with sludges derived from wastewater treatment. The steroid hormones and alkylphenols, in particular, could reach high concentrations in biosolids. Nevertheless, there is little direct evidence regarding the fates of EDCs during wastewater treatment and, for chemicals that separate with sludges, survival during solids handling and treatment processes. There is a critical need for these data when biosolids derived from sludge treatment are beneficially used as soil amendments.
http://www.reeis.usda.gov/web/crisprojectpages/151310.html

Zhang Y, Marrs CF, Simon C, Xi C., *Wastewater treatment contributes to selective increase of antibiotic resistance among Acinetobacter spp.,* The science of the total environment, 1 Jun 2009;407(12):3702-6. Epub 24 Mar 2009.

Chuanwu Xi of the University of Michigan School of Public Health and his team sampled water containing the bacteria Acinetobacter at five sites in and near Ann Arbor's wastewater treatment plant. Twenty or 30 years ago, antibiotics would have killed most of these strains, no problem," he said. Multiple antibiotic-resistant bacteria has emerged as one of the top public health issues worldwide in the last few decades as the overuse of antibiotics and other factors have caused bacteria to become resistant to common drugs. Xi's group chose to study Acinetobacter because it is a growing cause of hospital-acquired infections and because of its ability to acquire antibiotic resistance. Xi said the problem isn't that treatment plants don't do a good job of cleaning the water—it's that they simply aren't equipped to remove all antibiotics and other pharmaceuticals entering the treatment plants.
http://www.ncbi.nlm.nih.gov/pubmed/19321192?dopt=Abstract

Water Reclamation and Contaminants of Emerging Concern: i. Pesticides

Gilliom, R.J., et al. The Quality of Our Nation's Waters. Pesticides in the Nation's Streams and Ground Water, 1912-2001. U.S. Department of the Interior and U.S. Geological Survey. 2006.

One of a series of publications, The Quality of Our Nation's Waters, that describe major findings of the NAWQA Program on water-quality issues of regional and national concern. This report presents evaluations of pesticides in streams and ground water based on findings for the first decadal cycle of NAWQA. "Pesticides in the Nation's Streams and Ground Water, 1992–2001" greatly expands the analysis of pesticides presented in "Nutrients and Pesticides," which was the first report in the series and was based on early results from 1992 to 1995.
http://pubs.usgs.gov/circ/2005/1291/pdf/circ1291.pdf

Kalumuck, Kenneth M. Dynaflow Inc. Final Report: Development of a Cavitating Jet System for Removal of Pesticides and Other Pollutants from Wastewater Discharge. EPA National Center for Environmental Research, Project Period: April 1, 2002 - September 1, 2002.

[Ultrasonically induced cavitation] will provide a reliable, cost-effective means for the removal of pesticides and other contaminants from wastewater discharge, for remediation of contaminated water, or as part of a process for purifying water for various applications. The technology should be easy to implement at different scales, such that it could be effectively utilized for both small and large systems.
http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/5098/report/F

Pesticides website, US EPA.

On August 19th 2009 the Environmental Protection Agency (EPA) launched a new web page to better protect human health and the environment from pesticides. The website, "explains the development and evaluation of new technologies in molecular, cellular, and computational sciences to supplement or replace more traditional methods of toxicity testing and risk assessment."
http://www.epa.gov/opp00001/

Pesticides: Glossary. US EPA.

EPA Glossary of Pesticides and definitions.
http://www.epa.gov/opp00001/glossary/index.html

Water Reclamation and Contaminants of Emerging Concern: ii. Alkylphenols and Alkylphenol Ethoxylates (APEs) and Bisphenol A (BPA)

Roh, H.; Subramanya, et al. Biodegradation potential of wastewater micropollutants by ammonia-oxidizing bacteria. Chemosphere, (2009) 77, 8, November, pp.1084-1089.

This study examined the biodegradation potential of three wastewater micropollutants (triclosan, bisphenol A, and ibuprofen) by Nitrosomonas europaea and mixed ammonia-oxidizing bacteria in nitrifying activated sludge. N. europaea could degrade triclosan and bisphenol A, but not ibuprofen. The degradation was observed only in the absence of allylthiourea (an inhibitor for ammonia monooxygenase (AMO)), suggesting that AMO might be responsible for triclosan and bisphenol A degradation. Competitive inhibition among ammonia, triclosan, and bisphenol A was observed. Inactivation of N. europaea was observed after degrading a mixture of triclosan and bisphenol A. The inactivation might be due to product toxicity and/or antimicrobial effect of triclosan; however, the causes of the inactivation were not determined.
http://www.sciencedirect.com

Gehring, M., et al. Bisphenol A contamination of wastepaper, cellulose and recycled paper products, in, C.A. Brebbia, Waste Management and the Environment II. WIT Press, Billerica, MA, (2004) pp. 293-300.

Since both BPA and alkylphenol polyethoxylate surfactants are used in paper production the contamination of recycled paper products with these compounds can be expected. Therefore, the contamination of wastepaper, toilet paper and cellulose samples with selected EACs has been investigated. With one exception, all xenoestrogens studied were determined in all toilet paper samples at very high concentrations of 2 – 430 mg/kg dry mass (dm).
http://www.witpress.com/contents/c7388.pdf

Water Reclamation and Contaminants of Emerging Concern: iii. Polybrominated Diphenyl Ethers (PBDEs)

Arnold, R.G., et al. Fate of Polybrominated Diphenyl Ethers During Wastewater Treatment/Polishing and Sludge Stabilization/Disposal Annals of the New York Academy of Sciences, Volume 1140(1), Issue Environmental Challenges in the Pacific Basin (p 394-411), Oct. 2008 .

"Large quantities of polybrominated diphenyl ethers (PBDEs) have been used as flame retardants in clothing and plastic products since the 1970s. A small fraction of the PBDEs in manufactured products subsequently enters municipal wastewater. Nevertheless, the resistance of these compounds to chemical and biochemical transformations provides opportunities for accumulation in sediments that are in contact with wastewater effluent and agricultural soils that are amended with biosolids derived from wastewater treatment. Balances developed for PBDE congeners indicate that conventional wastewater treatment processes and soil infiltration of treated wastewater in recharge operations do not discriminate significantly among the major congeners in commercially available PBDE products."
http://www.ingentaconnect.com/content/bsc/nyas/2008/00001140/00000001/art00045

Barman, Miel, et al. Toxicity and Estrogenic Activity of Polybrominated Diphenyl Ethers (PBDEs). Wisconsin State Laboratory of Hygiene, Wisconsin Department of Natural Resources, Dec. 2004.

The purpose of this research was to 1) determine estrogenic activity of BDE-47 and BDE-99 using the E-screen assay, 2) determine the acute and chronic toxicity of BDE-47 to the aquatic invertebrate, Ceriodaphnia dubia, 3) determine the concentration of PBDEs in sediments of the Sheboygan River basin, and 4) determine the concentration of PBDEs in wastewater treatment plant and industrial effluents in the Sheboygan River basin.
http://dnr.wi.gov/environmentprotect/pbt/research/FinalPBDErpt_Harrahy.pdf

Court Annuls RoHS Exemption for DecaBDE. RSJ Technical Consulting, 2008.

The European Court of Justice (ECJ) has annulled the RoHS exemption for decaBDE in a decision issued April 1, 2008. Use of decaBDE will be prohibited beginning July 1, 2008.
http://www.rsjtechnical.com/NewsDecaBDE.htm

Langford, Katherine , Mark Scrimshaw, and John Lester. The Impact of Process Variables on the Removal of PBDEs and NPEOs During Simulated Activated Sludge Treatment. Archives of Environmental Contamination and Toxicology, Springer New York, pp. 1-7, 2007

This work illustrates that the removal of some endocrine-disrupting compounds from sewage treatment works effluent is dependent on parameters such as sludge age, influent concentrations, concentrations of co-pollutants and hydraulic retention time as well as physicochemical properties of the compound. Greater nonylphenol polyethoxylates (NPEO) and polybrominated diphenyl ether (PBDE) removal was observed at a higher sludge age, and it appeared that the enzymes required for NPEO degradation were already present. NPEO degradation was reduced in the presence of the more hydrophobic PBDE compounds as sorption of PBDEs occurred, rapidly reducing available sorption sites for NPEOs. The more hydrophobic NP and PBDEs demonstrated little degradation in comparison to longer-chain NPEO compounds. From this research, it is apparent that the principal environmental risk of PBDE contamination after wastewater treatment is via sludge-disposal routes. Treatment of wastewater containing NPEO surfactants poses environmental risks via two routes: some nonylphenolic compounds may pass through into receiving waters and degradation products such as nonylphenol and short-chain ethoxylate compounds will enter the environment via sludge disposal.
http://www.springerlink.com/content/j17260uj57661321/

PBDEs and Your Health. Alaska Community Action on Toxics, September 2007 (accessed October 2009) & Toxic Free Legacy Coalition Report, 2006. Pollution in People. Report online (accessed October 2009).

Polybrominated diphenyl ethers, or PBDEs, are a class of flame retardant chemicals added to many consumer products found in the home, office, automobiles, and airplanes. Three mixtures used widely—penta-BDE, octa-BDE, and deca-BDE—made up 14%, 6%, and 80% of the 1999 worldwide production, respectively. Commonly found in electronics, such as TVs, and used in some furniture foams, textiles, and kitchen appliances, industry voluntarily ended production in the United States of the formulations of penta and octa in 2004 after high levels were

found in breast milk. However, the deca formulation is still being produced and used primarily in plastic electronics such as television and computer casings, and is also used in furniture and mattresses.
http://www.toxicfreelegacy.org

PBDEs - Fire Retardants in Dust: Toxic Fire Retardants In American Homes, published on Environmental Working Group, 2004.

Like PCBs, their long-banned chemical relatives, the brominated fire retardants known as PBDEs (polybrominated diphenyl ethers) are persistent in the environment and bioaccumulative, building up in people's bodies over a lifetime. In minute doses they and other brominated fire retardants impair attention, learning, memory and behavior in laboratory animals.
http://www.ewg.org/book/export/html/8449

Polybrominated Diphenyl Ethers (PBDEs) Project Plan. U.S. Environmental Protection Agency, March 2006.

"Polybrominated diphenyl ethers (PBDEs) are a group of brominated flame retardant chemicals of increasing interest to scientists, government agencies, and the public. These chemicals have been used in a variety of manufactured products, including foam cushioning used in furniture and plastics used in televisions and computers. In the event of a fire involving these products, PBDEs slow ignition and rate of fire growth, allowing more time for people to extinguish or escape the fire. However, findings that PBDEs are widely distributed in the environment and are present at increasing levels in people have raised concerns about the potential risks of PBDE exposure to human health and the environment."
http://www.epa.gov/oppt/pbde/pubs/proj-plan32906a.pdf

A Review of Available Scientific Research, EPA Toxicity Assessment Unit, State of Illinois, 2006. Prepared at the request of the Illinois Legislature, via HB2572, to address concerns about polybrominated diphenyl ether (PBDE) flame retardants.

"Report...prepared to address the five issues posed by the Illinois Legislature to the Illinois Environmental Protection Agency in HB2572 regarding the use of Decabromodiphenyl ether (DecaBDE). The Agency reviewed numerous data sources, including some very recent information, pertaining to the five issues in order to respond in as thorough a manner as possible. However, data gaps exist in certain key areas that have hampered our ability to fully address some issues. / DecaBDE is bioaccumulating in the environment, and levels are increasing in some types of samples (sediments, some top predators, and possibly human blood and breast milk). / DecaBDE can be broken down by ultraviolet light and direct sunlight, and also by metabolic processes in animals and microorganisms, but uncertainty and controversy exists about the extent of breakdown by light under environmentally relevant conditions and the human health implications of the breakdown products"
http://www.epa.state.il.us/reports/decabde-study/available-research-review.pdf

Ross, P. S., C. M. Couillard, et al. (2009). "Large and growing environmental reservoirs of Deca-BDE present an emerging health risk for fish and marine mammals." Marine Pollution Bulletin 58(1): 7-10.

This paper reviews the research documenting the rapid emergence of PBDEs as a high priority environmental concern. PBDEs from sewage discharge and atmospheric deposition continue to find their way in to the aquatic environment. In certain environmental compartments, the congener BDE-209 is present in concentrations greater than PCBs or DDT. The threat is likely to be long-term because large environmental reservoirs of BDE-209 are being created in sediments, and it will break down into PBDE congeners that will be more persistent, bioaccumulative, and more toxic in the environment.
http://www.find-health-articles.com/rec_pub_18929373-large-growing-environmental-reservoirs-deca-bde-present-emerging.htm

---

Water Reclamation and Contaminants of Emerging Concern: iv. Steroids and Hormones

Birkett, Jason W. and John Norman Lester, Endocrine disrupters in wastewater and sludge treatment processes. CRC Press LLC, London, 2003, pp 128-129.

Covers research on the endocrine-disrupting effects of sewage and industrial effluents, covering the sources, fate, and transport of EDCs, and sludge treatment and disposal options considered in regard to their implications for receiving environments. It also addresses the potential sources and analysis of these substances in waters, sediments, and sludge. In addition, the authors review current legislation and potential management strategies for endocrine disrupters in the environment.
http://books.google.com/books?id=ZJDS0UqAFfYC&pg=RA1PA128&lpg=RA1PA128&dq=PBDE+removal+wastewater&source=bl&ots=yivFbVhe6Y&sig=kexp5OuaCMrWBj0BCxKV1ERp6ac&hl=en&ei=V8TgSonAJIvmM7yzuMMI&sa=X&oi=book_result&ct=result&resnum=5&ved=0CCcQ6AEwBA#v=onepage&q=PBDE%20removal%20wastewater&f=false

Gutjahr-Gobell, R.E., et al. Individual effects of estrogens on a marine fish, Cunner (Tautogolabrus adspersus), extrapolated to the population level. Ecotoxicology and Environmental Safety 63: 244-252, 2006.

Lab studies on endocrine disruptors with potential ecological effects. Describes estrogens as non-bioaccumulating, yet concerning due to constant exposure from effluent.
(PDF included in folder)

Koh, Y.K.K., et al. Treatment and Removal Strategies for Estrogens from Wastewater. Environmental Technology 29(3):245-267, Mar. 2008.

Scientific report describing treatment techniques for estrogens.
http://www.informaworld.com/smpp/section?content=a792950493&fulltext=713240928

Kolodziej, Edward P., et al. Dairy wastewater, aquaculture, and spawning fish as sources of steroid hormones in the aquatic environment. Environmental Science & Technology, 2004-Dec; vol 38 (issue 23): pp 6377-84.

A suite of androgens, estrogens, and progestins were measured in samples from dairy farms, aquaculture facilities, and surface waters with actively spawning fish using gas chromatography-tandem mass spectrometry (GC/MS/ MS) to assess the potential importance of these sources of steroid hormones to surface waters.
http://www.find-health-articles.com/rec_pub_15597895-dairy-wastewater-aquaculture-spawning-fish-sources-steroid-hormones.htm

Labadie, P., et al. 2007. Evidence for the migration of steroidal estrogens through riverbed sediments. Environmental Science and Technology, 41: 4299 -4304.

New research confirms that estrogenic contaminants can contaminate groundwater after being carried by sewage into rivers. Standard water treatment doesn't remove them from waste water effluent, so they pass from treatment plants into rivers. Once in river waters, this new research shows they can seep through river sediments and from there potentially into groundwater. Some types of sediment, for example, those rich in clay, will slow the process considerably.
http://www.environmentalhealthnews.org/newscience/2007/2007-1008labadieetal.html

Liedtke, Anja, et al. Internal exposure of whitefish (*Coregonus lavaretus*) to estrogens, Aquatic Toxicology 93: 158-165, 2009.

Abstract: Gonad malformations have been found in fish all over the world. Particularly in Lake Thun (Switzerland) a high prevalence of gonad deformations in whitefish has been observed. Very often, a link between exposure to endocrine disrupting compounds and altered gonad morphology exists. Hence, we analyzed the estrogenic burden in bile and muscle from whitefish (coregonids) from Lake Thun and linked it to observed gonad malformations. Estrogenicity in bile, measured with the yeast estrogen screen (YES) was exclusively caused by the natural steroids estrone and 17_-estradiol. Estrogenicity determined in muscle tissue using YES was similar in cases and controls, and between the sexes. Furthermore, endocrine active compounds in the lakewaterwere investigated using passive sampling devices to monitor tributaries and the main outflow of Lake Thun. Here, we found accumulated estrogenicity.With target chemical analysis small amounts of estrone and bisphenol A were determined. We conclude, that the whitefish from Lake Thun are not suffering from(xeno)estrogens. The present study contributed substantially to the search for the cause for gonad malformations in Lake Thun whitefish, even though the cause of the malformations remains yet to be discovered.
(PDF included in folder)

Nghiem, L.D., et al. Estrogenic hormone removal from wastewater using NF/RO membranes. Journal of Membrane Science, Volume 242, Issues 1-2, 15 October 2004, Pages 37-45.

This paper investigates the separation process of two estrogenic hormones, estrone and estradiol, using eight commercial NF and low pressure RO membranes. The results indicate that the separation mechanism of estrone and estradiol in membrane filtration processes is similar. While estrogenic hormone retention by more porous membranes decreases with decreasing adsorption and the subsequent retention is relatively low, tighter NF and RO membranes can retain estrogenic hormones effectively. It appears that the presence of organic matter in solution can enhance retention due to the interaction of such substances with estrogenic hormones. The results also suggest that physicochemical interactions within the membrane can play an important role. There is no cross-flow velocity effect on retention, whereas an increase in transmembrane pressure may lead to a decrease in steroid hormones retention for some membranes.
http://www.sciencedirect.com/

Surface Water Samples Test Free of Strong EEDC Activity. Fact Sheet, Surface Waters Ambient Monitoring Program (SWAMP).

Monitoring results suggest no strong endocrine-disrupting chemical activity in Central Valley and North Coast surface water samples
http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/factsheets/eedc.pdf

Tackling Fish Endocrine Disruption. A USGS headline from the Toxic Substances Hydrology Program. Accessed October 2009

Intersex, the presence of both male and female characteristics within the same fish, is being observed in fish in more streams across the Nation. Intersex is one manifestation of endocrine disruption in fish. Endocrine disruption can result in adverse effects on the development of the brain and nervous system, the growth and function of the reproductive system, and the response to stressors in the environment. U.S. Geological

Survey (USGS) scientists have documented the presence of endocrine disrupting contaminants in rivers and streams across the Nation. Additionally, USGS scientists and others have demonstrated that exposure to endocrine-active contaminants can cause endocrine disruption, which can have ruinous impacts on fish populations.
http://toxics.usgs.gov/highlights/fish_endocrine_disruption.html

---

Water Reclamation and Contaminants of Emerging Concern: v. Pharmaceuticals and Personal Care Products (PPCPs)

Aga, D.S. Fate of pharmaceuticals in the environment and in water treatment systems. CRC Press, Boca Raton: 2008.

Fate of PPCP's in treatment, treatment of drinking water, occurance and transformation. A collection of writings/reports and multiple authors.
http://books.google.com/books?id=9KJYr4xOADMC&pg=PA324&lpg=PA324&dq=%22fate+of+pharmaceuticals+in+the+environment+and+in+water+treatment+systems%22+diana+aga+pdf&source=bl&ots=jhKUrHQ3y6&sig=FTNCkzTYEZjlSjt5OwUeNzAHRUo&hl=en&ei=XvOeSoTzBoqAswO6u6GCDg&sa=X#v=onepage&q=&f=false

Benotti, M.J. and S.A. Snyder. Pharmaceuticals and Endocrine Disrupting Compounds: Implications for Ground Water Replenishment with Recycled Water, Ground Water. Jul.-Aug. 2009.

Discusses ground water recharge techniques, substrate interaction with PPCP's, and general treatment removal of PPCP's.
(PDF included in folder)

Johnson, Andrew, and Darton, Richard. Removing oestrogenic compounds from sewage effluent, web page accessed October 2009.

Risk and treatment in sewage plants of endocrine disrupting compounds. Experiments geared to "improve the performance of existing activated sludge treatment plants by placing supported biofilms in the aeration tanks, with staged flow of liquid through these packed zones." Includes photos.
http://www.eng.ox.ac.uk/chemeng/people/darton/oestrogens.pdf

Johnson, Andrew, et al. Removing steroid oestrogens from wastewater. The Chemical Engineer, June 2007, Issue 792, p35-37.

The article discusses a research project entitled "Endocrine Disruption Demonstration Project" designed to examine the effectiveness of various sewage treatment technologies in removing natural and synthetic steroid estrogen hormones. An alternative approach to estrogen removal would be to boost the efficiency of the existing biological treatment. Another way is the introduction of biofilms supported on appropriate media within the aeration tank. Includes photos.
http://www.eng.ox.ac.uk/chemeng/people/darton/tce%20article%20June%202007.pdf

Miege, C., et al. Fate of pharmaceuticals and personal care products in wastewater treatment plants, Environmental Pollution 157: 1721-1726, 2009.

Abstract: We created a database in order to quantitatively assess the occurrence and removal efficiency of pharmaceuticals and personal care products (PPCPs) in wastewater treatment plants (WWTPs). From 117 scientific publications, we compiled 6641 data covering 184 PPCPs. Data included the concentrations of PPCPs in WWTP influents and effluents, their removal efficiency and their loads to the aquatic environment. The first outputs of our database allowed to identify the most investigated PPCPs in WWTPs and the most persistent ones, and to obtain reliable and quantitative values on their concentrations, frequency of detection and removal efficiency in WWTPs. We were also able to compare various processes and pointed out activated sludge with nitrogen treatment and membrane bioreactor as the most efficient ones.
(PDF included in folder)

Okuda, Takashi et al., Development of extraction method of pharmaceuticals and their occurrences found in Japanese wastewater treatment plants. Environment International 35(8): 815-820, 7 Feb 2009.

Ultrasonic Solvent Extraction, presurized liquid extraction techniques for removal of compounds from primary sludge. 40-150% removal rate of 66 different compounds.
(PDF included in folder)

Petrović, Mira, and Damiá Barceló. Analysis, fate and removal of pharmaceuticals in the water cycle. Comprehensive Analytical Chemistry, Vol. 50, Elsivier, the Netherlands, 2007.

Pharmaceutically active substances are a class of new, so-called "emerging" contaminants that have raised great concern in recent years. Human and veterinary drugs are constantly being introduced into the environment, mainly as a result of the manufacturing process. Over a period of time, this level of chemical input may lead to long-term concentrations and promote continual, but unnoticed adverse effects on aquatic and terrestrial organisms.Analysis, Fate and Removal of Pharmaceuticals in the Water Cyclediscusses state-of-the-art analytical methods for trace determination of pharmaceuticals in environmental samples while reviewing the fate and occurrence of pharmaceuticals in the water cycle (elimination in wastewater and drinking water treatment). Focus is given to the newest developments in the treatment technologies, such as membrane bioreactors and advance oxidation processes. * Well-structured overview of latest developments in trace determination * Concise and critical compilation of literature published over the last few years * Focuses on new treatment technologies, such as membrane bioreactors and advance oxidation processes
http://books.google.com/books?id=kNPFpMObEn0C&source=gbs_navlinks_s

Ramirez, A.J. et al., Pharmaceuticals and Personal Care Products in the Environment, SETAC, 2009.
Freshwater *Pharmaceuticals in rivers near sewage plants. (Paper cited in LA article and obtained from Dr. Bryan Brooks, a co-author).*
http://web.stcloudstate.edu/aquatictox/Publications/Painter%20ETC_09%20copy.pdf

Repeating History: Pharmaceuticals in the Environment. Gerald T. Ankley U.S. EPA, Bryan W. Brooks, Baylor University, Duane B. Huggett, University Of North Texas, John P. Sumpter, Brunel University (U.K.)
Research and resource investments made to understand and assess endocrine-active chemicals can help scientists to define the ecological risks of pharmaceuticals.
http://pubs.acs.org/doi/pdf/10.1021/es072658j?cookieSet=1

Roberts, A. Lynn , and Bouwer, Edward J. Final Report: Pharmaceuticals and Antiseptics: Occurrence and Fate in Drinking Water, Sewage Treatment Facilities, and Coastal Waters. Johns Hopkins University. National Center for Environmental Research, Project Period: September 1, 2001 through August 31, 2004 (Extended to August 9, 2006).
Prior to initiating this research, there was a paucity of information concerning the occurrence, (eco)toxic risk, and fate of pharmaceuticals and antiseptics in U.S environmental systems. This research project is designed to redress critical aspects of this deficiency by providing an assessment of the prevalence of important pharmaceuticals and antiseptics in drinking water, sewage treatment plant (STP) influent and effluent, and receiving waters.
http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/1061/report/F

Scruggs, Caroline, et al. EDCS in Wastewater: What's the Next Step? Proceedings of the Water Environment Federation, WEFTEC 2004: Session 41 through Session 50, pp. 642-664(23).
"...most EDCs have not been identified and/or studied, analytical methods for many identified EDCs have yet to be developed, and the levels of toxicological significance or impact must be established. Additional work must also be done to determine the potential for (1) interactive toxicological effects in EDC mixtures and (2) the formation of undesirable byproducts through treatment. It is likely that the EPA will not consider regulating EDCs until more research has been completed. Research shows that complete biodegradation of many chemicals of concern can be achieved with adequate SRT and/or HRT in the activated sludge system. When contaminants are persistent or if extremely low effluent concentrations are required, however, higher level removal technology may be needed. Several advanced technologies, such as activated carbon adsorption, ozonation, AOPs, and NF/RO, have successfully removed potential EDCs from water. Most of these technologies, however, are expensive to implement and to operate. Optimization of the activated sludge process could be a less costly option. Issues of by-product formation and EDC additive effects will be important considerations in the design of any treatment strategy.
http://ww2.lafayette.edu/~kneya/endocrine/weftec.pdf

Snyder, S.A., et al. Pharmaceuticals*, Personal Care Products, and Endocrine Disruptors in Water: Implications for the Water Industry*. Environmental Engineers Science 20(5): 449-469, 2003.
Describes PPCPs and endocrine disruptors as being more polar than other compounds, different pH levels: some basic some acidic. Describes treatments that transform PPCP's into a neutralized state. Activated carbon and reverse osmosis can remove EDC and PPCP's as well as trace contaminants.
(PDF included in folder)

Thompson, A ; Griffin, P ; Stuetz, R ; Cartmell, E, *The Fate and Removal of Triclosan during Wastewater Treatment,* Water Environment, January 1, 2005.
This work examines the variation in removal efficiency of Triclosan in wastewater treatment works in the United Kingdom between November 2003 and April 2004. Concentrations of triclosan were measured at set points within three different types of wastewater treatment works: rotating biological contactors, trickling filters, and activated sludge. Overall removal of triclosan through these plants ranged from 58 to 96% (rotating biological contactors), 86 to 97% (trickling filter), and 95 to 98% (activated sludge). Water Environ. Res., 77, 63 (2005).
http://www.highbeam.com/DocPrint.aspx?DocId=1P3:815237081

Weigel S, Berger U, Jensen E, Kallenborn R, Thoresen H, Hu¨hnerfuss H. 2004. Determination of selected pharmaceuticals and caffeine in sewage and seawater from Tromst´o/Norway with emphasis on ibuprofen and its metabolites. Chemosphere 56:583–592

SW Reference in Brooks, et. al. 'Determination of anti-depressants in fish from an effluent-dominated stream'
http://www.sciencedirect.com/

Water Reclamation and Contaminants of Emerging Concern: vi. Perfluorinated Compounds (PFCs)

Perfluorinated Compounds (PFCs) and Human Health Concerns Fact Sheet. Web page of Global Health & Safey Initiative (accessed October 2009).

Perfl uorinated compounds (PFCs) are manmade compounds, based on the element fl uorine, which are widely used to create water and soil repellency in fabrics such as Crypton® and Crypton Green®, Tefl on®,Gore™, Stainmaster®, Scotchgard™, and in nanotech products such as Nano-Tex™ and GreenShield™.
http://www.globalhealthsafety.org/resources/library/2009-04-20PFCs_fact_sheet.pdf

Plumlee, Megan H.; Larabee, Jeannine ; Reinhard, Martin, Perfluorochemicals in water reuse. Chemosphere Volume 72, Issue 10, August (2008) pp. 1541-1547.

Faced with freshwater shortages, water authorities are increasingly utilizing wastewater reclamation to augment supplies. However, concerns over emerging trace contaminants that persist through wastewater treatment need to be addressed to evaluate potential risks. In the present study, perfluorinated surfactant residues were characterized in recycled water from four California wastewater treatment plants that employ tertiary treatment and one that treats primary sewage in a wetland constructed for both treatment and wildlife habitat. Effluent concentrations were compared with surface and groundwater from a creek where recycled water was evaluated as a potential means to augment flow (Upper Silver and Coyote Creeks, San Jose, CA).
http://www.sciencedirect.com/