PHYSICO-CHEMICAL PROCESSES FOR ORGANIC REMOVAL FROM WASTEWATER EFFLUENT

H.K. Shon, S. Phuntsho, S. Vigneswaran and J. Kandasamy
Faculty of Engineering, University of Technology, Sydney, Australia

J. Cho
NOM Ecology Lab., Gwangju Institute of Science and Technology, Gwangju, Korea

J. H. Kim
School of Applied Chemical Engineering & The Research Institute for Catalysis, Chonnam National University, Gwangju 500-757, Korea

Keywords: Effluent organic matter; Biologically treated sewage effluent; Wastewater reuse; Organic removal; Molecular weight distribution; Physico-chemical treatment; Flocculation; Adsorption; Ion exchange; Advanced oxidation process; Biofiltration; Endocrine disrupting chemical (EDC); Pharmaceutical and personal care product (PPCP)

Contents

Summary

This chapter covers physio-chemical processes including advanced oxidation processes for wastewater treatment. The approach used in this chapter is to first provide a brief introduction to each of the processes followed by a brief description of the process fundamentals in removing organic matter. The removal of effluent organic matter (EfOM) in terms of dissolved organic carbon (DOC), molecular weight distribution (MWD) for each process is then explained followed by removal of endocrine disrupting chemicals (EDCs) and pharmaceutical and personal care products (PPCPs) by each process.

1. Introduction

The physico-chemical method of wastewater treatment involves either physical process or chemical process or at many times a combination of both these processes. Although their basic principles are quite different, the processes are sometimes hard to distinguish as the two processes may occur simultaneously in a single treatment unit. Sometimes the physical entrainment of organic micro pollutants in water and wastewater is also associated with biological degradation depending on the treatment environment. The sorption (definition included in the following section) of micro pollutants onto solids and, accordingly, their behaviour during the physico-chemical treatment, depends basically on their physico-chemical properties, such as lipophilicity or acidity (Carballa et al., 2005). Two types of coefficients (K_{ow}: octanol-water partition coefficient) and (K_{oc}: organic carbon partition coefficient) are usually used to determine the sorption effectiveness and the affinity of a given substance to effluent organic matter (EfOM).

However some limitations for its applicability in endocrine disrupting chemicals (EDCs) and pharmaceutical and personal care products (PPCPs) have been reported (Holbrook et al., 2004) and another indicator known as solid–water distribution coefficient (Kd), defined as the ratio between the concentrations of a substance in the solid and in the aqueous phase at equilibrium conditions have also been sometimes used as a suitable parameter (Ternes et al., 2004).

This coefficient takes into account the two main sorption mechanisms: absorption (hydrophobic interactions characterized by the Kow value) and adsorption (electrostatic interactions related to the tendency of the substance to be ionized or dissociated in aqueous phase, which is characterized by the dissociation constant, pKa). According to their physico-chemical properties, EDCs/PPCPs can be divided into three main groups: lipophilic (with high Kow values), neutral (non-ionic) and acidic (hydrophilic and ionic) compounds (Carballa et al., 2005).

At sewage treatment facilities, the wastewater is subjected to various treatment regimes (depending on the size and sophistication of the treatment plant), resulting in "removals" of PPCPs that range from nearly complete to nearly zero. Although the removal efficiencies are a function of the individual EDC/PPCP properties as well as the treatment process(es), their removal is also essentially a collateral or incidental function of a sewage treatment plant, as these facilities were never specifically designed to remove exotic, bioactive xenobiotics (Daughton, 2007).

In the following sections the physicochemical processes such as coagulation-flocculation, adsorption, biofiltration, ion exchange (IX) and advanced oxidation processes (AOPs) have been reviewed for their roles in removing dissolved organic matter, molecular weight distribution and EDCs and PPCPs.

2. Overview of Physico-Chemical Processes

One of the main reasons for applying physico-chemical processes in the advanced treatment of biologically treated sewage effluent (BTSE) is to remove particulate organic matter (> 0.45 μm) and dissolved organic matter (DOC < 0.45 μm). EfOM removal can be shown in terms of DOC, MWD, fraction and EDCs/PPCPs. DOC presents a surrogate for general organic contaminant removal by physico-chemical processes, MWD provides specific removal of different organic sizes, fraction represents removal of different hydrophobic/philic fractions and removal of EDCs and PPCPs can be used as an indicator for the smallest MW compounds (about 150 – 500 Da). The four parameters provide a better understanding of organic removal by physico-chemical processes.

The effectiveness of specific processes in treating EfOM is strongly influenced by the size (or MW) and structure of EfOM. The size ranges of EfOM removed by different treatment methods are shown in Figure 1. In general, flocculation and biofiltration remove the majority of particulate organic matter. Adsorption, IX and AOPs remove the small size of EfOM.

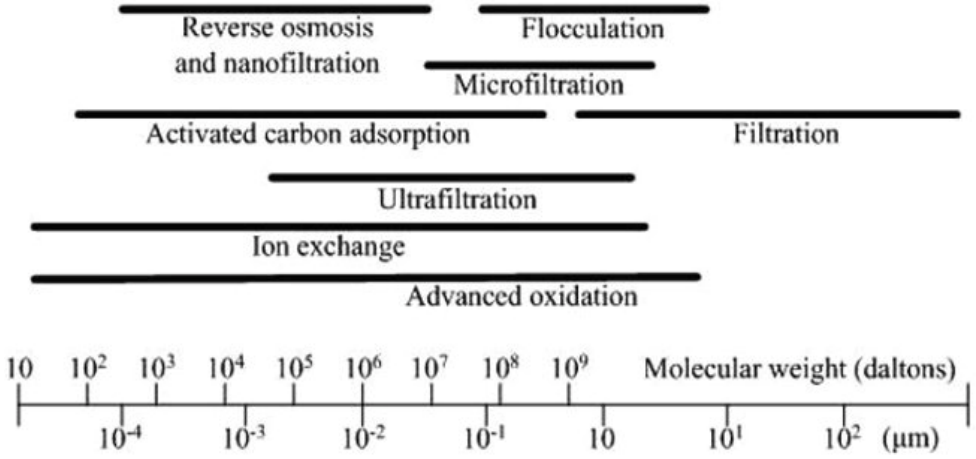

Figure 1 Size ranges of the applied treatments in treating EfOM

2.1 DOC Removal by Physico-Chemical Processes

Figure 2 shows the removal of EfOM from the same BTSE by different physico-chemical treatment at an optimum condition (Shon et al., 2006). The DOC removal depends significantly on the treatment processes used. Powdered activated carbon (PAC) adsorption and granular activated carbon (GAC) biofiltration result in relatively high DOC removal of EfOM in comparison to that of flocculation, IX and AOPs. This suggests that the EfOM consists mainly of small MW organic matter in the BTSE used.

Figure 3 shows the removal efficiency of EfOM from BTSE with chemical coupling. As expected, the removal increases significantly with chemical coupling. Enhanced removal was observed especially when coupling PAC adsorption with MIEX and PAC adsorption with flocculation which may be due to removal of different range MW by each process.

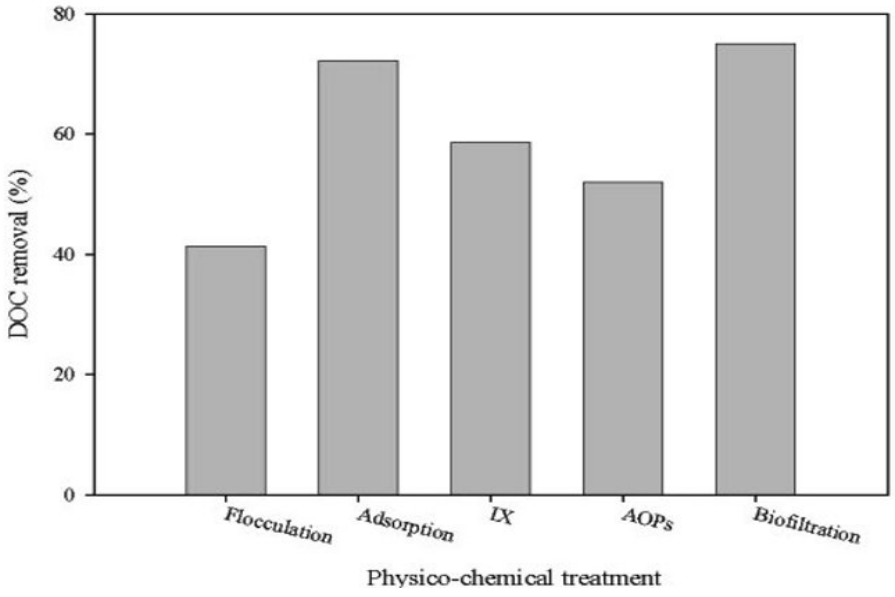

Figure 2 DOC removal by different physico-chemical processes ($FeCl_3$ flocculation, powdered activated carbon (PAC) adsorption, IX with magnetic ion exchange resin (MIEX®), AOPs (photocatalysis) with TiO_2, granular activated carbon (GAC) biofiltration) in BTSE from a wastewater treatment plant

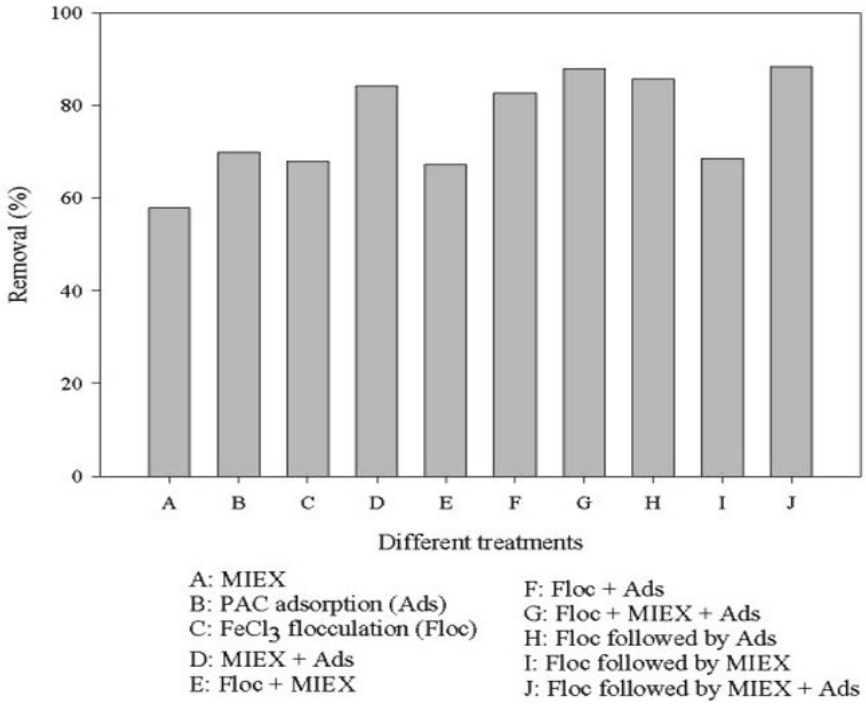

Figure 3 DOC removals from BTSE with different chemical couplings

2.2 MWD Removal by Physico-Chemical Processes

MWD of EfOM is very important in understanding the removal of micropollutants under different sizes by different treatment methods. Figure 4 shows the MWD of EfOM following treatment by different physical-chemical processes. The MWD of EfOM in the BTSE used is comprised of small (260 Da, 580 and 870) and large (43100 Da) MW compounds.

The organic concentration of biopolymers, humic substances, low MW acids and low MW neutrals including amphiphilic in BTSE was 0.7 mg/L (6% content), 6.3 mg/L (53%), 2.3 mg/L (20%) and 2.5 mg/L (21%), respectively (Haberkamp et al., 2007). Flocculation removed mainly the large MW compounds and did not remove the majority of small MW (263 Da, 330 and 580) while adsorption mainly removed the small MW compounds.

The five general MW peaks in BTSE are found in i) 30 kDa – 50 kDa, ii) 1500 Da – 800 Da, iii) 800 - 500 Da, iv) 250 Da and v) < 250 Da. The compounds in the range of 30 kDa – 50 kDa are biopolymers; 1500 Da – 800 Da are humic substances; 800 - 500 Da are building blocks; 250 Da are acids, and less than 200 Da are low MW neutrals and amphiphilics (Huber, 1998).

Here, biopolymers include polysaccharides and proteins; building blocks include hydrolysates of humic substances; acids include all free mono- and diprotic low-molar-mass organic acids; low MW neutrals and amphiphilics (slightly hydrophobic compounds) include sugars, alcohols, aldehydes, ketones and amino acids.

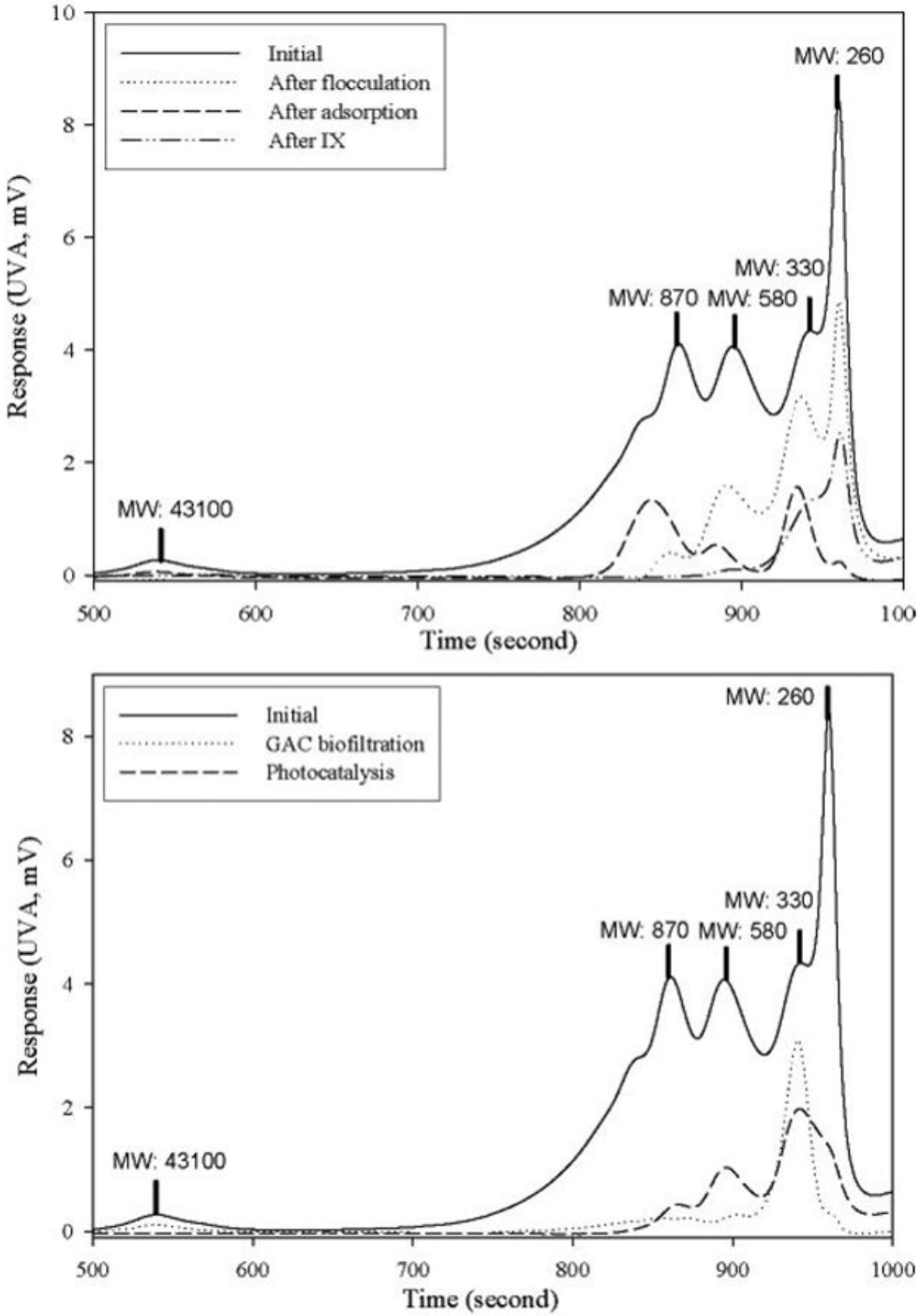

Figure 4 MWD of the influent BTSE and effluents from different physico-chemical treatments (flocculation, adsorption, GAC biofiltration, photocatalysis, and IX with MIEX®)

2.3 Fraction Removal by Physico-Chemical Processes

Removal of different organic fractions is also helpful in determining the efficiency of different physical-chemical treatments in removing hydrophobic (HP), transphilic (TP) and hydrophilic (HL) fractions (Table 1). $FeCl_3$ flocculation removed a higher amount of HL fraction. This is probably due to the ionic effects of EfOM. Flocculation removes HL fraction when the pollutants are more negatively charged. In general, flocculation and adsorption are used mainly to remove the HP fraction of large and small MW organics. The removal of HL by flocculation (in this case) may be due to the large dose of $FeCl_3$ used (through sweep flocculation mechanism) (Shon et al., 2005). The removal of HL by adsorption could be attributed to the physical affinity between HL organic molecules and PAC (through Vander Waals, electrostatic forces and chemisorption) (Shon et al., 2004). Ion exchange with MIEX® also exhibited very high removal of hydrophilic compounds (Zhang et al., 2005).

	Initial (mg/L)	**MIEX® (mg/L)**	**PAC adsorption (mg/L)**	**Flocculation (mg/L)**	**Photocatalysis (mg/L)**
HP	1.645	0.715 (56.5%)	0.460 (72.0%)	0.999 (39.3%)	0.802 (51.2%)
TP	1.034	0.705 (31.8%)	0.282 (72.7%)	0.802 (22.4%)	0.703 (32.0%)
HL	3.822	1.180 (69.1%)	1.258 (67.1%)	1.540 (59.7%)	2.810 (26.5%)

Table 1 Efficiency of different physico-chemical treatment processes in the removal of different fractions from BTSE

2.4 EDCs/PPCPs Removal by Physico-Chemical Processes

It is difficult to remove EDCs and PPCPs within the range from 100 to 500 Da in EfOM. Removal of EDCs and PPCPs is thus considered as the main parameter in determining the efficiency of a particular treatment method. Considering treatments by flocculation, adsorption and oxidation, the removal of these compounds showed very different trends (Table 2). Some of them are removed by up to 90%, while the others can only be partially removed (Barceló, 2003). This suggests that removal of the emerging contaminants requires the careful selection of treatment methods depending on the individual EDC and PPCP structure and treatment application/dose.

Treatments	**Compounds**
Flocculation	>50% removal of: benzo[a]pyrene, benzo [g,h,l]perylene, benzo[k]fluoranthene, mirex, benzo[b]fluoranthene, benzo[a]anthracene
	<10% removal of: diazepam, diclofenac, meprobamate, sulfamethoxazole, trimethoprim
Adsorption	>90% removal of: triclosan, fluoxetine, oxybenzone, mirex, DDT
	<50% removal: meprobamate, sulfamethoxazole, iopromide, trimethoprim, gemfibrozil
Chlorination	>90% removal of: 17β-estradiol, oxybenzone, triclosan, sulfamethoxazole, benzo[a]anthracene

	<40% removal of: androstenedione, progesterone, DDT, tri(2-chloroethyl) phosphate, mirex
Ozonation	>90% removal of: 17β-estradiol, fluoxetine, carbamazepine, progesterone, trimethoprim
	<50% removal of: lindane, musk ketone, iopromide, TCEP, meprobamate

Table 2 Unit processes and operations used for EDCs and PPCPs removal in WWTP

Group	**Classification**	**AC* adsorption**	**O_3/AOP**	**UV**	**Cl_2/ClO_2**	**Flocculation**
EDCs	Pesticides	E	L-E	E	P-E	P
	Industrial chemicals	E	F-G	E	P	P-L
	Steroids	E	E	E	E	P
	Metals	G	P	P	P	F-G
	Inorganics	P-L	P	P	P	P
	Organometallics	G-E	L-E	F-G	P-F	P-L
PPCPs	Antibiotics	F-G	L-E	F-G	P-G	P-L
	Antidepressants	G-E	L-E	F-G	P-F	P-L
	Anti-inflammatory	E	E	E	P-F	P
	Sunscreens	G-E	L-E	F-G	P-F	P-L
	Antimicrobials	G-E	L-E	F-G	P-F	P-L
	Surfactants/detergents	E	F-G	F-G	P	P-L

*AC, activated carbon; E, excellent (>90%); G, good (70-90%); F, fair (40-70%); L, low (20-40%); P, poor (<20%)

Table 3 Anticipated physico-chemical processes and operations for EDC and PPCP removal

Table 3 presents the universal performance of different unit processes in removing typical classes of EDCs and PPCPs (Snyder et al., 2003b). In general, flocculation cannot remove the majority of EDCs/PPCPs, while activated carbon can be used to adsorb many different EDCs/PPCPs. AOPs can moderately remove specific EDCs/PPCPs. Snyder et al., (2003b) reported that dissociated acidic EDCs/PPCPs were more reactive than protonated forms, suggesting that removal of EDCs/PPCPs is pH dependent. Functional groups that affect removal are in the order of thiols > amines > hydroxyl > carboxyl. Aromatic group of EDCs/PPCPs showed better removal in comparison to aliphatic compounds.

-
-
-

Bibliography

Abdessemed, D. and Nezzal G. (2002) Treatment of primary effluent by coagulation adsorption–ultrafiltration for reuse. Desalination 152, 367–373. [This presents approaches to the study of coagulation and adsorption pretreatment to UF]

Adams C., Wang Y., Loftin K., and Meyer M. (2002) Removal of antibiotics from surface and distilled water in conventional water treatment processes. J. Environ. Eng., 123, 253–260. [This presents approaches to the study of the removal of antibiotics from surface and distilled water]

Adin A., Soffer Y. and Ben Aim R. (1998) Effluent pre-treatment by iron coagulation applying various dose–pH combinations for optimum particle separation. Water Sci. Technol. 38, 27-34. [This presents approaches to the study of the performance of $FeCl_3$ flocculation as pretreatment for wastewater]

Al-Bastaki N.M. (2003) Performance of advanced methods for treatment of wastewater: UV/TiO2, RO and UF. Chem. Eng. Processing, 43, 935-940. [This presents approaches to the study of waste water treatment using advanced methods]

Al-Rasheed R. and Cardin D.J. (2003) Photocatalytic degradation of humic acid in saline waters. Part 1. Artificial seawater: influence of TiO_2, temperature, pH, and air-flow. Chemosphere 51, 925-933. [This presents approaches to the study of Influences of different parameters on PCO of humic acids in saline water]

An T., Gu H., Xiong Y., Chen W., Zhu X., Sheng G., and Fu J. (2003) Decolourization and COD removal from reactive dye-containing wastewater using sonophotocatalytic technology. Journal of Chemical Technology and Biotechnology, 78, 1141-1148. [This presents approaches to the study of decolourization and COD removal using sonophotocatalytic technology]

Andreozzi R., Caprio V., Insola A. and Marotta R. (1999) Advanced oxidation processes (AOP) for water purification and recovery. Catal. Today, 53, 51-59. [This presents approaches to the study of AOP for water purification and recovery]

Barceló D. (2003) Emerging pollutants in water analysis. Trends in Analytical Chemistry. 22, 14-16. [This presents approaches to the study of pollutants in water analysis]

Beltrán F.J., González M., Rivas F.J. and Alvarez P. (1996) Aqueous UV radiation and UV/H2O2 oxidation of Atrazine first degradtion products: Deethylatrazine and Deisopropylatrazine. Environmental Toxicology and Chemistry 15, 868-872. [This presents approaches to the study of of Atrazine first degradtion products using UV radiation]

Bertanz G., Pedrazzani R., Collivignarelli M.C. and Urbini G. (2002) II-086 – Comparison among hydrogen peroxide advanced oxidation processes for the treatment of industrial wastewaters. ABES - Associação Brasileira de Engenharia Sanitária e Ambiental. [This presents approaches to the study of comparison of H2O2 advanced oxidation processes in wastewater]

Bila D., Montalva˜o A.F., Azevedo D.A. and Dezotti M.R. (2007) Estrogenic activity removal of 17β-estradiol by ozonationand identification of by-products. Chemosphere 69, 736–746. [This presents approaches to the study of Estrogenic activity removal of 17β-estradiol using ozonationand identification]

Blanco J. and Malato S. (2003). Solar Detoxifications, UNESCO Publishing, France. [This presents approaches to the study of solar detoxifications]

Bolto B., Dixon D., Eldridge R., King S. and Linge K. (2002) Removal of natural organic matter by ion exchange. Water Research 36, 5057-5065. [This presents approaches to the study of removal of NOM by ion exchange]

Bourke M., O'Leary B. and Smith P. (1999) Scale-up of the MIEX DOC process for full scale water treatment plants. 18th Federal Convention AWWA Procedings 99, Adelaide, Australia. [This presents approaches to the study of MIEX DOC process for full scale water treatment plants]

Bowman J.C., Zhou J.L. and Readman J.W. (2002) Sediment–water interaction of nature oestrogens under estuarine conditions. Mar. Chem. 77, 263–276. [This presents approaches to the study of sediment–water interaction of nature oestrogens]

Boyd G.R., Reemtsma H., Grimm D.A. and Mitra S. (2003) Pharmaceuticals and personal care products (PPCPs) in surface and treated waters of Louisiana, USA and Ontario, Canada. Sci. Total Environ. 311, 135-149. [This presents approaches to the study of PPCPs in surface and treated waters of Louisiana, USA and Ontario]

Brattebo H., Odegaard H. and Halle O. (1987) Ion exchange for the removal of humic acids in water treatment. Water Research 21, 1045–1052. [This presents approaches to the study of humic acid removal using ion exchange in water treatment]

Carballa M., Omil F. and Lema J.M. (2005) Removal of cosmetic ingredients and pharmaceuticals innsewage primary treatment. Water Research 39, 4790–4796. [This presents approaches to the study of removal of cosmetic ingredients and pharmaceuticals in sewage primary treatment]

Chang S., Waite T.D., Ong P.E.A., Schäfer A.I. and Fane A.G. (2004) Assessment of Trace Estrogenic Contaminants Removal by Coagulant Addition, PAC Adsorption and PAC/MF Processes. Journal of Environmental Engineering, 130, 736-742. [This presents approaches to the study of coagulantion, PAC Adsorption and PAC/MF to remove Estrogenic contaminants]

Chapman H., Vigneswaran S., Ngo H.H., Dyer S. and Ben Aim R. (2002) Pre-flocculation of secondary treated wastewater in enhancing the performance of microfiltration. Desalination 146, 367–372. [This presents approaches to the study of enhancing the performance of MF using wastewater pre-flocculation]

Chaudhary D.S., Vigneswaran S., Ngo H.-H., Shim W.G. and Moon H. (2007) Biofilter in water and wastewater treatment. Korean Journal of Chemical Engineering 20, 1054-1065. [This presents approaches to the study of water and wastewater treatment using biofiltering systems]

Chen P.-J., Rosenfeldt E.J., Kullman S.W., Hinton D.E. and Linden K.G. (2007). Biological assessment of a mixture of endocrine disruptors at environmentally relevant concentrations in water following UV/H2O2 oxidation. Science of The Total Environment, 376, 18-26. [This presents approaches to the study of biological assessment following UV/H2O2 oxidation of a mixture of endocrine disruptors]

Chen P.-J., Linden K.G., Hinton D.E., Kashiwada S., Rosenfeldt E.J. and Kullman S.W. (2005) Biological assessment of bisphenol A degradation in water following direct photolysis and UV advanced oxidation. Chemosphere, 65, 1094-1102. [This presents approaches to the study of Biological assessment of bisphenol A degradation following direct photolysis and UV]

Chiron S., Fernandez-Alba A., Rodriguez A. and Garcia-Calvo E. (2000) Review paper - Pesticide chemical oxidation: state-of-the-art. Water Research, 34, 366-377. [This presents approaches to the study of review of pesticide chemical oxidation]

Choi K.J., Kim S.G., Kim C.W. and Park J.K. (2006) Removal efficiencies of endocrine disrupting chemicals by coagulation/flocculation, ozonation, powdered/granular activated carbon adsorption, and chlorination. Korean Journal of Chemical Engineering 23, 399-408. [This presents approaches to the study of coagulation/flocculation, ozonation, P/GAC adsorption, and chlorination to remove EDCs]

Choi K.J., Kim S.G., Kim C.W. and Kim S.H. (2005) Effects of activated carbon types and service life on removal of endocrine disrupting chemicals: amitrol, nonylphenol, and bisphenol-A. Chemosphere, 58, 1535-1545. [This presents approaches to the study of effects of activated carbon types and service life on removal of EDCs]

Choo K.H. and Kang S.K. (2003) Removal of residual organic matter from secondary effluent by iron oxides adsorption. Desalination 154, 139–146. [This presents approaches to the study of iron oxides adsorption for removing of residual OMs]

Chu W. and Wong C.C. (2004) The photocatalytic degradation of dicamba in TiO2 suspensions with the help of hydrogen peroxide by different near UV irradiations. Water Research 38, 1037–1043. [This presents approaches to the study of PCO of dicamba in TiO2 suspensions using H2O2]

Clancy J.L. and Hargy T.M. (2004) UV inactivation of microorganisms in water—A review. Water J. 31, 19-21. [This presents approaches to the study of complete review of UV inactivation of microorganisms in water]

Cook D., Chow C. and Drikas M. (2001) Laboratory Study of Conventional Alum Treatment versus MIEX Treatment for Removal of Natural Organic Matter, Proc. of 19th Federal Convention, Australian

Water Wastewater Asso, Canberra, Australia April. [This presents approaches to the study of removal of NOM using alum and MIEX treatment]

Crittenden J.C., Sanongraj S., Bulloch J.L., Hand D.W., Rogers T.N., Speth T.F. and Ulmer M. (1999a) Correlation of aqueous-phase adsorption isotherms. Environ. Sci. Technol. 33, 2926-2933. [This presents approaches to the study of the correlation between aqueous-phase adsorption isotherms]

Daughton C.G. Pharmaceuticals in the Environment: Sources and Their Management," 2007, Chapter 1, 1-58, In Analysis, Fate and Removal of Pharmaceuticals in the Water Cycle (M. Petrovic and D. Barcelo, Eds.), Wilson & Wilson's Comprehensive Analytical Chemistry series (D. Barcelo, Ed.), 50, ; 2007, 564. [This presents approaches to the study of pharmaceuticals in the Water Cycle]

DeWolfe J., Dempsey B., Taylor M. and Potter J.W. Guidance Manual for Coagulant Changeover. Denver, Co: AWWA Research Foundation, 2003. [This presents approaches to the study of species dynamics]

Dillert R., Vollmer S., Schober M., Theurich J., Bahnemann D., Arntz H., Pahlmann K., Wienefeld J., Schmedding T. and Sager G. (1999) Photocatalytic treatment of an industrial wastewater in the double-skin sheet reactor. Chem. Eng. Technol., 22, 931-936. [This presents approaches to the study of photocatalytic treatment of industrial wastewater]

Drewes J. E., Fox P. and Jekel M. (2001) Occurance of iodinated X-ray contrast media in domestic effluents and their fate during indirect potable reuse. J. of Env. Sci. Health part a-Toxic/Hazard Subs. Environ. Eng. 36, 1633-1645. [This presents approaches to the study of occurance of iodinated X-ray contrast media in domestic effluents during indirect potable reuse]

Eldib M.A. and Aly O.A. (1977) Removal of phenylamide pesticides from drinking waters. 1. Effect of chemical coagulation and oxidants. Water Research 11, 611-616. [This presents approaches to the study of effect of chemical coagulation and oxidants for removing of phenylamide pesticides]

Fearing D. ., Banks J., Jefferson B., Wilson D., Hillis P. and Campbell A.T. (2004) Combination of ferric and MIEX for the treatment of a humic rich water. Water Research 38, 2551–2558. [This presents approaches to the study of the humic rich water treatment using ferric and MIEX]

Frederick K., A look at uniform ion-exchange resins. Ultrapure Water. September, 66–67, 1997. [This presents approaches to the study of uniform ion-exchange resins]

Fuerhacker M., Durauer A. and Jungbauer A. (2001) Adsorption isotherms of 17 beta-estradiol on granular activated carbon (GAC). Chemosphere 44, 1573–1579. [This presents approaches to the study of using GAC for 17 beta-estradiol]

Fujishima A., Rao T. N. and Tryk D.A. (2000) Titanium dioxide photocatalysis. Journal of Photochemistry and Photobiology C: Photochemistry Reviews 1, 1-21. [This presents approaches to the study of TiO2 photocatalysis behavior]

Glaze W. H., Kang J. W. and Chapin D. H. (1987) The chemistry of water treatment processes involving ozone, hydrogen peroxide and UV-radiation. Ozone Sci. Eng. 9, 335-352. [This presents approaches to the study of the chemistry of water treatment processes involving ozone, H2O2 and UV]

Goel S., Hozalski R. M. and B. E. J. (1995) Biodegradation of NOM: Effect of NOM source and ozone dose." J. Am. Water Works Assoc. 87, 90. [This presents approaches to the study of effects of NOM source and ozone dose on NOM biodegradation]

Gogate P.R. and Pandit A.B. (2004) A review of comparative technologies for wastewater treatment I: Oxidation technologies at ambient conditions. Adv. Environ. Res. 8, 501-551. [This presents approaches to the study of review of oxidation technologies for wastewater treatment]

Gottlieb M. The reversible removal of naturally occuring organics using resins regenerated with sodium chloride. Ultrapure Water, November 53-58, 1996. [This presents approaches to the study of using resins with NaCl for reversible removal of NOMs]

Gur-Reznika S., Katz I. and Dosoretz C.G. (2008) Removal of dissolved organic matter by granular-activated carbon adsorption as a pretreatment to reverse osmosis of membrane bioreactor effluents. Water Research, 42, 1595-1605. [This presents approaches to the study of pre-treatment methods to RO of MBR to remove DOM]

Haberkamp J., Ruhl A.S., Ernst M. and Jekel M. (2007) Impact of coagulation and adsorption on DOC fractions of secondary effluent and resulting fouling behaviour in ultrafiltration. Water Research, 41, 3794-3802. [This presents approaches to the study of coagulation and adsorption in UF]

Hammann D., Bourke M. and Topham C. (2004) Magnetic ion exchange resin exceeds EPA disinfection byproduct (DBP) standards. Filtration Separation 41, 28-30. [This presents approaches to the study of magnetic ion exchange resin as filtration separation]

Heijman S. G. J. and Hopman R. (1999) Activated carbon filtration in drinking water production: Model prediction and new concepts. Colloids and Surfaces a-Physicochemical and Engineering Aspects, 151, 303–310. [This presents approaches to the study of Model prediction and new concepts of AC filtration in drinking water]

Herrmann J. M. (2005) Heterogenous photocatalysis: state of the art and present applications. Topics in catalysis 14, 48-65. [This presents approaches to the study of the art and present applications of heterogenous photocatalysis]

Herrmann J.-M. (1999) Heterogeneous photocatalysis: fundamentals and applications to the removal of various types of aqueous pollutants. Catalysis Today 53, 115–129. [This presents approaches to the study of fundamentals and applications of heterogeneous photocatalysis]

Hoignè J. (1985) Organic micropollutants and treatment process: kinetic and final effects of ozone and chlorine dioxide. The Science of the Total Environment 47, 169-185. [This presents approaches to the study of kinetic and final effects of ozone and chlorine dioxide]

Hoignè J. (1988) Organic micropollutants and treatment process: kinetic and final effects of ozone and chlorine dioxide. The Science of the Total Environment 47: 169-185. [This presents approaches to the study of kinetic and final effects of ozone and chlorine dioxide]

Hoignè J. and Bader H. (1983) Rate constants of reaction of ozone with organic and inorganic compounds in water. Part II: Dissociating organic compounds. Water Research 17, 185-194. [This presents approaches to the study of ozone reaction rate constants with organic and inorganic compounds]

Holbrook R.D., Love N.G. and Novak J.T. (2004) Sorption of`17b-estradiol and 17a-ethinylestradiol by colloidal organic carbon derived from biological wastewater treatment systems. Environ. Sci. Technol. 38, 3322-3329. [This presents approaches to the study of using colloidal organic carbon produced from BWW for Sorption of`17b-estradiol and 17a-ethinylestradiol]

Hu J.Y., Song L.F., Ong S.L., Phua E.T. and Ng W.J. (2005) Biofiltration pretreatment for reverse osmosis (RO) membrane in a water reclamation system. Chemosphere 59, 127-133. [This presents approaches to the study of biofiltration pretreatment for RO in water reclamation system]

Huber S.A. (1998) Evidence for membrane fouling by specific TOC constituents. Desalination, 119, 229-234. [This presents approaches to the study of effects of TOC constituents on membrane fouling]

Huber M.M., Canonica S., Park G.-Y. and von Guten U. (2003) Oxidation of pharmaceuticals during ozonation and advanced oxidation processes. Environ. Sci. Technol. 37, 1016–1024. [This presents approaches to the study of using ozonation and advanced oxidation processes for oxidation of pharmaceuticals]

Hutchinson D. H. and Robinson C. W. (1990) A microbial regeneration process for granular activated carbon —I. process modelling. Water Research 24, 1209-1215. [This presents approaches to the study of modeling microbial regeneration process for GAC]

Ireland J. C., Rice P., Klostermann E. and Klark R. (1993) Inactivation of Escherichia coli by titanium dioxide photo-catalytic oxidation. Appl. Environ. Microbiol. 59, 1668-1670. [This presents approaches to the study of PCO using TiO2 for Escherichia coli Inactivation]

Ito K., Jian W., Nishijima W., Baes A.U., Shoto E. and Okada M. (1998) Comparison of ozonation and AOPs combined with biodegradation for removal of THM precursors in treated sewage effluents. Water

Science and Technology 38, 179-186. [This presents approaches to the study of the comparison between ozone and AOPs to remove of THM]

IUPAC, manual of symbols and terminology for physicochemical quantities and units: appendix II-Definitions, Terminology and Symbols in Colloid and Surface Chemistry (part I), ed. D.H. Everett. 1971: International union of pure and applied chemistry, Division of physical chemistry. [This presents approaches to the study of physicochemical definitions and terms]

Johnson A.C. and Sumpter J.P. (2001) Removal of endocrine-disrupting chemicals in activated sludge treatment works. Environ. Sci. Technol. 35, 4697-4703. [This presents approaches to the study of EDCs removal in activated sludge]

Kaneko M. and Okura I. (2002) Photocatalysis: Science and Technology. Springer and Kodansha, Tokyo, 158-180. [This presents approaches to the study of photocatalysis definitions and applications]

Kim S. D., Cho J., Kim I. S., Vanderford B.J. and Snyder S.A. (2007) Occurrence and removal of pharmaceuticals and endocrinebdisruptors in South Korean surface, drinking, and waste waters. Water Research 41, 1013–1021. [This presents approaches to the study of occurrence and removal of micropollutants in South Korea]

Kim S.L., Chen J. P. and Ting Y. P. (2002) Study on feed pre-treatment for membrane filtration of secondary effluent. Separation Purification Technol 29, 171-179. [This presents approaches to the study of feed pre-treatment for membrane filtration]

Kositzi M., Poulios I., Malato S., Caceres J. and Campos A. (2004) Solar photocatalytic treatment of synthetic municipal wastewater. Water Research 38, 1147-1154. [This presents approaches to the study of synthetic municipal wastewater treatment using solar photocatalysis]

Lara R. and Ernst W. (1989) Interaction between polychlorinated biphenyls and marine humic substance. Determination of association coefficients. Chemosphere 19, 1655-1664. [This presents approaches to the study of determination of association coefficients of polychlorinated biphenyls and marine humics]

Legrini O., Oliveros E. and Braun A. M. (1993) Photochemical process for water treatment. Chemical Reviews 93, 671-698. [This presents approaches to the study of photochemical processes for water treatment]

Li W., Mia Y., Guo C., Hu W., Liu K., Wang Y. and Zhu T. (2007) Occurrence and behavior of four of the most used sunscreen UV filters in a wastewater reclamation plant. Water Research 41, 3506-3512. [This presents approaches to the study of occurrence and behavior of four of the sunscreen UV filters in wastewater reclamation plant]

Licsko I. (2003) Coagulation mechanisms – nano- and microprocesses. Nano and micro particles in water and wastewater treatment, Conference proceeding, 207-216. [This presents approaches to the study of coagulation mechanisms in water and wastewater treatment]

Marquet R., Mietton-Peuchot M. and Wheatley A. D. (1999) Characterisation of trickling filter effluent by particle size distribution and high performance size exclusion chromatography. Water Research 33, 1415-1424. [This presents approaches to the study of Characterisation of trickling filter effluent by PSD and HPSEC]

Tchobanoglous G and Burton F.L. Wastewater Engineering: treatment, disposal and reuse (3rd. ed),

McGraw Hill, Inc., Metcalf and Eddy Inc., New York. 1999. [This presents approaches to the study of

treatment and reuse of wastewater]

Molinari R., Grande C., Drioli E., Palmisano L. and Schiavello M. (2001) Photocatalytic membrane reactors for degradation of organic pollutants in water. Catal. Today 69, 273–279. [This presents approaches to the study of degradation of organic pollutants using photocatalytic membrane reactors in water]

Molinari R., Pirillo F., Loddo V. and Palmisano L. (2006) Heterogeneous photocatalytic degradation of pharmaceuticals in water by using polycrystalline TiO2 and a nanofiltration membrane reactor. Catalysis Today 118, 205-213. [This presents approaches to the study of using of polycrystalline TiO2 and NF for photocatalytic degradation of pharmaceuticals in water]

Montiel A. and Welte B. (1992) Alternative options for atrazines-Incidence on water-treatment device. Water Sci. Technol. 25, 103-110. [This presents approaches to the study of alternative options for atrazines-incidence on water-treatment device]

Nevskaia D.M., Sepulveda-Escribano A. and Guerrero-Ruiz A. (2001) Surface properties of activated carbons in relation to their ability to adsorb nonylphenol aqueous contaminant. Physical Chemistry Chemical Physics 3, 463–468. [This presents approaches to the study of activated carbons prosperities for adsorption of nonylphenol aqueous contaminant]

Paune F., Caixach J., Espadaler I., Om J. and Rivera J. (1998) Assessment on the removal of organic chemicals from raw and drinking water at a Llobregat river water works plant using GAC. Water Research 32, 3313–3324. [This presents approaches to the study of using GAC for removing of organics at a Llobregat river]

Pirkanniemi K. and Sillanp¨a¨a M. (2002) Heterogeneous water phase catalysis as an environmental application: A review. Chemosphere 48, 1047-1060. [This presents approaches to the study of comprehensive review for heterogeneous water phase catalysis]

Rajeshwar K., Chenthamarakshan C.R., Goeringer S. and Djukic M. (2001) Titania-based heterogeneous photocatalysis. Materials, mechanistic issues, and implications for environmental remediation. Pure Appl. Chem. 73, 1849-1860. [This presents approaches to the study of environmental remediation for titania-based heterogeneous photocatalysis]

Rebhun M., Meir S. and Laor Y. (1998) Using dissolved humic acid to remove hydrophobic contaminants from water by complexation–flocculation process. Environ. Sci. Technol. 32, 981–986. [This presents approaches to the study of using humic acids by complexation–flocculation process to remove hydrophobics]

Rincon A. G., Pulgarin C., Adler N. and Peringer P. (2001) Interaction between E. coli inactivation and DBP-precursors-dihhhydroxybenzene isomers-in the photocatalytic process of drinking-water disinfection with TiO2. J. Photochem. Photobiol. A: Chem. 139, 233-241. [This presents approaches to the study of interaction between E. coli inactivation and DBP-precursors-dihhhydroxybenzene isomers in drinking water]

Rivera-Utrilla J., Ferro-García M.A., Bautista-Toledo I., Sánchez-Jiménez C., Salvador F. and Merchán M. D. (2003) Regeneration of ortho-chlorophenol-exhausted activated carbons with liquid water at high pressure and temperature. Water Research 37, 1905-1911. [This presents approaches to the study of regeneration of ortho-chlorophenol-exhausted activated carbons at high pressure and temperature.]

Rodriguez-Mozaz S., Lopez de Alda M.J. and Barcelo D. (2004) Monitoring of estrogen, pesticides and bisphenol A in natural waters and drinking water treatment plants by solid-phase extraction–liquid chromatography–mass spectrometry. J. Chromatogr. A, 1045, 85-92. [This presents approaches to the study of monitoring of micropollutants in treatment plants]

Rother E. and Cornel P. (2004) Optimising design, operation and energy consumption of biological aerated filters (BAF) for nitrogen removal of municipal wastewater. Water Sci. Technol. 50, 131-139. [This presents approaches to the study of N2 removal using well-designed BAF in wastewater treatment]

Sacher F., Haist-Gulde B., Brauch H.-J., Preub G., Wilme U., Zullei-Seibert N., Meisenheimer M., Welsch H. and Ternes T. A. (2000) Behavior of selected pharmaceuticals during drinking water treatment. 219th ACS National Meeting, San Francisco CA pp. 116-118. [This presents approaches to the study of behavior of selected micropollutants during drinking water treatment]

San Miguel G., Lambert S. D. and Graham N. J. D. (2001) The regeneration of field-spent granular-activated carbons. Water Research 35, 2740-2748. [This presents approaches to the study of field-spent GAC regeneration]

Shon H.K., Vigneswaran S., Kim J.-H. and Ngo H.H. (2007) Application of Photocatalysis Hybrid Systems Coupled with Flocculation and Adsorption to Biologically Treated Sewage Effluent: A Detailed Organic Removal. The Korean Journal of Chemical Engineering (KJChE), 24, 618-623. [This presents approaches to the study of OMs removal using photocatalysis Hybrid Systems coupled with flocculation and Adsorption in BTSE]

Shon H. K., Phuntsho S. and Vigneswaran S. (2008b) Effect of photocatalysis on the membrane hybrid system for wastewater treatment. Desalination 225, 235–248. [This presents approaches to the study of effect of photocatalysis on the characteristics of membrane hybrid system for wastewater treatment]

Shon H. K., S. Vigneswaran, H. H. Ngo, D. H. Kim, N. E. Park, N. J. Jang and I. S. Kim (2003). Characterization of effluent organic matter (EfOM) of fouled nanofilter (NF) membranes. International Membrane Science and Technology (IMSTEC) Proceedings, Sydney, Australia, 2003. [This presents approaches to the study of Characterization of EfOM of fouled NF membranes]

Shon, H. K., Vigneswaran S., Kim I. S. and Ngo H. H. (2004b) Effect of pretreatment on the fouling of membranes: application in biologically treated sewage effluent. Journal of Membrane Science 234, 111-120. [This presents approaches to the study of the effects of pretreatment on membranes fouling in BTSW]

Shon H. K., Vigneswaran S., Kim I. S., Cho J. and Ngo H. H. (2004a) The effect of pretreatment to ultrafiltration of biologically treated sewage effluent: A detailed effluent organic matter (EfOM) characterization. Water Research 38, 1933–1939. [This presents approaches to the study of the effects of pretreatment to UF of BTSW]

Shon H. K., Vigneswaran S., Ben Aim R., Ngo H. H., Kim I. S. and Cho J. (2005) Influence of Flocculation and Adsorption as Pretreatment on the Fouling of Ultrafiltration and Nanofiltration Membranes: Application with Biologically Treated Sewage Effluent. Environ. Sci. Technol. 39, 3864-3871. [This presents approaches to the study of pre-treatment methods on UF/NF membranes fouling using BTSW]

Shon H. K., Vigneswaran S. and Snyder S. A. (2006) Effluent Organic Matter (EfOM) in Wastewater: Constituents, Effects, and Treatment. Critical Reviews in Environmental Science and Technology 36: 327–374. [This presents approaches to the study of the characteristics of EfOM in wastewater]

Shon H., Phuntsho S., Okour Y., Cho D.-L., Kim K. S., Li H.-J., Na S., Kim J. B. and Kim J.-H. (2008a) Visible Light Responsive Titanium Dioxide (TiO2). J. Korean Ind. Eng. Chem. 19, 1-16. [This presents approaches to the study of general review of VLR TiO2 as photocatalysis]

Snyder S., Wert E., Yoon Y. and Westerhoff P. (2005b) Role of oxidation in the removal of EDCs and Pharmaceuticals. Wastewater Reclamation and Reuse for Sustainability (WRRS2005) conference, Nov. 7 - 11, Jeju, Korea. [This presents approaches to the study of removal of EDCs and Pharmaceuticals by oxidation in wastewater]

Snyder S. A., Wert E., Yoon Y. and Westerhoff P. (2007) Role of membranes and activated carbon in the removal of endocrine disruptors and pharmaceuticals during water treatment processes. Desalination 202, 156-181. [This presents approaches to the study of micropollutants removal by membranes and activated carbon]

Snyder S.A., Leising J., Westerhoff P., Yoon Y., Mash H. and Vanderford B. (2004c) Biological and physical attenuation of endocrine disruptors and pharmaceuticals: implications of water reuse. Groundwater monitoring and remediation, 24,108-118. [This presents approaches to the study of biological and physical attenuation of micropollutants for water reuse]

Snyder S.A., Westerhoff P., Yoon Y. and Sedlak D. L. (2003b) Pharmaceuticals, Personal Care Products, and Endocrine Disruptors in Water: Implications for the Water Industry. Environmental Engineering Science 20, 449-469. [This presents approaches to the study of implications of micropollutants for water industry]

Snyder S. A., Yoon Y., Westerhoff P., Vanderford B., Pearson R. and Rexing D. (2003c). Evaluation of conventional and advanced drinking water treatment processes to remove endocrine disruptors and pharmaceutically active compounds: Bench-scale results In: 3rd International Conference on Pharmaceuticals and Endocrine Disrupting Compounds in Water., The National Ground Water Association, Minneapolis, Minnesota. [This presents approaches to the study of the removing of active micropollutants using conventional and advanced drinking water treatment processes]

Snyder S., Vanderford B., Pearson R. and Yoon Y. (2003a) Analytical method used to measure endocrine disrupting compound in water. Pract. Period. Hazard. Tox. Radioac. Waste manage. 7, 224-234. [This presents approaches to the study of measuring endocrine disrupting compound in water using analytical methods]

Snyder S., Wert E., Edwards J., Budd G., Long B. and Rexing D. (2004a) Magnetic Ion Exchange (MEIX®) for the removal of endocrine disrupting chemicals and pharmaceuticals. WQTC Conference, American Water Works Association. [This presents approaches to the study of micropollutants removal using MEIX®]

Snyder S., Wert E., Westerhoff P., Yoon Y., Rexing D. and Zegers R. (2005) Occurrence and Treatment of Endocrine Disruptors and Pharmaceuticals. Proceedings from the International Ozone Association 17th World Congress, Strasbourg France August 22-25, 2005. [This presents approaches to the study of occurrence and Treatment of micropollutants in wastewater]

Stackelberg P. E., Furlong E. T., Meyer M. T., Zaugg S. D., Henderson A. K. and Reissman D. B. (2004) Persistence of pharmaceutical compounds and other organic wastewater contaminants in a conventional drinking water treatment plant. Sci. Tot. Environ 329, 99–113. [This presents approaches to the study of persistence of pharmaceutical compounds and other organic contaminants in a conventional drinking water plant]

Stackelberga P.E., Gibs J., Furlong E. T., Meyer M. T., Zaugg S. D. and Lippincott R. L. (2007) Efficiency of conventional drinking-water-treatment processes in removal of pharmaceuticals and other organic compounds. Science of The Total Environment 377, 255-272. [This presents approaches to the study of the efficiency of conventional drinking-water processes in removal of pharmaceuticals and other organic compounds.]

Symons J. and Kim P., eds. Sorption and desorption behaviour of natural organic matter onto strong-base anion exchanger. 1995, In Ion Exchange Technology, ed. A. Sengupta, Chap. 4. Lancaster, PA: Technomic, 1995. [This presents approaches to the study of sorption and desorption behaviour of NOM onto strong-base anion exchanger]

Ternes T. A., Stuber J., HerrmanN., McDoweel D., Ried A., Kampmann M. and Teiser B. (2003) Ozonation: A tool for removal of pharmaceuticals, contrast media and musk fragrances from wastewater? Water Research 37, 1976–1982. [This presents approaches to the study of using ozonation process for removal of micropollutants from wastewater]

Ternes T. A., Meisenheimer M., McDowell D., Sacher F., Brauch H. J., Haiste-Gulde B., Preuss G., Wilme U. and Zulei-Seibert N. (2002) Removal of pharmaceuticals during drinking water treatment. Environmental Science Technololgy 36, 3855-3863. [This presents approaches to the study of removal of micropollutants during drinking water treatment]

Ternes T. A., Herrmann N., Bonerz M., Knacker T., Siegrist H. and Joss A. (2004) A rapid method to measure the solidwater distribution coefficient (Kd) for pharmaceuticals and musk fragrances in sewage sludge. Water Research 38, 4075-4084. [This presents approaches to the study of measuring the Kd for pharmaceuticals and musk fragrances in sewage sludge]

Thiruvenkatachari R., Shim W.G., Lee J.W. and Moon H. (2004) Effect of Powdered Activated Carbon (PAC) Type on the Performance of Adsorption- MF Submerged Hollow Fiber Membrane Hybrid System. Korean Journal of Chemical Engineering 21, 1044-1052. [This presents approaches to the study of the performance of MF hollow fiber membrane hybrid system using different types of PAC]

Urfer D., Huck P. M., Booth S. D. J. and Coffey B. M. (1997) Biological filtration for BOM and particle removal: A critical review. J. Am. Water Works Assoc. 89(12): 83–98. [This presents approaches to the study of comprehensive review of BOM and particle removal using biological filtration]

USEPA (2000) Wastewater Technology Fact Sheet: Trickling Filters, United States Environmental Protection Agency. [This presents approaches to the study of trickling filters uses and applications]

USEPA (2002) Wastewater Technology Fact Sheet: Rock Media Polishing Filter for Lagoons, Unted States Environmental Protection Agency. [This presents approaches to the study of rock media polishing filter uses and applications for Lagoons]

Verma M., Brar S. K., Blais J. F., Tyagi R. D. and Surampalli R. Y. (2006) Aerobic Biofiltration Processes—Advances in Wastewater Treatment. Pract. Periodical of Haz., Toxic, and Radioactive Waste Mgmt. 10, 264-276. [This presents approaches to the study of advanced aerobic biofiltration processes in Wastewater Treatment]

Vigneswaran S. and Visvanathan C. Water Treatment Processes: Simple Options. Boca Raton, FL: CRC Press, 1995. [This presents approaches to the study of comprehensive options for water treatment processes in treatment plants]

Vilge-Ritter A., Rose J., Masion A., Bottero J. and Laine J. M. (1999) Chemistry and structure of aggregates formed with Fe salts and natural organic matter. Colloids Surfaces 147, 297–308. [This presents approaches to the study of chemistry and structure of aggregates formed with Fe salts and NOM]

Wang Q. H., Zhang L., Tian S., Sun P. T.-C. and Xie W. (2007) Pilot-study on treatment of a waste gas containing butyl acetate, n-butyl alcohol and phenylacetic acid from pharmaceutical factory by bio-trickling filter. Biochemical Engineering Journal 37, 42-48. [This presents approaches to the study of using bio-trickling filter for treatment of a waste gas containing micropollutants from pharmaceutical factory]

Wang Y., Hu W., Cao Z., Fu X. and Zhu T. (2005) Occurrence of endocrine-disrupting compounds in reclaimed water from Tianjin, China. Analytical and Bioanalytical Chemistry 383, 857-863. [This presents approaches to the study of occurrence of endocrine-disrupting compounds in reclaimed water from China.]

Wert E. C., Edwards-Brandt J. C., Singer P. C. and Budd G. C. (2005) Evaluating magnetic ion exchange resin (MIEX®) pretreatment to increase ozone disinfection and reduce bromate formation. Ozone Sci. Eng. 27, 317–379. [This presents approaches to the study of increasing of ozone disinfection and reduction of bromate using MIEX® as pretreatment]

Wert E. C., Neemann J. J., Rexing D. J. and Zegers R. E. (2008) Biofiltration for removal of BOM and residual ammonia following control of bromate formation. Water Research 42, 372-378. [This presents approaches to the study of removal of BOM and residual ammonia following control of bromate formation using biofiltration process]

Westerhoff P. Removal of Endocrine Disruptors, Pharmaceuticals, and Personal Care Products During Water Treatment. Southwest Hydrology, 2003. November/December 2003. [This presents approaches to the study of removal of EDCs and PPCPs in water treatment]

Westerhoff P., Yoon Y., Snyder S. and Wert E. (2005) Fate of endocrine-disruptor, pharmaceutical, and personal care product chemicals during simulated drinking water treatment process. Environmental Science & Technololgy 39, 6649-6663. [This presents approaches to the study of the fate of different micropollutants during simulated drinking water treatment process]

Wu S.H. and Pendleton P. (2001) Adsorption of anionic surfactant by activated carbon: Effects of surface chemistry, ionic strength and hydrophobicity. Journal of Colloid Interface Science 243, 306-315. [This presents approaches to the study of the effects of activated carbon characteristics on the adsorption of anionic surfactants]

Ying G.-G., Kookana R., and Waite T.D. Endocrine Disrupting Chemicals (EDCs) and Pharmaceuticals and Personal Care Products (PPCPs) in Reclaimed Water in Australia., in Australian Water Conservation and Reuse Research. 2004, CSIRO and AWA. [This presents approaches to the study of occurrence and removal of EDCs and PPCPs in Australia]

Yoon Y., Westerhoff P. and Snyder S. A. (2005) Adsorption of 3H-labelled 17-β Estradiol on powdered activated carbon. Water, Air, and Soil Pollution 166, 343-351. [This presents approaches to the study of adsorption of 3H-labelled 17-β Estradiol on PAC]

Yoon Y., Westerhoff P., Snyder S. A. and Esparza M. (2003) HPLC-fluorescence detection and adsorption of bisphenol A, 17b-estradiol, and 17a-ethynyl estradiol on powdered activated carbon. Water Research 37, 3530–3537. [This presents approaches to the study of HPLC and using PAC for adsorption of different micropollutants]

Yoon Y., Westerhoff P., Snyder S., Song R. and Levine (2002) A Review on Removal of Endocrine-Disrupting Compounds and Pharmaceuticals by Drinking Water Treatment Processes. American Water Works Association 01-Nov-2002. [This presents approaches to the study of using drinking water treatment processes for removal of EDCS and PPCPs]

Zhang R., Vigneswaran S., Ngo H.H. and Nguyen H. (2006) Magnetic ion exchange (MIEX®) resin as a pre-treatment to a submerged membrane system in the treatment of biologically treated wastewater.

Desalination, 192, 296-302. [This presents approaches to the study of submerged membrane systems using MIEX® resin for BTWW treatment]

Zhang H. (2002) Regeneration of exhausted activated carbon by electrochemical method. Chemical Engineering Journal 85, 81-85. [This presents approaches to the study of using electrochemical methods to regenerate exhausted activated carbon]

Zhang Y. and Zhou J. L. (2005) Removal of estrone and 17β-estradiol from water by adsorption. Water Research 39, 3991-4003. [This presents approaches to the study of removal of micropollutants by adsorption]

Biographical Sketches

Dr H.K. Shon is currently a UTS Chancellor's postdoctoral research since 2006. His research interests include membrane processes and new analytical methods for wastewater treatment and reuse. He has made significant contributions to the understanding of membrane fouling in wastewater treatment processes.

Mr Sherub Phuntsho is an engineer working for the Department of Urban Development and Engineering under the Ministry of Works and Human Settlements, Royal Government of Bhutan, Thimphu. He heads the Urban Waste Management Section of the Urban Infrastructure Services Division. He is responsible for planning and design of any works related to urban sewerage and solid waste management system in the form of technical assistance to all the local municipal authorities in Bhutan. He recently reviewed the performance of a sewage treatment plant for Thimphu city which is soon expected to be published in a journal. He is currently working on a research to study the municipal solid waste management systems including the quality and quantity of waste generated in the urban centres of Bhutan. He is the also coordinating to organize a national level conference on solid waste management 2008 in Bhutan.

Dr S. Vigneswaran has been working on water and wastewater treatment and reuse related research since 1976. During the last twenty years, he has made significant contributions in physico-chemical water treatment related processes such as filtration, flocculation, membrane-filtration and adsorption. His research activities both on new processes development and mathematical modeling are well documented in reputed international journals such as Water Research, American Institute of Chemical Engineers Journal, Chemical Engineering Science, Journal of American Society of Civil Engineers, and Journal of Membrane Science. He has also been involved in a number of consulting activities in this field in Australia, Indonesia, France, Korea, and Thailand through various national and international agencies. He has authored two books in this field at the invitation of CRC press, USA, and has published more than 230 papers in journals and conference's proceedings. Currently a Professor of the Environmental Engineering Group at the University of Technology, Sydney, he was the founding Head of and the founding Co-ordinator of the University Key Research Strength Program in Water and Waste Management. He is coordinating the Urban Water Cycle and Water and Environmental Management of the newly established Research Institutes on Water and Environmental Resources Management and Nano-scale Technology respectively.

Dr J. Kandasamy is Senior Lecturer in the Faculty of Engineering University of Technology, Sydney, Australia. He obtained his PhD from University of Auckland., New Zealand where is also obtained his Bachelor in Civil Engineering and Masters in Civil Engineering. He has worked in the New South Wales Government as a Senior Engineer for 15 years and has wide industry knowledge.

Dr J. Cho, associate professor at Gwangju Institute of Science and Technology, has been studying on research for water reuse using various technologies, including constructed wetland and membrane filtration. He is recently interested in research of ecological engineering as well as related education. He is an editorial board member of Journal, Water Science and Technology, IWA and newsletter editor of Water Reuse Specialty Group in IWA.

Dr J.H Kim is presently working at the School of Applied Chemical Engineering, Chonnam National University, and the President of Photo and Environmental Technology Ltd. His research interest is a leading expert on the photocatalyst technology using TiO2 photocatalyst to purify air and water. He was

awarded an excellent innovative business award from INNO-Biz in 2001 and gold prize for Korean New Technology from the Prime Minister of Korea in 2003. He is also Director of The Research Institute for Catalysis and Research Center for Nano-Energy Materials in Chonnam National University. He has 26