Fate of Environmental Pollutants

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ABSTRACT: A review of the literature published in 2013 on topics relating to the fate of emerging environmental pollutants during wastewater treatment is presented. This review is divided into the following sections: emerging biological agents, estrogens, metals, nanomaterials, nutrients, persistent organic pollutants, pharmaceuticals and personal care products and herbicide, and trace organic contaminants.

KEYWORDS: emerging contaminants, pharmaceuticals and personal care products, herbicides, nanomaterials, industrial wastewater, estrogens, nutrients, trace organic contaminants, microconstituents, pathogens.

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Persistent Organic Pollutants

Persistent organic pollutants (POPs) are organic substances that have characteristics of persistence in the environment; transboundary movement, or the ability to travel long distances through air and water; toxicity; and bioaccumulation in living things.

Although limited number of organic compounds are assigned as POPs and listed under Stockholm Convention currently, the list is expanding including new candidate POPs. For instance, Horward and Muir (2013) screened 610 chemicals that are not on commercial chemical lists such as U.S. EPA's Inventory Update Rule but may be found as byproducts or impurities in commercial chemicals or are likely transformation products from commercial chemical use for their environmental persistency and bioaccumulative capacity. Among them, 320 chemicals (39 byproducts and impurities, and 281 transformation products) that could be potentially persistent and bioaccumulative were identified (Howard and Muir, 2013).

Current literature on occurrence and fate of polychlorinated, polyfluorinated and polybrominated organic compounds and innovative candidate technologies to treat them in water and wastewater were summarized.

Polychlorinated Compounds. The sorption behaviour of 1,2,4,5-tetrachlorobenzene (TeCB),

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pentachlorobenzene (PeCB) and hexachlorobenzene (HCB) to Aldrich humic acid (AHA) and municipal water resource recovery facilities (WRRFs) influent colloidal organic carbon (COC) was investigated using the gas–stripping technique. The logK_COC coefficients determined for WRRF influent COC were 3.86, 3.89 and 3.19 for TeCB, PeCB and HCB, respectively and did not follow the expected trend (TeCB < PeCB < HCB) based on hydrophobicity predicted by octanol/water partitioning. COC increased the mass transfer of TeCB, PeCB and HCB with the primary effluent to the secondary biological stage by 8.7%, 9.6% and 1.2%, respectively. In addition, COC also increased the solubility of TeCB, PeCB and HCB in the primary effluent by 14.4%, 22.0% and 6.5%, respectively (McPhedran et al., 2013).

The occurrence and removal of two groups of polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) in landfill leachate (LL) treated in three constructed wetland systems (CWs) of different construction and flow regime were investigated. It was confirmed that the major mechanism of PCB and PAH removal in CW systems was adsorption to the bottom sediments (in the SF system) or substrate of the beds (in the SSF systems) as well as adsorption to suspended solids, followed by sedimentation. The compounds characterized by higher octanol/water partition coefficient were more effectively retained in the sediments (Wojciechowska, 2013).

A field study was conducted to determine the occurrence and removal of short chain chlorinated paraffins (SCCPs) during the sewage treatment process in an advanced municipal WRRF in Beijing, China. SCCPs were detected in all sewage water and sludge samples, and 97% of the initial mass loading in raw sewage was found to be associated with suspended matter. After passing through treatment, 0.8% and 72.6% of the initial SCCP mass loading were ultimately found in the effluents and dewatered sludge, respectively, while the remaining 26.6% was biodegraded (Zeng et al., 2013).

Carbon nanofibers grown on the surface of a cordierite honeycomb monolith were tested as catalyst for the ozonation of atrazine (ATZ), bezafibrate, erythromycin, metolachlor, and nonylphenol. The process was evaluated both in laboratory and real conditions. It was shown that the use of carbon nanofibers slightly (by 2%) enhanced the mineralization of the organic pollutants tested compared to single ozonation (Derrouiche et al., 2013).

A study was conducted in order to understand the effects of model quinone compounds and humic acid (HA) on the degradation of 2,4,4’–trichlorobiphenyl (PCB28) by persulfate and the production of SO₄⁻ radical– from persulfate. It was found that quinones and HA can efficiently activate persulfate for the degradation of PCB28. In addition, the results indicated that production of SO₄⁻ radical– from persulfate and quinones was semi-quinone radical– dependent (Fang et al., 2013).

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In a study, a quantitative model for the adsorption of atrazine onto GAC surface was developed using the results of potentiometric titrations and three types of adsorption experiments which have been carried out in order to determine the nature and distribution of the functional groups on the GAC surface. Potentiometric
titrations indicated the existence of at least two different families of chemical groups on the GAC surface, including phenolic– and benzoic–type surface groups. Thermodynamic calculations suggested atrazine adsorption was mainly facilitated on benzoic–type surface groups on GAC (Grive et al., 2013).

A study carried out an economic assessment on treatment of a synthetic wastewater containing wastewater a mixture of five commercial pesticides by a solar photo–Fenton/MBR combined process. As Initial pesticide concentration tested was ranging from 500 mg/L to 50 mg/L, expressed as dissolved organic carbon concentration. The results suggested that the use of an MBR process permits lower photochemical oxidation requirements than other biological treatments, resulting in approximately 20% photo–Fenton cost reduction for highly polluted wastewater. Overall, 30% total cost reduction can be gained treating higher daily volumes depending on the pollution load with the proposed system (Perez et al., 2013).

**Polyfluorinated Compounds.** Perfluorooctane sulfonate (PFOS), a toxic chemical that never breaks down, was added to the Stockholm Convention on POPs and was listed in the Annex B restrictions with many exemptions to continue using PFOS. The occurrence of PFOS in the water system of Bangkok, Thailand, including the Chao Phraya and Bang Pakong Rivers, tap water in industrial zones and residential areas, drinking water, and industrial wastewater was investigated. Seasonal variations in PFOS between dry season and wet season was also monitored for more than 3 years. PFOS was detected in most water samples. The average concentration of PFOS in the Chao Phraya River (urban area) was 1.70 ng/L, whereas lower concentrations were detected in the Bang Pakong River (suburban area), residential tap water, and bottled drinking water, with averages of 0.7, 0.4, and 0.5 ng/L, respectively. Higher concentrations (an average of 25.1 ng/L) were found in the PFOS concentration in industrial tap water, whose sources were from surfacewater near the industrial zones was 25.1 ng/L whereas it was 100.8 ng/ in industrial wastewater. These results indicated that industrial wastewater was one of the major sources of PFOS contamination in the water systems (Boontanon et al., 2013).

Perfluoroalkyl sulfonates (PFASs) and perfluoroalkyl carboxylates (PFACs) were analyzed in sediment samples from the wastewater canal draining the industrial complex of Pancevo, Serbia which includes oil refinery, petrochemical plant, and fertilizer factory. The canal is directly connected to Europe's second largest river, the Danube, which drains its water into the Black Sea. PFOS up to 5.7 ng/g–dry weight (dw) and total perfluorinated compounds (PFCs) up to 6.3 ng/g–dw were detected. Compared to other reports, high levels of PFOS were found, even though PFCs are not used in the industrial production associated with this canal which indicates that PFCs have been transported from other sources (Beskoski et al., 2013).

Bioaccumulation of six kinds of perfluoroalkyl acids (PFAs) in water flea *Daphnia magna* was studied. The uptake rates of PFAs in *D. magna* ranged from 178 to 1338 L/kg.d, and they increased with increasing perfluoroalkyl chain length; the elimination rates ranged from 0.98 to 2.82 d⁻¹. The bioaccumulation factors (BAFs)
of PFAs ranged from 91 to 380 L/kg in wet weight after 25 d exposure; they increased with increasing perfluoroalkyl chain length and had a significant positive correlation with the log$K_{ow}$ of PFAs. This indicated that the hydrophobicity of PFAs plays an important role in their bioaccumulation (Dai et al., 2013).

Several classes of PFCs that are potential precursors to the PFCAs and PFSAs are present in aqueous film–forming foams (AFFF). To assess the persistence of these AFFF–derived precursors, groundwater, soil, and aquifer solids were obtained in 2011 from an unlined firefighter training area at a U.S. Air Force Base where AFFF was regularly used between 1970 and 1990. On a molar basis, precursors accounted for 41–100% of the total concentration of perfluoroalkyl substances (PFASs) in archived AFFF formulations. In the training area, precursors measured by the oxidation assay accounted for an average of 23% and 28% of total PFASs (i.e., precursors and perfluorinated carboxylates and sulfonates) in groundwater and solids samples, respectively. One precursor in AFFF, perfluorohexane sulfonamide amine, was observed on several highly contaminated soil and aquifer solids samples, but no other precursors present in AFFF formulations were detected in any samples at this field site. The fraction of PFASs consisting of perfluorinated carboxylates and sulfonates was greater in groundwater and solid samples than in any archived AFFF formulations, suggesting that much of the mass of precursors released at the site was converted to perfluorinated carboxylates and sulfonates (Houtz et al., 2013).

In the year 2010, effluents from 90 European WRRFs were analyzed for 156 polar organic chemical contaminants. The analyses were complemented by effect–based monitoring approaches aiming at estrogenicity and dioxin–like toxicity analyzed by in vitro reporter gene bioassays, and yeast and diatom culture acute toxicity optical bioassays. Analyses of organic substances were performed by solid–phase extraction (SPE) or liquid–liquid extraction (LLE) followed by liquid chromatography tandem mass spectrometry (LC–MS–MS) or gas chromatography high–resolution mass spectrometry (GC–HRMS). The obtained results show the presence of 125 substances (80% of the target compounds) in European wastewater effluents, in concentrations ranging from low nanograms to milligrams per liter where PFAS is one of them (Loos et al., 2013).

The formation of PFASs from their precursors in waters is of concern. A study investigating the formation of PFASs through biodegradation of precursors in incubation tests showed that indigenous microorganisms in groundwater were able to biodegrade perfluorooctane sulfonamide (FOSA) to yield PFOS. A 42–d incubation test using sources of groundwater recharge showed that PFOS, perfluorooctanoate, and perfluorononanoate were significantly and remarkably ($\geq 1.5$ x) formed from precursors in street runoff through biodegradation, but not in rainwater or wastewater effluent (Murakami et al., 2013).

Levels of seven major PFCAs and three PFSAs were analyzed in sludge from WRRF from Nigeria. Measurements were performed using an analytical
methodology using solid-phase extraction (SPE) and ultra-high performance liquid chromatography tandem mass spectrometry (UHPLC–MS–MS). All sludge samples taken from industrial, domestic and hospital WRRF contained measurable levels of PFASs. Levels of the quantified PFACs and PFASs concentrations ranged from 10 to 597 and 14 to 540 pg/g–dw, respectively. PFACs with carbon chain having 8 fluorinated carbons were detected in the analyzed sewage sludge samples at higher levels compared to carboxylates with less than 8 fluorinated carbon chain. The highest PFOS level was found in a hospital sewage sludge (539.6 pg/g) possibly indicating (minor) release from medical equipment where some are known to contain PFOS (Sindiku et al., 2013).

A nationwide inventory of 13 perfluoroalkyl substances (PFASs) in U.S. biosolids were made via analysis of samples collected by the U.S. Environmental Protection Agency in the 2001 National Sewage Sludge Survey using liquid chromatography tandem mass spectrometry. PFOS (403 ± 127 ng/g–dw) was the most abundant PFAS detected in biosolids composites followed by perfluorooctanoate (PFOA; 34 ± 22 ng/g–dw) and perfluorodecanoate (PFDA; 26 ± 20 ng/g–dw). Mean concentrations in U.S. biosolids of the remaining ten PFASs ranged between 2 and 21 ng/g–dw (Venkatesan and Halden, 2013b).

Environmental occurrence of a chlorinated polyfluorinated ether sulfonate (locally called F–53B, \( \text{C}_8\text{ClF}_{16}\text{O}_4\text{SK} \)) in China was investigated. F–53B was found in high concentrations (43–78 and 65–112 µg/L for the effluent and influent, respectively) in wastewater from the chrome plating industry in the city of Wenzhou, China. F–53B was not successfully removed by the WRRF in place. Consequently, it was detected in surface water that receives the treated wastewater at similar levels to PFOS (ca. 10–50 ng/L) and the concentration decreased with the increasing distance from the wastewater discharge point along the river. Initial data presented here suggest that F–53B is moderately toxic (Zebrafish LC50–96 h 15.5 mg/L) and is as resistant to degradation as PFOS (Wang, Huang et al., 2013).

In order to understand the levels, distribution and sources of PFCs in sediments which is of great significance for the management of aquatic environments, 26 sediment samples were collected from Dianchi Lake in China and ten PFCs compounds were measured. The concentrations of the total PFCs (EPFCs) in the sediments ranged from 0.21 to 2.45 ng/g–dw, with an average value of 0.95 ng/g–dw. PFOS was the most abundant compound among the ten PFCs with the average concentration of 0.33 ng/g–dw, followed by PFOA at 0.21 ng/g–dw. A two-dimensional HCA (hierarchical cluster analysis) heat map was depicted to analyze the spatial variation of individual PFCs compound and the possible origins in the sediments. Three models concluded consistent results that electroplating industry and food packaging process were the two main source categories for PFCs in the sediments (Xu, Tian et al., 2013).

The presence of PFASs in twenty–eight municipal WRRFs from eleven cites in economically developed areas of China were screened. Overall, PFOA and PFOS were dominant in wastewater and sludge, and
were not effectively removed during wastewater treatment. Elevated influent concentration ratios of perfluorobutanoic acid (PFBA) to PFOA and perfluorobutane sulfonate (PFBS) to PFOS in some WRRFs suggested that short chains substitution were adopted in these cities. Cluster analysis showed treatment processes had important impacts on PFASs profiles in effluent and sludge. Average concentration of total PFCAs in influent from each city and its gross domestic product (GDP) had significant positive correlation (Zhang, Zhang et al., 2013).

Polyfluorinated arenes are increasingly used in industry and can be considered emerging contaminants. In a study, it was demonstrated that the heterogeneous catalyst Rh/Al₂O₃ was capable of fully defluorinating and hydrogenating polyfluorinated benzenes in water under mild conditions (1 atm H₂, ambient temperature) with degradation half–lives between 11 and 42 min. Analysis of the degradation rates of the 12 fluorobenzene congeners showed two trends: slower degradation with increasing number of fluorine substituents and increasing degradation rates with increasing number of adjacent fluorine substituents. Besides defluorination and hydrogenation, the scope of the catalyst includes dehalogenation of polychlorinated benzenes, bromobenzene, iodobenzene, and selected mixed dihalobenzenes (Baumgartner et al., 2013).

Under relatively low temperatures of 25–45 degrees C, activated carbon (AC) activated persulfate oxidation of PFOA was evaluated. With presence of AC in PS oxidation, PFOA removal efficiency at 25 °C reached 68.2% with a high defluorination efficiency of 54.9% after 12 h and few intermediates of short–chain perfluorinated carboxylic acids (PFCAs) were found. The removal and defluorination rates with the combined AC/PS system were approximately 12 and 19 times higher than those of the PS–only system, respectively. It was found that activated carbon not only removes PFOA through adsorption, but also activates PS to form sulfate radicals that accelerate the decomposition and mineralization of PFOA (Lee et al., 2013).

In a study by Li, Zhang et al. (2013), three kinds of nanostructured In₂O₃ materials including porous microspheres, nanocubes and nanoplates were obtained by dehydration of the corresponding In(OH)₃ nanostructures at 500 °C for 2h and tested for PFOA decomposition. In₂O₃ nanomaterials showed great photocatalytic activity for PFOA decomposing. The decomposition rates of PFOA by different In₂O₃ materials, i.e. porous microspheres, nanoplates and nanocubes were 74.7, 41.9 and 17.3 times as fast as that by P25 TiO₂, respectively. The In₂O₃ porous microspheres showed the highest activity, by which the half–life of PFOA was shortened to 5.3 min.

A novel method to decompose PFOA in the presence of sunlight and ferric iron (Fe(III)) was demonstrated by Liu et al. (2013). About 97.8 ± 1.7% of 50 µM PFOA decomposed within 28 days into shorter–chain intermediates and fluoride (F⁻), with an overall defluorination extent of 12.7 ± 0.5%. No PFOA was removed under visible light, indicating that UV radiation is required for PFOA decomposition. Proposed process offers a simple and inexpensive remediation strategie for PFOA–contaminated water (Guo et al., 2013c).
The electrochemical mineralization mechanism of environmentally persistent PFOA at a Ce–doped modified porous nanocrystalline PbO₂ film anode was investigated using density functional theory (DFT) simulation and further validated experimentally. The potential energy surface was mapped out for all possible reactions during electrochemical mineralization reaction of PFOA. The hydroxyl radical (center dot OH), O₂ and H₂O took part in the mineralization process and played different roles. The center dot OH initiating process was found to be the main degradation pathway, and the existence of O₂ obviously accelerated the degradation process of PFOA in aqueous solution (Niu et al., 2013).

Zhang, Luo et al. (2013) introduced a mechanochemical method using a planetary ball mill for the treatment of PFC contain waste. Potassium hydroxide (KOH) was identified as the best comilling reagent and nearly complete destruction of both PFOS and PFOA was achieved. The measured water soluble fluoride accounted for most of the organic fluorine. The final products of PFOS after treatment were KF and K₂SO₄. The approach was also successfully applied for the destruction of PFOS and PFOA homologues with different chain lengths (Luo, Zhang et al., 2013).

Polybrominated compounds. In a study conducted by Munschy et al. (2013), levels and congener patterns of HBCDs (hexabromocyclododecanes) and PFCs were determined in filter-feeding molluscs collected in 2008 and 2010 along the coasts of mainland France. alpha-HBCD and PFOS were detected in all samples, revealing widespread contamination of the coastal environment by these emerging contaminants. The spatial distribution of sigma–HBCD concentrations showed higher median levels in samples from the Mediterranean Sea and English Channel respectively, i.e. 0.19 ng/g–ww (wet weight) and 0.08 ng/g–ww, related to high anthropogenic pressure from urban and industrial activities, while the median concentration was 0.05 ng/g–ww in samples from the Atlantic coast. Among PFCs, PFOS was the only compound detected in all samples and PFDA was the second most frequently detected compound (Munschy et al., 2013).

Seyed et al. (2013) determined the levels of polybrominated diphenyl ethers (PBDEs) and Dechloran Plus (DP) in the soil, sediment and atmospheric samples along the stretch of River Ravi in Punjab Province, Pakistan. Average concentrations of Sigma PBDEs in atmosphere, soils and sediments were 36 pg/m³, 40 ng/g and 640 ng/g. BDE–209 was the most abundant PBDE congener, showing that deca-BDE accounts for most of the total PBDE emitted in the environment of Pakistan. Total DP levels were calculated as 88 pg/m³, 0.8 ng/g and 1.9 ng/g in air, soil and sediment samples, respectively (Syed et al., 2013).

PBDE levels in influent, primary effluent, and final effluent collected from diverse treatment processes including four aerated lagoons, two facultative lagoons, four primary treatments, eight secondary biological treatments and two advanced treatments were determined in a study conducted by Kim et al. (2013). Measured concentrations were correlated with seasonal temperature, community sizes, industrial inputs, and operational
conditions. PBDE levels in influent were 21–1000 ng/L (median 190 ng/L). Higher concentrations in influent samples were found during summer, and in WRRFs which treated leachate and higher proportions of industrial wastewater vs. residential wastewater. Final effluent levels ranged between 3 and 270 ng/L (median 12 ng/L). Among all congeners, the sum of BDE–209, –47 and –99 accounted for 79 and 71% of total PBDEs in influent and final effluent, respectively, with BDE–209 having the highest proportion. Median removal efficiencies for all process types exceeded 90% except primary treatment at 70%. PBDE levels and removals were correlated to the levels and removals of conventional parameters that represent wastewater strength, such as chemical oxygen demand and total suspended solids. The role of the primary clarifier was significant (similar to 82% removal) and removal was associated with hydraulic retention time (HRT) and surface loading rate. Best removal of PBDEs was achieved at greater than 2000 mg/L mixed liquor suspended solids longer than 10 h of HRT, and 9 days of solids retention time (Kim et al., 2013a).

About 288 samples including primary sludge (PS), waste biological sludge and treated biosolids from 15 WRRFs in Canada were analyzed to investigate the factors affecting accumulation of PBDEs in sludge and biosolids. Effect of environmental sewershed conditions and operational parameters of WRRFs on the PBDE distribution was also assessed. PBDE concentrations in PS, WBS and treated biosolids were 230–82,000 ng/g, 530–8800 ng/g and 420–6000 ng/g, respectively; BDE–209, –99, and –47 were the predominant congeners. Authors pointed out that concentrations were mainly influenced by industrial input, leachate, and temperature. Several examinations including the measurement of BDE–202 indicated minimal debromination during wastewater treatment. Estimated solids–liquid distribution coefficients were moderately correlated to hydraulic retention time, solids loading rate, mixed liquor suspended solids, solids retention time, and removal of organic solids, indicating that PBDE partitioning to solids can be optimized by WRRFs’ operational conditions. Solids treatment type strongly affected PBDE levels in biosolids: 1.5 times increase after solids digestion, therefore, digestion efficiency could be a potential factor for variability of PBDEs concentration. In contrast, alkaline treatment reduced PBDE concentrations in biosolids (Kim et al., 2013b).

Pharmaceuticals and Personal Care Products (PPCPs) and Herbicides

Kim et al. (2013) analyzed ninety-nine pharmaceuticals and personal care products (PPCPs) in influent, final effluent and biosolids samples from a wastewater treatment plant employing a MBR. In influent wastewater the predominant PPCPs belonged to the analgesic/anti-inflammatory, psychomotor stimulants, and antidiabetics therapeutic categories; in final effluents antibiotics, antihypertensive drugs, and antidiabetics were largely present while in biosolids antibiotics and antifungal/antibacterials were most concentrated. Removal efficiencies of PPCPs by MBR were diverse, ranging from -34 to >99%.
The objective of the study by Nielsen et al. (2013) was to develop technologies that can reduce the content of active pharmaceutical ingredients (APIs) and bacteria from hospital wastewater. The results from the laboratory- and pilot-scale testing showed that efficient removal of the vast majority of APIs could be achieved by a MBR followed by ozone, ozone + hydrogen peroxide or powdered activated carbon (PAC). Chlorine dioxide (ClO\textsubscript{2}) was significantly less effective while MBR + PAC (450 mg/l) was the most efficient technology, and the most cost-efficient technology was MBR + ozone (156 mg O\textsubscript{3}/L applied over 20 min).

Bisphenol-A (BPA) biodegradation was studied in a MBR under aerobic conditions (Seyhi et al., 2013) along with the effects of the initial BPA concentration and initial COD concentration on BPA biodegradation. The degradation process followed a first-order kinetic (more than 98% of BPA was removed) with a kinetic rate constant of 1.134 h\textsuperscript{-1} using an initial BPA concentration of 1.0 mg/L. The kinetic rate constant decreased to 0.611 h\textsuperscript{-1} when the initial BPA concentration increased to 5.0 mg/L while the initial COD concentration (400 and 2,000 mg/L) did not affect the biodegradation kinetic of BPA.

The aim of the study by Bohdziewicz and Kaminska (2013) was to determine the sorption potential of carbon nanotubes (CNTs) to BPA contained in synthetic wastewater whose composition corresponds to biologically treated effluents. Their kinetics study indicated that adsorption of BPA on CNTs proceeded very fast, with the majority of the adsorbate being adsorbed in the first few seconds. The sorption capacity of nanotubes to BPA was the highest for single-walled CNTs.

The work by Huang et al. (2013) described the use of a new and strong complexing agent, ethylenediamine-N,N′-disuccinic acid (EDDS) in the homogeneous Fenton process. The performance of BPA oxidation in an EDDS-driven Fenton reaction was found to be much higher at near neutral or basic pH than at acidic pH. The reduction of Fe(III)-EDDS to Fe(II)-EDDS was found to be a crucial step that governed the formation of hydroxyl radical, mainly responsible for BPA degradation.

The concentrations of nine emerging contaminants, including pharmaceutically active compounds (ibuprofen, IBF; naproxen, NPX; diclofenac, DCF; ketoprofen, KFN) and endocrine disrupting chemicals (triclosan, TCS; BPA; nonylphenol, NP; nonylphenol monoethoxylate, NP1EO; nonylphenol diethoxylate, NP2EO), were determined in wastewater and sludge samples of two WRRFs by Samaras et al. (2013). A significant part of nonylphenols (NPs) and TCS in influent wastewater was bound to the particulate phase, while PhACs and BPA were mainly detected in the aqueous phase. Removal of target compounds during wastewater treatment ranged between 39% (DCF) and 100% (IBF).

The kinetics for reaction between BPA and permanganate was examined over pH range of 5.0-9.9 by Yang, Wen et al. (2013). Reaction kinetics followed the second-order rate law, with the apparent second-order rate constant of 15.1±1.1 M\textsuperscript{-1}s\textsuperscript{-1} at pH 6.0 and 25 °C and the activation energy of 48.7 kJ/mol. The kinetics exhibits pH dependency and the specific rate constants related to
speciation of BPA are $50 \pm 28 \, \text{M}^{-1} \cdot \text{s}^{-1}$, $9.6 \, (\pm 0.6) \times 10^3 \, \text{M}^{-1} \cdot \text{s}^{-1}$, and $1.4 \, (\pm 0.1) \times 10^4 \, \text{M}^{-1} \cdot \text{s}^{-1}$ for BPA, BPA$^-$ and BPA$^{2-}$, respectively.

The performance of an electro-Fenton process with Ti-based mixed metal oxides (Ti/MMO) cathode, a dimensionally stable electrode, was evaluated by Yuan, Gou et al. (2013) for degrading contaminants of emerging concerns in aqueous solutions. BPA (422 µg L$^{-1}$) was completely degraded in an undivided cell using Ti/MMO as the cathode in the presence of 6.9 mg/L Fe$^{2+}$ within 20 min under conditions of pH 4 and 25 mA. This electro-Fenton process was also found to be effective for degrading TCS and ibuprofen even at a high concentration of 5 mg/L.

Several chlorination batch tests were performed by Noutsopoulos et al. (2013) in order to assess the effectiveness of chlorination to remove BPA, TCS, nonylphenol (NP) and its ethoxylates (NP1EO and NP2EO) from secondary effluent. According to the results, an appreciable removal of NP, BPA, and TCS to the order of 60-84% was observed as an effect of moderate chlorination doses. This was not the case for NP1EO and NP2EO as even at high chlorine doses, removal efficiencies were lower (37% for NP1EO and 52% for NP2EO).

The degradation of 30 trace organic contaminants (TrOC) by a white-rot fungus-augmented MBR was investigated by Nguyen et al. (2013). The results show that white-rot fungal enzyme (laccase), coupled with a redox mediator (1-hydroxy benzotriazole, HBT), could degrade TrOC that are resistant to bacterial degradation (e.g. diclofenac, TCS, naproxen and atrazine) but achieved low removal of compounds (e.g. ibuprofen, gemfibrozin and amitriptyline) that are well removed by conventional activated sludge treatment. Overall, the fungus-augmented MBR showed better TrOC removal compared to a system containing conventional activated sludge, and it was observed that continuous mediator dosing to MBR may potentially enhance its performance, although not as effectively as for mediator-enhanced batch laccase systems.

The study by Maeng et al. (2013) investigated the influences of solid retention time (SRT), nitrification, and microbial activity on the attenuation of pharmaceuticals and estrogens and the total estrogenic activity, using identical bench-scale MBRs. Phenacetine, acetaminophen, pentoxifylline, caffeine, bezafibrate, ibuprofen, fenoprofen, 17β-estradiol, and estrone were effectively attenuated even at short SRT (8 d) while the attenuation efficiencies of gemfibrozil, ketoprofen, clofibrate acid, and 17α-ethinylestradiol were dependent upon SRTs (20 and 80 d). Relatively high removal efficiencies were observed for 17β-estradiol and estrone (natural estrogens) compared to 17α-ethinylestradiol (synthetic estrogen) when nitrification was inhibited while carbamazepine (CBZ) was found to be recalcitrant to biological wastewater treatment using MBRs regardless of the change of SRTs and microbial activity.

Pharmaceutical wastewater generated by an antibiotics (penicillin) company was treated by aerobic MBRs and sequencing batch reactors (SBRs) in a study by Lefebvre et al. (2014). Overall, the MBRs achieved better solid removal but the SBRs performed better in regards to the degradation of aromatic compounds, as determined by UV absorbance (UVA).
Benzotriazole (BTri), 4- and 5-tolyltriazole (4-TTri, 5-TTri) were monitored by Herzog et al. (2014) over one year in three WRRFs with a MBR and two conventional activated sludge systems (CAS-E, CAS-M). 5-TTri was removed best (mean removal 80%) in the WRRF mainly by biodegradation followed by BTri (mean removal 45%) and 4-TTri (mean removal 15%) that showed a significant lower elimination. All three WRRF proved a point source for these BTs into the aquatic environment but its impact strongly depended on the upstream water quality within the receiving river system.

Spiramycin removal from wastewater using four NF membranes (NF270, NF90, ESNA1-K1 and ESNA1-LF2-LD) was studied by Zhao, Fan et al. (2013). The results showed that increasing operating pressure resulted in the increase of both permeate flux and spiramycin rejection, but only the flux rate increased with temperature, while the spiramycin rejection decreased. The presence of cations reduced spiramycin rejection, with the strength of influence for the NF270 NF membrane following the order Mg$^{2+}$>Ca$^{2+}$$>$K$^+$. while the presence of anions also resulted in decreased spiramycin rejection, the strength of the effect following the order NO$_3^-$>$Cl^-$>SO$_4^{2-}$ for the NF270 membrane.

Urtiaga et al. (2013) assessed the removal of emerging contaminants from municipal wastewaters using a pilot system that integrated UF, RO, and electrooxidation, which mineralized the RO concentrate. For the majority of the micropolllutants, the UF removal efficiency was less than 20% while excellent removal efficiencies were achieved with the RO treatment. After the RO treatment, electrooxidation of the RO concentrate with boron-doped diamond electrodes reduced the total micropollutant content in the RO concentrate from 149 μg/L to less than 10 μg/L.

An effective, cheap and scalable methodology was introduced by Abdelmoez et al. (2013) to treat oily wastewater containing oil, lubricants, detergents, and solid particles. Their results showed that the turbidity and chemical oxygen demand (COD) values dramatically decreased by using the proposed treatment process, which consisted of coagulation, flocculation, sand filtration, and oxidation followed by sand as well as activated carbon filtration. The COD and turbidity values of the final treated wastewater were reduced by almost 88 and 100%, respectively.

In the study by Rakshita et al. (2013), authors aimed to assess the sorption mechanisms of ciprofloxacin (CIP), an important class of fluoroquinolone antibiotics, with magnetite nanoparticles using a combination of wet chemical and in situ ATR-FTIR spectroscopic measurements. CIP sorption was characterized as a function of pH, CIP concentration, ionic strength, and competing anion such as phosphate (0.1 mM) to cover a broad range of environmentally relevant geochemical conditions. Results indicated a bell-shaped sorption envelop where sorption of CIP on nano-Fe$_3$O$_4$(s) increased from 45% to 80% at pH 3.44-5.97; beyond that sorption gradually decreased to a value of 25% at pH 8.39.

The application of a NF-MBR was investigated for the treatment of two pharmaceutical compounds, cyclophosphamide and CIP (Zaviska et al., 2013). The two
antibiotics were weakly degraded even with acclimated sludge, and only a small fraction of these compounds was retained when the fouling of the membrane increased. However, COD, TSS and color were effectively removed and no unclogging operation was necessary (4 months of operation without chemical cleaning).

The photolytic degradation of norfloxacin, enrofloxacin and CIP, fluoroquinolone antibacterials widely used in human and veterinary medicine, was investigated by Babic et al. (2013) under simulated solar irradiation in different water matrices. The results showed that investigated fluoroquinolones degrade very quickly and photodegradation followed pseudo first order kinetics. In the case of pharmaceutical mixture irradiation, no significant differences in rate constants were observed compared to single-component experiments.

Tewari et al. (2013) collected water samples from five WRRFs, six canals, and in mainstream Chao Phraya River of Bangkok, in three sampling events representing different seasonal flow conditions. Fourteen major pharmaceuticals including acetaminophen, acetylsalicylic acid, atenolol, caffeine, CIP, diclofenac, ibuprofen, mefenamic acid, naproxen, roxithromycin, sulfamethazine, sulfamethoxazole, sulfathiazole and trimethoprim were analyzed. Levels of pharmaceutical residues in WRRF influents on average were the highest for acetylsalicylic acid (4700 ng/L), followed by caffeine (2250 ng/L) and ibuprofen (702 ng/L) while in effluents, the concentration of caffeine was the highest (307 n/L), followed by acetylsalicylic acid (261 ng/L) and mefenamic acid (251 ng/L).

Simulated sunlight experiments and matrix calculations were performed by Wei et al. (2013) to differentiate the photolytic reactivity for each dissociation species of CIP. The results showed that the five dissociation species of CIP do have dissimilar photolytic kinetics and products. Their results implied that for accurate ecological risk assessment of ionizable emerging pollutants, it is necessary to investigate the environmental photochemical behavior of all dissociation species.

The work by Bonvin et al. (2013) investigated the direct photolysis of human metabolites of the antibiotic sulfamethoxazole (SMX). All investigated metabolites, except sulfamethoxazole beta-D-glucuronide were found to be more photostable than SMX under environmentally relevant conditions. Photolytic back-transformation to SMX was observed for 4-nitroso-SMX, indicating that this metabolite may serve as an environmental source of SMX.

Borgman and Chefetz (2013) evaluated the combined effects of biosolids application and irrigation with treated effluents on the mobility of pharmaceutical compounds (PCs) in soil and elucidated the main mechanisms affecting their transport. Column-leaching experiments revealed that application of biosolids generally increased the retardation of PCs, whereas treated effluents increased the mobility of weakly acidic PCs in the biosolids-amended soils. Experiments conducted at environmentally relevant PC concentrations (similar to 1 µg/L) highlight the importance of irreversible sorption as a possible mechanism for low leachability.

Application of mesoporous C- and C, N-codoped TiO$_2$ in the removal of diclofenac from water was studied.
by Buda and Czech (2013). X-ray photoelectron spectroscopy (XPS), confirmed the incorporation of nitrogen and carbon atoms into TiO$_2$ lattice. The synthesized catalysts were effective in the removal of the studied pollutant from water and enabled reduction of the COD (chemical oxygen demand) value of the wastewater by at least 60%.

A benchtop continuous-flow reactor was developed by Carbonaro et al. (2013) for the purpose of studying the activity, inhibition, and deactivation of immobilized TiO$_2$ photocatalysts during water treatment applications. As a demonstration, degradation of four pharmaceutical micropollutants (iopromide, acetaminophen, sulfamethoxazole, and CBZ) was monitored in both a pH-buffered electrolyte solution and a biologically treated wastewater effluent to study the effects of non-target constituents enriched in the latter matrix. Results demonstrated the marked influence of non-target constituents present in complex matrices on long-term photocatalyst activity.

Passive water samplers (diffusive gradients in thin-films for organics, o-DGT) were deployed in the influent and effluent of a typical WRRF by Chen, Zhang et al. (2013); the influent was also sampled with a conventional automatic sampler (Auto) and by grab (Grab) sampling. The comparison between o-DGT and Auto and Grab samplings showed that o-DGT was more efficient in terms of cost, time, and labor. This study demonstrated that o-DGT may be an effective tool for the routine monitoring of antibiotics in wastewaters with respect to studying their occurrence, fate, and behavior in the environment.

Pd nano-crystallite decorated TiO$_2$ nano-tubes (Pd/TNTs) photoelectrode was prepared through electrochemical deposition by Cheng et al. (2013). Results showed that Pd/TNTs photoelectrode exhibited high transient photoinduced current of 0.094 mA/cm$^2$, open circuit photovoltage of -0.339 mV/cm$^2$ and effective photoelectrocatalytic efficiency of 67.7% for the degradation of diclofenac (DCF).

In the work by Collado et al. (2013), batch laboratory reactor data were obtained for the wet oxidation and biodegradation of four phenolic compounds present in a pharmaceutical wastewater and then compared with those collected from industrial continuous stirred tank reactors. For wet oxidation, batch laboratory degradation rates were significantly lower than those found in industrial continuous stirred operation. This behavior was explained by a different distribution of intermediate compounds in lab and industrial treatments, caused by the degree of backmixing and the synergistic effects between phenolic compounds (matrix effects).

A batch fluidized bed bioreactor was used to study the degradation of PCs present in urban wastewaters at their pre-existent concentrations under non-sterile conditions (Cruz-Morato et al., 2013). Complete removal of 7 out of the 10 initially detected PCs was achieved in non-sterile treatment, while only 2 were partially removed and 1 of the PCs analyzed increased its concentration. In addition, Microtox test showed an important reduction of toxicity in the wastewater after the treatment.

A magnetic nanoscaled catalyst cobalt ferrite (CoFe$_2$O$_4$) was successfully prepared and used for the
activation of oxone to generate sulfate radicals for the degradation of diclofenac (Deng et al., 2013). Results demonstrated that CoFe$_2$O$_4$ exhibited the best catalytic performance and almost complete removal of diclofenac was obtained in 15 min. The increase of catalyst and oxone dosage both had the positive effect on the degradation of diclofenac.

The effect of aquatic vegetation (Spyrogira sp. and Zannichellia palustris), light exposure and water quality (secondary-treated wastewater vs. ultrapure water) on the removal efficiency of six antibiotics (sulfonamides and tetracyclines) was studied by Garcia-Rodriguez et al. (2013) in laboratory-scale reactors. After 20 d of treatment, 3-59% of sulfonamides were eliminated in the reactors exposed to light while the removal was about 10% in unplanted reactors in darkness. The elimination of tetracycline (TC) and oxytetracycline (OTC) ranged between 83% and 97% in both planted and unplanted reactors; however, in dark unplanted reactors, OTC was largely removed (88%) while only 15% of TC was eliminated.

In the study by Igos et al. (2013), the environmental impacts of different wastewater treatment options, as a function of several advanced treatments as well as the centralized/decentralized implementation options, were evaluated using Life Cycle Assessment (LCA) methodology. These impacts were then weighted by the average removal rate of pharmaceuticals using a new Eco-efficiency Indicator EFI. The decentralized treatment option revealed no significant improvement on the avoided environmental impact, due to the comparatively small pollutant load coming from the hospital and the uncertainties in the average removal of the decentralized scenarios while when comparing the post-treatment technologies, UV radiation had a lower performance than both ozonation and activated carbon adsorption.

A TiO$_2$-coconut shell powder (TCNSP) composite, prepared by the controlled sol-gel method with a subsequent heat treatment, was investigated as an innovative photocatalytic absorbent for the removal of CBZ by Khraisheh et al. (2013). Authors found that calcinated TCNSP composites had higher CBZ removal efficiency (98%) than pure TiO$_2$ (23%) and coconut shell powder (34%) within a 40-min reaction time. Optimization of the process was obtained by a response surface methodology and a central composite design model, which indicated that the technology was successful in removing CBZ from a solution.

A pilot-scale hospital wastewater treatment plant consisting of a primary clarifier, membrane bioreactor, and five post-treatment technologies including ozone (O$_3$), O$_3$/H$_2$O$_2$, powdered activated carbon (PAC), and low pressure UV light with and without TiO$_2$ was operated to test the elimination efficiencies for 56 micropollutants. The extent of the elimination of the selected micropollutants (pharmaceuticals, metabolites and industrial chemicals) was successfully correlated to physical-chemical properties or molecular structure. By mass loading, 95% of all measured micropollutants in the biologically treated hospital wastewater feeding the post-treatments consisted of iodinated contrast media (ICM) while for the total load of analyzed pharmaceuticals and metabolites excluding
ICM the elimination by zonation, PAC, and UV at the same conditions was 90%, 86%, and 33%, respectively.

Wastewater from a pharmaceutical formulation facility was treated with a biological activated-sludge system followed by ozonation (Lester et al., 2013). Ozone efficiently degraded CBZ: at an O$_3$ dose-to-dissolved organic carbon ratio of 0.55 (O$_3$/DOC), the concentration of CBZ was reduced by >99% while a lower removal rate was observed for Venlafaxine (VLX), which was decreased by 98% at the higher O$_3$/DOC ratio of 0.87. Decreasing the pH of the biologically treated effluent from 7 to 5 significantly increased the ozone degradation rate of CBZ, while decreasing the degradation rate of VLX.

The effects of initial pH, humic acid concentration, and temperature on the removal of tetracycline by anaerobic granular sludge from aqueous solution were investigated by Li, Ji et al. (2013) using the batch adsorption technique. The results showed that the highest removal efficiency of 93% was achieved around pH 3.0 and the removal efficiency at the neutral pH range (pH 6.0-8.0) was about 91.5%. The thermodynamic analysis indicated that the adsorption kinetics followed the pseudo-second-order equation with Langmuir model better fitted than the Freundlich model for the description of the adsorption process.

Cefazolin, one of widely used cephalosporins, was targeted by Li, Wei et al. (2013) to explore its transformation behaviors in chlorination disinfection process. Authors proposed that two kinds of reactions occurred in chlorination system, one was oxidation of thioether-sulfur to sulfoxide and di-sulfoxide, and the other was base-catalyzed electrophilic substitution of alpha-H of amide by chlorine atom. The pH value determined the occurrence of reaction types, and increasing chlorine dose promoted transformation of cefazolin.

Chlorinated nitroaromatic antibiotic chloramphenicol (CAP) is a priority pollutant in wastewaters. A fedbatch bioelectrochemical system (BES) with biocathode with applied voltage of 0.5 V (served as extracellular electron donor) and glucose as intracellular electron donor was applied to reduce CAP to amine product (AMCl$_2$) by Liang et al. (2013). The biocathode BES converted 87.1 ± 4.2% of 32 mg/L CAP in 4 h, and the removal efficiency reached 96.0 ± 0.9% within 24 h; conversely, the removal efficiency of CAP in BES with an abiotic cathode was only 73.0 ± 3.2% after 24 h.

The gamma irradiation-induced degradation of sulfamethazine (SMT) in aqueous solution in the presence of hydrogen peroxide (H$_2$O$_2$) was investigated by Liu and Wang (2013). Their results showed that gamma irradiation was effective for removing SMT in aqueous solution and its degradation conformed to the pseudo first-order kinetics under the applied conditions. When initial H$_2$O$_2$ concentration was in the range of 0-30 mg/L, higher concentration of H$_2$O$_2$ was more effective for the decomposition and mineralization of SMT; however, the removal of total organic carbon (TOC) was not as effective as that of SMT.

The study by Lozano et al. (2013) presented a investigation of Triclocarban (TCC), TCS, and Methyltriclosan (MeTCS) concentrations in the liquid phase (dissolved + particulate) as well as solid phases
within a single, large WRRF. Total TCC and TCS concentrations decreased by >97% with about 79% of TCC and 64% of TCS transferred to the solids. The highest TCC and TCS removal rates from the liquid phase were reached in the primary treatment mainly through sorption and settling of solids.

The coupling of membrane separation and photocatalytic oxidation was studied by Martinez et al. (2013) for the removal of pharmaceutical pollutants. The retention properties of two different membranes (nanofiltration and reverse osmosis) were assessed along with the abatement of concentrated pharmaceuticals of the rejected stream by means of heterogeneous photocatalytic oxidation using TiO$_2$ and Fe$_2$O$_3$/SBA-15 in presence of hydrogen peroxide as photo-Fenton system. Both photocatalytic treatments showed significant removals of pharmaceutical compounds, achieving values between 80 and 100%.

The aim of the paper by Michael et al. (2013) was to critically review the fate and removal of various antibiotics in wastewater treatment, focusing on different processes in view of the current concerns related to the induction of toxic effects in aquatic and terrestrial organisms, and the occurrence of antibiotics that may promote the selection of antibiotic resistance genes and bacteria, as reported in the literature. Authors found that the removal efficiency during wastewater treatment processes varied and was mainly dependent on a combination of antibiotics’ physicochemical properties and the operating conditions of the treatment systems. As a result, the application of alternative techniques including membrane processes, activated carbon adsorption, advanced oxidation processes (AOPs), and combinations of them, which may lead to higher removals, was found to be necessary before the final disposal of the effluents for their reuse for irrigation or groundwater recharge.

The fate and removal of 48 PPCPs during anaerobic digestion of sewage sludge were investigated in four full-scale WRRF by Narumiya et al. (2013). Their results showed changes in $K_d$ values of PPCPs with carboxyl or amino functional groups, probably due to a shift of dissociation equilibrium with the increase in pH. Sulfamethoxazole and trimethoprim were almost completely degraded (>90%); TCS, TCC, and ofloxacin were moderately degraded (around 30-50%); but CBZ was not eliminated.

The research by Ottmar et al. (2013) attempted to evaluate a previously developed model for predicting influent concentrations of prescription pharmaceuticals and understand why some drugs are more accurately predicted than others. It also investigated the impact of demographics on influent drug concentrations in municipal WRRFs. Samples from two WRRFs in the southeastern United States indicated that the model generated concentration estimates that were accurate to within at least one order of magnitude for a diverse set of drug compounds.

A photocatalytically active stainless steel filter (P-SSF) was prepared by Ramasundaram et al. (2013) integrating electrospun TiO$_2$ nanofibers on SSF surface through a hot-press process where a poly(vinylidene fluoride) (PVDF) nanofibers interlayer acted as a binder. By quantifying the photocatalytic oxidation of cimetidine
under ultraviolet radiation and assessing the stability of TiO$_2$ nanofibers integrated on the P-SSF against sonication, the optimum thickness of the TiO$_2$ and PVDF layer was determined.

The main objective of the study by Rivera-Utrilla et al. (2013) was to conduct an exhaustive review of the literature on the presence of pharmaceutical-derived compounds in water and on their removal. The most representative pharmaceutical families found in water were described and related water pollution issues were analyzed. The performances of different water treatment systems in the removal of pharmaceuticals were also summarized.

Comprehensive study on the occurrence and fate of several classes of antimicrobials, including sulfonamides, trimethoprim, fluoroquinolones and macrolides, in Croatians municipal wastewaters was performed by Senta et al. (2013) using an integrated approach, which comprised analysis of both dissolved and particulate fractions. A nation-wide screening showed ubiquitous occurrence of human-use antimicrobials in raw wastewater samples with the total concentrations ranging from 2 to 20 µg/L, while veterinary antimicrobials were typically present in much lower concentrations (<100 ng/L). The percentage of the particulate fraction in raw wastewater varied significantly depending on the type of the antimicrobial and the load of suspended solids.

The study by Subedi et al. (2013) included a nationwide survey of psychoactive pharmaceuticals (i.e., antischizophrenics, anxiolytics, and antidepressants) in sludge from 40 representative WRRFs that receive domestic, industrial, or mixed (domestic plus industrial) wastewaters in Korea. A total of 16 psychoactive pharmaceuticals (0.12-460 ng/g-dw) and nine of their metabolites (0.97-276 ng/g-dw) were determined in sludge. The median concentrations of psychoactive drugs in sludge from domestic WRRFs were 1.2-3.2 times higher than the concentrations found in WRRFs that receive combined domestic and industrial wastewaters.

A new photocatalyst, magnetic TiO$_2$-graphene, was designed and produced by combining sol-gel and assembling processes (Tang, Zhang et al., 2013). Taking advantages of graphene and TiO$_2$, the catalyst exhibited strong light absorption in the visible region and high adsorption capacity to organic pollutants, resulting in almost 100% photocatalytic removal efficiency of typical herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) from water under simulated solar light irradiation.

The degradation of caffeine in different kind of effluents, via photo-Fenton process, was investigated in lab-scale and in a solar pilot plant by Trovo et al. (2013). The treatment conditions (caffeine, Fe$^{2+}$ and H$_2$O$_2$ concentrations) were defined by experimental design. The optimized conditions for each variable, obtained using the response factor (% mineralization), were: 52.0 mg/L caffeine, 10.0 mg/L Fe$^{2+}$ and 42.0 mg/L H$_2$O$_2$ (replaced in kinetic experiments). Although lower mineralization rates were verified for high organic load, under the same operational conditions, less H$_2$O$_2$ was necessary to mineralize the dissolved organic carbon as the initial organic load increases.

The objective of the work by Wang, Wang et al. (2013) was to investigate the effectiveness of ultrasonic
radiation for the degradation of tetracycline. Their results showed that the ultrasonic degradation of tetracycline followed pseudo first-order kinetics. The tetracycline degradation rate is highly pH-dependent and favored at higher pH.

The study by Xiao et al. (2013) investigated the oxidative transformation kinetics of acetaminophen (APAP) by delta-MnO$_2$ under different conditions. APAP was rapidly oxidized by delta-MnO$_2$ with the generation of Mn$^{2+}$. The measured APAP reaction rate considerably increased with an increase in initial delta-MnO$_2$ and APAP concentration, but decreased as pH increased.

In the study by Xu, Sheng et al. (2013), the roles of EPS in the migration and removal of sulfamethazine (SMZ), in activated sludge process were investigated. Their results showed that removal of SMZ was influenced by interaction with EPS and SMZ could be effectively adsorbed on EPS, which accounted for up to 61.8% of total SMZ adsorbed by sludge at the initial adsorption stage and declined to around 35.3% at the subsequent biodegradation stage. The enrichment of SMZ by EPS was beneficial for SMZ removal and acquisition by microbes at the subsequent biodegradation stage.

The study by Yu et al. (2013) reported the absolute rate constants for reaction of diclofenac sodium and model compound (2, 6-dichloraniline) with the two major AO/RP radicals: the hydroxyl radical (center dot OH) and hydrated electron (e$_{aq}^-$). The bimolecular reaction rate constants (M$^{-1}$ s$^{-1}$) for diclofenac for center dot OH was $9.29 \pm 0.11 \times 10^9$, and for e$_{aq}^-$ was $1.53 \pm 0.03 \times 10^9$.

The paper by Zhao, Feng et al. (2013) investigated the effects of selected common chemical species in natural waters (HCO$_3^-$, NO$_3^-$ and humic acids (HA)) on the photodegradation of amoxicillin (AMO) under simulated irradiation using a 300 W xenon lamp. Their results indicated that AMO photodegradation followed pseudo-first-order kinetics. Bicarbonate, as a hydroxyl radical (center dot OH) scavenger, also adversely affected AMO photodegradation.

**Estrogens**

Methods using biological analysis, Xenopus model for thyroid disruption and the medaka model for oestrogenic disruption, were used for assessing endocrine disruption potential of wastewater samples (Castillo et al., 2013). Assays using the genetically modified organisms were conducted on 9 influent and 32 effluent samples. The thyroidal effect of wastewater was either reduced or removed by the treatment plant; no oestrogenic effect was detected in any of the wastewater samples.

A fluidized bed reactor, filled with laccase-based beads, was employed to bioremediate aqueous solutions polluted by endocrine disruptors, octylphenol and nonylphenol (Catapane et al., 2013). The catalytic activity of free and immobilized laccase from Trametes versicolor was characterized as a function of pH, temperature and substrate concentration in the reaction medium. The immobilized laccase exhibited a lower affinity for octylphenol than for nonylphenol, but all the other parameters of applicative interest resulted more significant for octylphenol. The study of cell proliferation with MPP89
cells, a human mesothelioma cell line, and the assay with the YES test indicated the loss of estrogenic activity of the APs solutions after laccase treatment.

Another class of EDCs, dithiocarbamates (DTCs), were examined in the study by Padhye et al. (2013) to evaluate their potential to form nitrosamines, highly carcinogenic chemicals, when in contact with various water and wastewater disinfection oxidants. Their results showed that DTCs can serve as nitrosamine precursors, by release of secondary amines through hydrolysis or through reactions with oxidants. The reactions of DTCs with monochloramine and ozone were found to be particularly problematic in the risk of generating nitrosamines, though all four tested oxidants, including free chlorine and chlorine dioxide, formed nitrosamines.

The efficacy of two rhizobacteria (Sphingobium fuliginis TIK1 and Sphingobium sp. IT4) of Phragmites australis for the sustainable treatment of water polluted with phenolic EDCs was investigated by Toyama et al. (2013). In sequencing batch reactor experiments using Phragmites in association with TIK1 or IT4, both associations repeatedly removed phenolic EDCs from polluted secondary effluent water (BPA, BPS, 4-tert-butylphenol, 4-tert-octylphenol and 4-nonylphenol) from polluted secondary effluent water. The results showed that hydroponic systems using Phragmites-TIK and Phragmites-IT4 associations would be useful for sustainable treatment of polluted waters containing various phenolic EDCs.

In the study by Yost et al. (2013) the distribution of steroid hormones, phytoestrogens, and estrogenic activity was thoroughly characterized within the anaerobic waste lagoon of a typical commercial swine sow operation. The isoflavone metabolite equol was by far the predominant phytoestrogen species, with daidzein, genistein, formononetin, and coumestrol present at lower levels while phytoestrogens were often more abundant than steroidal estrogens, but contributed minimally toward total estrogenic activity. Analytes were significantly elevated in the solid phases of the lagoon; although low observed log K\textsubscript{OC} values suggested enhanced solubility in the aqueous phase, perhaps due to dissolved or colloidal organic carbon.

Garcia et al. (2013) performed comparative, analysis of effluent water quality from model decentralized aerobic and septic on-site wastewater treatment systems and a centralized municipal wastewater treatment plant. Parameters used to assess centralized wastewater treatment plant effluent water quality such as whole effluent toxicity and endocrine active substances appeared useful for water quality assessments of decentralized discharges. Authors concluded that aerobic on-site wastewater treatment systems may represent more robust options than traditional septic systems for on-site wastewater treatment in watersheds with appreciable groundwater - surface water exchange.

Green et al. (2013) studied hydrological models to estimate concentrations of pharmaceutical and natural steroid estrogens in a water stressed catchment in South Australia alongside a UK catchment and to forecast their concentrations in 2050 based on demographic and climate
change predictions. The results showed that despite their differing climates and demographics, modeled concentrations of steroid estrogens in effluents from Australian sewage treatment works and a receiving river were predicted (simulated) to be similar to those observed in the UK and Europe, exceeding the combined estradiol equivalent's predicted no effect concentration for feminization in wild fish. Furthermore, by 2050 a moderate increase in estrogenic contamination and the potential risk to wildlife was predicted with up to a 2-fold rise in concentrations.

A real field water sample was fortified at the part-per-billion level (50 µg/L) with estrone-3-sulfate (E1-3S) before being ozonated (Bourgin et al., 2013). The estrogenic activity of these water samples spiked with E1-3S before and after treatment was assessed by the ER-CALUX assay and was found to decrease significantly after 10 min of ozonation. This methodological strategy demonstrated its suitability and relevancy for revealing unknown compounds generated from water treatment, and permitted to generate new results regarding specifically the impact of ozonation on estrone-3-sulfate.

The study by Mashtare et al. (2013) focused on the difference in anaerobic transformation rates and formation of metabolites from 17 alpha-E2, 17 beta-E2, and E1 under nitrate- and sulfate-reducing conditions. Under both redox conditions, degradation was stereospecific and followed similar trends in half-lives, 17 beta-E2 < 17 alpha-E2 < E1, with degradation considerably slower under sulfate reducing conditions. Results supported the inclusion of isomer-specific behavior and the potential for reversible transformation and interconversion in anaerobic sediments in modeling fate in stream networks and developing risk management strategies.

Qiang et al. (2013) investigated the degradation efficiencies of several typical endocrine-disrupting chemicals (EDCs) during sludge ozonation, including estrone (E1), estriol (E3), 17 alpha-ethynylestradiol (EE2), BPA, and 4-nonylphenol (NP). Results indicated that the EDCs present in activated sludge could be effectively removed by ozone even though the apparent rate constants in sludge were 3-4 orders of magnitude lower than those in water; however, authors noted that the applied ozone dose should be prudently controlled because a low dose may lead to an increase of BPA and NP concentrations in the liquid phase of activated sludge. Furthermore, H2O2 addition or pH adjustment could improve the removal of most studied EDCs, but could exert a negative effect on the more hydrophobic and refractory compound, NP.

The removal of six EDCs, including El, E2, E3, EE2, BPA, and NP, was investigated by Qing et al. (2013) in 20 rural WRRFs using one of the four treatment processes: activated sludge (AS), constructed wetland (CW), stabilization pond (SP), and micro-power biofilm reactor (MP). Results indicated that all the six EDCs were detected in wastewater samples with NP showing a maximum detection frequency (97%) and a maximum influent concentration (5002 ng/L). After biological treatment, the concentrations of E2, E3 and NP decreased remarkably, while E1, EE2 and BPA exhibited varying removal efficiencies that depended on the specific treatment process and sampling season. In general, the
centralized AS process outperformed those decentralized processes (i.e., CW, SP and MP) and a higher removal of El, EE2, NP and BPA in the AS process was observed in summer (>70%) than in winter while among the three decentralized processes, the removal of EDCs in the SP process was limited, especially for El, EE2 and BPA (18-46%) in winter.

Home-made Polar Organic Chemical Integrative Samplers (POCIS) were studied by Vallejo et al. (2013) for passive sampling of 15 EDCs (4 alkylphenols and steroid hormones) in influent and effluent samples of WRRFs as well as up- and downstream of the receiving river water. While the influent concentration of BPA, cisADT, E1, TT, PG, EE2 reached the µg/L level, the rest of the target analytes were determined at ng/L. The analyte concentrations in the effluent never exceed ng/L level except for BPA.

A sequential relative rate technique was used to investigate the effects of water components on the rates of (OH)-O-center dot generation and EE2 degradation in a modified flat plate serpentine reactor, including NO$_3^-$, H$_2$PO$_4^-$, SO$_4^{2-}$, CO$_3^{2-}$, Cl$^-$, Na$^+$, Fe$^{3+}$, dissolved organic matter (DOM) etc. (Wang, Li et al., 2013). The results reflected that NO$_3^-$ and DOM accelerated the photodegradation of EE2 (3.2% and 21.2%, respectively) while Cl$^-$ and Fe$^{3+}$ inhibited that process (5.2% and 3.1%, respectively). A model for the photocatalytic degradation of EE2 was found to be in good agreement with experimental profiles.

To assess the potential risks on this irrigation practice, the degradation kinetics and mechanisms of 17 alpha-estradiol-3-sulfate were systematically investigated in aqueous solutions blended with dairy wastewater by Zheng et al. (2013). Dissipation of the conjugated estrogen was dominated by biodegradation under both aerobic and anaerobic conditions. Under the same incubation conditions, anaerobic degradation rates of 17 alpha-estradiol-3-sulfate were significantly less than aerobic degradation rates, suggesting that this hormone contaminant may accumulate in anaerobic or anoxic environments where the major degradation mechanisms were distinctly different.

**Trace Organic Chemicals**

**Hydrocarbons.** Occurrence of fossil organic carbon in wastewater and its fate in WRRF were investigated by Law et al. (2013). Stable and radiocarbon isotopes (C$^{13}$ and C$^{14}$) were measured throughout the process train in four municipal WRRFs equipped with secondary activated sludge treatment. Isotopic mass balance analyses indicate that 4–14% of influent total organic carbon (TOC) was of fossil origin with concentrations between 6 and 35 mg/L; 88–98% of this was removed from the wastewater. The TOC mass balance analysis suggested that 39–65% of the fossil organic carbon from the influent was incorporated into the activated sludge through adsorption or from cell assimilation while 29–50% is likely transformed to carbon dioxide (CO$_2$) during secondary treatment. The fossil organic carbon fraction in the sludge undergo further biodegradation during anaerobic digestion with a 12% decrease in mass. 1.4–6.3% of the influent TOC consists of both biogenic and fossil carbon.
was estimated to be emitted as fossil CO$_2$ from activated sludge treatment alone. Authors pointed out that current greenhouse gas accounting guidelines, which assume that all CO$_2$ emission from wastewater is biogenic may lead to underestimation of emissions (Law et al., 2013).

Occurrence and removal of six polycyclic aromatic hydrocarbons (PAHs) (fluoranthene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[ghi]perylene and indeno [1,2,3–cd]pyrene) in wastewater were monitored in three WRRFs governing different treatment processes by using ultra performance liquid chromatography–tandem mass spectrometry (UPLC–MS/MS). The total concentrations of six PAHs were 427, 318, and 220 ng/L in the influent of three WRRF, respectively. Among six PAHs, the content of fluoranthene was the highest, accounting for 62–66% of total PAHs. Throughout the wastewater treatment process, different treatment units exhibited different removal efficiencies for six PAHs. Biological treatment stage and aerated grit chamber appeared to be necessary for effective removal of six PAHs. The removal efficiencies of six PAHs were 73–83% at biological treatment units, and 24–56% at the aerated grit stage, respectively. The final sedimentation and disinfection for PAH removal was minor (Wu et al., 2013).

Efficiency of zero–valent magnesium and a protic co–solvent on degradation of oxygenated polycyclic aromatic hydrocarbons compounds, specifically 9–fluorenone, 9,10–anthraquinone, 7,12–benz(a)anthraquinone, and 7H–benz(de)anthracene–7–one was evaluated. At room temperature conditions, greater than 86% degradation efficiency was achieved within 24 h of reaction time for a mixture containing 0.05 g of magnesium and four selected oxygenated aromatic hydrocarbons with 250 mg/L concentrations. It is noted that glacial acetic acid is needed as an activator for the degradation reaction to proceed. Reductive was the possible pathway of transformation (Elie et al., 2013).

Degradation of benzene by coil, bolt, and rod shaped electrodes in a dielectric barrier/packed–bed discharge plasma reactor were systematically investigated by Jiang et al. (2013). The reactor using the coil electrode showed better performance in reducing the dielectric loss in the barrier compared to that using the bolt or rod electrodes. In the case of the coil electrode, both the
benzene degradation efficiency and energy yield were higher than those for the other electrodes, which can be attributed to the increased role of surface mediated reactions. Irrespective of the electrode geometry, the packed–bed discharge plasma was superior to the dielectric barrier discharge plasma in benzene degradation at any specific applied voltage. The main gaseous products of benzene degradation were CO, CO$_2$, H$_2$O, and formic acid. Discharge products such as O$_3$, N$_2$O, N$_2$O$_5$, and HNO$_3$ were also detected in the outlet gas (Jiang et al., 2013).

Sorption of phenanthrene (PHE) by plant–residue derive biochars (PLABs) and animal waste–derived biochars (ANIBs) obtained at two heating treatment temperatures (450 and 600 °C) and their corresponding deashed biochars was investigated. Organic carbon (OC)–normalized distribution coefficients ($K_{oc}$) of PHE by biochars generally increased after deashing, likely due to enhancement of favorable and hydrophobic sorption sites caused by mineral removal. Positive correlation between PHE log $K_{oc}$ by PLABs and bulk polarity combined with negative correlation between PHE log $K_{oc}$ values by ANIBs and surface polarity suggested PLABs and ANIBs have different sorption mechanisms (Sun et al., 2013).

Plumes containing more than one contaminant can be found in sites polluted by gasoline or chlorinated solvents. Yeh et al. (2013) designed an experiment to test degradation of organic compounds in couples. Perchloroethylene, trichloroethylene, cis–1,2–dichloroethylene, methyl–t–butyl–ether, benzene, and toluene were mixed in pairs and degraded by the goethite–catalyzed Fenton–like reaction at neutral pH and low H$_2$O$_2$ doses. Results revealed that the amount of each compound removed in bicontaminant systems was less than that in one–contaminant systems. This decline in removal was related to the reactivity constant ($k_{(\text{HO center dot})}$), initial concentration ($C_0$), and number of double bonds of the compounds. When the $k_{(\text{HO center dot})}$ values of two compounds differed considerably, the one with the larger $k_{(\text{HO center dot})}$ value or the higher $C_0$ reduced or inhibited the Fenton–like reaction of the pollutant with the smaller $k_{(\text{HO center dot})}$ or lower $C_0$. Compounds with few double bonds tended to be less competitive for Fenton–like removal. By adding H$_2$O$_2$ repeatedly, the removal of a compound that is less competitive for the Fenton–like reaction can be recovered (Yeh et al., 2013).

**Phenolics.** Nationwide inventories of alkylphenol surfactants in U.S. sewage sludges (SS) using samples from the U.S. Environmental Protection Agency's 2001 national SS survey showed that nonylphenol (NP) was the most abundant analyte (534 ± 192 mg/kg) in SS composites, followed by its mono– and di–ethoxylates (62.1 ± 28 and 59.5 ± 52 mg/kg, respectively). The mean annual load of NP and its ethoxylates in SS was estimated at 2408–7149 metric tonnes, of which 1204–4289 is applied on U.S. land. NP compounds showed observable loss from SS/soil mixtures (1:2), with mean half–lives ranging from 301 to 495 days. Surfactant levels in U.S. SS ten–times in excess of European regulations, substantial releases to U.S. soils, and prolonged half–lives found under field conditions (Venkatesan and Halden, 2013a).

Liu, Zhang et al. (2013) investigated the occurrence of 14 phenolic compounds (PCs) in the raw,
treated wastewater, dewatered sludge and gas samples from a coking WRRF in China. It was found that 3-cresol was the dominant compound in the raw coking wastewater with a concentration of 183 mg/L, and that chlorophenols and nitrophenols were in the level of µg/L. Phenol was the dominant compound in the gas samples, while 2,4,6-trichlorophenol predominated in the dewatered sludge sample. The anaerobic and aerobic treatment units played key roles in the elimination of chlorophenols and phenols, respectively. Analysis of daily mass flows of PCs in WRRF showed that 89–98% of phenols and 83–89% of nitrophenols were biodegraded, and that 44–69% of chlorophenols were adsorbed to sludge, indicating that the fate of PCs was highly influenced by their biodegradability and physical–chemical property.

The degradation of m-cresol solution using an electrochemical oxidation system with Ti/SnO$_2$–Sb$_2$O$_3$–IrO$_2$ anode for anodic oxidation and porous carbon–nanotube–containing cathode for H$_2$O$_2$ electrogeneration along with Fe$^{3+}$ reduction was studied. The porous cathode made of graphite, carbon nanotube (CNT) and polytetrafluoroethene (PIPE) exhibited a higher catalytic activity toward O$_2$ reduction producing H$_2$O$_2$ and Fe$^{3+}$ reduction for Fe$^{2+}$ regeneration, favoring m-Cresol degradation by electro–Fenton oxidation. Furthermore, the aerobic biological treatment showed that the electrochemical treatment was able to evidently enhance the biodegradability of m-cresol solution (Chu et al., 2013).

Magnetic TiO$_2$ (MT) composites were prepared and applied to decompose phenol, which is one of the listed priority pollutants. The total organic carbon and ring–remaining intermediates of o-DHB, p-DHB and 1,4-BQ in solution were detected during the photodegradation of phenol. The results suggested that recyclable MT composites prepared in this study, which belonged to the category of recyclable green materials, exhibit good photocatalytic activity to degrade phenol so as to possess applicable potential for the degradation of refractory organics in the aqueous solution (Chang and Tseng, 2013).

The electrochemical degradation of o-aminophenol (OAP) in aqueous solution by galvanostatic electrolysis using Ti/SnO$_2$–Sb$_2$O$_3$/PbO$_2$ as anode was investigated. The experimental results showed that the refractory organics in wastewater can be removed by pure electrochemical process. COD removal efficiency of 91.6% was obtained in 70 min at initial pH 11.0 and current density was equal to 50 mA cm$^2$. Addition of a novel catalyst, gamma–Al$_2$O$_3$ supported Ce–doped CuO, improved the efficiency of degradation and COD removal reached to 91.7% in 20 min under mild conditions (Chen, Yu et al., 2013).

Simultaneous oxidation of sulfite and organic pollutants in water using Photo–sulfite reaction as a green advanced oxidation process was studied by Guo, Lou et al. (2013). The photo–sulfite system (UV–Fe(III)–sulfite) efficiently decomposed 2,4,6-trichlorophenol (2,4,6–TCP) and other organic pollutants at all conditions tested. The reactivity of photo–sulfite system was sustained due to the spontaneous switch of photoactive species from Fe(III)–sulfito to Fe(III)–hydroxo complexes with the depletion of sulfite and the decrease in pH. In contrast, in the absence of
light the performance of the Fe(III)–sulfite system was greatly diminished after the consumption of sulfite. The formation of the Fe(III)–sulfito complex is a necessary step for initiating the photo–sulfite reaction. Inhibition of the or more of the oxidation of 2,4,6-TCP and methyl orange (MO) was observed in the presence of ligands that can stabilize one of the reactants: Fe(III), Fe(II), or sulfite (Guo et al., 2013c).

Jing et al. (2013) showed that modification of nano–oxides (e.g., nano–SiO$_2$) with cationic surfactants (e.g., cetlyl pyridinium chloride, CPC) has superior sorptive capacity for the removal of organic contaminants from wastewater. The partitioning of nonpolar naphthalene into coated CPC was induced by hydrophobic effect alone and presenting linear isotherms, while that of polar p–nitrophenol was induced by not only the hydrophobic effect but also the hydrogen–bonding interaction and presenting isotherm nonlinearity (Jing et al., 2013).

UV$_C$, H$_2$O$_2$/UV$_C$, Fenton and photo–Fenton treatment of a nonylphenol polyethoxylate (NP–10) were comparatively studied and acute toxicity of treated solutions on Vibrio fischeri was tested. Formic, acetic and oxalic acids were all identified as the degradation products of NP–10; however, the common carboxylic acid was found to be formic acid for every treatment processes tested. The percent relative inhibition towards Vibrio fischeri increased from 9% to 33% and 24% after 120 min–UV$_C$ and H$_2$O$_2$/UV$_C$ treatment, respectively. Complete NP–10 and 70% of its total organic carbon (TOC) content was removed by the photo–Fenton process, which ensured the fastest removal rates and lowest inhibitory effect (8% after 120 min treatment). The acute toxicity pattern being observed during H$_2$O$_2$/UV$_C$ and photo–Fenton treatment positively correlated with temporal evolution of the identified carboxylic acids, whereas unidentified oxidation products were the most likely origin of the acute toxicity in UV$_C$ photolysis (Karci et al., 2013).

In a study, mesoporous Fe$_2$O$_3$/TiO$_2$ (10, 30, 50, 70 and 90 wt% Fe$_2$O$_3$) photocatalysts were synthesized by sol–gel process and their photocatalytic activity was tested for the degradation of 4–chlorophenol in aqueous medium using sunlight. The activity of the catalysts followed the order: meso–30 wt% Fe$_2$O$_3$/TiO$_2$ > meso–10 wt% Fe$_2$O$_3$/TiO$_2$ > meso–50 wt% Fe$_2$O$_3$/TiO$_2$ > meso–70 Fe$_2$O$_3$/TiO$_2$ > meso–90 wt% Fe$_2$O$_3$/TiO$_2$ > meso–Fe$_2$O$_3$ > meso–TiO$_2$. This order concluded that mesoporous Fe$_2$O$_3$/TiO$_2$ could be an active catalyst for pollutant degradation, as TiO$_2$ with framework Fe$^{3+}$ and photosensitization with free Fe$_2$O$_3$ were involved in the activity (Palanisamy et al., 2013).

Efficiency of an anaerobic sequencing batch reactor (ASBR) fed with increasing phenol concentrations (from 120 to 1200 mg/L) was assessed and the relationship between phenol degradation capacity and the microbial community structure was evaluated. Up to a feeding concentration of 800 mg/L, the initial degradation rate steadily increased with phenol concentration (up to 180 mg/L.d) and the elimination capacity remained relatively constant around 27 mg phenol removed/gVSS.d. Operation at higher concentrations (1200 mg/L) resulted in a still efficient but slower process: the elimination capacity and the initial degradation rate decreased to, respectively, 11
mg phenol removed/gVSS.d and 154 mg/L.d. As revealed by Denaturing Gradient Gel Electrophoresis (DGGE) analysis, ASBR functional performance was essentially driven by specific community traits. Under the highest feeding concentration, the most abundant ribotype probably involved in successful phenol degradation at 1200 mg/L was affiliated to the Anaerolineaceae family (Rosenkranz et al., 2013).

Enzymes have already been extensively applied to degrade various organic pollutants in industrial wastewater. In a study conducted by Li, Lou et al. (2013), Trametes versicolor laccase immobilized on poly(glycidyl methacrylate–methacrylic acid) microspheres was used to remove p–benzenediol from wastewater. The removal efficiency was 88.5%.

In a study by Wang, Mao et al. (2013), Fe₃O₄ nanoparticles were prepared and used to degrade organic pollutants efficiently over a wide pH range, using phenol as a model. Under optimized conditions, the nano–Fe₃O₄ heterogeneous Fenton system could achieve phenol and COD removal efficiencies of 100 and 70% respectively within a wide pH range (2–9).

Oxidation of phenol by a Fenton–like catalyst prepared with schwertmannite through a hydrothermal method was investigated. The study confirmed that schwertmannite had a good catalytic activity in the oxidation of phenol via a center dot OH radical mechanism over a wide pH range. The synthesized schwertmannite also showed a high catalytic ability in the oxidation of phenol in the presence of 0.5 M nitrate, chloride or sulfate anions at initial pH 5.0, indicating its potential application in the treatment of high salinity wastewater. In addition, phenol removal percentage could still reach 98% after schwertmannite was successively used for 12 cycles, indicating the good reusability of this catalyst, although a phase transformation of schwertmannite to goethite was observed (Wang, Song et al., 2013).

Nitrosamines. Formation of N–nitrosodimethylamine (NDMA) during disinfection of wastewater for reuse is a particular concern. Experiments conducted on chloramination and chlorination of secondary wastewater done by Hatt et al. (2013) have confirmed that significant NDMA formation arises only from chlorination, with its concentration varying with test conditions used. A full factor analysis revealed all parameters studied (temperature, pH, monochloramine dose and contact time), both individually and synergistically, to have a statistically significant impact on NDMA formation with contact time being the most important. At raw water temperatures below 10 °C, the NDMA concentration can be minimized to below the 10 ng/L threshold by not exceeding a monochloramine dose of 2 mg/L as Cl₂. However, at higher water temperatures other measures are required to suppress NDMA formation, such as reducing the contact time (which could prove impractical in most applications) or maintaining a pH below 6 (Hatt et al., 2013).

Occurrence of N–nitrosamines in WRRFs, the formation potential of N–nitrosamines on chloramination (FPNH₂Cl) during wastewater treatment, and the efficiency of FPNH₂Cl reduction by biological treatment were investigated. In addition, the residual FPNH₂Cl in the final discharge was studied. The efficiencies of removal of N–
nitrosamines ranged from 35 to 94% (WRRF O; residential area), from 58 to 98% (WRRF E; industrial area), and from 58% to > 99% (WRRF N; industrial area). In WRRF O, the rates of production of NDMA (42%) and NDBA (58%) were the highest. In WRRF E, only NDBA (34%) was produced. In WRRF N, NPYR and NPIP (both > 99%) were produced. NDMA FPNH2Cl values were very high in influent in all WRRFs. The efficiencies of removal of N–nitrosamine FPNH2Cl during biological treatment ranged from 20% to > 99%. Residual N–nitrosamine FPNH2Cl ranged from 2 to 22 ng/L. Thus, the authors concluded that N–nitrosamines could be produced in water purification or reclamation plants using discharge from WRRF (Yoon, Nakada et al., 2013).

Homme and Sharp (2013) showed that bacterial strain *Rhodococcus jostii* RHA1 can biotransform N–nitrosodiethylamine (NDEA), N–nitrosodi–n–propylamine (NDPA), N–nitrosopyrrolidine (NPYR), and possibly N–nitrosomorpholine (NMOR) in addition to N–nitrosodimethylamine (NDMA). Growth of cells on propane as the sole carbon source greatly enhanced degradation rates when contrasted with cells grown on complex organics which verified that propane monoxygenase involves in the biotransformation along with the genetics experiments. Propane–induced rates in order of fastest to slowest were NDMA > NDEA > NDPA > NPYR > NMOR at concentrations <2000 µg/L. Removal rates for linear functional groups scaled inversely with mass and cyclic nitrosamines were more recalcitrant than linear nitrosamines. Controls demonstrated significant NDEA and NDPA losses independent of biomass, suggesting abiotic processes may play a role in attenuation of these two compounds under experimental conditions tested (Homme and Sharp, 2013).

The attenuation of bulk organic matter and trace organic contaminants (TOrCs) was evaluated for various aquifer recharge and recovery (ARR)–ozone (O3) hybrid treatment process combinations using soil–batch reactor and bench–scale ozonation experiments as a proof of concept prior to pilot and/or field studies. NDMA was eliminated below the method detection limit (<5 ng/L) both during ARR treatment alone and the ARR–ozone hybrid (Yoon, Drewes et al., 2013).

**Explosives.** A study showed that aggressive TAML activator with peroxides boosts the effectiveness of the known surfactant/base promoted breakdown of 2,4,6–trinitrotoluene (TNT) and transforms the surfactant induced nondestructive binding of base to 1,3,5–trinitrobenzene (TNB) into an extensive multistep degradation process. Treatment of basic cationic surfactant solutions of either TNT or TNB with TAML/peroxide (hydrogen peroxide and tert–butylhydroperoxide, TBHP) gave complete pollutant removal for both in less than 1 h with above 75% of the nitrogen and above 20% of the carbon converted to nitrite/nitrate and formate, respectively (Kundu et al., 2013).

A novel highly photocatalytic graphene–ZnO–Au nanocomposites (G–ZnO–Au NCs) has been developed by Roy et al. (2013) and used to reduce nitrobenzene. About 97.8% of nitrobenzene was reduced to aniline during a reaction course of 140 min was achieved. The efficiency of G–ZnO–Au NCs is 3.5– and 4.5–fold higher than those provided by commercial TiO2 and ZnO NSs, respectively.
The result also revealed that the reduction of NB to aniline was through nitrosobenzene to phenylhydroxylamine in the photoelectrocatalytic reaction, while via nitrosobenzene directly in the photocatalytic reaction. G–ZnO–Au NC photocatalyst holds great potential in removal of organic pollutants like nitrobenzene and in the production of aniline (Roy et al., 2013).

**Acidic compounds.** Misiti, Tandukar et al. (2013) measure naphthenic acids (NAs) in crude oil, desalter brine, influent, activated sludge mixed liquor and effluent refinery samples received from six United States refineries. The total acid number (TAN) of the six crudes tested ranged from 0.12 to 1.5 mg KOH/g crude oil and correlated to the total NA concentration in the crudes. The total NA concentration in the desalter brine, influent, activated sludge mixed liquor and effluent samples ranged from 4.2 to 40.4, 4.5 to 16.6, 9.6 to 140.3 and 2.8 to 11.6 mg NA/L, respectively. The NAs in all wastewater streams accounted for less than 16% of the total COD, indicating that many other organic compounds are present and that NAs are a minor component in refinery wastewaters.

Susceptibility tests showed that none of the activated sludge heterotrophic microcosms was completely inhibited by NAs up to 400 mg/L. Growth inhibition ranging from 10 to 59% was observed in all microcosms at and above 100 mg NA/L. Throughout a 90–day incubation period, the total NA concentration decreased by 33 and 51% in PAC–free and PAC–containing mixed liquor microcosms, respectively. The lower molecular weight fraction of NAs was preferentially degraded in both mixed liquors. The persistence of the residual, higher molecular weight NAs is likely a combination of molecular recalcitrance and decreased bioavailability when chronically–sorbed to the biomass and/or PAC (Misiti, Tezel et al., 2013).

Electro–Fenton (EF) oxidation of salicylic acid (SA) from an aqueous solution was studied in a continuous stirred tank reactor with the purpose of optimizing the process parameters on a laboratory scale. In this study, electrolytic reactions carried out for 100 mg/L of SA solution, the parameters of catalyst concentration, pH, voltage, flow rate (residence time), and electrode spacing were varied. A maximum of 70% oxidation was obtained at an initial Fe²⁺ concentration of 5 mg/L, pH of 2.5, voltage of 2.5 V, flow rate of 10 mL/min, and electrode spacing of 3 cm, after 10 h of electrolysis (George et al., 2013).

In a study by Gu et al. (2013), a sewage sludge derived porous carbon (SC), which was prepared by physicochemical activation and carbonization (600 °C), was applied for the adsorption and degradation of 1–diazo–2–naphthol–4–sulfonic acid (1,2,4–Acid) in the presence of H₂O₂ and the performance was compared to that of pure Fe₃O₄ magnetic nanoparticles (MNPs). Experiments revealed that SC had a higher adsorption capacity and degradation efficiency of 1,2,4–Acid than bare Fe₃O₄. The subsequent degradation experiments were conducted at conditions (pH 5.0 in the presence of 15 mM H₂O₂) with regard to 1,2,4–Acid degradation efficiency and metal ions leach. The 120 min's treatment in SC/H₂O₂ system achieved 94% of 1,2,4–Acid (from 150 mg/L after adsorption equilibrium to 9 mg/L) and 48.1% TOC...
reduction, far higher than the efficiency of 46% and 24.3% by using Fe$_3$O$_4$ MNP (Gu et al., 2013).

A process consisted of a zero–valent iron (Fe$^0$) column followed by a biologically active carbon (BAC) column that were efficient in degrading tri- and di–HAAs, and mono- and di–HAAs, respectively was developed by Tang, Wang et al. (2013). The process tested to remove trichloroacetic acid (TCAA). An empty bed contact time of 10 min achieved nearly complete removal of 1.2 µM TCAA and its subsequent products, dichloroacetic acid (DCAA) and monochloroacetic acid (MCAA). HAA removal was a result of chemical dehalogenation and biodegradation rather than physical adsorption. Preliminary kinetic analyses were conducted and the pseudo–first–order rate constants were estimated at ambient conditions for Fe reduction of TCAA and biodegradation of DCAA and MCAA by SAC.

**Siloxanes.** The fate and behavior of cyclic volatile methyl-siloxanes (cVMS) octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6) in the environment were reviewed by Wang, Norwood et al. (2013). They evaluated cVMS usage data and patterns, physico–chemical properties, toxicology, partitioning and degradation, methods of detection, and concentrations. The use of cVMS as an intermediate in the formation of silicone polymers, personal care and household products has resulted in their widespread environmental exposure; they have been detected in biogas, air, water, soil, biosolid, sediment, and biota samples. Modeled and experimental results suggest that cVMS may be subject to long–range atmospheric transport, but have low potential to contaminate the Arctic. For D4 and D5, there was no evidence of trophic biomagnification in aquatic food webs, while some aquatic organisms demonstrated a high degree of bioconcentration and bioaccumulation. High concentrations of cVMS observed in indoor air and biosolids resulted from point sources. Concentrations of cVMS in water, sediment, and soil were all below their no–observed–effect–concentrations.

The occurrence and fate of 5 cyclic (D3 to D7) and 12 linear (L3 to L14) siloxanes in raw and treated wastewater (both particulate and dissolved phases) as well as in sludge from a WRRF in Athens, Greece were investigated. Cyclic and linear siloxanes (except for L3) were detected in all influent wastewater and sludge samples at mean concentrations of (sum of 17 siloxanes) 20 µg/L and 75 mg/kg, respectively. The predominant compounds in wastewater were L11 (24% of the total siloxane concentration), L10 (16%), and D5 (13%), and in sludge were D5 (20%) and L10 (15%). For 10 of the 16 compounds detected in influents, the removal efficiency was higher than 80%. Sorption to sludge and biodegradation and/or volatilization losses are important factors that affect the fate of siloxanes in WRRFs. The mean total mass of siloxanes that enter into the WRRF via influent was 15.1 kg/day, and the mean total mass released into the environment via effluent was 2.67 kg/day (Bletsou et al., 2013).

In a study, occurrence of three cyclic volatile methylsioxanes (cVMS) octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and
dodecamethylcyclohexasiloxane (D6) in environmental compartments impacted by wastewater effluent discharges was evaluated in the samples taken from eleven WRRFs, representative of those found in Southern Ontario and Southern Quebec, Canada. In addition, receiving water and sediment impacted by WRRF effluents, and biosolid–amended soil from agricultural fields were also analyzed for a preliminary evaluation of the environmental exposure of cVMS in media impacted by wastewater effluent and solids. Concentrations of D4, D5, and D6 in influents to the 11 WRRFs were in the range 0.282–6.69 µg/L, 7.75–135 µg/L, and 1.53–26.9 µg/L, respectively. In general, wastewater treatment showed cVMS removal rates of greater than 92%, regardless of treatment type. The D4, D5, and D6 concentration ranges in effluent were <0.009–0.045 µg/L, <0.027–1.56 µg/L, and <0.022–0.093 µg/L, respectively. The concentrations in receiving water influenced by effluent, were lower compared to those in effluent in most cases, with the ranges <0.009–0.023 µg/L, <0.027–1.48 µg/L, and <0.022–0.151 µg/L for D4, D5, and D6, respectively. Sediment concentrations ranged from <0.003–0.049 µg/g–dw, and 0.011–5.84 µg/g–dw, and 0.004–0.371 µg/g–dw for D4, D5, and D6, respectively. The concentrations in biosolid–amended soil, having values of <0.008–0.017 µg/g–dw, <0.007–0.221 µg/g–dw, and <0.009–0.711 µg/g–dw for D4, D5, and D6, respectively, were lower than those in sediment impacted by wastewater effluent in most cases. In comparison with the no–observed–effected concentrations (NOEC) and IC50 (concentration that causes 50% inhibition of the response) values, the potential risks to aquatic, sediment-dwelling, and terrestrial organisms from these reported concentrations are low (Wang, Steer et al., 2013).

In another study, the occurrence and fate of four cyclic and two linear volatile siloxanes in a municipal WWRF, Beijing City, China were studied. Aqueous and sludge samples were analyzed by solid–phase microextraction (SPME) coupled with gas chromatography mass spectrometry (GC MS). In the studied WRFF, four cyclic analogs (D3–D6) had significantly higher concentrations and frequencies than the two linear analogs [Octamethyltrisiloxane (L3) and Decamethyldetrasiloxane (L4)], with inputs into the WRRF ranging from 78.2 to 387.7 kg/year. Removal efficiencies of volatile cyclic siloxanes in two parallel secondary treatment processes ranged from 59.3 to 92.7%. For volatile cyclic siloxanes, relative fractions of mass loss by adsorption to sludge ranged from 8.3 to 53.0%, and their adsorption capacities were significantly affected by the dissolved organic matter. Besides adsorption, they were eliminated mainly in anaerobic units (44.4–84.3%). Through in vitro biodegradation experiments, we concluded that in the anaerobic compartments, Hexamethylcyclotrisiloxane (D3) and D6 were eliminated mostly by volatilization, while D4 and D5 may be eliminated by both volatilization and degradation. Furthermore, microbial hydrolysis was identified as one of the main degradation pathways for D4 and D5 in anaerobic compartments (Xu, Shi et al., 2013).

In a study by Ducom et al. (2013), accelerated degradation tests were performed on polydimethylsiloxane (PDMS) fluids in aqueous solutions and in extreme chemical conditions (pH 2–4 and 9–2). Results confirmed
that silicones can be degraded by hydrolysis. Higher degradation levels were achieved in very acidic and alkaline conditions. Degradation products were polar siloxanols. In alkaline conditions, the counterion was found to have a strong influence on degradation level. Degradation kinetic studies (46 days) were also performed at different pH values. Supposing zeroth–order kinetics, degradation rate constants at 24 °C were estimated to 0.28 mgSi/L.d in NaOH solution (pH 12), 0.07 mgSi/L.d in HCl solution (pH 2) and 0.002 mgSi/L.d in demineralized water (pH 6) (Ducom et al., 2013).

**Nanomaterials**

Engineered nanomaterials (ENMs) already occur in sewage and wastewater biosolids due to their release from commercial products (Westerhoff et al., 2013). Increasing levels and diversity of nanomaterials may enter sewage and WRRFs in the future as they are released from products containing nanomaterials (e. g., coatings) embedded in products, or from industrial processes that use nanomaterials (e. g., polishing). Some metallic nanomaterials may dissolve (e. g., silver-, zinc-, or copper-based) or biodegrade (e. g., fullerenes) in wastewater, and subsequently sorb to settable biomass, precipitate as inorganic solids, or form stable aqueous complexes. Nanomaterials themselves sorb onto bacterial biomass in WRRFs, leading to their removal from water, but accumulation in biosolids that are disposed to land surface spreading fields, landfills, or incineration where their fate needs to be further considered. Because of the dense biological communities in WRRF unit processes, under typical conditions, >90% of the nanomaterials may attach to biomass, which is removed within the WRRF. Additional research is needed to be able to monitor the transformation and removal of nanomaterials throughout WRRFs and biosolids treatment to assure they are not released into the environment where they may pose human or ecological risks.

Hendren et al. (2013) provided a critical review of traditional and emerging exposure modeling approaches to highlight the challenges that scientists and decision-makers face when developing environmental exposure and risk assessments for nanomaterials. Authors found that accounting for nanospecific properties, overcoming data gaps, realizing model limitations, and handling uncertainty were key to developing informative and reliable environmental exposure and risk assessments for engineered nanomaterials. They also found methods suited to recognizing and addressing significant uncertainty to be most appropriate for near-term environmental exposure modeling, given the current state of information and the current insufficiency of established deterministic models to address environmental exposure to engineered nanomaterials.

To understand the relative impact of humic (HA) and fulvic fraction of NOM on the stability and mobility of silver nanoparticles (AgNPs), a combination of dynamic light scattering and quartz crystal microgravimetry with dissipation monitoring was used by Furman et al. (2013). Authors found that in the absence of unbound NOM, (1) surface modification on either AgNP or silica substrate by different NOM fractions could lead to substantial changes...
in the extent and kinetics of AgNP aggregation and deposition, and (2) HA has a greater capability to enhance the transport of AgNPs by reducing their aggregation and deposition. With unbound NOM, HA competed more successfully for binding sites on the substrate under electrostatically favorable conditions and formed a steric layer to prevent subsequent deposition of AgNPs.

Time-resolved dynamic light scattering was employed by He et al. (2013) to measure the aggregation kinetics of AgNPs over a range of monovalent electrolyte (NaCl) concentrations. An aggregation dissolution model, in which the proportion of accessible reactive sites on primary particles as well as the aggregate size and 131 were assumed to be key determinants of reactivity, was found to provide an excellent description of the decline of normalized rate of dissolution of AgNPs during aggregation for different NaCl concentrations. The model also provided fundamental insights into the factors accounting for the observed change in rate of dissolution of AgNPs on injection into seawater thereby facilitating improved prediction of the likely toxicity of AgNPs in the marine environment.

Kaegi et al. (2013) conducted experiments addressing the behavior of Ag-NP in sewers and in WRRF by spiking Ag-NP to a 5 km long main trunk sewer and collecting 40 wastewater samples after 500 m, 2400 m and 5000 m each according to the expected travel times of the Ag-NP. Mass closure of the Ag derived by multiplying the measured Ag concentrations times the volumetric flow rates indicated an efficient transport of the Ag-NP without substantial losses to the sewer biofilm. Ag-NP reacted with raw wastewater in batch experiments were sulfidized to roughly 15% after 5 h reaction time as revealed by X-ray absorption spectroscopy (XAS). Authors concluded that Ag-NP discharged to the wastewater stream may become sulfidized to various degrees in the sewer system and can be efficiently transported to the WRRF where very high removal efficiencies may divert most of the Ag-NP mass flow to the digester and only a small fraction of the Ag may be released to surface waters.

Levard et al. (2013) focused on the dissolution behavior of AgNPs in chloride-containing systems and also investigates the effect of chloride on the growth inhibition of E.coli (ATCC strain 33876) caused by Ag toxicity. Their results suggested that the kinetics of dissolution were strongly dependent on the Cl/Ag ratio and can be interpreted using the thermodynamically expected speciation of Ag in the presence of chloride. They also showed that the toxicity of AgNPs to E.coli at various Cl- concentrations was governed by the amount, of dissolved AgClx(x-1)- species suggesting an ion effect rather than a nanoparticle effect.

Li, Hartmann et al. (2013) analyzed the field-collected samples from nine municipal WRRFs to evaluate the reduction in AgNPs by mechanical and biological treatments in sequence in WRRFs. The AgNPs concentrations in influent were all low (<1.5 µg/L) and decreased (average removal efficiency of similar to 35%) significantly after mechanical treatment, indicating that the mechanical treatment contributed to the AgNPs removal. Afterward, more than 72% of the remaining AgNPs in the semi treated wastewater (i.e., wastewater after mechanical
treatment) were reduced by biological treatment. Together, these processes reduced 95% of the AgNPs that entered WRRFs, which resulted in low concentration of AgNPs in the effluents (<12 ng/L).

Park et al. (2013) investigated the removal of engineered NPs (AgNPs, TiO$_2$NPs, and SiO$_2$NPs) using activated sludge by evaluating the effects of several important factors of the NPs, including physicochemical properties, contact time between NPs and activated sludge, aquatic chemistry of sewage, and the presence of extracellular polymeric substances (EPS) in the activated sludge. For all three types of NPs tested, a considerable amount of NPs were removed after exposure to activated sludge in a time-dependent manner; nevertheless, the removal efficiencies depended on the type of NPs and seemed to be affected by the NP stability relative to the hydrodynamic diameter (HDD) and zeta potential. In addition, the presences of both ionic compounds and EPS significantly enhanced the NP removal efficiency, indicating that the instability of the NPs resulting from the ionic strength in sewage and entrapment of NP by EPS played an important role in NP removal by activated sludge.

Yuan, Chen et al. (2013) investigated the dissolution, aggregation, and reaction kinetics of AgNPs with the three types of water disinfectants (ultraviolet, sodium hypochlorite, and ozone) under the different conditions of pH, ionic strength, or humic acid (HA). The physicochemical changes of AgNPs were measured by using UV-Vis spectroscopy, transmission electron microscopy, and inductively coupled plasma optical emission spectrometer. The results showed that when AgNPs contacted the disinfectants, oxidative dissolution was the primary reaction while the reaction kinetics studies revealed that the reaction rate of AgNPs with disinfectants was significantly influenced by different disinfectants along with different pH and the presence of sodium nitrate and HA.

The extent and mechanism of sulfidation of ZnO NPs were investigated by Ma et al. (2013), and the properties of resulting products were characterized. Synchrotron X-ray absorption spectroscopy and X-ray diffraction analysis revealed that transformation of ZnO to ZnS occurs readily at ambient temperature in the presence of inorganic sulfide. The extent of sulfidation depends on sulfide concentration, and close to 100% conversion can be obtained in 5 days given sufficient addition of sulfide. Sulfidation also led to NP aggregation and a decrease of surface charge which suggested that sulfidation of ZnO NPs alters the behavior, fate, and toxicity of ZnO NPs in the environment.

Bolyard et al. (2013) sought to understand the behavior of engineered nanoparticles in landfill leachate by examining the interactions between nanoparticles and leachate components. The primary foci of their study were the effects of ZnO, TiO$_2$, and Ag nanoparticles on biological landfill processes and the form of Zn, Ti, and Ag in leachate following the addition of nanoparticles. Coated nanoparticles did not affect biological processes when added to leachate; five-day biochemical oxygen demand and biochemical methane potential results were not statistically different when exposed to nanoparticles,
presumably due to the low concentration of dissolved free ionic forms of the associated metals resulting from the interaction with leachate components.

The removal of uncoated ZnO nanoparticles (ZnO NPs) during simulated wastewater treatment processes and its impact on treatment performance were examined by Hou et al. (2013). They found that simulated primary clarification removed the majority (about 70%) of the dosed ZnO NPs while during simulated sequencing batch reactor (SBR) processes, ZnO NPs were completely removed in each cycle throughout the 11-day experimental duration. Continuous input of ZnO NPs into the wastewater (at concentrations up to 5 mg/L) did not reduce chemical oxygen demand (COD) removal while NH$_4^+$-N removal was reduced at a dosing concentration of 5 mg/L ZnO NPs per cycle.

Chowdhury et al. (2013) studied the aggregation kinetics and stability of graphene oxide (GO) using time-resolved dynamic light scattering over a wide range of aquatic chemistries (pH, salt types (NaCl, MgCl$_2$, CaCl$_2$), ionic strength) relevant to natural and engineered systems. Although pH did not have a notable influence on GO stability from pH 4 to 10, salt type and ionic strength had significant effects on GO stability due to electrical double layer compression, similar to other colloidal particles. It was found that the natural organic matter significantly improved the stability of GO in water primarily due to steric repulsion while long-term stability studies demonstrated that GO was highly stable in both natural and synthetic surface waters; while GO remained stable in synthetic influent wastewater, effluent wastewater collected from a treatment plant rapidly destabilized GO, indicating GO will settle out during the wastewater treatment process and likely accumulate in biosolids and sludge.

Khan et al. (2013) evaluated the influence of organic matter type and concentration in landfill-relevant conditions on SWNT transport through a packed-bed of mixed municipal solid waste collectors. Results indicated that SWNT transport may be significant in mature waste environments, with mobility decreasing with decreasing humic acid concentration. SWNT mobility in the presence of acetic acid was inhibited, suggesting their mobility in young waste environments may be small. SWNTs also exhibited collector media-dependent transport, with greatest transport in glass and least in paper.

To better assess the potential risk of ENMs to the environment via input through WRRF effluents, a review by Neale et al. (2013) considered ENM detection methods, fate in WRRFs and potential effects on biota exposed to wastewater associated ENMs. Characterising ENMs in complex matrices presented many challenges, especially at low concentrations. Combining separation methods with techniques to assess particle size and chemical composition appeared to be the most suitable approach for wastewater.

**Metals**

The removal performance of heavy metals, Be, Sc, V, Cr, Mn, Co, Ni, Cu, Zn, As, Mo, Cd, Ba, Sn, Sb, Pb and U, by two experimental full-scale membrane bioreactors (microfiltration and ultrafiltration) and the influence of activated sludge TSS concentration were studied by Arevalo et al. (2013) under real operational
conditions. Removal efficiencies up to 80% were obtained regardless of whether microfiltration or ultrafiltration membranes were used, except for As, Mo and Sb. Authors found that the removal yields of different heavy metals can be strengthened by increasing the activated sludge TSS concentration, mainly at concentrations above 10 g/L.

The study by Awual et al. (2013) aimed to develop a highly selective Lewis base adsorbent to investigate the selective sorption and recovery of Eu(III) and Sm(III) from wastewater. The oxygen and nitrogen donor atoms containing Lewis base N-methyl-N-phenyl-1,10-phenanthroline-2-carboxamide (MePhPTA) ligand was synthesized and subsequently an adsorbent was prepared by direct immobilization onto mesoporous silica. Their results suggested that hybrid Lewis base adsorbent has a good prospect of promising applications for separation/sorption of lanthanide ions from effluents.

Jackson et al. (2013) evaluated the removal of mercury from wastewater using chemical reduction and air stripping with a full-scale treatment system. Their results indicated that chemical reduction coupled with air stripping can effectively treat large volumes of water to emerging part-per-trillion regulatory standards for mercury.

Pasakarnis et al. (2013) evaluated the reduction of Hg(II) by magnetites with varying Fe(II) content in both the absence and presence of chloride. In the absence of chloride, reduction of Hg(II) to Hg(0) was observed over a range of magnetite stoichiometries (0.29 < x < 0.50) in purged headspace reactors and unpurged low headspace reactors. In the presence of chloride, however, X-ray absorption near edge spectroscopy indicated the formation of a metastable Hg(I) calomel species (Hg₂Cl₃) from the reduction of Hg(II).

Investigations were undertaken by Jayaranjan and Annachhatre (2013) to utilize flue gas desulfurization (FGD) gypsum for the treatment of leachate from the coal ash (CA) dump sites. Leaching tests of coal bottom ash (CBA) carried out at acidic pH revealed the existence of several heavy metals such as Cd, Cr, Hg, Pb, Mn, Cu, Ni and Zn. Sulfide rich effluent from the sulfate reduction process was used to precipitate heavy metals as metal sulfides from CBA leachate with removal efficiencies ranging from 40 to 100%.

Kamei-Ishikawa et al. (2013) studied the fate of stable strontium (Sr) in the sewage treatment process as a means to predict the fate of radiostrontium. In the mass balance of Sr in the sewage treatment plant, 76% of the Sr entering the plant was discharged to the receiving water on average; additionally, 14% of the Sr flowing through the plant was transferred to the sewage sludge and then concentrated in the sludge ash without being released to the atmosphere. Sr was also shown to sorb on the activated sludge; however, the measurements indicated Sr desorption from activated sludge occurred 48 h after the contact.

The research by Luo, Tian et al. (2013) investigated the fate of As(V) adsorbed on nano-TiO₂ in the presence of sulfate reducing bacteria (SRB) Desulfovibrio vulgaris strains DP4 and ATCC 7757. The incubation results demonstrated that As(V) was desorbed from nano TiO₂, and subsequently reduced to As(III) in aqueous solution. The release of adsorbed As(V) was two to three times higher in biotic samples than that in abiotic controls.
The study by Xu, Capito et al. (2013) focused on selective removal of arsenic and monovalent ions from brackish groundwater reverse osmosis (RO) concentrate for beneficial use and safe environmental disposal using in situ and pre-formed hydrous ferric oxides/hydroxides adsorption, and electrodialysis (ED) with monovalent permselective membranes. A method using ferric sludge from surface water treatment plant was demonstrated as an efficient adsorbent to remove arsenic from RO concentrate, providing a promising low cost, "waste treat waste" approach.

Muehe et al. (2013) described the Fe mineralogy and As mobility during the reduction of As-loaded biogenic and abiogenic Fe(III) minerals by Shewanella oneidensis MR-1. They found that microbial reduction of As(III)-bearing biogenic Fe(III) (oxyhydr)oxides released more As than reduction of abiogenic Fe(III) (oxyhydr)oxides. In contrast, As was immobilized more effectively during reduction of As(V)-loaded biogenic than abiogenic Fe(III) (oxyhydr)oxides during secondary Fe mineral formation.

Norris et al. (2013) aimed to enhance heavy metal removal of filter drain gravel with an iron oxide mineral amendment to increase surface area for heavy metal scavenging in sustainable urban drainage system (SuDS). Experiments showed that amendment-coated and uncoated (control) gravel removed similar quantities of heavy metals; moreover, when normalized to surface area, iron oxide coated gravels (IOCGs) showed poorer metal removal capacities than uncoated gravel. Inspection of the uncoated microgabbro gravel indicated that clay particulates on the surface (a natural product of weathering of this material) augmented heavy metal removal, generating metal sequestration capacities that were competitive compared with IOCGs.

Advanced biodegradable and non-toxic organic chelators were synthesized on the basis of the S,S-ethylenediamine-disuccinate (S,S-EDDS) ligand by Ullmann et al. (2013). The novel process was developed for the simultaneous removal of both heavy metals and organic pollutants from contaminated soils, sediments or sludge from wastewater. The new chelators were designed to bind various target metal ions, to promote extraction of these ions into organic solvents.

The method of continuous flow ultracentrifugation was developed by Zhang et al. (2013) to separate three size fractions (<1 μm, <0.6 μm and <0.2 μm) of the submicron particles from the soil polluted by wastewater and smelter dust respectively. A higher enrichment factor of the metals in the fractions of <1 μm or less were observed in the soil contaminated by wastewater than by smelter dust. The organic substance in the wastewater and calcite from lime application were assumed to play an important role in the metal accumulation in the fine particles of the wastewater polluted soil.

**Nutrients**

Extensive research in urban watersheds has broadened our knowledge about point and non-point pollutant sources, but the fate of nutrients is not completely understood (Carey et al., 2013). The effect of prolonged reclaimed water irrigation is also unknown. Stable isotopes
have been used to trace pollutants, but distinguishing sources (e.g., fertilizers, wastewater, etc.) can be difficult. Identifying pollutant sources may aid our understanding of harmful algal blooms because the extent of the relationship between urban nutrient sources and algal blooms is unclear. Further research on the delivery and fate of nutrients within urban watersheds is needed to address manageable water quality impacts.

The fate of organics and nitrogen during the biological treatment with MBR and subsequent membrane filtration processes (nano filtration, NE; reverse osmosis, RO) were investigated by Insel et al. (2013) for a landfill leachate. The chemical oxygen demand (COD) and total Kjeldahl nitrogen (TKN) removal performances of membrane bioreactor (MBR) were obtained to be around 89% and 85%, respectively. NF/RO post treatment after MBR system was required to increase COD and total nitrogen (TN) removal performances up to 99%.

A study was carried out to understand the fate of biodegradable dissolved organic nitrogen (BDON) and bioavailable dissolved organic nitrogen (ABDON) along the treatment trains of a WRRF equipped with an activated sludge (AS) system and a WRRF equipped with a two-stage trickling filter (TF) process. Results showed that BDON and ABDON varied significantly within the treatment facility and between the two facilities; from after primary clarification to final effluent, the TF facility removed 65% of BDON and 63% of ABDON while the AS facility removed 68% of BDON and 56% of ABDON. For the TF facility, BDON and ABDON were 62% and 71% of the effluent dissolved organic nitrogen (DON), while they were 26% and 47% of the effluent DON for the AS WRRF.

The survey of 60 hybrid constructed wetlands (CWs) from 24 countries reported after 2003 revealed that hybrid constructed wetlands were primarily used in Europe and in Asia while in other continents their use is limited (Vymazal, 2013) with the most commonly used hybrid system as vertical flow (VF) – horizontal flow (HF) constructed wetland. The more detailed analysis revealed that VF-HF hybrid constructed wetlands were slightly more efficient in ammonia removal than other hybrid systems. All types of hybrid CWs were comparable with single VF CWs in terms of NH$_4$-N removal rates; on the other hand, CWs with free water surface units removed substantially more total nitrogen as compared to other types of hybrid constructed wetlands. However, all types of hybrid constructed wetlands were more efficient in total nitrogen removal than single HF or VF constructed wetlands.

An integrated approach, which combined freshwater microalgae Chlorella zofingiensis cultivation with piggery wastewater treatment, was investigated by Zhu et al. (2013). The characteristics of algal growth, lipid and biodiesel production, and nutrient removal were examined by using tubular bubble column photobioreactors to cultivate C. zofingiensis in piggery wastewater with six different concentrations. The diluted piggery wastewater with 1900 mg/L COD provided an optimal nutrient concentration for C. zofingiensis cultivation, where the advantageous nutrient removal and the highest productivities of biomass, lipid and biodiesel were presented.
Guo, Liu et al. (2013) studied the inhibition of roxarsone on biological phosphorus removal processes for roxarsone-contaminated wastewater treatment, in terms of the removal and rates of chemical oxygen demand (COD), phosphate. Results showed that presence of roxarsone considerably limited the COD removals, especially at roxarsone concentration exceeding 40 mg/L. Additionally, roxarsone inhibited both phosphorus release and uptake processes, consistent with the phosphate profiles during the biological phosphorus removal processes; whereas, roxarsone is more toxic to phosphorus uptake process, than release function. The results indicated that it is roxarsone itself, rather than the inorganic arsenics, inhibit biological phosphorus removal processes within both aerobic and anaerobic roxarsone-contaminated wastewater treatment.

**Emerging Biological Agents**

**Pathogens.** Interest in the analysis and mitigation of the impact of WRRF effluents on receiving water bodies has been increasing particularly the fate of pathogens.

The role of a WRRF on the *E. coli* level at eight nearby marine beaches in Tsuen Wan was studied by Chan et al. (2013) using a 3D deterministic hydrodynamic model. The model precisely predicted the *E. coli* levels on the beaches which justified that the model is valuable in the interpretation of the complex variation of beach water quality which depends on tidal level, solar radiation and other hydro–meteorological factors therefore can be used in optimization of disinfection dosage and in emergency response situations (Chan et al., 2013).

In a study, shotgun viral metagenomics was applied to 10 sewage sludge samples from 5 WRRFs throughout the continental U.S, each serving between 100 000 and 1 000 000 people to characterize and understand infectious risks associated with land application, and to describe the diversity of viruses in human populations. 43 different types of human viruses were identified in sewage sludge. Newly emerging viruses (e.g., *Coronavirus HKU1*, *Klassevirus*, and *Cosavirus*) were highly abundant followed by respiratory viruses, and *Enteroviruses* (Bibby and Peccia, 2013).

A water quality model involving the analysis of several sewer systems (SS) discharging their polluting overflows on the coast in a sensitive marine environment has been developed by De Marchis et al. (2013). The proposed model was tested in a real case study (the Acicastello bay in Italy) where data were available both for SS model and for receiving water body propagation model calibration. The analysis showed a good agreement between the model and monitored data. The integrated model was demonstrated to be a valuable tool for investigating the pollutant propagation and to highlight the most impacted areas (De Marchis et al., 2013).

The persistency of human–specific *Bacteroidales spp.* as promising indicators for fecal contamination in river water during a 3–week agitation was investigated. Water temperature and the presence of predator were identified as the leading factors affecting the fate of *Bacteroidales spp.* in the environment thus they have to be critically evaluated while identifying fecal pollution sources (Kobayashi et al., 2013).
Stormwater carries a wide spectrum of pollutants including fecal indicator bacteria (FIB). A study investigated the ability of simplified bioinfiltration systems containing quartz sand and iron oxide–coated quartz sand (IOCS) to remove two FIB (Enterococcus faecalis and Escherichia coli) suspended in synthetic stormwater with and without natural organic matter (NOM) as well as the potential for accumulated FIB to be remobilized during intermittent flow. Results indicated that using geomedia such as IOCS that promote irreversible attachment of bacteria, and maintaining saturated condition, could minimize the mobilization of previous attached bacteria from bioinfiltration systems, although NOM may significantly decrease these benefits (Mohanty et al., 2013).

The concentrations of the indigenous pathogen indicators Escherichia coli, Clostridium perfringens and somatic coliphage were tracked for 30 days under stable operation of a two–stage laboratory–scale digester treating a mixture of food waste and blackwater. The study showed that anaerobic digestion reduces E. coli numbers mainly in the thermophilic stage but Clostridium perfringens and somatic coliphage numbers did not change in both stages (Rounsefell et al., 2013).

In a study, the use of low–cost, consumer level, UV based disinfection systems coupled to constructed wetlands for wastewater treatment in three constructed wetlands in Israel, Jordan and in the Palestinian Authority. Stabilized wetland system efficiently treated the COD. The UV system coupled with the wetland was able to inactivate indicator bacteria (fecal and E. coli) to levels suitable for irrigation even at low UV transmission (Azaizeh et al., 2013).

In another study conducted in Italy, the wastewater disinfection process with ozone applied to a medium size WRRF which has high organic and industrial load (45,000 Population Equivalents) was presented with a view to assessing the microbiological abatement efficacy and the presence of dangerous substances. Ozone disinfection applied was inefficient to satisfy discharge criterion set by EU Directive 2000/60/EC which is 5,000 CFU/100 mL (Ostoich et al., 2013).

Bench–scale experiments were performed to evaluate virus control by an integrated electrochemical–microfiltration (MF) process from turbid (15 NTU) surface water containing moderate amounts of dissolved organic carbon (DOC, 5 mg C/L) and calcium hardness (50 mg/L as CaCO₃). Higher reductions in MS2 bacteriophage concentrations were obtained by aluminum electrocoagulation and electroflotation compared with conventional aluminum sulfate coagulation. Sweep flocculation was the primary virus destabilization mechanism (Vigueras–Cortes et al., 2013).

A novel class of photocatalytic coating prepared either undopped or dopped capable of degrading bacterial and chemical contaminants in the presence of visible sunlight wavelengths was produced by depositing a stable photocatalytic TiO₂ film on the internal lumen of glass bottles via a sol–gel method. The presence of doped and undoped TiO₂ films was found to accelerate the degradation of methylene blue in the presence of natural sunlight, while copper–doped TiO₂ films were found to
accelerate bacterial inactivation (of *Escherichia coli* and *Enterococcus faecalis*) in the presence of natural sunlight (Fisher et al., 2013).

In a study by Schaar et al. (2013), an ozonation plant designed mainly for micropollutant removal from tertiary effluent was tested also for its pathogen removal efficiency. At specific ozone consumptions of 0.6 and 0.9 g O$_3$/g dissolved organic carbon (DOC) a 2–log colony forming unit (CFU) reduction was achieved for indigenous *Escherichia coli* and enterococci, and the limits of the European bathing water directive for the excellent quality of inland waters were met. In addition, the surrogate virus MS2 was reduced by 4–5 log while no significant inactivation was detected for *B. subtilis* spores (Schaar et al., 2013).

**Antibiotic resistance genes (ARGs).** Antibiotics are crucial drugs used for the control of infectious diseases in human and animals. Due to their extensive use, large amounts of antibiotics are released into municipal wastewater due to incomplete metabolism in humans or due to disposal of unused antibiotics, which finally find their ways into different natural environmental compartments. The presence of antibiotics in the environmental media emerged evolution and dissemination of antibiotic resistant bacteria (ARB) and antibiotic resistance genes (ARGs) which now become an increasing concern about the potential environmental and public health risks. ARB and ARGs have been detected extensively in wastewater samples. Available data show significantly higher proportion of antibiotic resistant bacteria contained in raw and treated wastewater relative to surface water. According to these studies, the conditions in WRRFs proliferate ARB and cause dissemination of ARGs. Moreover, another concern with regards to the presence of ARB and ARGs is their effective removal from wastewater (Bouki et al., 2013). This section of the review aims to give highlights on the current literature on fate of ARB and ARGs in the WRRFs and environment effected by WRRF effluent.

A study was performed to determine the effect of direct addition of sulfamethoxazole and silver nanoparticles (Ag NPs, or nanosilver) at environmentally–relevant concentrations as potential selection pressures for ARGs on the occurrence of ARGs in thermophilic anaerobic digesters. During the study, tetracycline (tet(O), tet(W)) and sulfonamide (sulI, sulII) ARGs and the integrase enzyme gene (intI1) associated with Class 1 integrons were measured in raw sludge, test thermophilic digesters, a control thermophilic digester, and a control mesophilic digester. There was no significant difference between ARG gene copy numbers (absolute or normalized to 16S rRNA genes) in amended thermophilic digesters and the control thermophilic digester. Antibiotic resistance gene reductions remained constant despite the application of selection pressures, which suggests that digester operating conditions are a strong governing factor of the bacterial community composition and thus the prevalence of ARGs (Miller et al., 2013).

Concentration and removal of ARGs in three municipal WRRFs employing different advanced treatment systems (biological aerated filter, constructed wetland, and ultraviolet (UV) disinfection) were investigated. The concentrations of tetM, tetO, tetQ, tetW, sulI, sulII, intI1,
and 16S rDNA genes were examined in wastewater and biosolid samples. In secondary effluents, ARG reductions of 1–3 orders of magnitude were observed, and no difference was found among the three municipal WRRFs with different treatment processes ($p > 0.05$). On the other hand when tertiary effluents were compared, 1–3 orders of magnitude of reductions in ARGs were observed in constructed wetlands, 0.6–1.2 orders of magnitude of reductions in ARGs were observed in the biological aerated filter, but no apparent decrease by UV disinfection was observed (Chen and Zhang, 2013a).

Abundance of four tetracycline resistance genes (tetM, tetO, tetQ and tetW) and two sulfonamide resistance genes (sulI and sulII) were determined in 4 municipal and 8 rural WRRFs with different wastewater handling abilities and treatment processes using quantitative polymerase chain reaction (qPCR). Significant reductions (1–3 orders of magnitude) in ARGs were observed in municipal wastewater treatment systems, but a smaller reduction was found in the rural domestic sewage treatment systems (Chen and Zhang, 2013b).

Pathogenic and extended-spectrum beta-lactamase (ESBL) producing *Escherichia coli* in effluents of a municipal WRRF receiving wastewater from a slaughterhouse was measured. A total of 1248 isolates were screened for the presence of virulence genes associated with enterohemorrhagic *E. coli* (EHEC) and extraintestinal pathogenic *E. coli* (ExPEC). The most potentially pathogenic ExPEC were isolated from city wastewater and from the treated effluent which indicated that pathogenic and/or ESBL-producing *E. coli* were mainly present in human wastewater, and at a lesser extend in animal wastewater. Treatment failed to eliminate these strains which were discharged into the river, and then these strains could be transmitted to animals and humans via the environment (Diallo et al., 2013).

Treated wastewater is increasingly being reused to achieve sustainable water management in arid regions. Three separate reclaimed wastewater distribution systems in the western U.S. were examined for distribution of antibiotic genes in the recycled water. Quantitative polymerase chain reaction (qPCR) was used to quantify ARGs corresponding to resistance to sulfonamides, macrolides, tetracycline, glycopeptides, and methicillin, in addition to genes present in waterborne pathogens. A broader range of ARGs were detected after the reclaimed water passed through the distribution systems, highlighting the importance of considering bacterial re-growth and the overall water quality at the point of use (POU) which suggests that reclaimed water may be an important reservoir of ARGs thus it may have implications for human health (Fahrenfeld et al., 2013).

*Enterococcus* spp. from two poultry farms and proximate surface and ground water sites in an area of intensive poultry production were tested for resistance to 16 clinical antibiotics in study conducted by Furtula et al. (2013). Resistance patterns were compared to assess trends and possible correlations for specific antimicrobials and levels of resistance. Overall, 86% of litter isolates, 58% of surface water isolates and 100% of ground water isolates were resistant to more than one antibiotic. The results suggested that antibiotic resistance in the water
environment was mainly due to the presence of antibiotic residuals originated from the poultry farms (Furtula et al., 2013).

Changes in the total (intrinsic and acquired) resistance of bacteria in a river which is a receiver of treated wastewater were monitored. An increase in the populations of tetracycline–resistant and fluoroquinolone–resistant microorganisms was noted in downstream river water samples in comparison with upstream river water samples, but the above trend was not observed in bacteria resistant to macrolides and beta–lactams. The counts of doxycycline–resistant bacteria were significantly correlated with doxycycline levels which indicated that the presence of doxycycline–resistant bacteria is a robust indicator of anthropogenic stress in river water (Harnisz, 2013).

Water from two WRRFs, one receiving hospital effluent and the other not were examined for E. coli expressing resistance to seven antimicrobials including ampicillin, streptomycin, cefoxitin, cefotaxime, tetracycline, sulphonamide and CIP. Resistant E. coli were present in WRRF influent and effluent, irrespective of receiving hospital effluent, and are being released into the environment. The results suggest that the release of hospital effluent does not significantly affect the frequency with which resistant E. coli are detected in effluent however it increases the frequency of bacteria resistance to hospital specific antibiotics such as CIP (Harris et al., 2013).

An extensively drug–resistant Ochrobactrum intermedium CCUG 57381 has been isolated from an Indian WRRF receiving industrial wastewater from pharmaceutical production contaminated with high levels of quinolones by Johnning et al. (2013). Antibiotic susceptibility testing against 47 antibiotics showed that the strain was 4 to > 500 times more resistant to sulfonamides, quinolones, tetracyclines, macrolides, and the aminoglycoside streptomycin than the type strain O. intermedium LMG 3301. The results of the study highlight that WRRFs serving antibiotic manufacturing may provide nearly ideal conditions for the recruitment of resistance genes into human commensal and pathogenic bacteria (Johnning et al., 2013).

A study assessed the impact of the activated sludge process on fluoroquinolone resistance. Large collections of CIP–resistant Enterobacteriaceae strains from sludge (n = 112) and from raw sewage (n = 89) was screened for resistance genes and mobile genetic elements. Plasmid–mediated quinolone resistance determinants were readily detected in isolates from both environments. However, resistance determinants were more abundant in bacteria isolated from sludge than raw sewage which indicates resistance is disseminated in the activated sludge (Kaplan et al., 2013).

The presence of ESBL–positive Enterobacteriaceae in municipal sewage and their emission to the ambient air and the river receiving effluent from a WFFR was investigated. In the group of 455 isolated strains, up to 19.8% (90 isolates) were phenotypic ESBL–producers. They were detected in the 63 (100%) of sewage samples analyzed, 7 (33.3%) of river water and in 10 (23.8%) of air samples collected at the WFFR area. This study demonstrated that despite the treatment, the municipal sewage may be a reservoir of antibiotic–resistant
microorganisms and plasmid–mediated antibiotic resistance genes which can be spread in the environment through air (Korzeniewska and Harnisz, 2013).

The fate of ESBL–producing *Escherichia coli* and their genes encoding antibiotic resistance in both untreated sewage from hospitals, and in sewage after different stages of treatment was investigated. From among 167 and 147 *E. coli* strains isolated from hospital effluents and municipal sewage up to 37.1% and 17.7%, respectively, were ESBL–positive. From among 38 and 43 strains isolated from river water and the air up to 18.4% and 27.9%, respectively, were ESBL–producers. Most of the resistance genes were located on a plasmid. More than 38% out of ESBL–producing isolates carried several bla genes. The multiple–antibiotic–resistant strains were more abundant hospital effluents and air samples strains isolated from other samples (Korzeniewska et al., 2013).

In a study, to determine if hospital effluent input has an ecological impact on downstream aquatic environment, antibiotic resistance in *Enterococcus spp.* along a medical center–retirement home–WRRF–river continuum in France was determined using a culture–based method. Data on antibiotic consumption among hospitalized and general populations and levels of water contamination by antibiotics were collected. Along the continuum, from 89 to 98% of enterococci, according to the sampled site, were identified as *Enterococcus faecium*. All *E. faecium* isolates from hospital and retirement home effluents were resistant to multiple antibiotics, but the relative proportion of resistant *E. faecium* decreased in the continuum (Leclercq et al., 2013).

Levels of chloramphenicol–resistance genes in the wastewater from swine feedlots and the correspondingly impacted agricultural fields in Beijing were investigated using culture independent methods. Resistance genes were present in all samples, with the highest absolute concentrations of $1.50 \times 10^6$ copies/g in soil and $6.69 \times 10^6$ copies/mL in wastewater. Significant correlations were found between chloramphenicol–resistance genes and chloramphenicol residues ($r = 0.79, p = 0.0008$) as well as between chloramphenicol–resistance genes in swine feedlots and corresponding agricultural soils and wastewater (Li, Shi et al., 2013).

Levels of lincomycin–resistance genes and lincomycin residues in water and soil samples collected from multiple sites near wastewater discharge areas were investigated. Sixteen lincomycin–resistance and 16S rRNA genes were detected using real–time PCR. A gradual reduction in the levels of lincomycin–resistance genes and lincomycin residues in the waters and soils were detected from multiple sites along the path of wastewater discharging to the surrounding environment from the swine farms. Significant correlations were found between levels of lincomycin–resistance genes in paired water and soil samples ($r = 0.885, p = 0.019$), and between lincomycin–resistance genes and lincomycin residues ($r = 0.975, p < 0.01$). This study showed the potential risk of dissemination of lincomycin–resistance genes associated with lincomycin residues in surrounding environments adjacent to swine farms (Li, Sun et al., 2013).

Effect of WRRF discharges on the prevalence of ARGs and bacterial community composition in biofilm and
sediment samples of a receiving river was investigated using culture-independent approaches such as quantitative PCR and pyrosequencing. Concentration of antibiotics in WRRF influent and effluent were also determined. ARGs were detected in all biofilm and sediment samples analyzed. Moreover, a significant increase in the relative abundance of ARGs in biofilm samples collected downstream of the WRRF discharge was observed. Significant differences with respect to community structure and composition between upstream and downstream samples were identified. Overall the results indicated that WRRF discharges may contribute to the spread of ARGs into the environment and may also impact on the bacterial communities of the receiving river (Marti et al., 2013).

A study investigated whether fecal coliforms (FC) isolated from surface waters located near a WRRF outflows display TCS resistance and, if so, whether such organisms exhibit increased resistance to antibiotics. Water samples were collected at two streams in Morris County, NJ that receive WRRF effluent: Loantaka Brook and the Whippany River. Water samples were collected at three sites within each location near the WRRF effluent outflow. Abiotic river parameters were measured and FCs were enumerated for each sample. River parameters were analyzed to determine if TCS or antibiotic resistance was correlated to water quality. TCS resistance levels were determined for individual isolates, and isolates were screened against seven classes of antibiotics at clinically relevant levels to assess cross-resistance. Environmental FC isolates resistant to high level TCS included species of *Escherichia, Enterobacter, Serratia* and *Citrobacter*. There was no correlation between river water quality and resistance of isolates to TCS which also display multidrug resistance. Presence of isolates not resistant to TCS, but resistant to other antibiotics, were significantly correlated to increased river flow, precipitation, and decreased nutrient levels, suggesting that observed resistance is due to run–off events (Middleton and Salierno, 2013).

In another study, the abundance and proportion dynamics of seven antibiotic resistance genes in the wetland media biofilm and in the influent and effluent of parallel horizontal subsurface flow mesocosm cells of a newly established hybrid constructed wetland treating municipal wastewater were examined. The targeted genes encoding resistance to major antibiotic classes such as tetracyclines, macrolides, sulfonamides, penicillins, and fluoroquinolones were quantified. All targeted antibiotic resistance genes were detectable in the tested mesocosm environments, with the tetA, sul1, and qnrS genes being the most abundant in the mesocosm effluents. The abundance of 16S rRNA and antibiotic resistance genes, and the proportion of antibiotic resistance genes in the microbial community, were reduced during the wastewater treatment by the constructed wetland. The results also revealed a relationship between antibiotic resistance genes abundance and the removal efficiencies of NO$_2^-$–N, NH$_4^+$–N, and organic matter (Nolvak et al., 2013).

In a study, raw and treated wastewater composite samples were collected from an urban WRFF over 14 sampling dates. Samples were characterized for the occurrence of tetracyclines, penicillins, sulfonamides, quinolones, TCS, arsenic, cadmium, lead, chromium and
mercury; antibiotic resistance percentages for tetracycline, sulfamethoxazole, CIP and amoxicillin and the community composition. Variations on the bacterial community structure of the final effluent were significantly correlated with the occurrence of tetracyclines, penicillins, sulfonamides, quinolones and TCS in the raw inflow. Members of the class Epsilonproteobacteria presented positive correlations with those antimicrobials, whereas negative correlations were observed with Beta– and Gamma–proteobacteria and Firmicutes. Antibiotic resistance percentages presented different trends of variation in heterotrophs/enterobacteria and in enterococci, varied over time and after wastewater treatment. Antibiotic resistance was positively correlated with the occurrence of tetracyclines residues and high temperature. A relationship between antibiotic residues, bacterial community structure and composition and antibiotic resistance was demonstrated (Novo et al., 2013).

Antimicrobial resistance profile and the occurrence of Klebsiella pneumoniae carbapenemase (KPC)–producing Gram–negative rods in sewage samples obtained from a Brazilian teaching hospital and from the WRRF that receives it for treatment was investigated. Multidrug–resistant bacteria as well as KPC–2–producing Aeromonas spp. and several Enterobacteriaceae species, including Kluyvera spp., in the hospital effluent and in different sites of the WRRF were identified. Most isolates contained resistance genes on mobile genetic elements. Although secondary treatment seems to decrease the amount of KPC producers in sewage, multidrug–resistant isolates are continually disposed in the urban river (Picao et al., 2013).

To assess the extent of transmission of antibiotic resistances from human sources into the environment, the resistance patterns of Escherichia coli strains isolated from human patients were compared to those found in strains isolated from sewage sludge by Reinhthaler et al. (2013). The results showed that multi drug resistance was evolved parallel in the environment and human (Reinhthaler et al., 2013).

A study investigated the resistance of environmental Rhodospirillaceae isolated in the catchment area of the river Swist (Germany) to antibiotics used in human medicine. In total, 614 isolates were tested for antibiotic susceptibility. Resistant Rhodospirillaceae were detected in wastewater effluent from a municipal sewage treatment plant, as well as in non–polluted upper reaches. The highest multi–resistance level was detected in small tributaries and it surprisingly decreased with an increasing influence of municipal wastewater which indicated that the detected resistances were acquired rather than intrinsic (Schreiber and Kistemann, 2013).

In another study, the diversity of culturable antibiotic resistant bacteria from treated and raw wastewaters was identified by a modified standard agar recovery method and subsequent pyrosequencing. Proteobacteria was dominant in each sample tested. Diversity analysis revealed most of the samples to have similar diversities at phylum level being dominated by Proteobacteria, though a few samples, typically recovered
from CIP or doxycycline amended agars were often
dissimilar. Arcobacter spp. or E. coli were dominant in the
bacterial communities recovered on agars amended with
CIP or doxycycline, respectively. These results suggested
that Bacterial populations containing multiple antibiotic
resistance (MAR) in the final treated effluent were possible
(Sigala and Unc, 2013).

In order to assess hospital effluent (HE)
influence on wastewater treatment plant biomass, lab–scale
conventional activated sludge systems (CAS) were
continuously fed with real HE or urban effluent as a
control. The comparative metagenomic analysis of the CAS
showed that HE treatment resulted in an increase of class 1
resistance integrons (RIs) and the introduction of
_Pseudomonas_ spp. into the bacterial community. HE
treatment did not reduce the CAS process performance;
nevertheless it increases the risk of dissemination into the
environment of bacterial species and genetic determinants
(RIs) involved in antibiotic resistance acquisition (Stalder
et al., 2013).

A study investigated the presence of methicillin–
resistant _Staphylococcus aureus_ (MRSA) in untreated
hospital wastewaters (UHWW), their transmission into the
receiving WRRF and survival through the WRRF. 224 _S.
aureus_ strains were isolated from UHWW–1, UHWW–2
and its receiving WRRF inlet and post–treatment outlet.
Among them, 131 were identified as MRSA strains. 24 of
MRSA strains were also vancomycin resistant. Multidrug
resistant strains (including MRSA) were more prevalent in
hospital wastewaters than in the WRRF. The study also
showed the survival of MRSA strains in UHWWs and their
transit to the WRRF and then through to the final treated
effluent and chlorination stage (Thompson et al., 2013).

It has been suggested that laterally transferred
genetic agents, such as integrons, play a role in the spread
of resistant bacteria throughout ecosystems. The
distribution of three integron classes throughout a coastal
estuarine ecosystem was compared in a study by Uyaguri et
al. (2013). Integron distribution patterns were determined
in the sediment and water collected at seven sites
throughout two estuaries with different levels of
anthropogenic input by qPCR. The results showed that all
three integron classes were present in each sample.
However, the relative abundance was different; with class 2
integrons significantly elevated in areas of high
anthropogenic input and class I integrons elevated in areas
of low input (Uyaguari et al., 2013).

In a study, the occurrence of vancomycin
resistant enterococci (VRE) in a hospital effluent and in the
receiving urban WRRF was investigated. Vancomycin and
CIP resistant bacteria occurred in the hospital effluent and
in raw municipal inflow at densities of $10^3$ to $10^2$ CFU/mL,
being significantly more prevalent in the hospital effluent
than in the urban wastewater. Most of the VRE isolated
from the hospital effluent belonged to the species
_Enterococcus faecalis_ and _Enterococcus faecium_ and
presented multidrug–resistance phenotypes to CIP,
tetracycline, erythromycin, and high–level gentamicin.
Thus results suggested that hospital effluents discharged
into urban WRRF may be a relevant source of resistance
spread to the environment (Varela et al., 2013).
Occurrence, diversity and abundance of antibiotic resistance genes (ARGs) and mobile genetic elements (MGEs) in aerobic and anaerobic sludge of a full-scale tannery WRRF were investigated using Illumina high-throughput sequencing. Sequencing reads from aerobic and anaerobic sludge revealed differences in the abundance of functional genes between both microbial communities. Genes coding for antibiotic resistance were identified in both communities. Aerobic and anaerobic sludge contained various ARGs with high abundance, such as sulfonamide resistance genes. Tetracycline resistance genes were highly rich in the anaerobic sludge compared to aerobic sludge. Over 70 types of insertion sequences were detected in each sludge sample, and class 1 integrase genes were prevalent in the WRRF (Wang, Zhang et al., 2013).

The IncF antibiotic resistance and virulence plasmid pRSB225, isolated from an unknown bacterium released with the treated wastewater from a municipal WRRF into the environment has been analyzed at the genomic level by pyrosequencing. The accessory modules of the plasmid mainly comprise genes conferring resistance to ampicillin, chloramphenicol, erythromycin, kanamycin and neomycin, streptomycin, sulphonamides, tetracycline and trimethoprim, as well as mercuric ions (Wibberg et al., 2013).

The molecular architecture of class 2 integrons among gram–negative bacteria from wastewater environments was investigated in Jinan, China. Out of the 391 antibiotic–resistant bacteria isolated, 38 isolates harboring class 2 integrons encoding potentially transferrable genes that could confer antibiotic resistance were found. Results showed that water sources in the Jinan region harbored a diverse community of both typical and atypical class 2 integrons, raising concerns about the overuse of antibiotics and their careless disposal into the environment (Xia et al., 2013).

In a study, the transfer discipline and dissemination of the RP4 plasmid in MBRs were investigated by the counting plate method, the MIDI microorganism identification system, and quantitative polymerase chain reaction (qPCR) techniques. The results showed that the average transfer frequency of the RP4 plasmid from the donor strain to cultivable bacteria in MBR system was greater than the transfer frequency in wastewater and conventional system reported previously. This suggests that antibiotic resistance can be disseminated faster in MBR systems (Yang, Wang et al., 2013).

A study examined the potential for membrane treatment of microconstituent ARGs and the effect of native wastewater colloids on the extent of their removal. Plasmids containing vanA (vancomycin) and bla(TEM) (beta–lactam) ARGs were spiked into three representative WRRF effluents versus a control buffer and tracked by quantitative polymerase chain reaction through a cascade of microfiltration and ultrafiltration steps ranging from 0.45 µm to 1 kDa. The results suggested that advanced membrane treatment technology is promising for managing public health risks of ARGs in wastewater effluents and that removal may even be enhanced by colloids in real–world wastewaters. Alumina membranes removed ARGs to a greater extent than polyvinylidene fluoride membranes of the same pore size (0.1 µm) (Breazeal et al., 2013).
Using a treatment facility composed of a lagoon followed by wetland as a model system the presence of nutrients, micropollutants (i.e., pesticides, pharmaceuticals), and ARGs in lagoon outputs, and their potential removal by the treatment wetland prior to release to surface waters in 2012 were investigated. The results of this study indicated that while the treatment wetland may effectively attenuate excess nutrients and remove some micropollutants and bacteria, it does not does not achieve efficient ARGs removal (Anderson et al., 2013).

Burch et al. (2013) investigated whether air–drying beds reduce antibiotic resistance gene (ARC) concentrations in residual municipal wastewater solids. Three laboratory–scale drying beds were operated for a period of nearly 100 days. Abundance of total bacteria, fecal bacteria and human fecal bacteria as well as the integrase gene of class 1 integrons and five ARGs representing a cross–section of antibiotic classes and resistance mechanisms (erm(B), sul1, tet(A), tet(W), and tet(X)) were monitored. The results showed that air–drying beds were capable of reducing all gene target concentrations by 1 to 5 orders of magnitude, and the nature of this reduction was consistent with both a net decrease in the number of bacterial cells and a lack of selection within the microbial community (Burch et al., 2013b).

In another study, performance of conventional aerobic digestion in reducing the quantity of ARGs in untreated wastewater solids was investigated. A bench scale aerobic digester was fed untreated wastewater solids collected from a full–scale municipal wastewater treatment facility for more than 200 days at a residence time of approximately 40 days. During this time, the quantities of tet(A), tet(W), and erm(B) decreased by more than 90%. In contrast, int1 did not decrease, and tet(X) increased in quantity by 5–fold. These results demonstrated that aerobic digestion can be used to reduce the quantity of ARGs in untreated wastewater solids, but that rates can vary substantially depending on the reactor design (i.e., batch vs continuous–flow) and the specific ARG (Burch et al., 2013a).

The UV disinfection of antibiotic resistant heterotrophic bacteria and their relevant genes in the wastewater of a municipal wastewater treatment plant has been evaluated. Two commonly used antibiotics, erythromycin and tetracycline were selected because of their wide occurrences in regard to the antibiotic resistance problem. UV treatment at a fluence of 5 mJ/cm² removed the total erythromycin– and tetracycline–resistance genes by $3.0 \pm 0.1$ log and $1.9 \pm 0.1$ log, respectively. UV treatment was effective in reducing antibiotic resistance in the wastewater (Guo et al., 2013b).

To understand the effect of UV disinfection on antibiotic resistant bacteria, both total heterotrophic bacteria and antibiotic resistant bacteria (including cephalaxin–, CIP–, erythromycin–, gentamicin–, vancomycin–, sulfadiazine–, rifampicin–, tetracycline– and chloramphenicol–resistant bacteria) were examined in secondary effluent samples from a municipal wastewater treatment plant. UV disinfection results in the log reductions of nine types of antibiotic resistant bacteria varied from $1.0 \pm 0.1$ to $2.4 \pm 0.1$ for total heterotrophic
bacteria, as well as all antibiotic resistant bacteria at a fluence of 5 mJ/cm². On the other hand results indicated that UV disinfection led to enrichment of bacteria with resistance to sulfadiazine, vancomycin, rifampicin, tetracycline and chloramphenicol, while the proportions of cephalexin–, erythromycin–, gentamicin– and CIP–resistant bacteria in the wastewater decreased (Guo et al., 2013a).

The effect of UV radiation on antibiotic–resistant E. coli strains was compared with that of chlorination process. Under the investigated conditions, UV disinfection process resulted in a total inactivation after 60 min of irradiation (1.25 x 10⁴ µ W s/cm²) compared to 120 min chlorine contact time (initial chlorine dose of 2 mg/L). However, both disinfection processes were not effective in the inactivation of ARB, and the simultaneous release of ARB and antibiotics at sub–lethal concentrations into WRRF effluent may promote the development of resistance among bacteria in receiving water (Rizzo et al., 2013).

Efficiency of two vertical flow constructed wetlands characterized by volcanic (CW1) and zeolite (CW2) respectively, at removing three common antibiotics (CIP HCl, oxytetracycline HCl, and sulfamethazine) and tetracycline resistance (tet) genes (tetM, tetO, and tetW) from swine wastewater was investigated. The result indicated that the two systems could significantly reduce the wastewater antibiotics content, and elimination rates were in the following sequence: oxytetracycline > CIP > sulfamethazine. The zeolite–medium system was superior to that of the volcanic–medium system both in antibiotic and resistance gene removal (Liu, Liu et al., 2013).

References

Abdelmoez, W.; Barakat, N. A. M.; Moaz, A. (2013) Treatment of Wastewater Contaminated with Detergents and Mineral Oils Using Effective and Scalable Technology. Water Sci. Technol., 68(5), 974–981.

Anderson, J. C.; Carlson, J. C.; Low, J. E.; Challis, J. K.; Wong, C. S.; Knapp, C. W.; Hanson, M. L. (2013) Performance of a Constructed Wetland in Grand Marais, Manitoba, Canada: Removal of Nutrients, Pharmaceuticals, and Antibiotic Resistance Genes from Municipal Wastewater. Chemistry Central Journal, 7(54), 1–15.

Arevalo, J.; Ruiz, L. M.; Perez, J.; Moreno, B.; Gomez, M. A. (2013) Removal Performance of Heavy Metals in Mbr Systems and Their Influence in Water Reuse. Water Sci. Technol., 67(4), 894–900.

Awual, M. R.; Kobayashi, T.; Miyazaki, Y.; Motokawa, R.; Shiwaku, H.; Suzuki, S.; Okamoto, Y.; Yaita, T. (2013) Selective Lanthanide Sorption and Mechanism Using Novel Hybrid Lewis Base (N-Methyl-N-Phenyl-1,10-Phenanthroline-2-Carboxamide) Ligand Modified Adsorbent. J. Hazard. Mater., 252, 313–320.

Azaizeh, H.; Linden, K. G.; Barstow, C.; Kalbouneh, S.; Tellawi, A.; Albala, A.; Gerchman, Y. (2013) Constructed Wetlands Combined with UV Disinfection Systems for Removal of Enteric Pathogens and Wastewater Contaminants. Water Sci. Technol., 67(3), 651–657.

Babic, S.; Perisa, M.; Skoric, I. (2013) Photolytic Degradation of Norfloxacin, Enrofloxacin and Ciprofloxacin in Various Aqueous Media. Chemosphere, 91(11), 1635–1642.

Baumgartner, R.; Stieger, G. K.; McNeill, K. (2013) Complete Hydrodehalogenation of Polyfluorinated and Other Polyhalogenated Benzenes under Mild Catalytic Conditions. Environ. Sci. Technol., 47(12), 6545–6553.

Beskoski, V. P.; Takemine, S.; Nakano, T.; Beskoski, L. S.; Gojic–Cvijovic, G.; Ilic, M.; Miletic, S.; Vrvice, M. M. (2013) Perfluorinated Compounds in Sediment Samples from the Wastewater Canal of Pancevo (Serbia) Industrial Area. Chemosphere, 91(10), 1408–1415.

Bibby, K.; Peccia, J. (2013) Identification of Viral Pathogen Diversity in Sewage Sludge by Metagenome Analysis. Environ. Sci. Technol., 47(4), 1945–1951.

Bletsou, A. A.; Asimakopoulos, A. G.; Stasinakis, A. S.; Thomaidis, N. S.; Kannan, K. (2013) Mass Loading and Fate of Linear and Cyclic Silioxanes in a Wastewater Treatment Plant in Greece. Environ. Sci. Technol., 47(4), 1824–1832.
Chowdhury, I.; Duch, M. C.; Mansukhani, N. D.; Hersam, M. C.; Dai, Z. N.; Xia, X. H.; Guo, J.; Jiang, X. M. (2013) Effect of Intermediate Genes in Wastewater Treatment Plants from Hangzhou, China. Environ. Sci. Technol., 47(15), 8157–8163.
Chen, H.; Zhang, M. M. (2013b) Occurrence and Removal of Antibiotic Resistance Genes in Municipal Wastewater and Rural Domestic Sewage Treatment Systems in Eastern China. Environ. Int., 55, 9–14.
Cheng, X. W.; Liu, H. L.; Chen, Q. H.; Li, J. J.; Wang, P. (2013) Preparation and Characterization of Palladium Nanocrystallite Decorated TiO₂ Nano-Tubes Photocathode and Its Enhanced Photocatalytic Efficiency for Degradation of Diclofenac. J. Hazard. Mater., 254, 141–148.

Chowdhury, I.; Duch, M. C.; Mansukhani, N. D.; Hersam, M. C.; Bouchard, D. (2013) Colloidal Properties and Stability of Graphene Oxide Nanomaterials in the Aquatic Environment. Environ. Sci. Technol., 47(12), 6288–6296.
Chu, Y. Y.; Zhang, D. M.; Liu, L.; Qian, Y.; Li, L. L. (2013) Electrochemical Degradation of M-Cresol Using Porous Carbon–Nanotube–Containing Cathode and Ti/SnO₂–Sb₂O₃–IrO₂ Anode: Kinetics, Byproducts and Biodegradability. J. Hazard. Mater., 252, 306–312.
Collado, S.; Laca, A.; Diaz, M. (2013) Effect of Intermediate Compounds and Products on Wet Oxidation and Biodegradation Rates of Pharmaceutical Compounds. Chemosphere, 92(2), 207–212.
Cruz-Morato, C.; Ferrando-Climent, L.; Rodriguez-Mozaz, S.; Barcelo, D.; Marco-Urrea, E.; Vicent, T.; Sarra, M. (2013) Degradation of Pharmaceuticals in Non-Sterile Urban Wastewater by Trametes Versicolor in a Fluidized Bed Bioreactor. Water Res., 47(14), 5200–5210.
Dai, Z. N.; Xia, X. H.; Gao, J.; Jiang, X. M. (2013) Bioaccumulation and Uptake Routes of Perfluoroalkyl Acids in Daphnia Magna. Chemosphere, 90(5), 1589–1596.
De Marchis, M.; Freni, G.; Napoli, E. (2013) Modelling of E. coli Distribution in Coastal Areas Subjected to Combined Sewer Overflows. Water Sci. Technol., 68(5), 1123–1136.
Deng, J.; Shao, Y. S.; Gao, N. Y.; Tan, C. Q.; Zhou, S. Q.; Hu, X. H. (2013) Cofe2o4 Magnetic Nanoparticles as a Highly Active Heterogeneous Catalyst of Oxone for the Degradation of Diclofenac in Water. J. Hazard. Mater., 262, 836–844.
Derrouiche, S.; Bourdin, D.; Roche, P.; Houssais, B.; Machinal, C.; Coste, M.; Restivo, J.; Orfao, J. J. M.; Pereira, M. F.; R.; Marco, Y.; Garcia–Bordeje, E. (2013) Process Design for Wastewater Treatment: Catalytic Ozonation of Organic Pollutants. Water Sci. Technol., 68(6), 1377–1383.
Diallo, A. A.; Brugere, H.; Kerouredan, M.; Dupouy, V.; Toutain, P. L.; Bousquet-Melou, A.; Oswald, E.; Bibbal, D. (2013) Persistence and Prevalence of Pathogenic and Extended–Spectrum Beta–Lactamase–Producing Escherichia coli in Municipal Wastewater Treatment Plant Receiving Slaughterhouse Wastewater. Water Res., 47(13), 4719–4729.
Ducom, G.; Laubie, B.; Ohannessian, A.; Chottier, C.; Germain, P.; Chatain, V. (2013) Hydrosilylation of Polydimethylsiloxane Fluids in Controlled Aqueous Solutions. Water Sci. Technol., 68(4), 813–820.
Elie, M. R.; Clausen, C. A.; Yestrebsky, C. L. (2013) Reductive Degradation of Oxygenated Polycyclic Aromatic Hydrocarbons Using an Activated Magnesium/Co–Solvant System. Chemosphere, 91(9), 1273–1280.
Fahrenfeld, N.; Ma, Y. J.; O'Brien, M.; Pruden, A. (2013) Reclaimed Water as a Reservoir of Antibiotic Resistance Genes: Distribution System and Irrigation Implications. Frontiers in Microbiology, 4(130), 1–10.
Fang, G. D.; Gao, J.; Dionysiou, D. D.; Liu, C.; Zhou, D. M. (2013) Activation of Persulfate by Quinones: Free Radical Reactions and Implication for the Degradation of PCBs. Environ. Sci. Technol., 47(9), 4605–4611.
Fisher, M. B.; Keane, D. A.; Fernandez–Ibanez, P.; Colreavy, J.; Hinder, S. J.; McGuigan, K. G.; Pillai, S. C. (2013) Nitrogen and Copper Doped Solar Light Active TiO₂ Photocatalysts for Water Decontamination. Appl. Catal. B-Environ., 130, 8–13.
Furman, O.; Usenko, S.; Lau, B. L. T. (2013) Relative Importance of the Humic and Fulvic Fractions of Natural Organic Matter in the Aggregation and Deposition of Silver Nanoparticles. Environ. Sci. Technol., 47(3), 1349–1356.
Furtula, V.; Jackson, C. R.; Farrell, E. G.; Barrett, J. B.; Hiot, L. M.; Chambers, P. A. (2013) Antimicrobial Resistance in Enterococcus spp. Isolated from Environmental Samples in an Area of Intensive Poultry Production. Int. J. Env. Res. Public Health, 10(3), 1020–1036.
Garcia, S. N.; Clubbs, R. L.; Stanley, J. K.; Scheffe, B.; Yelderman, J. C.; Brooks, B. W. (2013) Comparative Analysis of Effluent Water Quality from a Municipal Treatment Plant and Two on-Site Wastewater Treatment Systems. Chemosphere, 92(1), 38–44.
Garcia-Rodriguez, A.; Matamoros, V.; Fontas, C.; Salvado, V. (2013) The Influence of Light Exposure, Water Quality and Vegetation on the Removal of Sulfonamides and Tetracyclines: A Laboratory-Scale Study. Chemosphere, 90(8), 2297–2302.

George, S. J.; Gandhimathi, R.; Nidheesh, P. V.; Ramesh, S. T. (2013) Electro-Fenton Method Oxidation of Salicylic Acid in Aqueous Solution with Graphite Electrodes. Environ. Eng. Sci., 30(12), 750–756.

Green, C.; Williams, R.; Churchley, J.; He, Y.; Thomas, S.; Goonan, P.; Kumar, A.; Jobling, S. (2013) Modeling of Steroid Estrogen Contamination in Uk and South Australian Rivers Predicts Modest Increases in Concentrations in the Future. Environ. Sci. Technol., 47(13), 7224–7232.

Grive, M.; Garcia, D.; Domenech, C.; Richard, L.; Rojo, I.; Martinez, X.; Rovira, M. (2013) A Quantitative Speciation Model for the Adsorption of Organic Pollutants on Activated Carbon. Water Sci. Technol., 68(6), 1370–1376.

Gu, L.; Zhu, N. W.; Guo, H. Q.; Huang, S. Q.; Lou, Z. Y.; Yuan, H. P. (2013) Adsorption and Fenton-Like Degradation of Naphthalene Dye Intermediate on Sewage Sludge Derived Porous Carbon. J. Hazard. Mater., 246, 145–153.

Guo, M. T.; Yuan, Q. B.; Yang, J. (2013a) Microbial Selectivity of Uv Treatment on Antibiotic-Resistant Heterotrophic Bacteria in Secondary Effluents of a Municipal Wastewater Treatment Plant. Water Res., 47(16), 6388–6394.

Guo, M. T.; Yuan, Q. B.; Yang, J. (2013b) Ultraviolet Reduction of Erythromycin and Tetracycline Resistant Heterotrophic Bacteria and Their Resistance Genes in Municipal Wastewater. Chemosphere, 93(11), 2864–2868.

Guo, Q. F.; Liu, L.; Hu, Z. H.; Chen, G. W. (2013) Biological Phosphorus Removal Inhibition by Roxarsone in Batch Culture Systems. Chemosphere, 92(1), 138–142.

Guo, Y. G.; Lou, X. Y.; Fang, C. L.; Xiao, D. X.; Wang, Z. H.; Liu, J. S. (2013) Novel Photo-Sulfite System: Toward Simultaneous Transformations of Inorganic and Organic Pollutants. Environ. Sci. Technol., 47(19), 11174–11181.

Harnisz, M. (2013) Total Resistance of Native Bacteria as an Indicator of Changes in the Water Environment. Environ. Pollut., 174, 85–92.

Harris, S.; Morris, C.; Morris, D.; Cornican, M.; Cummins, E. (2013) The Effect of Hospital Effluent on Antimicrobial Resistant E. coli within a Municipal Wastewater System. Environmental Science–Processes & Impacts, 15(3), 617–622.

Hatt, J. W.; Lamy, C.; Germain, E.; Tupper, M.; Judd, S. J. (2013) NDMA Formation in Secondary Wastewater Effluent. Chemosphere, 91(1), 83–87.

He, D.; Bligh, M. W.; Waite, T. D. (2013) Effects of Aggregate Structure on the Dissolution Kinetics of Citrate-Stabilized Silver Nanoparticles. Environ. Sci. Technol., 47(16), 9148–9156.

Hendren, C. O.; Lowry, M.; Grieger, K. D.; Money, E. S.; Johnston, J. M.; Wiesner, M. R.; Beaulieu, S. M. (2013) Modeling Approaches for Characterizing and Evaluating Environmental Exposure to Engineered Nanomaterials in Support of Risk-Based Decision Making. Environ. Sci. Technol., 47(3), 1190–1205.

Herzog, B.; Lemmer, H.; Helmreich, B.; Horn, H.; Muller, E. (2014) Monitoring Benzotriazoles: A 1 Year Study on Concentrations and Removal Efficiencies in Three Different Wastewater Treatment Plants. Water Sci. Technol., 69(4), 710–717.

Homme, C. L.; Sharp, J. O. (2013) Differential Microbial Transformation of Nitrosamines by an Inducible Propane Monoxygenase. Environ. Sci. Technol., 47(13), 7388–7395.

Hou, L. L.; Xia, J.; Li, K. Y.; Chen, J.; Wu, X. L.; Li, X. Q. (2013) Removal of Zno Nanoparticles in Simulated Wastewater Treatment Processes and Its Effects on Cod and Nh4+-N Reduction. Water Sci. Technol., 67(2), 254–260.

Houtz, E. F.; Higgins, C. P.; Field, J. A.; Sedlak, D. L. (2013) Persistence of Perfluoroalkyl Acid Precursors in AFFF-Impacted Groundwater and Soil. Environ. Sci. Technol., 47(15), 8187–8195.

Howard, P. H.; Muir, D. C. G. (2013) Identifying New Persistent and Bioaccumulative Organics among Chemicals in Commerce. III: Byproducts, Impurities, and Transformation Products. Environ. Sci. Technol., 47(10), 5259–5266.

Huang, W. Y.; Brigante, M.; Wu, F.; Mousty, C.; Hanna, K.; Mailhot, G. (2013) Assessment of the Fe(III)-Edds Complex in Fenton-Like Processes: From the Radical Formation to the Degradation of Bisphenol A. Environ. Sci. Technol., 47(4), 1952–1959.
Igos, E.; Benetto, E.; Venditti, S.; Kohler, C.; Cornelissen, A. (2013) Comparative and Integrative Environmental Assessment of Advanced Wastewater Treatment Processes Based on an Average Removal of Pharmaceuticals. *Water Sci. Technol.*, **67**(2), 387–394.

Insel, G.; Dagdar, M.; Dogruel, S.; Dizge, N.; Cokgor, E. U.; Keskinler, B. (2013) Biodegradation Characteristics and Size Fractionation of Landfill Leachate for Integrated Membrane Treatment. *J. Hazard. Mater.*, **260**, 825–832.

Jackson, D. G.; Looney, B. B.; Craig, R. R.; Thompson, M. C.; Kmetz, T. F. (2013) Development of Chemical Reduction and Air Stripping Processes to Remove Mercury from Wastewater. *J. Environ. Eng.-ASCE*, **139**(11), 1336–1342.

Jayaranjan, M. L. D.; Annachhatre, A. P. (2013) Precipitation of Heavy Metals from Coal Ash Leachate Using Biogenic Hydrogen Sulfide Generated from Fgd Gypsum. *Water Sci. Technol.*, **67**(2), 311–318.

Jiang, N.; Lu, N.; Shang, K. F.; Li, J.; Wu, Y. (2013) Effects of Electrode Geometry on the Performance of Dielectric Barrier/Packed–Bed Discharge Plasmas in Benzene Degradation. *J. Hazard. Mater.*, **262**, 387–393.

Jing, Q. F.; Yi, Z. L.; Lin, D. H.; Zhu, L. Z.; Yang, K. (2013) Enhanced Sorption of Naphthalene and p–Nitrophenol by Nano–SiO\(_2\) Modified with a Cationic Surfactant. *Water Res.*, **47**(12), 4006–4012.

Johnning, A.; Moore, E. R. B.; Svensson–Stadler, L.; Shouche, Y. S.; Larsson, D. G. J.; Kristiansson, E. (2013) Acquired Genetic Mechanisms of a Multiresistant Bacterium Isolated from a Treatment Plant Receiving Wastewater from Antibiotic Production. *Appl. Environ. Microbiol.*, **79**(23), 7256–7263.

Kaei, R.; Voegelin, A.; Ott, C.; Sinnet, B.; Thalmann, B.; Krismer, J.; Hagendorfer, H.; Elumelu, M.; Mueller, E. (2013) Fate and Transformation of Silver Nanoparticles in Urban Wastewater Systems. *Water Res.*, **47**(12), 3866–3877.

Kamei-Ishikawa, N.; Ito, A.; Umita, T. (2013) Fate of Stable Strontium in the Sewage Treatment Process as an Analog for Radiostromium Released by Nuclear Accidents. *J. Hazard. Mater.*, **260**, 420–424.

Kaplan, E.; Ofek, M.; Jurkevitch, E.; Cytryn, E. (2013) Characterization of Fluoroquinolone Resistance and Qnr Diversity in *Enterobacteriaceae* from Municipal Biosolids. *Frontiers in Microbiology*, **4**(144), 1–7.

Karci, A.; Arslan-Alaton, I.; Bekbolet, M. (2013) Oxidation of Nonylphenol Ethoxylates in Aqueous Solution by UV–C Photolysis, H\(_2\)O\(_2\)/UV–C, Fenton and Photo–Fenton Processes: Are These Processes Toxicologically Safe? *Water Sci. Technol.*, **68**(8), 1801–1809.

Khan, I. A.; Berge, N. D.; Sabo-Attwood, T.; Ferguson, P. L.; Saleh, N. B. (2013) Single-Walled Carbon Nanotube Transport in Representative Municipal Solid Waste Landfill Conditions. *Environ. Sci. Technol.*, **47**(15), 8425–8433.

Khraisheh, M.; Kim, J.; Campos, L.; Al-Muhtaseb, A. H.; Walker, G. M.; AlGhouti, M. (2013) Removal of Carbamazepine from Water by a Novel TiO\(_2\)-Coconut Shell Powder/Uv Process: Composite Preparation and Photocatalytic Activity. *Environ. Sci. Eng.*, **30**(9), 515–526.

Kim, M.; Guerra, P.; Shah, A.; Parsa, M.; Alaee, M.; Smyth, S. (2013) Pharmaceuticals and Personal Care Products Removal in a Membrane Bioreactor Wastewater Treatment Plant. *Proceedings of 7th International Water Association Specialised Membrane Technology Conference & Exhibition for Water and Wastewater Treatment and Reuse [CD-ROM]; Toronto, Canada, August 26–29; International Water Association: London, United Kingdom.

Kim, M.; Guerra, P.; Theocharides, M.; Barclay, K.; Smyth, S. A.; Alaee, M. (2013a) Parameters Affecting the Occurrence and Removal of Polybrominated Diphenyl Ethers in Twenty Canadian Wastewater Treatment Plants. *Water Res.*, **47**(7), 2213–2221.

Kim, M.; Guerra, P.; Theocharides, M.; Barclay, K.; Smyth, S. A.; Alaee, M. (2013b) Polybrominated Diphenyl Ethers in Sewage Sludge and Treated Biosolids: Effect Factors and Mass Balance. *Water Res.*, **47**(17), 6496–6505.

Kobayashi, A.; Sano, D.; Okabe, S. (2013) Effects of Temperature and Predator on the Persistence of Host–Specific Bacteroides Prevotella Genetic Markers in Water. *Water Sci. Technol.*, **67**(4), 838–845.

Korzeniewska, E.; Harnisz, M. (2013) Extended–Spectrum Beta–Lactamase (ESBL)–Positive Enterobacteriaceae in Municipal Sewage and Their Emission to the Environment. *J. Environ. Manage.*, **128**, 904–911.

Korzeniewska, E.; Korzeniewska, A.; Harnisz, M. (2013) Antibiotic Resistant Escherichia Coli in Hospital and Municipal Sewage and Their Emission to the Environment. *Ecotoxicol. Environ. Saf.*, **91**96–102.
Kovalova, L.; Siegrist, H.; von Gunten, U.; Eugster, J.; Hagenbuch, M.; Wittmer, A.; Moser, R.; McArdell, C. S. (2013) Elimination of Micropollutants During Post-Treatment of Hospital Wastewater with Powdered Activated Carbon, Ozone, and Uv. *Environ. Sci. Technol.*, 47(10), 7899–7908.

Kundu, S.; Chanda, A.; Khetan, S. K.; Ryabov, A. D.; Collins, T. J. (2013) TAMLM Activator/Peroxide–Catalyzed Facile Oxidative Degradation of the Persistent Explosives Trinitrotoluene and Trinitrobenzene in Mice Liver Solutions. *Environ. Sci. Technol.*, 47(10), 5319–5326.

Law, Y.; Jacobsen, G. E.; Smith, A. M.; Yuan, Z. G.; Lant, P. (2013) Fossil Organic Carbon in Wastewater and Its Fate in Treatment Plants. *Water Res.*, 47(14), 5270–5281.

Leclercq, R.; Oberle, K.; Galopin, S.; Cattoir, V.; Budzinski, H.; Petit, F. (2013) Changes in Enterococcal Populations and Related Antibiotic Resistance Along a Medical Center–Wastewater Treatment Plant–River Continuum. *Appl. Environ. Microbiol.*, 79(7), 2428–2434.

Lee, Y. C.; Lo, S. L.; Kuo, J.; Huang, C. P. (2013) Promoted Degradation of Perfluorooctanoic Acid by Persulfate When Adding Activated Carbon. *J. Hazard. Mater.*, 261, 463–469.

Lefebvre, O.; Shi, X.; Wu, C. H.; Ng, H. Y. (2014) Biological Treatment of Pharmaceutical Wastewater from the Antibiotics Industry. *Water Sci. Technol.*, 69(4), 855–861.

Lester, Y.; Mamane, H.; Zucker, I.; Avisar, D. (2013) Treating Wastewater from a Pharmaceutical Formulation Facility by Biological Process and Ozone. *Water Res.*, 47(13), 4349–4356.

Levard, C.; Mitra, S.; Yang, T.; Jew, A. D.; Badireddy, A. R.; Lowry, G. V.; Brown, G. E. (2013) Effect of Chloride on the Dissolution Rate of Silver Nanoparticles and Toxicity to E. Coli. *Environ. Sci. Technol.*, 47(11), 5738–5745.

Li, C. C.; Lou, Y. H.; Wan, Y. Z.; Wang, W. Q.; Yao, J. L.; Zhang, B. (2013) Laccase Immobilized onto Poly(GMA–MAA) Microspheres for p–Benzenediol Removal from Wastewater. *Water Sci. Technol.*, 67(10), 2287–2293.

Li, J.; Shao, B.; Shen, J. Z.; Wang, S. C.; Wu, Y. N. (2013) Occurrence of Chloramphenicol–Resistance Genes as Environmental Pollutants from Swine Feedlots. *Environ. Sci. Technol.*, 47(6), 2892–2897.

Li, K.; Ji, F.; Liu, Y. L.; Tong, Z. L.; Xinmin, Z.; Hu, Z. H. (2013) Adsorption Removal of Tetracycline from Aqueous Solution by Anaerobic Granular Sludge: Equilibrium and Kinetic Studies. *Water Sci. Technol.*, 67(7), 1490–1496.

Li, L. P.; Wei, D. B.; Wei, G. H.; Du, Y. G. (2013) Transformation of Cefazolin During Chlorination Process: Products, Mechanism and Genotoxicity Assessment. *J. Hazard. Mater.*, 262, 48–54.

Li, L. X. Y.; Hartmann, G.; Doblinger, M.; Schuster, M. (2013) Quantification of Nanoscale Silver Particles Removal and Release from Municipal Wastewater Treatment Plants in Germany. *Environ. Sci. Technol.*, 47(13), 7317–7323.

Li, L.; Sun, J.; Liu, B. T.; Zhao, D. H.; Ma, J.; Deng, H.; Li, X.; Hu, F. Y.; Liao, X. P.; Liu, Y. H. (2013) Quantification of Lincomycin Resistance Genes Associated with Lincomycin Residues in Waters and Soils Adjacent to Representative Swine Farms in China. *Frontiers in Microbiology*, 4(364), 1–9.

Li, Z. M.; Zhang, P. Y.; Shao, T.; Wang, J. L.; Jin, L.; Li, X. Y. (2013) Different Nanostructured InO3 for Photocatalytic Decomposition of Perfluorooctanoic Acid (PFOA). *J. Hazard. Mater.*, 260, 40–46.

Liang, B.; Cheng, H. Y.; Kong, D. Y.; Gao, S. H.; Sun, F.; Cui, D.; Kong, F. Y.; Zhou, A. J.; Liu, W. Z.; Ren, N. Q.; Wu, W. M.; Wang, A. J.; Lee, D. J. (2013) Accelerated Reduction of Chlorinated Nitroaromatic Antibiotic Chloramphenicol by Biocathode. *Environ. Sci. Technol.*, 47(10), 5353–5361.

Liu, L.; Liu, C. X.; Zheng, J. Y.; Huang, X.; Wang, Z.; Liu, Y. H.; Zhu, G. F. (2013) Elimination of Veterinary Antibiotics and Antibiotic Resistance Genes from Swine Wastewater in the Vertical Flow Constructed Wetlands. *Chemosphere*, 91(8), 1088–1093.

Liu, M. M.; Zhang, Y.; Ding, R.; Gao, Y. X.; Yang, M. (2013) Response of Activated Sludge to the Treatment of Oxytetracycline Production Waste Stream. *Appl. Microbiol. Biotechnol.*, 97(19), 8805–8812.

Liu, Y. K.; Wang, J. L. (2013) Degradation of Sulfamethazine by Gamma Irradiation in the Presence of Hydrogen Peroxide. *J. Hazard. Mater.*, 250, 99–105.

Loos, R.; Carvalho, R.; Antonio, D. C.; Cornero, S.; Locoro, G.; Tavazii, S.; Paracchini, B.; Ghiani, M.; Lettieri, T.; Blaha, L.; Jarosova, B.; Voorspoels, S.; Servaes, K.; Haglund, P.; Fick, J.; Lindberg, R. H.; Schwesig, D.; Gawlik, B. M. (2013) EU–Wide Monitoring Survey on Emerging Polar Organic Contaminants in Wastewater
Lozano, N.; Rice, C. P.; Ramirez, M.; Torrents, A. (2013) Fate of Triclocarban, Triclosan and Methyltriclosan During Wastewater and Biosolids Treatment Processes. *Water Res.*, **47**(13), 4519–4527.

Luo, T.; Tian, H. X.; Guo, Z.; Zhuang, G. Q. (2013) Fate of Arsenate Adsorbed on Nano-TiO$_2$ in the Presence of Sulfate Reducing Bacteria. *Environ. Sci. Technol.*, **47**(19), 10939–10946.

Maeng, S. K.; Choi, B. G.; Lee, K. T.; Song, K. G. (2013) Influence of Solid Retention Time, Nitrification and Microbial Activity on the Attenuation of Pharmaceuticals and Estrogens in Membrane Bioreactors. *Water Res.*, **47**(9), 3151–3162.

Martinez, F.; Lopez-Munoz, M. J.; Melero, J. A.; Arsuaga, J.; Soto, A.; Molina, R.; Segura, Y.; Pariente, M. I.; Revilla, A.; Cerro, L.; Carenas, G. (2013) Coupling Membrane Separation and Photocatalytic Oxidation Processes for the Degradation of Pharmaceutical Pollutants. *Water Res.*, **47**(15), 5647–5658.

Ma, R.; Levard, C.; Michel, F. M.; Brown, G. E.; Lowry, G. V. (2013) Sulfidation Mechanism for Zinc Oxide Nanoparticles and the Effect of Sulfidation on Their Solubility. *Environ. Sci. Technol.*, **47**(6), 2527–2534.

Ma, R.; Nicolussi, D.; Fantin, A.; Lowry, G. V. (2013) Influence of Solid Retention Time, Nitrification and Microbial Activity on the Attenuation of Pharmaceuticals and Estrogens in Membrane Bioreactors. *Water Res.*, **47**(9), 3151–3162.

Marti, E.; Jofre, J.; Balcazar, J. L. (2013) Prevalence of Antibiotic Resistance Genes and Bacterial Community Composition in a River Influenced by a Wastewater Treatment Plant. *PLoS One*, **8**(10), 1–8.

Martinez, F.; Lopez-Munoz, M. J.; Aguado, J.; Melero, J. A.; Arsuaga, J.; Soto, A.; Molina, R.; Segura, Y.; Pariente, M. I.; Revilla, A.; Cerro, L.; Carenas, G. (2013) Coupling Membrane Separation and Photocatalytic Oxidation Processes for the Degradation of Pharmaceutical Pollutants. *Water Res.*, **47**(15), 5647–5658.

Mashare, M. L.; Lee, L. S.; Nies, L. F.; Turco, R. F. (2013) Transformation of 17 Alpha-Estradiol, 17 Beta-Estradiol, and Estrone in Sediments under Nitrate- and Sulfate-Reducing Conditions. *Environ. Sci. Technol.*, **47**(13), 7178–7185.

McPhedran, K. N.; Seth, R.; Drouillard, K. G. (2013) Hydrophobic Organic Compound (Hoc) Partitioning Behaviour to Municipal Wastewater Colloidal Organic Carbon. *Water Res.*, **47**(7), 2222–2230.

Michael, I.; Rizzo, L.; Mc Ardell, C. S.; Manaia, C. M.; Merlin, C.; Schwartz, T.; Dagot, C.; Fatta-Kassinos, D. (2013) Urban Wastewater Treatment Plants as Hotspots for the Release of Antibiotics in the Environment: A Review. *Water Res.*, **47**(3), 957–995.

Middleton, J. H.; Salierno, J. D. (2013) Antibiotic Resistance in Triclosan Tolerant Fecal Coliforms Isolated from Surface Waters near Wastewater Treatment Plant Outflows (Morris County, NJ, USA). *Ecotoxicol. Environ. Saf.*, **88**, 79–88.

Miller, J. H.; Novak, J. T.; Knocke, W. R.; Young, K.; Hong, Y. J.; Vikesland, P. J.; Hull, M. S.; Pruden, A. (2013) Effect of Silver Nanoparticles and Antibiotics on Antibiotic Resistance Genes in Anaerobic Digestion. *Water Environ. Res.*, **85**(5), 411–421.

Misiti, T.; Tandukar, M.; Tezel, U.; Pavlostathis, S. G. (2013) Inhibition and Biotransformation Potential of Naphthenic Acids under Different Electron Accepting Conditions. *Water Res.*, **47**(1), 406–418.

Misiti, T.; Tezel, U.; Pavlostathis, S. G. (2013) Fate and Effect of Naphthenic Acids on Oil Refinery Activated Sludge Wastewater Treatment Systems. *Water Res.*, **47**(1), 449–460.

Mohanty, S. K.; Torkelson, A. A.; Dodd, H.; Nelson, K. L.; Boehm, A. B. (2013) Engineering Solutions to Improve the Removal of Fecal Indicator Bacteria by Bioinfiltration Systems During Intermittent Flow of Stormwater. *Environ. Sci. Technol.*, **47**(19), 10791–10798.

Muehe, E. M.; Scheer, L.; Daus, B.; Kappler, A. (2013) Fate of Arsenic During Microbial Reduction of Biogenic Versus Abiogenic as-Fe(III)-Mineral Coprecipitates. *Environ. Sci. Technol.*, **47**(15), 8297–8307.

Munsch, C.; Marchand, P.; Venisseau, A.; Veyrand, B.; Zendong, Z. (2013) Levels and Trends of the Emerging Contaminants HBCDs (Hexabromocyclododecanes) and PFCs (Perfluorinated Compounds) in Marine Shellfish Along French Coasts. *Chemosphere*, **91**(2), 233–240.

Murakami, M.; Nishikoori, H.; Sakai, H.; Oguma, K.; Takada, H.; Takizawa, S. (2013) Formation of Perfluorinated Surfactants from Precursors by Indigenous Microorganisms in Groundwater. *Chemosphere*, **93**(1), 140–145.

Narumiya, M.; Nakada, N.; Yamashita, N.; Tanaka, H. (2013) Phase Distribution and Removal of Pharmaceuticals and Personal Care Products During Anaerobic Sludge Digestion. *J. Hazard. Mater.*, **260**, 305–312.

Neale, P. A.; Jamting, A. K.; Escher, B. I.; Herrmann, J. (2013) A Review of the Detection, Fate and Effects of
Engineered Nanomaterials in Wastewater Treatment Plants. *Water Sci. Technol.*, **68**(7), 1440–1453.

Nguyen, L. N.; Hai, F. I.; Yang, S.; Kang, J.; Leusch, F. D.; Roddick, F.; Price, W. E.; Nghiem, L. D. (2013) Removal of Trace Organic Contaminants by an Mbr Comprising a Mixed Culture of Bacteria and White-Rot Fungi. *Bioresour Technol.*, **148**(234–241).

Niehen, U.; Hastrup, C.; Klausen, M. M.; Pedersen, B. M.; Kristensen, G. H.; Jansen, J. L.; Bak, S. N.; Tuerk, J. (2013) Removal of Aps and Bacteria from Hospital Wastewater by Mbr Plus O(3), O(3) + H(2)O(2), Pac or Clo(2). *Water Sci. Technol.*, **67**(4), 854–862.

Niu, J. F.; Lin, H.; Gong, C.; Sun, X. M. (2013) Theoretical and Experimental Insights into the Electrochemical Mineralization Mechanism of Perfluorooctanoic Acid. *Environ. Sci. Technol.*, **47**(24), 14341–14349.

Nolvak, H.; Truu, M.; Tiirik, K.; Oopkaup, K.; Sildvee, T.; Kaasik, A.; Mander, U.; Truu, J. (2013) Dynamics of Antibiotic Resistance Genes and Their Relationships with System Treatment Efficiency in a Horizontal Subsurface Flow Constructed Wetland. *Sci. Total Environ.*, **461**, 636–644.

Norris, M. J.; Pulford, I. D.; Haynes, H.; Dorea, C. C.; Phoenix, V. R. (2013) Treatment of Heavy Metals by Iron Oxide Coated and Natural Gravel Media in Sustainable Urban Drainage Systems. *Water Sci. Technol.*, **68**(3), 674–680.

Noutsopoulos, C.; Mamais, D.; Samaras, V.; Bouras, T.; Marneri, M.; Antoniou, K. (2013) Effect of Wastewater Chlorination on Endocrine Disruptor Removal. *Water Sci. Technol.*, **67**(7), 1551–1556.

Novo, A.; Andre, S.; Viana, P.; Nunes, O. C.; Manaia, C. M. (2013) Antibiotic Resistance, Antimicrobial Residues and Bacterial Community Composition in Urban Wastewater. *Water Res.*, **47**(5), 1875–1887.

Ostoich, M.; Serena, F.; Falletti, L.; Fantoni, A. (2013) Control of Dangerous Substances in Discharges and Microbiological Abatement: European Framework and a Case Study of an Ozone Disinfection System. *Water Sci. Technol.*, **67**(6), 1238–1246.

Ottmar, K. J.; Colosi, L. M.; Smith, J. A. (2013) Evaluation of a Prediction Model for Influent Pharmaceutical Concentrations. *J. Environ. Eng.-ASCE*, **139**(7), 1017–1021.

Padhiye, L. P.; Kim, J.-H.; Huang, C.-H. (2013) Oxidation of Dithiocarbamates to Yield N-Nitrosamines by Water Disinfection Oxidants. *Water Res.*, **47**(2), 725–736.

Palanisamy, B.; Babu, C. M.; Sundaravel, B.; Anandan, S.; Murugesan, V. (2013) Sol–Gel Synthesis of Mesoporous Mixed FeOₓ/TiO₂ Photocatalyst: Application for Degradation of 4-Chlorophenol. *J. Hazard. Mater.*, **252**, 233–242.

Park, H. J.; Kim, H. Y.; Cha, S.; Ahn, C. H.; Roh, J.; Park, S.; Kim, S.; Choi, K.; Yi, J.; Kim, Y.; Yoon, J. (2013) Removal Characteristics of Engineered Nanoparticles by Activated Sludge. *Chemosphere*, **92**(5), 524–528.

Pasakarnis, T. S.; Boyanov, M. I.; Kemner, K. M.; Mishra, B.; O'Loughlin, E. J.; Parkin, G.; Scherer, M. M. (2013) Influence of Chloride and Fe(II) Content on the Reduction of Hg(II) by Magnetite. *Environ. Sci. Technol.*, **47**(13), 6987–6994.

Perez, J. A. S.; Sanchez, I. M. R.; Carra, I.; Reina, A. C.; Lopez, J. L. C.; Malato, S. (2013) Economic Evaluation of a Combined Photo–Fenton/Mbr Process Using Pesticides as Model Pollutant. Factors Affecting Costs. *J. Hazard. Mater.*, **244**, 195–203.

Picao, R. C.; Cardoso, J. P.; Campana, E. H.; Nicoletti, A. G.; Petrolini, F. V. B.; Assis, D. M.; Juliano, L.; Gales, A. C. (2013) The Route of Antimicrobial Resistance from the Hospital Effluent to the Environment: Focus on the Occurrence of KPC–Producing *Aeromonas* spp. And *Enterobacteriaceae* in Sewage. *Diagn. Microbiol. Infect. Dis.*, **76**(1), 80–85.

Qiang, Z. M.; Nie, Y. F.; Ben, W. W.; Qu, J. H.; Zhang, H. Q. (2013) Degradation of Endocrine-Disrupting Chemicals During Activated Sludge Reduction by Ozone. *Chemosphere*, **91**(3), 366–373.

Qing, Z. M.; Dong, H. Y.; Zhu, B.; Qu, J. H.; Nie, Y. F. (2013) A Comparison of Various Rural Wastewater Treatment Processes for the Removal of Endocrine-Disrupting Chemicals (Edcs). *Chemosphere*, **92**(8), 986–992.

Rakshita, S.; Sarkar, D.; Elzinga, E. J.; Punamiya, P.; Datta, R. (2013) Mechanisms of Ciprofloxacin Removal by Nano-Sized Magnetite. *J. Hazard. Mater.*, **246**, 221–226.

Ramasesh, S.; Yoo, H. N.; Song, K. G.; Lee, J.; Choi, K. J.; Hong, S. W. (2013) Titanium Dioxide Nanofibers Integrated Stainless Steel Filter for Photocatalytic Degradation of Pharmaceutical Compounds. *J. Hazard. Mater.*, **258**, 124–132.

Reinholer, F. F.; Galler, H.; Feierl, G.; Haas, D.; Leitner, E.; Mascher, F.; Melkes, A.; Posch, J.; Pertschy, B.; Winter, I.; Himmel, W.; Marth, E.; Zarfel, G. (2013) Resistance Patterns of *Escherichia coli* Isolated from
Sewage Sludge in Comparison with Those Isolated from Human Patients in 2000 and 2009. J. Water Health, 11(1), 13–20.

Rivera-Utrilla, J.; Sanchez-Polo, M.; Ferro-Garcia, M. A.; Prados-Joya, G.; Ocampo-Perez, R. (2013) Pharmaceuticals as Emerging Contaminants and Their Removal from Water. A Review. Chemosphere, 93(7), 1268–1287.

Rizzo, L.; Fiorentino, A.; Anselmo, A. (2013) Advanced Treatment of Urban Wastewater by UV Radiation: Effect on Antibiotics and Antibiotic–Resistant E. coli Strains. Chemosphere, 92(2), 171–176.

Rosenkranz, F.; Cabrol, L.; Carballa, M.; Donoso–Bravo, A.; Cruz, L.; Ruiz–Filippi, G.; Chamy, R.; Lema, J. M. (2013) Relationship between Phenol Degradation Efficiency and Microbial Community Structure in an Anaerobic SBR. Water Res., 47(17), 6739–6749.

Rounsefell, B. D.; O’Sullivan, C. A.; Chinivasagam, N.; Batstone, D.; Clarke, W. P. (2013) Fate of Pathogen Indicators in a Domestic Blend of Food Waste and Wastewater through a Two-Stage Anaerobic Digestion System. Water Sci. Technol., 67(2), 366–373.

Roy, P.; Periasamy, A. P.; Liang, C. T.; Chang, H. T. (2013) Synthesis of Graphene–ZnO–Au Nanocomposites for Efficient Photocatalytic Reduction of Nitrobenzene. Environ. Sci. Technol., 47(12), 6688–6695.

Samaras, V. G.; Stasinakis, A. S.; Mamais, D.; Thomaidis, N. S.; Lekkas, T. D. (2013) Fate of Selected Pharmaceuticals and Synthetic Endocrine Disrupting Compounds During Wastewater Treatment and Sludge Anaerobic Digestion. J. Hazard. Mater., 244, 259–267.

Schaar, H.; Sommer, R.; Schurhagl, R.; Yillia, P.; Kreuzinger, N. (2013) Microorganism Inactivation by an Ozonation Step Optimized for Micropollutant Removal from Tertiary Effluent. Water Sci. Technol., 68(2), 311–318.

Schreiber, C.; Kistemann, T. (2013) Antibiotic Resistance among Autochthonous Aquatic Environmental Bacteria. Water Sci. Technol., 67(1), 117–123.

Senta, L.; Terzic, S.; Ahel, M. (2013) Occurrence and Fate of Dissolved and Particulate Antimicrobials in Municipal Wastewater Treatment. Water Res., 47(2), 705–714.

Seyhi, B.; Drogui, P.; Buelna, G.; Blais, J. F. (2013) Biodegradation of Bisphenol-A in Aerobic Membrane Bioreactor Sludge. Water Sci. Technol., 68(9), 1926–1931.

Sigala, J.; Unc, A. (2013) Pyrosequencing Estimates of the Diversity of Antibiotic Resistant Bacteria in a Wastewater System. Water Sci. Technol., 67(7), 1534–1543.

Simsek, H.; Kasi, M.; Ohm, J. B.; Blonigen, M.; Khan, E. (2013) Bioavailable and Biodegradable Dissolved Organic Nitrogen in Activated Sludge and Trickling Filter Wastewater Treatment Plants. Water Res., 47(9), 3201–3210.

Sindiku, O.; Orata, F.; Weber, R.; Osibanjo, O. (2013) Per– and Polyfluoroalkyl Substances in Selected Sewage Sludge in Nigeria. Chemosphere, 92(3), 329–335.

Stalder, T.; Alrhmoun, M.; Louvet, J. N.; Casellas, M.; Maftah, C.; Carrion, C.; Pons, M. N.; Pahl, O.; Ploy, M. C.; Dagot, C. (2013) Dynamic Assessment of the Floc Morphology, Bacterial Diversity, and Integron Content of an Activated Sludge Reactor Processing Hospital Effluent. Environ. Sci. Technol., 47(14), 7909–7917.

Subedi, B.; Lee, S.; Moon, H. B.; Kannan, K. (2013) Psychoactive Pharmaceuticals in Sludge and Their Emission from Wastewater Treatment Facilities in Korea. Environ. Sci. Technol., 47(23), 13321–13329.

Sun, K.; Kang, M. J.; Zhang, Z. Y.; Jin, J.; Wang, Z. Y.; Pan, Z. Z.; Xu, D. Y.; Wu, F. C.; Xing, B. S. (2013) Impact of Deashing Treatment on Biochar Structural Properties and Potential Sorption Mechanisms of Phenanthrene. Environ. Sci. Technol., 47(20), 11473–11481.

Syed, J. H.; Malik, R. N.; Li, J.; Wang, Y.; Xu, Y.; Zhang, G.; Jones, K. C. (2013) Levels, Profile and Distribution of Dechloran Plus (DP) and Polybrominated Diphenyl Ethers (PBDEs) in the Environment of Pakistan. Chemosphere, 93(8), 1646–1653.

Tang, S.; Wang, X. M.; Yang, H. W.; Xie, Y. F. F. (2013) Haloacetic Acid Removal by Sequential Zero–Valent Iron Reduction and Biologically Active Carbon Degradation. Chemosphere, 90(4), 1563–1567.

Tang, Y. H.; Zhang, G.; Liu, C. B.; Luo, S. L.; Xu, X. L.; Chen, L.; Wang, B. G. (2013) Magnetic TiO2–Graphene Composite as a High-Performance and Recyclable Platform for Efficient Photocatalytic Removal of Herbicides from Water. J. Hazard. Mater., 252, 115–122.

Tewari, S.; Jindal, R.; Kho, Y. L.; Eo, S.; Choi, K. (2013) Major Pharmaceutical Residues in Wastewater Treatment Plants and Receiving Waters in Bangkok, Thailand, and Associated Ecological Risks. Chemosphere, 91(5), 697–704.

Thompson, J. M.; Gundogdu, A.; Stratton, H. M.; Katouli, M. (2013) Antibiotic Resistant Staphylococcus aureus in
Hospital Wastewaters and Sewage Treatment Plants with Special Reference to Methicillin–Resistant Staphylococcus aureus (MRSA). J. Appl. Microbiol., 114(1), 44–54.

Toyama, T.; Ojima, T.; Tanaka, Y.; Mori, K.; Morikawa, M. (2013) Sustainable Biodegradation of Phenolic Endocrine-Disrupting Chemicals by Phragmites Australis-Rhizosphere Bacteria Association. Water Sci. Technol., 68(3), 522–529.

Trovo, A. G.; Silva, T. F. S.; Comes, O.; Machado, A. E. H.; Neto, W. B.; Muller, P. S.; Daniel, D. (2013) Degradation of Caffeine by Photo-Fenton Process: Optimization of Treatment Conditions Using Experimental Design. Chemosphere, 90(2), 170–175.

Ullmann, A.; Brauner, N.; Vazana, S.; Katz, Z.; Goikhman, R.; Seemann, B.; Marom, H.; Gozin, M. (2013) New Biodegradable Organic-Soluble Chelating Agents for Simultaneous Removal of Heavy Metals and Organic Pollutants from Contaminated Media. J. Hazard. Mater., 260, 676–688.

Urtiaga, A. M.; Pérez, G.; Ibáñez, R.; Ortiz, I. (2013) Removal of Pharmaceuticals from a Wwtp Secondary Effluent by Ultrafiltration/Reverse Osmosis Followed by Electrochemical Oxidation of the Ro Concentrate. Desalination, 331(0), 26–34.

Uyaguari, M. I.; Scott, G. I.; Norman, R. S. (2013) Abundance of Class 1–3 Integrons in South Carolina Estuarine Ecosystems under High and Low Levels of Anthropogenic Influence. Mar. Pollut. Bull., 76(1–2), 77–84.

Vallejo, A.; Prieto, A.; Moeder, M.; Usobiaga, A.; Zuloaga, O.; Etxebarria, N.; Paschke, A. (2013) Calibration and Field Test of the Polar Organic Chemical Integrative Samplers for the Determination of 15 Endocrine Disrupting Compounds in Wastewater and River Water with Special Focus on Performance Reference Compounds (Prc). Water Res., 47(8), 2851–2862.

Varela, A. R.; Ferro, G.; Vredenburg, J.; Yanik, M.; Vieira, L.; Rizzo, L.; Lameiras, C.; Manaia, C. M. (2013) Vancomycin Resistant Enterococci: From the Hospital Effluent to the Urban Wastewater Treatment Plant. Sci. Total Environ., 450, 155–161.

Venkatesan, A. K.; Halden, R. U. (2013a) National Inventory of Alkylphenol Ethoxylate Compounds in U.S. Sewage Sludges and Chemical Fate in Outdoor Soil Mesocosms. Environ. Pollut., 174, 189–193.

Venkatesan, A. K.; Halden, R. U. (2013b) National Inventory of Perfluoroalkyl Substances in Archived Us Biosolids from the 2001 Epa National Sewage Sludge Survey. J. Hazard. Mater., 252, 413–418.

Vigueras-Cortes, J. M.; Villanueva-Fierro, I.; Garzon-Zuniga, M. A.; Navar-Chaidez, J. D.; Chaires-Hernandez, I.; Hernandez-Rodriguez, C. (2013) Performance of a Biofilter System with Agave Fiber Filter Media for Municipal Wastewater Treatment. Water Sci. Technol., 68(3), 599–607.

Vymazal, J. (2013) The Use of Hybrid Constructed Wetlands for Wastewater Treatment with Special Attention to Nitrogen Removal: A Review of a Recent Development. Water Res., 47(14), 4795–4811.

Wang, D. G.; Norwood, W.; Alaee, M.; Byer, J. D.; Brimble, S. (2013) Review of Recent Advances in Research on the Toxicity, Detection, Occurrence and Fate of Cyclic Volatile Methyl Siloxanes in the Environment. Chemosphere, 93(5), 711–725.

Wang, D. G.; Steer, H.; Tait, T.; Williams, Z.; Pacepavicius, G.; Young, T.; Ng, T.; Smyth, S. A.; Kinsman, L.; Alaee, M. (2013) Concentrations of Cyclic Volatile Methylsiloxanes in Biosolid Amended Soil, Influent, Effluent, Receiving Water, and Sediment of Wastewater Treatment Plants in Canada. Chemosphere, 93(5), 766–773.

Wang, D. W.; Li, Y.; Li, G. P.; Wang, C.; Zhang, W. L.; Wang, Q. (2013) Modeling of Quantitative Effects of Water Components on the Photocatalytic Degradation of 17 Alpha-Ethynylestradiol in a Modified Flat Plate Serpentine Reactor. J. Hazard. Mater., 254, 64–71.

Wang, S. W.; Huang, J.; Yang, Y.; Hui, Y. M.; Ge, Y. X.; Larssen, T.; Yu, G.; Deng, S. B.; Wang, B.; Harman, C. (2013) First Report of a Chinese PFOS Alternative Overlooked for 30 Years: Its Toxicity, Persistence, and Presence in the Environment. Environ. Sci. Technol., 47(18), 10163–10170.

Wang, W. M.; Song, J.; Han, X. (2013) Schwertmannite as a New Fenton-Like Catalyst in the Oxidation of Phenol by H$_2$O$_2$. J. Hazard. Mater., 262, 412–419.

Wang, W.; Mao, Q.; He, H. H.; Zhou, M. H. (2013) Fe$_3$O$_4$ Nanoparticles as an Efficient Heterogeneous Fenton Catalyst for Phenol Removal at Relatively Wide pH Values. Water Sci. Technol., 68(11), 2367–2373.

Wang, X. K.; Wang, Y. N.; Li, D. L. (2013) Degradation of Tetracycline in Water by Ultrasonic Irradiation. Water Sci. Technol., 67(4), 715–721.
Wang, Z.; Zhang, X. X.; Huang, K. L.; Miao, Y.; Shi, P.; Liu, B.; Long, C.; Li, A. M. (2013) Metagenomic Profiling of Antibiotic Resistance Genes and Mobile Genetic Elements in a Tannery Wastewater Treatment Plant. *PLoS One*, 8(10), 1–9.

Wei, X. X.; Chen, J. W.; Xie, Q.; Zhang, S. Y.; Ge, L. K.; Qiao, X. L. (2013) Distinct Photolytic Mechanisms and Products for Different Dissociation Species of Ciprofloxacin. *Environ. Sci. Technol.*, 47(9), 4284–4290.

Westerhoff, P. K.; Kiser, A.; Hristovski, K. (2013) Nanomaterial Removal and Transformation During Biological Wastewater Treatment. *Environ. Eng. Sci.*, 30(3), 109–117.

Wibberg, D.; Szczepanowski, R.; Eikmeyer, F.; Puhler, A.; Schluter, A. (2013) The IncF Plasmid PRSB225 Isolated from a Municipal Wastewater Treatment Plant's on–Site Preflooder Combining Antibiotic Resistance and Putative Virulence Functions is Highly Related to Virulence Plasmids Identified in Pathogenic *E. coli* Isolates. *Plasmid*, 69(2), 127–137.

Wojciechowska, E. (2013) Removal of Persistent Organic Pollutants from Landfill Leachates Treated in Three Constructed Wetland Systems. *Water Sci. Technol.*, 68(5), 1164–1172.

Wu, M. L.; Wang, L. L.; Xu, H. N.; Ding, Y. (2013) Occurrence and Removal Efficiency of Six Polycyclic Aromatic Hydrocarbons in Different Wastewater Treatment Plants. *Water Sci. Technol.*, 68(8), 1844–1851.

Xia, R. R.; Ren, Y.; Guo, X. H.; Xu, H. (2013) Molecular Diversity of Class 2 Integrons in Antibiotic–Resistant Gram–Negative Bacteria Found in Wastewater Environments in China. *Ecotoxicology*, 22(2), 402–414.

Xiao, H.; Song, H. Y.; Xie, H. Q.; Huang, W.; Tan, J.; Wu, J. Z. (2013) Transformation of Acetaminophen Using Manganese Dioxide - Mediated Oxidative Processes: Reaction Rates and Pathways. *J. Hazard. Mater.*, 250, 138–146.

Xu, J.; Sheng, G. P.; Ma, Y.; Wang, L. F.; Yu, H. Q. (2013) Roles of Extracellular Polymeric Substances (EPS) in the Migration and Removal of Sulfamethazine in Activated Sludge System. *Water Res.*, 47(14), 5298–5306.

Xu, J.; Tian, Y. Z.; Zhang, Y.; Guo, C. S.; Shi, G. L.; Zhang, C. Y.; Feng, Y. C. (2013) Source Apportionment of Perfluorinated Compounds (PFCs) in Sediments: Using Three Multivariate Factor Analysis Receptor Models. *J. Hazard. Mater.*, 260, 483–488.

Xu, L.; Shi, Y. L.; Cai, Y. Q. (2013) Occurrence and Fate of Volatile Siloxanes in a Municipal Wastewater Treatment Plant of Beijing, China. *Water Res.*, 47(2), 715–724.

Xu, P.; Capito, M.; Cath, T. Y. (2013) Selective Removal of Arsenic and Monovalent Ions from Brackish Water Reverse Osmosis Concentrate. *J. Hazard. Mater.*, 260, 885–891.

Yang, D.; Wang, J. F.; Qiu, Z. G.; Jin, M.; Shen, Z. Q.; Chen, Z. L.; Wang, X. W.; Zhang, B.; Li, J. W. (2013) Horizontal Transfer of Antibiotic Resistance Genes in a Membrane Bioreactor. *J. Biotechnol.*, 167(4), 441–447.

Yang, J. J.; Wen, G.; Zhao, J.; Shao, X. L.; Ma, J. (2013) Oxidation of Bisphenol A by Permanganate: Reaction Kinetics and Removal of Estrogenic Activity. *Water Sci. Technol.*, 67(8), 1867–1872.

Yeh, K. J.; Chen, T. C.; Young, W. L. (2013) Competitive Removal of Two Contaminants in a Goethite–Catalyzed Fenton Process at Neutral pH. *Environ. Eng. Sci.*, 30(2), 47–52.

Yoon, M. K.; Drewes, J. E.; Amy, G. L. (2013) Fate of Bulk and Trace Organics During a Simulated Aquifer Recharge and Recovery (ARR)–Ozone Hybrid Process. *Chemosphere*, 93(9), 2055–2062.

Yoon, S.; Nakada, N.; Tanaka, H. (2013) Occurrence and Fate of N–Nitrosamines and Their Formation Potential in Three Wastewater Treatment Plants in Japan. *Water Sci. Technol.*, 68(10), 2118–2126.

Yost, E. E.; Meyer, M. T.; Dietze, J. E.; Meissner, B. M.; Worley-Davis, L.; Williams, C. M.; Lee, B.; Kullman, S. W. (2013) Comprehensive Assessment of Hormones, Phytosterogens, and Estrogenic Activity in an Anaerobic Swine Waste Lagoon. *Environ. Sci. Technol.*, 47(23), 13781–13790.

Yu, H.; Nie, E.; Xu, J.; Yan, S. W.; Cooper, W. J.; Song, W. H. (2013) Degradation of Diclofenac by Advanced Oxidation and Reduction Processes: Kinetic Studies, Degradation Pathways and Toxicity Assessments. *Water Res.*, 47(5), 1909–1918.

Yuan, S. H.; Gou, N.; Alshawabkeh, A. N.; Gu, A. Z. (2013) Efficient Degradation of Contaminants of Emerging Concerns by a New Electro-Fenton Process with Ti/MnO2 Cathode. *Chemosphere*, 93(11), 2796–2804.

Yuan, Z. H.; Chen, Y. B.; Li, T. T.; Yu, C. P. (2013) Reaction of Silver Nanoparticles in the Disinfection Process. *Chemosphere*, 93(4), 619–625.
Zaviska, F.; Drogui, P.; Grasmick, A.; Azais, A.; Héran, M. (2013) Nanofiltration Membrane Bioreactor for Removing Pharmaceutical Compounds. *Journal of Membrane Science*, 429(0), 121–129.

Zeng, L. X.; Li, H. J.; Wang, T.; Gao, Y.; Xiao, K.; Du, Y. G.; Wang, Y. W.; Jiang, G. B. (2013) Behavior, Fate, and Mass Loading of Short Chain Chlorinated Paraffins in an Advanced Municipal Sewage Treatment Plant. *Environ. Sci. Technol.*, 47(2), 732–740.

Zhang, B.; Luo, Y. M.; Makino, T.; Wu, L. H.; Nanzyo, M. (2013) The Heavy Metal Partition in Size-Fractions of the Fine Particles in Agricultural Soils Contaminated by Waste Water and Smelter Dust. *J. Hazard. Mater.*, 248, 303–312.

Zhang, W.; Zhang, Y. T.; Taniyasu, S.; Yeung, L. W. Y.; Lam, P. K. S.; Wang, J. S.; Li, X. H.; Yamashita, N.; Dai, J. Y. (2013) Distribution and Fate of Perfluoroalkyl Substances in Municipal Wastewater Treatment Plants in Economically Developed Areas of China. *Environ. Pollut.*, 176, 10–17.

Zhao, C.; Fan, W.; Wang, T.; Hou, D.; Luan, Z. (2013) The Effects of Operating Parameters on Spiramycin Removal by Nanofiltration Membrane. *Water Sci. Technol.*, 68(7), 1512–1519.

Zhao, Q.; Feng, L.; Cheng, X.; Chen, C.; Zhang, L. Q. (2013) Photodegradation of Amoxicillin in Aqueous Solution under Simulated Irradiation: Influencing Factors and Mechanisms. *Water Sci. Technol.*, 67(7), 1605–1611.

Zheng, W.; Zou, Y. H.; Li, X. L.; Machesky, M. L. (2013) Fate of Estrogen Conjugate 17 Alpha-Estradiol-3-Sulfate in Dairy Wastewater: Comparison of Aerobic and Anaerobic Degradation and Metabolite Formation. *J. Hazard. Mater.*, 258, 109–115.

Zhu, L. D.; Wang, Z. M.; Shu, Q.; Takala, J.; Hilunen, E.; Feng, P. Z.; Yuan, Z. H. (2013) Nutrient Removal and Biodiesel Production by Integration of Freshwater Algae Cultivation with Piggery Wastewater Treatment. *Water Res.*, 47(13), 4294–4302.