



UNIVERSITAT DE BARCELONA

Facultat de Química

DEPARTAMENT DE QUÍMICA FÍSICA

Laboratori d'Electroquímica dels Materials i del Medi Ambient

**ELECTROCHEMICAL ADVANCED OXIDATION PROCESSES
FOR THE REMOVAL OF THE DRUGS
PARACETAMOL, CLOFIBRIC ACID AND CHLOROPHENE
FROM WATERS**

DOCTORAL THESIS

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PART C

REFERÈNCIES

REFERENCES



12. REFERÈNCIES / REFERENCES

- [1] Petrovic, M., Hernando, M.D., Díaz-Cruz, S., Barceló, D., Liquid chromatography-tandem mass spectrometry for the analysis of pharmaceutical residues in environmental samples: A review. *J. Chromatogr. A* **1067** (2005) 1-14.
- [2] Carson, R.L., *Silent Spring*, Houghton Mifflin, Boston, 1962, 1st Ed.
- [3] Connell, D.W., *Basic concepts of environmental chemistry*, Lewis Publ., Boca Raton, New York, 1997, 1st Ed.
- [4] Barceló, D., Petrovic, M., Ethel, E., López de Alda, M.J., Kampioti, A., in: Heftmann, E. (Ed.), *J. Chromatogr. Library*, Elsevier Science Ltd., Oxford, 2004, Vol. 69B, Chapter 21, 6th Ed., 987-1036.
- [5] <http://www.epa.gov> (*Environmental Protection Agency*, visited for the last time in 2006)
- [6] National Research Council, *Identifying Future Drinking Water Contaminants*, National Academy Press, Washington D.C., 1999.
- [7] Daughton, C.G., Ternes, T.A., Pharmaceuticals and Personal Care Products in the environment: Agents of subtle change?. *Environ. Health Perspect.* **107** (1999) 907-944.

- [8] Daughton, C.G., Jones-Lepp, T.L. (Eds.), *Pharmaceuticals and Personal Care Products in the Environment: Scientific and Regulatory Issues*, Symposium Series 791, American Chemical Society, Washington D.C., 2001.
- [9] Kümmerer, K. (Ed.), *Pharmaceuticals in the environment: Sources, Fate, Effects and Risks*, Springer-Verlag, Berlin, 2001, 1st Ed.
- [10] Dietrich, D., in: Webb, S.F., Petry, T. (Eds.), *Hot Spot Pollutants: Pharmaceuticals in the Environment*, Elsevier Science Ltd., Oxford, 2004.
- [11] Barceló, D. (Ed.), *Emerging Organic Pollutants in Waste Waters and Sludge*, Springer-Verlag, Berlin, 2004, Vol. 1.
- [12] ENVIRPHARMA. European conference on human and veterinary pharmaceuticals in the environment, Lyon (France), 14-16 April 2003.
- [13] 4th International Conference on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Minneapolis (USA), 13-15 October 2004.
- [14] Symposium on Environmental Chemistry of Pharmaceuticals and Personal Care Products (PPCPs) at the ACS 228th National Meeting, Philadelphia (USA), 22-26 August 2004.
- [15] AGEESA-Workshop, Aachen (Germany), 26 March 2004.
- [16] 33rd Annual Conference on Environmental Law, Keystone (USA) 11-14 March 2004.
- [17] Mini-symposium "Pharmaceuticals in the Environment. Current Research and Regulatory Aspects", Södra Paviljongen (Stockholm), March 2004.
- [18] <http://www.epa.gov/esd/chemistry/ppcp/conference-past.htm> (Conferences on PPCPs, visited for the last time in 2006)
- [19] Zuccato, E., Castiglioni, S., Fanelli, R., Reitano, G., Bagnati, R., Chiabrando, C., Pomati, F., Rossetti, C., Calamari, D., *Pharmaceuticals in the environment in Italy: Causes, occurrence, effects and control. Environ. Sci. Pollut. Res.* **13** (2006) 15-21.
- [20] Tauxe-Wuersch, A., De Alencastro, L.F., Grandjean, D., Tarradellas, J., *Occurrence of several acidic drugs in sewage treatment plants in Switzerland*

- and risk assessment. *Water Res.* **39** (2005) 1761-1772.
- [21] Bendz, D., Paxéus, N.A., Ginn, T.R., Loge, F.J., Occurrence and fate of pharmaceutically active compounds in the environment, a case study: Høje River in Sweden. *J. Hazard. Mater.* **122** (2005) 195-204.
- [22] Bound, J.P., Voulvoulis, N., Household disposal of pharmaceuticals as a pathway for aquatic contamination in the United Kingdom. *Environ. Health Perspect.* **113** (2005) 1705-1711.
- [23] Sacher, F., Lange, F.T., Brauch H.J., Blankenhorn I., Pharmaceuticals in groundwaters: Analytical methods and results of a monitoring program in Baden-Württemberg, Germany. *J. Chromatogr. A* **938** (2001) 199-210.
- [24] Zimmerman, M.J., Occurrence of organic wastewater contaminants, pharmaceuticals, and personal care products in selected water supplies, USGS, Massachusetts, Report 2005-1206.
- [25] Lissemore, L., Hao, C., Yang, P., Sibley, P.K., Mabury, S., Solomon, K.R., An exposure assessment for selected pharmaceuticals within a watershed in Southern Ontario. *Chemosphere* **64** (2006) 717-729.
- [26] www.wasseranalytik.de (*Arbeitsgruppe Wasser der Technischen Universität Berlin*, visited for the last time in 2006)
- [27] Kolpin, D.W., Furlong, E.T., Meyer, M.T., Thurman, E.M., Zaugg, S.D., Barber, L.B., Buxton, H.T., Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000. A national reconnaissance. *Environ. Sci. Technol.* **36** (2002) 1202-1211.
- [28] <http://toxics.usgs.gov/highlights/impact.html> (visited for the last time in 2006)
- [29] Zwiener, C., Frimmel, F.H., Oxidative treatment of pharmaceuticals in water. *Water Res.* **34** (2000) 1881-1885.
- [30] Ravina, M., Campanella, L., Kiwi, J., Accelerated mineralization of the drug diclofenac via Fenton reactions in a concentric photo-reactor. *Water Res.* **36** (2002) 3553-3560.
- [31] Huber, M.M., Canonica, S., Park, G.-Y., von Gunten, U., Oxidation of

- pharmaceuticals during ozonation and advanced oxidation processes. *Environ. Sci. Technol.* **37** (2003) 1016-1024.
- [32] Ternes, T.A., Meisenheimer, M., McDowell, D., Sacher, F., Brauch, H.J., Haist-Gulde, B., Preuss, G., Wilme, U., Zulei-Seibert, N., Removal of pharmaceuticals during drinking water treatment. *Environ. Sci. Technol.* **36** (2002) 3855-3863.
- [33] Ternes, T.A., Stüber, J., Herrmann, N., McDowell, D., Ried, A., Kampmann, M., Teiser, B., Ozonation: a tool for removal of pharmaceuticals, contrast media and musk fragrances from wastewater?. *Water Res.* **37** (2003) 1976-1982.
- [34] Ternes, T.A., Janex-Habibi, M.-L., Knacker, T., Kreuzinger, N., Siegrist, H., Assessment of technologies for the removal of Pharmaceuticals and Personal Care Products in sewage and drinking water facilities to improve the indirect potable water reuse, Report of POSEIDON project 2001-2004, 2006.
- [35] Römbke, J., Knacker, T., Stahlschmidt-Allner, P., Umweltprobleme durch Arzneimittel, Literaturstudie, Umweltbundesamt , UBA Texte 60 / 96, Berlin, 1996.
- [36] Boxall, A.B.A., Fogg, L.A., Blackwell, P.A., Kay, P., Pemberton, E.J., Croxford, A., Veterinary medicines in the environment. *Rev. Environ. Contam. Toxicol.* **180** (2004) 1-91.
- [37] Wiegel, S., Aulinger, A., Brockmeyer, R., Harms, H., Löffler, J., Reincke, H., Schmidt, R., Stachel, B., von Tümpling, W., Wanke, A., Pharmaceuticals in the river Elbe and its tributaries. *Chemosphere* **57** (2004) 107-126.
- [38] Carballa, M., Omil, F., Lema, J.M., Llompарт, M., García, C., Rodríguez, I., Gómez, M., Ternes, T.A., Behaviour of pharmaceuticals and personal care products in a sewage treatment plant of northwest Spain. *Water Sci. Technol.* **52** (2005) 29-35.
- [39] Zondek, B., Sulman, F., Inactivation of estrone and diethylstilbestrol by microorganisms. *Endocrinology* **33** (1943) 204-208.
- [40] Soulides, D.A., Pinck, L.A., Allison, F.E., Antibiotics in soils: V. Stability and release of soil adsorbed antibiotics. *Soil Sci.* **94** (1962) 239-244.

- [41] Tabak, H.H., Bunch, R.L., Steroid hormones as water pollutants: I. Metabolism of natural and synthetic ovulation-inhibiting hormones by microorganisms of activated sludge and primary settled sewage. *Dev. Ind. Microbiol.* **11** (1970) 367-376.
- [42] Blume, R.R., Younger, R.L., Aga, A., Myers, C.J., Effects of residues of certain antihelmintics in bovine manure on *Onthophagus gazella*, a non-target organism. *Southwest. Entomol.* **1** (1976) 100-103.
- [43] Patten, D.K., Wolf, D., Kunkle, W.E., Douglass, L.W., Effect of antibiotics in beef cattle feces on nitrogen and carbon mineralization in soil and on plant growth and composition. *J. Environ. Qual.* **9** (1980) 167-172.
- [44] Garrison, A.W., Pope, J.D., Allen, F.R., in: Keith, C.H. (Ed.), Identification and Analysis of Organic Pollutants in Water, Ann Arbor Science Publ. Inc., Michigan, 1976, 517-556.
- [45] Richardson, M.L., Bowron, J.M., The fate of pharmaceutical chemicals in the aquatic environment. *J. Pharm. Pharmacol.* **37** (1985) 1-12.
- [46] Raloff, J., Drugged Waters. Does it matter that pharmaceuticals are turning up in water supplies?. *Science News* **153** (1998) 187-189.
- [47] Díaz-Cruz, S., López de Alda, M.J., Barceló, D., Environmental behavior and analysis of veterinary and human drugs in soils, sediments and sludge. *TrAC, Trends Anal. Chem.* **22** (2003) 340-351.
- [48] Daughton, C.G., Non-regulated water contaminants: Emerging research. *Environ. Impact Assess. Rev.* **24** (2004) 711-732.
- [49] Jacobsen, P., Berglind, L., Persistence of oxytetracycline in sediments from fish farms. *Aquaculture* **70** (1988) 365-370.
- [50] Jorgensen, S.E., Halling-Sorensen, B., Drugs in the environment (editorial). *Chemosphere* **40** (2000) 691-699.
- [51] Heberer, T., Occurrence, fate, and removal of pharmaceutical residues in the aquatic environment: A review of recent research data. *Toxicol. Lett.* **131** (2002) 5-17.

- [52] Kümmerer, K., Pharmaceuticals in the aquatic environment, AGEESA-Workshop, Aachen (Germany), 26 March 2004.
- [53] Ternes, T.A., Hirsch, J., Mueller, J., Haberer, K., Methods for the determination of neutral drugs as well as betablockers and β 2-sympathomimetics in aqueous matrices using GC/MS and LC/MS/MS. *Fres. J. Anal. Chem.* **362** (1998) 329-340.
- [54] Buser, H.-R., Poiger, T., Müller, M.D., Occurrence and fate of the pharmaceutical drug diclofenac in surface waters: Rapid photodegradation in a lake. *Environ. Sci. Technol.* **32** (1998) 3449-3456.
- [55] Halling-Sorensen, B., Nielsen, S.N., Lanksky, P.F., Ingerslev, F., Holten-Lützhof, H.C., Jorgensen, S.E., Occurrence, fate and effects of pharmaceutical substances in the environment – A review. *Chemosphere* **36** (1998) 357-393.
- [56] Jones, O.A., Lester, J.N., Voulvoulis, N., Pharmaceuticals: A threat to drinking water?. *Trends in Biotechnol.* **23** (2005) 163-167.
- [57] Heberer, T., Tracking persistent pharmaceutical residues from municipal sewage to drinking water. *J. Hydrology* **266** (2002) 175-189.
- [58] Zuccato, E., Calamari, D., Natangelo, M., Fanelli, R., Presence of therapeutic drugs in the environment. *Lancet* **355** (2000) 1789-1790.
- [59] Webb, S., Ternes, T., Gibert, M., Olejniczak, K., Indirect human exposure to pharmaceuticals via drinking water. *Toxicol. Lett.* **142** (2003) 157-167.
- [60] <http://www.globeandmail.com/servlet/ArticleNews/PEstory/TGAM/20030210/UWATEN/> (The Globe and mail, Drug traces found in cities' water, Martin Mittelstaedt, 10 February 2003)
- [61] http://www.ctv.ca/servlet/ArticleNews/story/CTVNews/1044053088271_39462288/ (CTV Canada News, Pharmaceuticals found in four cities' tap water, Mark Stevenson, 9 February 2003)
- [62] Guivarch, E., Traitement des polluants organiques en milieux aqueux par procédé électrochimique d'oxydation avancée 'Electro-Fenton'. Application à la minéralisation des colorants synthétiques. Doctoral Thesis (2004). Université de Marne La Vallée (Paris, France).

- [63] Cleuvers, M., Mixture toxicity of the anti-inflammatory drugs diclofenac, ibuprofen, naproxen, and acetylsalicylic acid. *Ecotoxicol. Environ. Saf.* **59** (2004) 309-315.
- [64] Christiansen, L.B., Winther-Nielsen, M., Helweg, C., Feminisation of fish: The effect of estrogenic compounds and their fate in sewage treatment plants and nature, Danish EPA, Environmental Project 2002-729.
- [65] Servos, M., Burnison, K., Lee, B., Bennie, D., Seto, P., Innes, E., Metcalfe, C., Pharmaceuticals and Personal Care Products in the Canadian Environment, ENVIRPHARMA, Lyon (France), 14 April 2003.
- [66] Society of Environmental Toxicology and Chemistry (SETAC Press), in: Williams, R.T. (Ed.), Human Pharmaceuticals: Assessing the impacts on aquatic ecosystems, Allen Press/ACG Publ., Kansas, 2005.
- [67] Zuccato, E., Rapporto scientifico finale sul Progetto pilota 'Farmaci ad uso umano e zootecnico come inquinanti ambientali', Istituto di Ricerche Farmacologiche "Mario Negri", Università dell'Insubria, Fondazione Lombardia per l'Ambiente, Milan, 1999.
- [68] Montforts, M.H.M.M., Validation of the EU Environmental Risk Assessment for Veterinary Medicines. Doctoral Thesis (2005). Leiden University (Leiden, Netherlands).
- [69] VICH. Environmental Impact Assessment (EIAs) for Veterinary Medicinal Products (VMPs) – Phase I, London, CVMP/VICH 2000, CVMP/VICH/592/98-final.
- [70] Spaepen, K.R.I., Van Leemput, L.J.J., Wislocki, P.G., Verschueren, C., A uniform procedure to estimate the predicted environmental concentration of the residues of veterinary medicines in soil. *Environ. Toxicol. Chem.* **16** (1997) 1997-1982.
- [71] European Parliament and Council, Directive 2004/28/CE, 31st March 2004.
- [72] Daughton, C.G., Cradle-to-Cradle stewardship of drugs for minimizing their environmental disposition while promoting human health: I. Rationale for and

- avenues toward a green pharmacy. *Environ. Health Perspect.* **111** (2003) 757-774.
- [73] Boreen, A.L., Arnold, W.A., McNeill, K., Photodegradation of pharmaceuticals in the aquatic environment: A Review. *Aquat. Sci.* **65** (2003) 320-341.
- [74] Andreatti, R., Marotta, R., Pinto, G., Pollio, A., Carbamazepine in water: persistence in the environment, ozonation treatment and preliminary assessment on algal toxicity. *Water Res.* **36** (2002) 2869-2877.
- [75] Andreatti, R., Canterino, M., Marotta, R., Paxeus, N., Antibiotic removal from wastewaters: The ozonation of amoxicillin. *J. Hazard. Mater.* **122** (2005) 243-250.
- [76] Huber, M.M., Göbel, A., Joss, A., Hermann, N., Löffler, D., McArdell, C.S., Ried, A., Siegrist, H., Ternes, T.A., von Gunten, U., Oxidation of pharmaceuticals during ozonation of municipal wastewater effluents: A pilot study. *Environ. Sci. Technol.* **39** (2005) 4290-4299.
- [77] Huber, M.M., Coronen, S., Ternes, T.A., von Gunten, U., Oxidation of pharmaceuticals during water treatment with chlorine dioxide. *Water Res.* **39** (2005) 3607-3617.
- [78] Joss, A., Keller, E., Alder, A.C., Göbel, A., McArdell, C.S., Ternes, T., Siegrist, H., Removal of pharmaceuticals and fragrances in biological wastewater treatment. *Water Res.* **39** (2005) 3139-3152.
- [79] Joss, A., Zabczynski, S., Göbel, A., Hoffmann, B., Löffler, D., McArdell, C.S., Ternes, T.A., Thomsen, A., Siegrist, H., Biological degradation of pharmaceuticals in municipal wastewater treatment: Proposing a classification échème. *Water Res.* **40** (2006) 1686-1696.
- [80] Larsen, T.A., Lienert, J., Joss, A., Siegrist, H., How to avoid pharmaceuticals in the aquatic environment. *J. Biotechnol.* **113** (2004) 295-304.
- [81] Blanco, J., Malato, S., Tecnología de Fotocatálisis Solar, Cuadernos Monográficos 31, Instituto de Estudios Almerienses de la Diputación de Almería, Almería, 1996.
- [82] European Commission, Establishing the List of Priority Pollutants in the Field of Water Policy and Amending Directive 2000/60/EC. *Official Journal of the*

- European Community*, Decision N° 2455/2001/EC of the European Parliament and of the Council, L331/1, 15.12.2001.
- [83] European Commission, Environment 2010: Our Future, Our Choice [FPA1], presented by the European Commissioner, 24 January 2001.
- [84] Cheremisinoff, P.N., Handbook of Water and Wastewater Treatment Technology, Marcel Dekker Inc., New York, 1995.
- [85] Henze, M., Harremoës, P., La Cour Jansen, J., Arvin, E., Wastewater Treatment: Biological and Chemical Processes, Springer-Verlag, Berlin, 2000, 3rd Ed.
- [86] Boye, B., Decontamination of chlorophenoxy acid herbicides in aqueous medium by Advanced Electrochemical Oxidation methods using boron-doped diamond thin-layer film and O₂-diffusion electrodes. Doctoral Thesis (2003). Universitat de Barcelona (Barcelona, Spain).
- [87] Kabdasli, I., Gurel, M., Characterization and treatment of textile printing wastewaters. *Environ. Technol.* **21** (2000) 1147-1155.
- [88] Getman, G.D., Pittman Jr., C.U., Solvated Electron Reductions: A Versatile Alternative for Waste Remediation, in: Tarr, M.A. (Ed.), Chemical Degradation Methods for Wastes and Pollutants, Marcel Dekker Inc., New York, 2003, 343-369.
- [89] Gillham, R.W. (Ed.), Resurgence in research concerning organic transformations enhanced by zero-valent metals and potential application in remediation of contaminated groundwater, 209th National Meeting, American Chemical Society, Anaheim, CA, **35** (1995) 691-694.
- [90] Hunsberger, J.F., Standard reduction potentials, in: Weast, R.C. (Ed.), Handbook of Chemistry and Physics, CRC Press, Ohio, 1977, 58th Ed., D141-D144.
- [91] Canosa, P., Morales, S., Rodríguez, I., Rubí, E., Cela, R., Gómez, M., Aquatic degradation of triclosan and formation of toxic chlorophenols in presence of low concentrations of free chlorine. *Anal. Bioanal. Chem.* **383** (2005) 1119-1126.
- [92] Lee, J., Tryk, D.A., Fujishima, A., Park, S.-M., Electrochemical generation of

- ferrate in acidic media at boron-doped diamond electrodes. *Chem. Commun.* **5** (2002) 486-487.
- [93] Sharma, V.K., Kazama, F., Jiangyong, H., Ray, A.K., Ferrates (iron(VI) and iron(V)): Environmentally friendly oxidants and disinfectants. *J. Water Health* **3** (2005) 45-58.
- [94] Lee, Y., Yoon, J., von Gunten, U., Kinetics of the oxidation of phenols and phenolic endocrine disruptors during water treatment with ferrate (Fe(VI)). *Environ. Sci. Technol.* **39** (2005) 8978-8984.
- [95] Munter, R., Advanced Oxidation Processes – Current status and prospects. *Proc. Estonian Acad. Sci. Chem.* **50** (2001) 59-80.
- [96] Dempsey, C.R., Oppelt, E.R., Incineration of hazardous waste: A critical review. *Air and Waste* **43** (1993) 25-73.
- [97] Rutberg, Ph. G., Some plasma environmental technologies developed in Russia. *Plasma Sources Sci. Technol.* **11** (2002) A159-A165.
- [98] Abdelmalek, F., Gharbi, S., Benstaali, B., Addou, A., Brisset, J.L., Plasmachemical degradation of azo dyes by humid air plasma: Yellow Supranol 4 GL, Scarlet Red Nylosan F3 GL and industrial waste. *Water Res.* **38** (2004) 2339-2347.
- [99] Moussa, D., Abdelmalek, F., Benstaali, B., Addou, A., Hnatiuc, E., Brisset, J.L., Acidity control of the gliding arc treatments of aqueous solutions: Application to pollutant abatement and biodecontamination. *Eur. Phys. J. Appl. Phys.* **29** (2005) 189-199.
- [100] Glaze, W.H., Kang, J.W., Chapin, D.H., The chemistry of water treatment processes involving ozone, hydrogen peroxide and ultraviolet radiation. *Ozone: Sci. Eng.* **9** (1987) 335-352.
- [101] Land, E.J., Ebert, M., Pulse radiolysis studies of aqueous phenol. *Trans. Faraday Soc.* **63** (1967) 1181-1190.
- [102] Glaze, W.H., Beltrán, F., Tuhkanen, T., Kang, J.W., Chemical models of advanced oxidation processes, *Water Pollut. Res. J. Can.* **27** (1992) 23-42.

- [103] Haag, W.R., Yao, C.C.D., Rate constants for reaction of hydroxyl radicals with several drinking water contaminants. *Environ. Sci. Technol.* **26** (1992) 1005-1013.
- [104] Glaze, W.H., An overview of advanced oxidation processes: Current status and kinetic models. *Chem. Oxid.* **2** (1994) 44-57.
- [105] Walling, C., Johnson, R.A., Fenton's reagent: V. Hydroxylation and side chain cleavage of aromatics. *J. Am. Chem. Soc.* **97** (1975) 363-367.
- [106] Buxton, G.V., Greenstock, C.L., Helman, W.P., Ross, A.B., Critical review of rate constants for reactions of hydrated electrons, hydrogen atoms and hydroxyl radicals ($\cdot\text{OH}/\text{O}\cdot$) in aqueous solution. *J. Phys. Chem. Ref. Data* **17** (1988) 513-886.
- [107] Andreozzi, R., Caprio, V., Insola, A., Marotta, R., Advanced Oxidation Processes (AOP) for water purification and recovery. *Catal. Today* **53** (1999) 51-59.
- [108] Hancock, F.E., Catalytic strategies for industrial water reuse. *Catal. Today* **53** (1999) 3-9.
- [109] Blesa, M.A. (Ed.), Eliminación de Contaminantes por fotocatalisis heterogénea, Red CYTED VIII-G, Buenos Aires, 2001.
- [110] Tarr, M.A. (Ed.), Chemical Degradation Methods for Waste Pollutants: Environmental and Industrial Applications, Marcel Dekker Inc., New York, 2003.
- [111] Parsons, S. (Ed.), Advanced Oxidation Processes for Water and Wastewater Treatment, IWA Publishing, London, 2004.
- [112] Gogate, P.R., Pandit, A.B., A review of imperative technologies for wastewater treatment: I. Oxidation technologies at ambient conditions. *Adv. Environ. Res.* **8** (2004) 501-551.
- [113] Gogate, P.R., Pandit, A.B., A review of imperative technologies for wastewater treatment: II. Hybrid methods. *Adv. Environ. Res.* **8** (2004) 553-597.
- [114] EPA Handbook on Advanced Photochemical Oxidation Processes, United States Environmental Protection Agency, Cincinnati, 1998, EPA/625/R-98/004.

- [115] Panizza, M., Cerisola, G., Removal of organic pollutants from industrial wastewater by electrogenerated Fenton's reagent. *Water Res.* **35** (2001) 3987-3992.
- [116] 2nd Int. Conf. On Oxidation Technologies of Water and Wastewater Treatment. Cutec Institut GmbH, Clausthal-Zellerfeld (Germany), 29-31 May 2000.
- [117] The 2nd European Workshop on Water, Air and Soil Treatment by Advanced Oxidation Technologies: Innovative and Commercial Applications, École Supérieure d'Ingénieurs de Poitiers (France), 28 February - 2 March 2001.
- [118] 2nd European Meeting on Solarchemistry and Photocatalysis: Environmental Applications, Saint-Avold (France), 27-31 May 2002.
- [119] The 8th International Conference on Advanced Oxidation Technologies for Water and Air Remediation, Sheraton Centre Toronto Hotel (Ontario, Canada) 17-21 November 2002.
- [120] 3rd Conference on Oxidation Technologies for Water and Wastewater Treatment. Special Topic: AOPs for Recycling and Reuse, Goslar (Germany), 18-22 May 2003.
- [121] 3rd European Meeting on Solarchemistry and Photocatalysis: Environmental Applications, Barcelona (Spain), 30 June - 2 July 2004.
- [122] EAAOP-1: Environmental Applications of Advanced Oxidation Processes, Chania (Greece), 7-9 September 2006.
- [123] Rajeshwar, K., Ibañez, J., Environmental Electrochemistry: Fundamentals and Applications in Pollution Abatement, Academic Press Inc., San Diego, 1997, Chapter 5.
- [124] Ullman's Encyclopedia of Industrial Chemistry, VCH, Weinheim, 1989, Vol. A13., 460-461.
- [125] Kinoshita, K., Electrochemical Oxygen Technology, John Wiley and Sons, New York, 1992, 369-372.
- [126] Fenton, H.J.H., Oxidation of tartaric acid in presence of iron *J. Chem. Soc.* **65** (1894) 899-910.

- [127] Haber, F., Weiss, J., Über die Katalyse des Hydroperoxydes. *Naturwiss* **51** (1932) 948-950.
- [128] Haber, F., Weiss, J., The catalytic decomposition of hydrogen peroxide by iron salts. *Proc. Roy. Soc. London A* **147** (1934) 332-351.
- [129] Brown, R.F., Jamison, S.E., Pandit, K., Pinkus, J., White, G.R., Braendlin, H.P., The reaction of Fenton's reagent with phenoxyacetic acid and some halogen-substituted phenoxyacetic acids. *J. Org. Chem.* **29** (1964) 146-153.
- [130] Prousek, J., Fenton reaction after a century. *Chem. Listy* **89** (1995) 11-21.
- [131] Merz, J.H.W., Waters, A., Mechanism of oxidation of alcohols with Fenton's reagent. *Discuss. Faraday Soc.* **2** (1947) 179-188.
- [132] Barb, W.G., Baxendale, J.H., George, P., Hargrave, K.R., Reactions of ferrous and ferric ions with hydrogen peroxide: Part I. The ferrous ion reaction. *Trans. Faraday Soc.* **47** (1951a) 462-500.
- [133] Barb, W.G., Baxendale, J.H., George, P., Hargrave, K.R., Reactions of ferrous and ferric ions with hydrogen peroxide: Part II. The ferric ion reaction. *Trans. Faraday Soc.* **47** (1951b) 591-616.
- [134] Walling, C., Fenton's reagent revisited. *Acc. Chem. Res.* **8** (1975) 129-131.
- [135] Koppenol, W.H., The centennial of the Fenton reaction. *Free Radic. Biol. Med.* **15** (1993) 645-651.
- [136] Haber, F., Willstätter, R., Unpaarigkeit und radikalkettin im reaktionsmechanismus organischer und enzymatischer vorgänge. *Chem. Ber.* **64** (1931) 2844-2856.
- [137] Koppenol, W.H., Facts and fiction in free radical biochemistry: The Haber-Weiss cycle, Sunrise Free Radical School, San Diego (USA), 17-20 November 2000.
- [138] Gallard, H., De Laat, J., Legube, B., Influence du pH sur la vitesse d'oxydation de composés organiques par Fe(II)/H₂O₂. Mécanismes réactionnels et modélisation. *New J. Chem.* **22** (1998) 263-268.
- [139] Safarzadeh-Amiri, A., Bolten, J.R., Cater, S.R., The use of iron in advanced

- oxidation processes. *J. Adv. Oxid. Technol.* **1** (1996)18-26.
- [140] Wadley, S., Waite, T.D., in: Parsons, S. (Ed.), *Advanced Oxidation Processes for Water and Wastewater Treatment*, IWA Publishing, London, 2004, 111-136.
- [141] Lunak, S., Muzart, J., Brodivolá, J., Photochemical hydroxylation of salicylic-acid derivatives with hydrogen peroxide, catalyzed with Fe(III) and sensitized with methylene-blue. *Collect. Czech. Chem. Commun.* **59** (1994) 905-912.
- [142] Lindsey, M.E., Tarr, M.A., Inhibition of hydroxyl radical reaction with aromatics by dissolved natural organic matter. *Environ. Sci. Technol.* **34** (2000) 444-449.
- [143] Lindsey, M.E., Tarr, M.A., Quantitation of hydroxyl radical during Fenton oxidation following a single addition of iron and peroxide. *Chemosphere* **41** (2000) 409-417.
- [144] Bray, W.C., Gorin, M.H., Ferryl ion, a compound of tetravalent iron. *J. Am. Chem. Soc.* **54** (1932) 2124-2125.
- [145] Bossmann, S.H., Oliveros, E., Göb, S., Siegwart, S., Dahlen, E.P., Payawan, Jr., Straub, M., Wörner, M., Braun, A.M., New evidence against hydroxyl radicals as reactive intermediates in the thermal and photochemically enhanced Fenton reactions. *J. Phys. Chem. A* **102** (1998) 5542-5550.
- [146] Kremer, M.L., Mechanism of the Fenton reaction: Evidence for a new intermediate. *Phys. Chem. Chem. Phys.* **1** (1999) 3595-3605.
- [147] Buda, F., Ensing, B., Gribnau, M.C.M., Baerends, E.J., DFT study of the active intermediate in the Fenton reaction. *Chem. Eur. J.* **7** (2001) 2775-2783.
- [148] Ensing, B., Buda, F., Blöchl, P.E., Baerends, E.J., A Car-Parrinello study of the formation of oxidising intermediates from Fenton's reagent in aqueous solution. *Phys. Chem. Chem. Phys.* **4** (2002) 3619-3627.
- [149] Pignatello, J.J., Liu, D., Huston, P., Evidence for additional oxidant in the photoassisted Fenton reaction. *Environ. Sci. Technol.* **33** (1999) 1832.
- [150] Hug, S.J., Leupin, O., Iron-catalyzed oxidation of arsenic(III) by oxygen and by hydrogen peroxide: pH-dependent formation of oxidants in the Fenton

- reaction. *Environ. Sci. Technol.* **37** (2003) 2743-2742.
- [151] Yamazaki, I., Piette, L.H., EPR Spin-Trapping study on the oxidizing species formed in the reaction of the ferrous ion with hydrogen peroxide. *J. Am. Chem. Soc.* **113** (1991) 7588-7593.
- [152] Gallard, H., De Laat, J., Legube, B., Spectrophotometric study of the formation of iron(III)-hydroperoxycomplexes in homogeneous aqueous solution. *Water Res.* **33** (1999) 2929-2936.
- [153] Tang, W.Z., Huang, C.P., 2,4-Dichlorophenol oxidation kinetics by Fenton's reagent. *Environ. Technol.* **17** (1996) 1371-1378.
- [154] Pignatello, J.J., Dark and photoassisted Fe³⁺-catalyzed degradation of chlorophenoxy herbicides by hydrogen peroxide. *Environ. Sci. Technol.* **26** (1992) 944-951.
- [155] De Laat, J., Gallard, H., Catalytic decomposition of hydrogen peroxide by Fe(III) in homogeneous aqueous solution: Mechanism and kinetic modeling. *Environ. Sci. Technol.* **33** (1999) 2726-2732.
- [156] Sun, Y., Pignatello, J.J., Photochemical reactions involved in the total mineralization of 2,4-D by Fe³⁺/H₂O₂/UV. *Environ. Sci. Technol.* **27** (1993) 304-310.
- [157] Pera-Titus, M., García-Molina, V., Baños, M.A., Giménez, J., Esplugas, S., Degradation of chlorophenols by means of advanced oxidation processes: A general review. *Appl. Catal. B: Environ.* **47** (2004) 219-256.
- [158] Rush, J.D., Bielski, B.H.J., Pulse radiolytic studies of the reactions of hydrodioxy/superoxide with Fe(II)/Fe(III) ions. The reactivity of hydrodioxy/superoxide with ferric ions and its implication on the occurrence of the Haber-Weiss reaction. *J. Phys. Chem.* **89** (1985) 5062-5066.
- [159] Al-Hayek, L., Doré, M., Oxidation des phénols par le peroxide d'hydrogène en milieu aqueux en présence de fer supporté sur alumine. *Water Res.* **24** (1990) 973-982.
- [160] Lin, S.S., Gurol, M.D., Catalytic decomposition of hydrogen peroxide on iron oxide: Kinetics, mechanism and implications. *Environ. Sci. Technol.* **32** (1998)

- 1417-1423.
- [161] Zinder, B., Furrer, G., Stumm, W., A coordination chemical approach to the kinetics of weathering: II. Dissolution of Fe(III) oxides. *Geochim. Cosmochim. Acta* **50** (1986) 1861-1869.
- [162] Gurol, M.D., Lin, S., Continuous catalytic oxidation process. US Patent N^o.5/755/977.
- [163] Chen, R., Pignatello, J.J., Role of quinine intermediates as electron shuttles in Fenton and photoassisted Fenton oxidations of aromatic compounds. *Environ. Sci. Technol.* **31** (1997) 2399-2406.
- [164] Sundstrom, D.W., Weir, B.A., Klei, H.E., Destruction of aromatic compounds by UV light catalyzed oxidation with hydrogen peroxide. *Environ. Prog.* **8** (1989) 6-11.
- [165] Millar, R.M., Singer, G.M., Rosen, J.D., Bartha, R., Sequential degradation of chlorophenols by photolytic and microbial treatment, *Environ. Sci. Technol.* **22** (1988) 1215-1219.
- [166] Zuo, Y., Hoigné, J., Formation of hydrogen peroxide and depletion of oxalic acid in atmospheric water by photolysis of iron(III)-oxalato complexes. *Environ. Sci. Technol.* **26** (1992) 1014-1022.
- [167] Baxendale, J.H., Wilson, J.A., Photolysis of hydrogen peroxide at high light intensities. *Trans. Faraday Soc.* **53** (1957) 344-356.
- [168] Huston, P.L., Pignatello, J.J., Degradation of selected pesticide active ingredients and commercial formulations in water by the photo-assisted Fenton reaction. *Water Res.* **33** (1999) 1238-1246.
- [169] Pignatello, J.J., Sun, Y., Complete oxidation of metolachlor and methyl parathion in water by the photoassisted Fenton reaction. *Water Res.* **29** (1995) 1837-1844.
- [170] Benítez, F.J., Beltrán-Heredia, J., Acero, J.L., Rubio, F.J., Oxidation of several chlorophenolic derivatives by UV irradiation and hydroxyl radicals. *J. Chem. Technol. Biotechnol.* **76** (2001) 312-320.

- [171] Karpel, N., Doré, M., Mécanisme d'action des radicaux OH^\bullet sur les acides glycolique, glyoxylique, acétique et oxalique en solution aqueuse: incidence sur la consommation de peroxyde d'hydrogène dans les systèmes $\text{H}_2\text{O}_2/\text{UV}$ et $\text{O}_3/\text{H}_2\text{O}_2$. *Water Res.* **31** (1997) 1383-1397.
- [172] <http://env.snu.ac.kr/research.html> (visited for the last time in 2005)
- [173] Balmer, M.E., Sultzberger, B., Atrazine degradation in irradiated iron/oxalate systems: Effects of pH and oxalate. *Environ. Sci. Technol.* **33** (1999) 2418-2424.
- [174] Safardeh-Amiri, A., Bolton, J.R., Cater, S.R., Ferrioxalate-mediated photodegradation of organic pollutants in contaminated water. *Water Res.* **31** (1997) 787-798.
- [175] Walling, C., Kato, S., The oxidation of alcohols by Fenton's reagent: The effect of copper ion. *J. Am. Chem. Soc.* **93** (1971) 4275-4281.
- [176] Walling, C., Goosen, A., Mechanism of the ferric ion catalyzed decomposition of hydrogen peroxide: Effect of organic substrates. *J. Am. Chem. Soc.* **95** (1973) 2987-2991.
- [177] Gallard, H., De Laat, J., Legube, B., Comparative study of the rate of decomposition of H_2O_2 and of atrazine by $\text{Fe(III)/H}_2\text{O}_2$, $\text{Cu(II)/H}_2\text{O}_2$, $\text{Fe(III)/Cu(II)/H}_2\text{O}_2$. *Rev. Sci. Eau* **12** (1999) 713-728.
- [178] Bielski, B.H.J., Cabelli, D.E., Arudi, R.L., Ross, A.B., Reactivity of $\text{HO}_2^\bullet/\text{O}_2^\bullet$ radicals in aqueous solution. *J. Phys. Chem. Ref. Data* **14** (1985) 1041-1100.
- [179] Sharma, V.K., Millero, F.J., Oxidation of copper(I) in seawater. *Environ. Sci. Technol.* **22** (1988) 768-771.
- [180] <http://www.insituoxidation.com> (In Situ Oxidative Technologies Inc., visited for the last time in 2006)
- [181] <http://www.mecx.net> (Service-Disabled Veteran-Owned Small Business, visited for the last time in 2006)
- [182] Anipsitakis, G.P., Dionysiou, D.D., Degradation of organic contaminants in water with sulphate radicals generated by the conjunction of peroxymonosulfate with cobalt. *Environ. Sci. Technol.* **37** (2003) 4790-4797.

- [183] Anipsitakis, G.P., Dionysiou, D.D., Transition metal / UV-based advanced oxidation technologies for water decontamination. *Appl. Catal. B: Environ.* **54** (2004) 155-163.
- [184] Le Paulouë, J., Langlais, B., State of the art of ozonation in France. *Ozone Sci. Eng.* **21** (1999) 153-162.
- [185] Hoigné, J., Chemistry of aqueous ozone and transformation of pollutants by ozonation and advanced oxidation processes, in: Hrube, J. (Ed.), *The Handbook of Environmental Chemistry*, Springer-Verlag, Berlin, 1998, Vol. 5, Part C: Quality and Treatment of Drinking Water II.
- [186] Bailey, P.S., The reactions of ozone with organic compounds. *Chem. Rev.* **58** (1958) 925-1010.
- [187] Langlais, B., Reckhow, D.A., Brink, D.R. (Eds.), *Ozone in Water Treatment: Application and Engineering*, Lewis Publishers Inc., Chelsea (Michigan), 1991.
- [188] Gottschalk, C., Libra, J.A., Saupe, A. (Eds.), *Ozonation of water and waste water: A practical guide to understanding ozone and its application*, Wiley-VCH, Weinheim, 2000.
- [189] Peyton, G.R., Glaze, W.H., Destruction of pollutants in water with ozone in combination with ultraviolet radiation: 3. Photolysis of aqueous ozone. *Environ. Sci. Technol.* **22** (1988) 761-767.
- [190] Peyton, G.R., in: Ram, M., Christman, R.F., Cantor, K.P. (Eds.), *Significance and Treatment of Volatile Organic Compounds in Water Supplies*, Lewis Publishers Inc., Chelsea (Michigan), 1990, 313-362.
- [191] Staehelin, J., Hoigné, J., Decomposition of ozone in water: Rate of initiation by hydroxide ions and hydrogen peroxide. *Environ. Sci. Technol.* **16** (1982) 676-681.
- [192] Glaze, W.H., Kang, J.W., Advanced oxidation processes for treating groundwater contaminated with TCE and PCE: Laboratory studies. *J. Am. Water Works Assoc.* **80** (1988) 57-63.
- [193] Glaze, W.H., Kang, J.W., Advanced oxidation processes: Test of a kinetic model for the oxidation of organic compounds with ozone and hydrogen peroxide in

- a semibatch reactor. *Ind. Eng. Chem. Res.* **28** (1989) 1580-1587.
- [194] Skoumal, M., Cabot, P.L., Centellas, F., Arias, C., Rodríguez, R.M., Garrido, J.A., Brillas, E., Mineralization of paracetamol by ozonation catalyzed with Fe²⁺, Cu²⁺ and UVA light. *Appl. Catal. B: Environ.* **66** (2006) 228-240.
- [195] Abe, K.I., Tanaka, K., Degradation of phenol, asulam and lignin in aqueous solution by ozonation. *Toxicol. Environ. Chem.* **54** (1996) 187-193.
- [196] Contreras, S., Degradation and biodegradability enhancement of nitrobenzene and 2,4-dichlorophenol by means of advanced oxidation processes based on ozone. Doctoral Thesis (2002). Universitat de Barcelona (Barcelona, Spain).
- [197] Böhme, A., Ozone technology of German industrial enterprises. *Ozone Sci. Eng.* **21** (1999) 163-176.
- [198] Lowndes, R., State of the art for ozone U.K. experience. *Ozone Sci. Eng.* **21** (1999) 201-205.
- [199] Rice, R.G., Ozone in the United States of America – State of the art. *Ozone Sci. Eng.* **21** (1999) 99-118.
- [200] Fujishima, A., Honda, K., Electrochemical photolysis of water at a semiconductor electrode. *Nature* **238** (1972) 37-38.
- [201] Ollis, D., Al-Ekabi, H. (Eds.), Photocatalytic purification and treatment of water and air, Elsevier Science Ltd., New York, 1993.
- [202] Mansilla, H.D., Yeber, M.C., Freer, J., Rodríguez, J., Baeza, J., Homogeneous and heterogeneous advanced oxidation of a bleaching effluent from the pulp and paper industry. *Water Sci. Technol.* **35** (1997) 273-278.
- [203] Doll, T.E., Frimmel, F.H., Removal of selected persistent organic pollutants by heterogeneous photocatalysis in water. *Catal. Today* **101** (2005) 195-202.
- [204] Fujishima, A., Zhang, X., Titanium dioxide photocatalysis: present situation and future approaches. *C. R. Chimie* **9** (2006) 750-760.
- [205] Guillard, C., Disdier, J., Herrmann, J.M., Lehaut, C., Chopin, T., Malato, S., Blanco, J., Comparison of various titania samples of industrial origin in the solar photocatalytic detoxification of water containing 4-chlorophenol.

- Catal. Today* **54** (1999) 217-228.
- [206] Franch, M.I., Ayllón, J.A., Peral, J., Domènech, X., Photocatalytic degradation of short-chain organic acids. *Catal. Today* **76** (2002) 221-233.
- [207] Serpone, S., Emelie, V., Suggested terms and definitions in photocatalysis and radiocatalysis. *Int. J. Photoenergy* **4** (2002) 91-131.
- [208] Yue, B., Zhou, Y., Xu, J., Wu, Z., Zhang, X., Zou, Y., Jin, S., Photocatalytic degradation of aqueous 4-chlorophenol by silica-immobilized polyoxometalates. *Environ. Sci. Technol.* **36** (2002) 1325-1329.
- [209] Giménez, J., Curcó, D., Marco, P., Reactor modelling in the photocatalytic oxidation of wastewater. *Water Sci. Technol.* **35** (1997) 207-213.
- [210] Pichat, P., Heterogeneous photocatalysis, in: Knözinger, E.G., Weitkamp, J. (Eds.), *Handbook of Heterogeneous Catalysis*, Wiley-VCH, Weinheim, 1997, Vol. 4, 2111-2122.
- [211] Ollis, D.F., Heterogeneous photocatalysis. *CatTech* **2** (1999) 149-157.
- [212] Fujishima, A., Hashimoto, K., Watanabe, T., *TiO₂ Photocatalysis: Fundamentals and Applications*, BKC, Tokyo, 1999.
- [213] Blake, D.M., *Bibliography of Work on the Photocatalytic Removal of Hazardous Compounds from Water and Air*. NREL/TP-510-31319, Golden, CO: National Renewable Energy Laboratory (<http://www.nrel.gov/>)
- [214] Zimmermann, F.J., Waste disposal, U.S. Patent 2/665//249, 5 January 1954.
- [215] Li, L., Peishi, C., Earnest, F.G., Generalized kinetic model for wet oxidation of organic compounds. *AIChE J.* **37** (1991) 1687-1697.
- [216] Garcia, V., *Wet oxidation processes for water pollution remediation*. Doctoral Thesis (2006). Universitat de Barcelona (Barcelona, Spain).
- [217] Kritzer, P., Dinjius, E., An assessment of supercritical water oxidation (SCWO) existing problems, possible solutions and new reactor concepts. *Chem. Eng. J.* **83** (2001) 207-214.
- [218] Debellefontaine, H., Chakchouk, M., Foussard, J.N., Tissot, D., Striolo, P., Treatment of organic aqueous wastes: Wet air oxidation and wet peroxide

- oxidation. *Environ. Pollut.* **92** (1996) 155-164.
- [219] Posada, D., Betancourt, P, Liendo, F., Brito, J.L., Catalytic wet air oxidation of aqueous solution of substituted phenols. *Catal. Lett.* **106** (2006) 81-87.
- [220] Nagata, Y., Hirai, K., Bandow, H., Maeda, Y., Decomposition of hydroxybenzoic and humic acids in water by ultrasonic irradiation. *Environ. Sci. Technol.* **30** (1996) 1133-1138.
- [221] Hao, H., Chen, Y., Wu, M., Wang, H., Yin, Y., Lü, A., Sonochemistry of degrading *p*-chlorophenol in water by high frequency ultrasound. *Ultrason. Sonochem.* **11** (2004) 43-46.
- [222] Adewuyi, Y.G., Sonochemistry: environmental science and engineering applications. *Ind. Eng. Chem. Res.* **40** (2001) 4681-4715.
- [223] Chaychian, M., Silverman, J., Sheikhy, M.A., Poster, D.L., Neta, P., Ionizing radiation induced degradation of tetrachlorobiphenyl in transformer oil. *Environ. Sci. Technol.* **33** (1999) 2461-2464.
- [224] Gehringer, P., Eschweiler, H., The use of radiation-induced advanced oxidation for water reclamation. *Water Sci. Technol.* **34** (1996) 343-349.
- [225] Weavers, L.K., Hua, I., Hoffmann, M.R., Degradation of triethanolamine and chemical oxygen demand reduction in wastewater by photoactivated periodate. *Water Environ. Res.* **69** (1997) 1112-1119.
- [226] Walsh, F.C., Electrochemical technology for environmental treatment and clean energy conversion. *Pure Appl. Chem.* **73** (2001) 1819-1837.
- [227] Cabot, P.L., Centelles, M., Segarra, L., Casado, J., Electrodehalogenation of trichlorofluoromethane on lead cathodes using hydrogen diffusion cathodes. *J. Electrochem. Soc.* **147** (2000) 3734-3738.
- [228] Inaba, M., Sawai, K., Ogumi, Z., Takehara, Z., Electroreduction of a chlorofluoroethane on a solid polymer electrolyte composite electrode. *Chem. Lett.* **24** (1995) 471-472.
- [229] Farmer, J., Wang, F.T., Lewis, P.R., Summers, L.J., Destruction of chlorinated organics by Co(III)-mediated electrochemical oxidation. *J. Electrochem. Soc.* **139**

- (1992) 3025-3029.
- [230] Kraft, A., Blaschke, M., Kreysig, D., Sandt, B., Schröder, F., Rennau, J., Electrochemical water disinfection: Part II. Hypochlorite production from potable water, chlorine consumption and the problem of calcareous deposits. *J. Appl. Electrochem.* **29** (1999) 895-902.
- [231] Brillas, E., Cabot, P.L., Casado, J., Electrochemical Methods for Degradation of Organic Pollutants in Aqueous Media, in: Tarr, M.A. (Ed.), Chemical Degradation Methods for Wastes and Pollutants, Marcel Dekker Inc., New York, 2003, 235-304.
- [232] Chen, G., Electrochemical technologies in wastewater treatment. *Sep. Purif. Technol.* **38** (2004) 11-41.
- [233] Pletcher, D., Walsh, F.C., Industrial Electrochemistry, Chapman and Hall, London, 1990, 2nd Ed.
- [234] Il'in, V.I., Sedashova, O.N., An electroflotation method and plan for removing oil products from effluents. *Chem. Pet. Eng.* **35** (1999) 480-481.
- [235] Comninellis, Ch., Pulgarin, C., Anodic oxidation of phenol for waste water treatment. *J. Appl. Electrochem.* **21** (1991) 703-708.
- [236] Comninellis, Ch., Pulgarin, C., Electrochemical oxidation of phenol for wastewater treatment using SnO₂ anodes. *J. Appl. Electrochem.* **23** (1993) 108-112.
- [237] Tennakoon, C.L.K., Bhardwaj, R.C., Bockris, J.O'M., Electrochemical treatment of human wastes in a packed bed reactor. *J. Appl. Electrochem.* **26** (1996) 18-29.
- [238] Tahar, N.B., Savall, A., Mechanistic aspects of phenol electrochemical degradation by oxidation on a Ta/PbO₂ anode. *J. Electrochem. Soc.* **145** (1998) 3427-3434.
- [239] Bonfatti, F., Ferro, S., Lavezzo, F., Malacarne, M., Lodi, G., De Battisti, A., Electrochemical incineration of glucose as a model organic substrate: I. Role of the electrode material. *J. Electrochem. Soc.* **146** (1999) 2175-2179.
- [240] Bonfatti, F., Ferro, S., Lavezzo, F., Malacarne, M., Lodi, G., De Battisti, A., Electrochemical incineration of glucose as a model organic substrate: II. Role of

- active chlorine mediation. *J. Electrochem. Soc.* **147** (2000) 592-596.
- [241] Rodgers, J.D., Bunce, N.J., Electrochemical treatment of 2,4,6-trinitrotoluene and related compounds. *Environ. Sci. Technol.* **35** (2001) 406-410.
- [242] Flox, C., Garrido, J.A., Rodríguez, R.M., Centellas, F., Cabot, P.L., Arias, C., Brillas, E., Degradation of 4,6-dinitro-*o*-cresol from water by anodic oxidation with a boron-doped diamond electrode. *Electrochim. Acta* **50** (2005) 3685-3692.
- [243] Feng, J., Johnson, D.C., Electrocatalysis of anodic oxygen-transfer reactions. *J. Electrochem. Soc.* **137** (1990) 507-510.
- [244] Kaba, L., Hitchens, G.D., Bockris, J.O'M., Electrochemical incineration of wastes. *J. Electrochem. Soc.* **137** (1990) 1341-1345.
- [245] Murphy, O.J., Hitchens, G.D., Kaba, L., Verotsko, C.E., Direct electrochemical oxidation of organics for wastewater treatment. *Water Res.* **26** (1992) 331-344.
- [246] Feng, J., Houk, L.L., Johnson, D.C., Lowery, S.N., Carey, J.J., Electrocatalysis of anodic oxygen-transfer reactions: the electrochemical incineration of benzoquinone. *J. Electrochem. Soc.* **142** (1995) 3626-3632.
- [247] Wu, Z.C., Zhou, M.H., Partial degradation of phenol by advanced electrochemical oxidation process. *Environ. Sci. Technol.* **35** (2001) 2698-2703.
- [248] Johnson, S.K., Houk, L.L., Feng, J., Houk, R.S., Johnson, D.C., Electrochemical incineration of 4-chlorophenol and the identification of products and intermediates by mass spectrometry. *Environ. Sci. Technol.* **33** (1999) 2638-2644.
- [249] Comninellis, Ch., Electrocatalysis in the electrochemical conversion/combustion of organic pollutants for waste water treatment. Proceedings of the Symposium on Water Purification by Photocatalytic, Photoelectrochemical and Electrochemical Processes, The Electrochemical Society, Pennington (UK), 1994, Vol. 94-19, 75-86.
- [250] Comninellis, Ch., De Battisti, A., Electrocatalysis in anodic oxidation of organics with simultaneous oxygen evolution. *J. Chim. Phys.* **93** (1996) 673-679.
- [251] Marselli, B., Garcia-Gomez, J., Michaud, P.-A., Rodrigo, M.A., Comninellis, Ch., Electrogeneration of hydroxyl radicals on boron-doped diamond electrodes.

- J. Electrochem. Soc.* **150** (2003) D79-D83.
- [252] Haenni, W., Baumann, H., Comninellis, Ch., Gandini, D., Niedermann, P., Perret, A., Skinner, N., Diamond-sensing microdevices for environmental control and analytical applications. *Diamond Relat. Mater.* **7** (1998) 569-574.
- [253] Perret, A., Haenni, W., Skinner, N., Tang, X.M., Gandini, D., Comninellis, C., Correa, R., Foti, G., Electrochemical behavior of synthetic diamond thin film electrodes. *Diamond Relat. Mater.* **8** (1999) 820-823.
- [254] Rodrigo, M.A., Michaud, P.-A., Duo, I., Panizza, M., Cerisola, G., Comninellis, Ch., Oxidation of 4-chlorophenol at boron-doped diamond electrodes for wastewater treatment. *J. Electrochem. Soc.* **148** (2001) D60-D64.
- [255] Panizza, M., Michaud, P.A., Cerisola, G., Comninellis, Ch., Electrochemical treatment of wastewaters containing organic pollutants on boron.doped diamond electrodes: Prediction of specific energy consumption and required electrode area. *Electrochem. Commun.* **3** (2001) 336-339.
- [256] Ventura, A., Jacquet, G., Bermond, A., Camel, V., Electrochemical generation of the Fenton's reagent: application to the atrazine degradation. *Water Res.* **36** (2002) 3517-3522.
- [257] Oturan, M.A., Pinson, J., Polyhydroxylation of salicylic acid by electrochemically generated HO[•] radicals. *New. J. Chem.* **16** (1992) 705-710.
- [258] Tzedakis, T., Savall, A., Clifton, M.J., The electrochemical regeneration of Fenton's reagent in the hydroxylation of aromatic substrates: batch and continuous processes. *J. Appl. Electrochem.* **19** (1989) 911-921.
- [259] Sudoh, M., Kodera, T., Sakai, K., Zhang, J.Q., Koide, K., Oxidative degradation of aqueous phenol effluent with electrogenerated Fenton's reagent. *J. Chem. Eng. Jpn.* **19** (1986) 513-518.
- [260] Brillas, E., Mur, E., Casado, J., Iron(II) catalysis of the mineralization of aniline using a carbon-PTFE O₂-fed cathode. *J. Electrochem. Soc.* **143** (1996) L49-L53.
- [261] Brillas, E., Bastida, R.M., Llosa, E.F., Casado, J., Electrochemical destruction of aniline and 4-chloroaniline for wastewater treatment using a carbon-PTFE

- O₂-fed cathode. *J. Electrochem. Soc.* **142** (1995) 1733-1741.
- [262] Da Pozzo, A., Merli, C., Sirés, I., Garrido, J.A., Rodríguez, R.M., Brillas, E., Removal of herbicide amitrole from water by anodic oxidation and electro-Fenton. *Environ. Chem. Lett.* **3** (2005) 7-11.
- [263] Harrington, T., Pletcher, D., The removal of low levels of organics from aqueous solutions using Fe(II) and hydrogen peroxide formed in situ at gas diffusion electrodes. *J. Electrochem. Soc.* **146** (1999) 2983-2989.
- [264] Pletcher, D., Indirect oxidations using electrogenerated hydrogen peroxide. *Acta Chim. Scand.* **53** (1999) 745-750.
- [265] Brillas, E., Sauleda, R., Casado, J., Peroxi-coagulation of aniline in acidic medium using an oxygen diffusion cathode. *J. Electrochem. Soc.* **144** (1997) 2374-2379.
- [266] Brillas, E., Sauleda, R., Casado, J., Degradation of 4-chlorophenol by anodic oxidation, electro-Fenton, photoelectro-Fenton and peroxi-coagulation processes. *J. Electrochem. Soc.* **145** (1998) 759-765.
- [267] Brillas, E., Mur, E., Sauleda, R., Sánchez, L., Peral, J., Doménech, X., Casado, J., Aniline mineralization by AOPs: Anodic oxidation, photocatalysis, electro-Fenton and photoelectro-Fenton processes. *Appl. Catal. B: Environ.* **16** (1998) 31-42.
- [268] Brillas, E., Sauleda, R., Casado, J., Destruction of aromatic contaminants in an Fe/O₂ battery. *Electrochem. Solid-State Lett.* **1** (1998) 168-171.
- [269] Brillas, E., Sauleda, R., Casado, J., Use of an acidic Fe/O₂ cell for wastewater treatment: degradation of aniline. *J. Electrochem. Soc.* **146** (1999) 4539-4543.
- [270] Brillas, E., Casado, J., Aniline degradation by Electro-Fenton and peroxi-coagulation process using a flow reactor for wastewater treatment. *Chemosphere* **47** (2002) 241-248.
- [271] Brillas, E., Boye, B., Baños, M.A., Calpe, J.C., Garrido, J.A., Electrochemical degradation of chlorophenoxy and chlorobenzoic herbicides in acidic aqueous medium by the peroxi-coagulation method. *Chemosphere* **51** (2003) 227-235.

- [272] Brillas, E., Boye, B., Dieng, M.M., General and UV-assisted cathodic Fenton treatments for the mineralization of herbicide MCPA. *J. Electrochem. Soc.* **150** (2003) E583-E589.
- [273] Brillas, E., Boye, B., Dieng, M.M., Peroxi-coagulation and photoperoxi-coagulation treatments of the herbicide 4-chlorophenoxyacetic acid in aqueous medium using an oxygen-diffusion cathode. *J. Electrochem. Soc.* **150** (2003) E148-E154.
- [274] Boye, B., Dieng, M.M., Brillas, E., Electrochemical degradation of 2,4,5-trichlorophenoxyacetic acid in aqueous medium by peroxi-coagulation. Effect of pH and UV light. *Electrochim. Acta* **48** (2003) 781-790.
- [275] Brillas, E., Baños, M.A., Camps, S., Arias, C., Cabot, P.L., Garrido, J.A., Rodríguez, R.M., Catalytic effect of Fe²⁺, Cu²⁺ and UVA light on the electrochemical degradation of nitrobenzene using an oxygen-diffusion cathode. *New J. Chem.* **28** (2004) 314-322.
- [276] Flox, C., Ammar, S., Arias, C., Brillas, E., Vargas-Zavala, A.V., Abdelhedi, R., Electro-Fenton and photoelectro-Fenton degradation of indigo carmine in acidic aqueous medium. *Appl. Catal. B: Environ.* **67** (2006) 93-104.
- [277] (a) Do, J.S., Chen, C.P., In situ oxidative degradation of formaldehyde with electrogenerated hydrogen peroxide. *J. Electrochem. Soc.* **140** (1993) 1632-1637.
(b) Do, J.S., Chen, C.P., In situ oxidative degradation of formaldehyde with hydrogen peroxide electrogenerated on the modified graphites. *J. Appl. Electrochem.* **24** (1994) 936-942.
(c) Do, J.S., Chen, C.P., Kinetics of in situ degradation of formaldehyde with electrogenerated hydrogen peroxide. *Ind. Eng. Chem. Res.* **33** (1994) 387-394.
- [278] (a) Da Pozzo, A., Ferrantelli, P., Merli, C., Petrucci, E., Oxidation efficiency in the electro-Fenton process. *J. Appl. Electrochem.* **35** (2005) 391-398.
(b) Da Pozzo, A., Di Palma, L., Merli, C., Petrucci, E., An experimental comparison of a graphite electrode and a gas diffusion electrode for the cathodic production of hydrogen peroxide. *J. Appl. Electrochem.* **35** (2005) 413-419.

- [279] Amadelli, R., Bonato, T., De Battisti, A., Babak, A., Velichenko, A., A comparative study of the electro-oxidation of some phenolic compounds by electrogenerated O₃ and by direct electrolysis at PbO₂ anodes. Proceedings of the Symposium on Energy and Electrochemical Processing for a Cleaner Environment, The Electrochemical Society, Pennington (UK), 1998, 51-60.
- [280] Wang, A., Qu, J., Ru, J., Liu, H., Ge, J., Mineralization of an azo dye Acid Red 14 by electro-Fenton's reagent using an activated carbon fiber cathode. *Dyes Pigm.* **65** (2005) 227-233.
- [281] Do, J.S., Yeh, W.C., In situ paired electrooxidative degradation of formaldehyde with electrogenerated hydrogen peroxide and hypochlorite ion. *J. Appl. Electrochem.* **28** (1998) 703-710.
- [282] Hsiao, Y.L., Nobe, K., Hydroxylation of chlorobenzene and phenol in a packed bed flow reactor with electrogenerated Fenton's reagent. *J. Appl. Electrochem.* **23** (1993) 943-946.
- [283] Ponce de Leon, C., Pletcher, D., Removal of formaldehyde from aqueous solutions via oxygen reduction using a reticulated vitreous carbon cathode. *J. Appl. Electrochem.* **25** (1995) 307-314.
- [284] Alvarez-Gallegos, A., Pletcher, D., The removal of low level organics via hydrogen peroxide formed in a reticulated vitreous carbon cathode cell: Part 2. The removal of phenols and related compounds from aqueous effluents. *Electrochim. Acta.* **44** (1999) 2483-2492.
- [285] Badellino, C., Rodrigues, C.A., Bertazzoli, R., Oxidation of pesticides by in situ electrogenerated hydrogen peroxide: Study for the degradation of 2,4-dichlorophenoxyacetic acid. *J. Hazard. Mater. B* **137** (2006) 856-864.
- [286] Oturan, M.A., Aaron, J.J., Oturan, N., Pinson, J., Degradation of chlorophenoxyacid herbicides in aqueous media, using a novel electrochemical method. *Pestic. Sci.* **55** (1999) 558-562.
- [287] Fokedey, E., Van Lierde, A., Coupling and cathodic reactions for phenol electro-oxidation using three-dimensional electrodes. *Water Res.* **36** (2002)

- 4169-4175.
- [288] Meinero, S., Zerbinati, O., Oxidative and energetic efficiency of different electrochemical oxidation processes for chloroanilines abatement in aqueous medium. *Chemosphere* **64** (2006) 386-392.
- [289] Oturan, M.A., Pinson, J., Oturan, N., Deprez, D., Hydroxylation of aromatic drugs by the electro-Fenton method: Formation and identification of the metabolites of riluzole. *New J. Chem.* **23** (1999) 793-794.
- [290] Oturan, M.A., An ecologically effective water treatment technique using electrochemically generated hydroxyl radicals for in situ destruction of organic pollutants: Application to herbicide 2,4-D. *J. Appl. Electrochem.* **30** (2000) 475-482.
- [291] Oturan, M.A., Peiroten, J., Chartrin, P., Acher, A.J., Complete destruction of *p*-nitrophenol in aqueous medium by electro-Fenton method. *Environ. Sci. Technol.* **34** (2000) 3747-3749.
- [292] Aaron, J.J., Oturan, M.A., New photochemical and electrochemical methods for the degradation of pesticides in aqueous media: Environmental applications. *Turk. J. Chem.* **25** (2001) 509-520.
- [293] Oturan, M.A., Oturan, N., Lahitte, C., Trévin, S., Production of hydroxyl radicals by electrochemically assisted Fenton's reagent: Application to the mineralization of an organic micropollutant. *J. Electroanal. Chem.* **507** (2001) 96-102.
- [294] Guivarch, E., Trevin, S., Lahitte, C., Oturan, M.A., Degradation of azo dyes in water by electro-Fenton process. *Environ. Chem. Lett.* **1** (2003) 38-44.
- [295] Edelahi, M.C., Oturan, N., Oturan, M.A., Padellec, Y., Bermond, A., El Kacemi, K., Degradation of diuron by the electro-Fenton process. *Environ. Chem. Lett.* **1** (2004) 233-236.
- [296] Oturan, N., Oturan, M.A., Degradation of three pesticides used in viticulture by electrogenerated Fenton's reagent. *Agron. Sustain. Dev.* **25** (2005) 267-270.
- [297] Irmak, S., Yavuz, H.I., Erbatur, O., Degradation of 4-chloro-2-methylphenol in aqueous solution by electro-Fenton and photoelectro-Fenton processes.

- Appl. Catal. B* **63** (2005) 243-248.
- [298] Pérez-Estrada, L.A., Malato, S., Gernjak, W., Agüera, A., Thurman, E.M., Ferrer, I., Fernández-Alba, A.R., Photo-Fenton degradation of diclofenac: Identification of main intermediates and degradation pathway. *Environ. Sci. Technol.* **39** (2005) 8300-8306.
- [299] Cáceres, J., Malato, S., Fernández-Alba, A.R., Evaluación analítica y optimización de procesos de oxidación avanzada en planta piloto solar, Ciemat, Madrid, 2003.
- [300] Ajona, J.A., Vidal, A., The use of CPC collectors for detoxification of contaminated water: Design, construction and preliminary results. *Sol. Energy* **68** (2000) 109-120.
- [301] Blanco, J., Malato, S., Solar Detoxification. UNESCO, Natural Sciences, WORLD SOLAR PROGRAMME 1996-2005, 2001.
- [302] Zhang, T., Oyama, T., Horikoshi, S., Zhao, J., Hidaka, H., Serpone, N., Assessment and influence of operational parameters on the TiO₂ photocatalytic degradation of sodium benzene sulfonate under highly concentrated solar light illumination. *Sol. Energy* **71** (2001) 305-313.
- [303] Qiang, Z., Chang, J.H., Huang, C.P., Electrochemical regeneration of Fe²⁺ in Fenton oxidation processes. *Water Res.* **37** (2003) 1308-1319.
- [304] Gözmen, B., Oturan, M.A., Oturan, N., Erbatur, O., Indirect electrochemical treatment of bisphenol A in water via Electrochemically Generated Fenton's Reagent. *Environ. Sci. Technol.* **37** (2003) 3716-3723.
- [305] Fryda, M., Matthée, Th., Mulcahy, S., Höfer, M., Schäfer, L., Tröster, I., Applications of DIACHEM electrodes in electrolytic water treatment, The Electrochemical Society Interface, 2003.
- [306] Khoufi, S., Aloui, F., Sayadi, S., Treatment of olive oil mill wastewater by combined process electro-Fenton reaction and anaerobic digestion. *Water Res.* **40** (2006) 2007-2016.
- [307] García-Montano, J., Torrades, F., García-Hortal, J.A., Domenèch, X., Peral, J.,

- Combining photo-Fenton process with aerobic sequencing batch reactor for commercial hetero-bireactive dye removal. *Appl. Catal B* **67** (2006) 86-92.
- [308] Farré, M.J., Doménech, X., Peral, J., Assessment of photo-Fenton and biological treatment coupling for Diuron and Linuron removal from water. *Water Res.* **40** (2006) 2533-2540.
- [309] Brillas, E., Maestro, A., Moratalla, M., Casado, J., Electrochemical extraction of oxygen from air via hydroperoxide ion. *J. Appl. Electrochem.* **27** (1997) 83-92.
- [310] Foller, P.C., Bombard, R.T., Processes for the production of mixtures of caustic soda and hydrogen peroxide via the reduction of oxygen. *J. Appl. Electrochem.* **25** (1995) 613-627.
- [311] Alcaide, F., Brillas, E., Cabot, P.L., Casado, J., Electrogenation of hydroperoxide ion using an alkaline fuel cell. *J. Electrochem. Soc.* **145** (1998) 3444-3449.
- [312] Tseung, A.C.C., Jasem, S.M., An integrated electrochemical-chemical method for the extraction of O₂ from air. *J. Appl. Electrochem.* **11** (1981) 209-215.
- [313] Casado, J., Bastida, R.M., Brillas, E., Vandermeiren, M., Electrolytic purification of contaminated waters by using oxygen diffusion cathodes. Spanish Patent ES 9400299, 1994; PCT Int Appl WO 95/22509, 1995.
- [314] Drogui, P., Elmaleh, S., Rumeau, M., Bernard, C., Rambaud, A., Hydrogen peroxide production by water electrolysis: Application to disinfection. *J. Appl. Electrochem.* **31** (2001) 877-882.
- [315] Drogui, P., Elmaleh, S., Rumeau, M., Bernard, C., Rambaud, A., Oxidising and disinfecting by hydrogen peroxide produced in a two-electrode cell. *Water. Res.* **35** (2001) 3235-3241.
- [316] Zhang, L., Li, J., Chen, Z., Tang, Y., Yu, Y., Preparation of Fenton reagent with H₂O₂ generated by solar light-illuminated nano-Cu₂O/MWNTs composites. *Appl. Catal. A* **299** (2006) 292-297.
- [317] Pastor-Moreno, G., Electrochemical Applications of CVD Diamond. Doctoral Thesis (2002). University of Bristol (Bristol, UK).

- [318] Pleskov, Y.V., Electrochemistry of diamond: A review. *Russ. J. Electrochem.* **38** (2002) 1275-1291.
- [319] Panizza, M., Cerisola, G., Application of diamond electrodes to electrochemical processes. *Electrochim. Acta* **51** (2005) 191-199.
- [320] Kalish, R., Doping of diamond. *Carbon* **37** (1999) 781-785.
- [321] Chen, Q., Gruen, D.M., Krauss, A.R., Corrigan, T.D., Witek, M., Swain, G.M., The structure and electrochemical behaviour of nitrogen-containing nanocrystalline diamond films deposited from CH₄/N₂/Ar mixtures. *J. Electrochem. Soc.* **148** (2001) E44-E51.
- [322] Siné, G., Ouattara, L., Panizza, M., Comninellis, Ch., Electrochemical behaviour of fluorinated boron-doped diamond. *Electrochem. Solid-State Lett.* **6** (2003) D9-D11.
- [323] Ferro, S., De Battisti, A., The 5-V window of polarizability of fluorinated diamond electrodes in aqueous solutions. *Anal. Chem.* **75** (2003) 7040-7042.
- [324] Pleskov, Y.V., Sakharova, A.Y., Krotova, M.D., Bouilov, L.L., Spitsyn, B.V., Photoelectrochemical properties of semiconductor diamond. *J. Electroanal. Chem. Interf. Electrochem.* **228** (1987) 19-27.
- [325] Fujishima, A., Rao, T.N., New directions in structuring and electrochemical applications of boron-doped diamond thin films. *Diamond Relat. Mater.* **10** (2001) 1799-1803.
- [326] Michaud, P.-A., Comportement anodique du diamant synthétique dopé au bore. Doctoral Thesis (2002). École Polytechnique Fédérale de Lausanne (Lausanne, Switzerland).
- [327] Marselli, B., Electrochemical oxygen transfer reaction on synthetic Boron-Doped Diamond thin film electrode. Doctoral Thesis (2004). École Polytechnique Fédérale de Lausanne (Lausanne, Switzerland).
- [328] Comninellis, Ch., Electrocatalysis in the electrochemical conversion/combustion of organic pollutants for waste water treatment. *Electrochim. Acta* **39** (1994) 1857-1862.

- [329] Simond, O., Schaller, V., Comninellis, Ch., Theoretical model for the anodic oxidation of organics on metal oxide electrodes. *Electrochim. Acta* **42** (1997) 2009-2012.
- [330] Foti, G., Gandini, D., Comninellis, Ch., Anodic oxidation of organics on thermally prepared oxide electrodes. *Curr. Top. Electrochem.* **5** (1997) 71-91.
- [331] Gandini, D., Mahé, E., Michaud, P.-A., Haenni, W., Comninellis, Ch., Oxidation of carboxylic acids at boron-doped diamond electrodes for wastewater treatment. *J. Appl. Electrochem.* **30** (2000) 1345-1350.
- [332] Cañizares, P., Lobato, J., Paz, R., Rodrigo, M.A., Sáez, C., Electrochemical oxidation of phenolic wastes with boron-doped diamond electrodes. *Water Res.* **39** (2005) 2687-2703.
- [333] Polcaro, A.M., Vacca, A., Mascia, M., Palmas, S., Oxidation at boron doped diamond electrodes: an effective method to mineralise triazines. *Electrochim. Acta* **50** (2005) 1841-1847.
- [334] Tian, Y., Chen, X., Shang, C., Chen, G., Active and stable Ti/Si/BDD anodes for electro-oxidation. *J. Electrochem. Soc.* **153** (2006) J80-J85.
- [335] Latto, M.N., The Electrochemistry of Diamond. Doctoral Thesis (2001). University of Bristol (Bristol, UK).
- [336] Zhi, J.-F., Wang, H.-B., Nakashima, T., Rao, T.N., Fujishima, A., Electrochemical incineration of organic pollutants on boron-doped diamond electrode: Evidence for direct electrochemical oxidation pathway. *J. Phys. Chem. B* **107** (2003) 13389-13395.
- [337] Serrano, K., Michaud, P.A., Comninellis, C., Savall, A., Electrochemical preparation of peroxodisulfuric acid using boron doped diamond thin film electrodes. *Electrochim. Acta* **48** (2002) 431-436.
- [338] Tchobanoglous, G., Burton, F., Wastewater engineering: Treatment, disposal, and reuse, Metcalf&Eddy Inc., McGraw-Hill Book Co., New York, 1991, 3rd Ed.
- [339] Welcher, F.J. (Ed.), Standard Methods of Chemical Analysis, R.E. Krieger Publ. Co., Huntington, 1975, Vol. 2, Part B, 6th Ed., 1827.

- [340] Vogels, A.I. (Ed.), Vogel's Textbook of Quantitative Inorganic Analysis, Longman, London, 1981, 4th Ed., 750-751.
- [341] Panizza, M., Michaud, P.A., Cerisola, G., Comninellis, Ch., Anodic oxidation of 2-naphtol at boron-doped diamond electrodes. *J. Electroanal. Chem.* **507** (2001) 206-214.
- [342] AWWA, Standard Methods for the examination of water and wastewater, Washington, 1985, 16th Ed.
- [343] Furman, N.H. (Ed.), Standard Methods of Chemical Analysis, R.E. Krieger Publ. Co., Huntington, 1975, Vol. 1, 6th Ed., 553.
- [344] Sandell, E.B., in: Clarke, B.L., Elving, P.J., Kolthoff, I.M. (Eds.), Chemical Analysis, Interscience Publishers Inc., New York, 1959, Vol. III, 3rd Ed., 522.
- [345] Bedner, M., Maccrehan, W.A., Transformation of acetaminophen by chlorination produces the toxicants 1,4-benzoquinone and *N*-acetyl-*p*-benzoquinone imine. *Environ. Sci. Technol.* **40** (2006) 516-522.
- [346] Johnston, J.J., Savarie, P.J., Primus, T.M., Eisemann, J.C., Hurley, J.C., Kohler, K.J., Risk assessment of an acetaminophen baiting program for chemical control of Brown Tree snakes on Guam: evaluation of baits, snake residues, and potential primary and secondary hazards. *Environ. Sci. Technol.* **36** (2002) 3827-3833.
- [347] Rao, E.K., Sastry, C.S., Spectrophotometric determination of some phenols using *m*-phenylenediamine and sodium metaperiodate. *Mikrochim. Acta* **1** (1984) 313-319.
- [348] <http://chemdat.merck.de> (Merck, visited for the last time in 2003)
- [349] O'Brien, P.J., Khan, S., Jatoe, S.D., Formation of biological reactive intermediates by peroxidases: halide mediated acetaminophen oxidation and cytotoxicity. *Adv. Exp. Med. Biol.* **283** (1991) 51-64.
- [350] Chen, W., Koenigs, L.L., Thompson, S.J., Peter, R.M., Rettie, A.E., Trager, W.F., Nelson, S.D., Oxidation of acetaminophen to its toxic quinone imine and non-toxic catechol metabolites by baculovirus-expressed and purified human

- cytochromes P450 2E1 and 2A6. *Chem. Res. Toxicol.* **11** (1998) 295-301.
- [351] The Acetaminophen Research Group, The 2000-2005 World Outlook for Acetaminophen (paracetamol), Icon Group International Inc., San Diego, 2000.
- [352] Jane Williams, Insider's Guide to the World of Pharmaceutical Sales, Principle Publications Inc., Arlington, 2004, 7th Ed.
- [353] Ternes, T.A., Occurrence of drugs in German sewage treatment plants and rivers. *Water Res.* **32** (1998) 3245-3260.
- [354] Ashton, D., Hilton, M., Thomas, K.V., Investigating the environmental transport of human pharmaceuticals to streams in the United Kingdom. *Sci. Total Environ.* **333** (2004) 167-184.
- [355] Vogna, D., Marotta, R., Napolitano, A., d'Ischia, M., Advanced oxidation chemistry of paracetamol. UV/H₂O₂ -induced hydroxylation/degradation pathways and ¹⁵N-aided inventory of nitrogenous breakdown products. *J. Org. Chem.* **67** (2002) 6143-6151.
- [356] Andreozzi, R., Caprio, V., Marotta, R., Vogna, D., Paracetamol oxidation from aqueous solutions by means of ozonation and H₂O₂/UV system. *Water Res.* **37** (2003) 993-1004.
- [357] Bobu, M.-M., Siminiceanu, I., Neamtu, M., La degradación del paracetamol en medio acuoso por medio de métodos de oxidación avanzada, Tercer Colloquio Franco-Rumano de Química Aplicada (COFrRoCA), Slánic Moldova (Romania), 22-25 Septiembre 2004.
- [358] Waterston, K., Wang, J.W., Bejan, D., Bunce, N.J., Electrochemical waste water treatment: Electrooxidation of acetaminophen. *J. Appl. Electrochem.* **36** (2006) 227-232.
- [359] Trudeau, V.L., Metcalfe, C.D., Mimeault, C., Moon, T.W., Pharmaceuticals in the environment. Drugged fish?. *Biochem. Mol. Biol. Fishes* **6** (2005) 475-493.
- [360] Emblidge, J.P., DeLorenzo, M.E., Preliminary risk assessment of the lipid-regulating pharmaceutical clofibric acid, for three estuarine species. *Environ. Res.* **100** (2006) 216-226.

- [361] Winkler, M., Lawrence, J.R., Neu, T.R., Selective degradation of ibuprofen and clofibric acid in two model river biofilm systems. *Water Res.* **35** (2001) 3197-3205.
- [362] Heberer, T., Reddersen, K., Mechlinski, A., From municipal sewage to drinking water: fate and removal of pharmaceutical residues in the aquatic environment in urban areas. *Water Sci. Technol.* **46** (2002) 81-88.
- [363] Stumpf, M., Ternes, T.A., Heberer, K., Seel, P., Baumann, W., Determination of pharmaceuticals in sewage plants and river water. *Vom Wasser* **86** (1996) 291-303.
- [364] Hignite, C., Azarnoff, D.L., Drugs and drug metabolites as environmental contaminants: chlorophenoxyisobutyrate and salicylic acid in sewage water effluent. *Life Sci.* **20** (1977) 337-342.
- [365] Stan, H.J., Heberer, T., Linkerhägner, M., Occurrence of clofibric acid in the aquatic system – does the medical application cause contamination of surface, ground and drinking water?. *Vom Wasser* **83** (1994) 57-68.
- [366] Heberer, T., Schmidt-Baumler, K., Stan, H.J., Occurrence and distribution of organic contaminants in the aquatic system in Berlin: Part I: drug residues and other polar contaminants in Berlin surface and groundwater. *Acta Hydrochim. Hydrobiol.* **26** (1998) 272-278.
- [367] Buser, H.-R., Müller, M.D., Theobald, N., Occurrence of the pharmaceutical drug clofibric acid and the herbicide mecoprop in various Swiss lakes and in the North Sea. *Environ. Sci. Technol.* **32** (1998) 188-192.
- [368] Weigel, S., Kuhlmann, J., Hühnerfuss, H., Drugs and personal care products as ubiquitous pollutants: occurrence of clofibric acid, caffeine and DEET in the North Sea. *Sci. Total Environ.* **295** (2002) 131-141.
- [369] Thomas, K.V., Hilton, M.J., Occurrence of selected human pharmaceutical compounds in UK estuaries. *Marine Poll. Bull.* **49** (2004) 436-444.
- [370] Stumpf, M., Ternes, T.A., Wilken, R.-D., Rodrigues, S.V., Baumann, W., Polar drug residues in sewage and natural waters in the state of Rio de Janeiro, Brazil. *Sci. Total Environ.* **225** (1999) 135-141.

- [371] Andreozzi, R., Caprio, V., Marotta, R., Radovnikovic, A., Ozonation and H₂O₂/UV treatment of clofibric acid in water: a kinetic investigation. *J. Hazard. Mater. B* **103** (2003) 233-246.
- [372] Packer, J.L., Werner, J.J., Latch, D.E., McNeill, K., Arnold, W.A., Photochemical fate of pharmaceuticals in the environment: Naproxen, diclofenac, clofibric acid, and ibuprofen. *Aquat. Sci.* **65** (2003) 342-351.
- [373] Doll, T.E., Frimmel, F.H., Fate of pharmaceuticals-photodegradation by simulated solar UV-light. *Chemosphere* **52** (2003) 1757-1769.
- [374] Zwiener, C., Frimmel, F.H., Short-term tests with a pilot sewage plant and biofilm reactors for the biological degradation of the pharmaceutical compounds clofibric acid, ibuprofen, and diclofenac. *Sci. Total Environ.* **309** (2003) 201-211.
- [375] Doll, T., Frimmel, F.H., Kinetic study of photocatalytic degradation of carbamazepine, clofibric acid, iomeprol and iopromide assisted by different TiO₂ materials – determination of intermediates and reaction pathways. *Water Res.* **38** (2004) 955-964.
- [376] Canterino, M., Andreozzi, R., Caprio, V., Iamarino, M., Marotta, R., Tufano, V., Removal of organic pollutants from soil: The ozonation of clofibric acid in aqueous slurries. *Ozone Sci. Eng.* **28** (2006) 47-52.
- [377] Ferro, S., De Battisti, A., Duo, I., Comninellis, Ch., Haenni, W., Perret, A., Chlorine evolution at highly boron-doped electrodes. *J. Electrochem. Soc.* **147** (2000) 2614-2619.
- [378] http://www.who.int/multimedia/antibiotic_res/index.html (WHO/CDS2000.2, World Health Organization report on infectious diseases 2000: Overcoming microbial resistance, visited for the last time in 2003)
- [379] <http://ntp.niehs.nih.gov> (visited for the last time in 2006)
- [380] Zhang, H., Huang, C.-H., Oxidative transformation of triclosan and chlorophene by manganese oxides. *Environ. Sci. Technol.* **37** (2003) 2421-2430.
- [381] Arnold, W.A., McNeil, K., Packer, J.L., Latch, D.E., Boreen, A.L.,

- Photochemical fate of pharmaceutical compounds discharged and detected in natural waters, Report of the USGS-WRRI 104G National Grants Competition, 2003, 18-23.
- [382] Boehmer, W., Ruedel, H., Wenzel, A., Schroeter-Kermani, C., Retrospective monitoring of triclosan and methyl-triclosan in fish: Results from the German environmental specimen bank. *Organohalogen* **66** (2004) 1516-1521.
- [383] Thomas, K.V., Balaam, J., Barnard, N., Dyer, R., Jones, C., Lavender, J., McHugh, M., Characterization of potentially genotoxic compounds in sediments collected from United Kingdom estuaries. *Chemosphere* **49** (2002) 247-258.
- [384] Ternes, T.A., Stumpf, M., Schuppert, B., Haberer, K., Simultaneous determination of antiseptics and acidic drugs in sewage and river. *Vom Wasser* **90** (1998) 295-309.
- [385] Zhang, H., Metal oxide-facilitated oxidation of antibacterial agents. Doctoral Thesis (2004). Georgia Institut of Technology (Georgia, USA).