

Synopsis of Significant Works & Contributions on PPCPs and Emerging Contaminants

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Pharmaceuticals and Personal Care Products (PPCPs) as Environmental Contaminants

"PPCPs" as environmental contaminants: the acronym was coined for "pharmaceuticals and personal care products" in this first synoptic review of PPCPs; subtle effects were first postulated as a major concern [1999]

Daughton, C.G.; Ternes, T.A. "Pharmaceuticals and Personal Care Products in the Environment: Agents of Subtle Change?" *Environ. Health Perspect.* 1999, 107(suppl 6), 907-938.
<http://www.epa.gov/nerlesd1/bios/daughton/errata.pdf>

Book on PPCPs: among the first two books on PPCPs (as an outcome from the first all-day conference on PPCPs in North America, 219th ACS National Meeting, 27 March 2000) [2001]
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, 416 pp; DOI 10.1021/bk-2001-0791.
<http://www.epa.gov/nerlesd1/bios/daughton/book.htm>

PPCPs overview: an update to the original 1999 review article [2001]
Daughton, C.G. "Pharmaceuticals in the environment: Overarching issues and overview," in *Pharmaceuticals and Personal Care Products in the Environment: Scientific and Regulatory Issues*, Daughton, C.G. and Jones-Lepp, T.L. (eds.), Symposium Series 791; American Chemical Society: Washington, D.C., 2001, pp. 2-38; DOI 10.1021/bk-2001-0791.ch001.
<http://www.epa.gov/nerlesd1/bios/daughton/book-summary.htm>

Research needs and gaps for PPCPs: first comprehensive examination (arranged around the risk assessment paradigm) [2004]
Daughton, C.G. "PPCPs in the Environment: Future Research — Beginning with the End Always in Mind," In *Pharmaceuticals in the Environment*, Kümmerer, K. (Ed.), 2nd edition, Springer, 2004, Chapter 33, pp. 463-495.
<http://www.epa.gov/nerlesd1/bios/daughton/researchneeds-chapter.pdf>

PPCPs in drinking water: first comprehensive review; assessment of ramifications for human health [2008]

Daughton CG "Pharmaceuticals as Environmental Pollutants: the Ramifications for Human Exposure," In: *International Encyclopedia of Public Health*, Kris Heggenhougen and Stella Quah (Eds.), Vol. 5, Oxford: Academic Press; 2008, pp. 66-102; DOI: 10.1016/B978-012373960-5.00403-2.

<http://www.epa.gov/nerlesd1/bios/daughton/EoPH2008.pdf>

PPCPs in ground water: drug residues in reused/recycled water; ramifications for human health and perception of risk [2004]

Daughton, C.G. "Groundwater Recharge and Chemical Contaminants: Challenges in Communicating the Connections and Collisions of Two Disparate Worlds," *Ground Water Monitoring & Remediation*, Spring 2004, 24(2):127-138.

<http://www.epa.gov/nerlesd1/bios/daughton/water-reuse.pdf>

PPCPs sources and origins: review of the pathways of entry to the environment [2007]

Daughton CG "Pharmaceuticals in the Environment: Sources and Their Management," 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.), Volume 50, Elsevier Science; 2007, 564pp; doi:10.1016/S0166-526X(07)50001-2.

http://www.epa.gov/nerlesd1/bios/daughton/Chap1_Petrovic&Barcelo.pdf

"Pseudopersistence": concept first introduced [2002, 2003]

Daughton, C.G. "Environmental stewardship and drugs as pollutants," *The Lancet* 2002, 360, 1035-1036.

<http://www.epa.gov/nerlesd1/bios/daughton/lancet-page.pdf>

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.* 2003, 111(5):757-774.

<http://www.epa.gov/nerlesd1/bios/daughton/green1.pdf>

Aquatic bioconcentration of PPCPs: First synoptic review of the literature [2009 - in press]

Daughton CG and Brooks BW "Pharmaceutical Active Ingredients in Aquatic Organisms," In: Beyer WN and Meador JP (eds), *Environmental Contaminants in Biota: Interpreting Tissue Concentrations*, 2nd ed., Taylor and Francis, Boca Raton, FL; targeted for 2011; submitted, March 2009.

Previously unrecognized pathways to the environment and routes to human exposure for certain pharmaceuticals; sweat and dermal transfer first identified as routes of release and exposure [2009 - in press]

Daughton CG and Ruhoy IS "Chemicals from the Practice of Healthcare: Challenges and Unknowns Posed by Residues in the Environment," *Environmental Toxicology & Chemistry*, Special Issue on Pharmaceuticals in the Environment, in press 2009, 28:12, ; doi:10.1897/09-138.1.

http://www.setacjournals.org/archive/1552--8618/preprint/2009/pdf/10.1897_09-138.1.pdf

"*pharmEcokinetics*": concept introduced as an umbrella interconnecting all the transformation processes that pharmaceutical ingredients undergo during therapy and in the environment [2009 - in press]

Daughton CG and Ruhoy IS "Environmental Footprint of Pharmaceuticals - The Significance of Factors Beyond Direct Excretion to Sewers," *Environmental Toxicology & Chemistry*, Special Issue on Pharmaceuticals in the Environment, in press 2009, 28:12, ; doi:10.1897/08-382.1.
http://www.setacjournals.org/archive/1552-8618/preprint/2009/pdf/10.1897_08-382.1.pdf

PPCPs in a reference book: first presentation of topic targeted to high-school and college students [2003]

Daughton, C.G. "Chemicals from Pharmaceuticals and Personal Care Products," in *Water: Science and Issues*, E. Julius Dasch (ed.), New York: Macmillan Reference USA, 2003, vol. 1, p 158-164.

<http://www.epa.gov/nerlesd1/bios/daughton/Macmillan-PPCPs.pdf>

Illicit drugs and "sewage forensics": introduction of new tool using sewage monitoring for illicit drugs to estimate community-wide usage (dose reconstruction); sometimes later erroneously termed sewer "epidemiology" [2001]

Daughton, C.G. "Illicit Drugs in Municipal Sewage: Proposed New Nonintrusive Tool to Heighten Public Awareness of Societal Use of Illicit/Abused Drugs and Their Potential for Ecological Consequences," in *Pharmaceuticals and Personal Care Products in the Environment: Scientific and Regulatory Issues*, Daughton, C.G. and Jones-Lepp, T.L. (eds.), Symposium Series 791; American Chemical Society: Washington, D.C., 2001, pp. 348-364.

<http://www.epa.gov/nerlesd1/bios/daughton/book-conclude.htm>

PPCPs published-literature database: largest publically available compilation of citations [19 February 2008-present]

<http://www.epa.gov/ppcp/lit.html>

Web site devoted to PPCPs: first PPCPs web site created in April 2000 and subsumed by the US EPA's current PPCPs web site on 18 July 2007 [2000-present]

<http://www.epa.gov/ppcp>

"*Literature forensics*": critical importance to science of the thorough examination of the literature [2001]

Daughton, C.G. "Literature Forensics? Door to What Was Known but Now Forgotten," *Environ. Forensics* 2001, 2: 277-282.

<http://www.epa.gov/nerlesd1/bios/daughton/forensics.pdf>

Pharmaceutical Waste Management/Disposal and Environmental Stewardship

PPCPs and environmental stewardship: topic first introduced to the medical literature [2001]
Daughton, C.G. "Environmental stewardship and drugs as pollutants," *The Lancet* 2002, 360,
1035-1036.

<http://www.epa.gov/nerlesd1/bios/daughton/lancet-page.pdf>

"Green Pharmacy": concept first introduced; comprehensive approach for environmental
stewardship, pollution prevention, and waste reduction for pharmaceuticals [2003]
Daughton CG "Cradle-to-Cradle Stewardship of Drugs for Minimizing Their Environmental
Disposition while Promoting Human Health," *Environ. Health Perspect.* 2003, 111(5):757-785.
[two-part monograph]

<http://www.epa.gov/nerlesd1/bios/daughton/green1.pdf>

<http://www.epa.gov/nerlesd1/bios/daughton/green2.pdf>

"pharmEcovigilance": concept first introduced - linking protection of the environment with the
quality of medical care and the environment [2008]

Daughton CG and Ruhoy IS "The Afterlife of Drugs and the Role of PharmEcovigilance," *Drug
Safety*, 2008, 31(12):1069-1082; doi:10.2165/0002018-200831120-00004.

Daughton CG and Ruhoy IS "PharmEcovigilance: Aligning Pharmacovigilance with Environmental
Protection," In: *An Introduction to Environmental Pharmacology*, SZ Rahman, M Shahid, and
V Gupta (Eds.), Ibn Sina Academy, Aligarh, India; 2008, Chapter 1 (Introductory Overview),
pp 21-34; ISBN # 978-81-906070-5-6.

<http://www.epa.gov/nerlesd1/bios/daughton/IntroEnvironPharmacol-Chapter1-2008.pdf>

Daughton CG and Ruhoy IS "Accumulation and disposal of leftover medications: A key aspect of
pharmEcovigilance," In: *An Introduction to Environmental Pharmacology*, SZ Rahman, M
Shahid, and V Gupta (Eds.), Ibn Sina Academy, Aligarh, India; 2008, Chapter 5, pp 101-107;
ISBN # 978-81-906070-5-6.

<http://www.epa.gov/nerlesd1/bios/daughton/IntroEnvironPharmacol-Chapter5-2008.pdf>

Medication site-accumulation and disposal: first comprehensive examination of where and why
[2008]

Ruhoy IS and Daughton CG "Beyond the Medicine Cabinet: An Analysis of Where and Why
Medications Accumulate," *Environ. Internat.*, 2008, 34(8):1157-1169;
doi:10.1016/j.envint.2008.05.002.

<http://www.epa.gov/nerlesd1/bios/daughton/EnvInt2008.pdf>

Medication waste: consumer sources and waste management [2007]

Daughton CG "Pharmaceuticals in the Environment: Sources and Their Management," 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.), Volume 50, Elsevier Science; 2007, 564pp; doi:10.1016/S0166-526X(07)50001-2.

http://www.epa.gov/nerlesd1/bios/daughton/Chap1_Petrovic&Barcelo.pdf

Drug disposal data: first comprehensive summary for a particular sub-population of a single metropolitan area over the span of a year [2008]

Ruhoy IS and Daughton CG "Beyond the Medicine Cabinet: An Analysis of Where and Why Medications Accumulate," *Environ. Internat.*, 2008, 34(8):1157-1169; doi:10.1016/j.envint.2008.05.002.

<http://www.epa.gov/nerlesd1/bios/daughton/EnvInt2008.pdf>

Coroner office drug data: first methodology for measuring the disposal of drugs to sewage and the overall contribution of drug waste disposal to environmental contamination [2007]

Ruhoy IS and Daughton CG "Types and Quantities of Leftover Drugs Entering the Environment via Disposal to Sewage - Revealed by Coroner Records," *Sci. Total Environ.*, 2007, 388(1-3):137-148; doi 10.1016/j.scitotenv.2007.08.013.

<http://www.epa.gov/nerlesd1/bios/daughton/SOTE2007.pdf>

Drug disposal: options available to the consumer [2009]

Glassmeyer ST, Hinchey EK, Boehme SE, Daughton CG, Ruhoy IS, Conerly O, Daniels RL, Lauer L, McCarthy M, Nettesheim TG, Sykes K, and Thompson VG. "Disposal Practices for Unwanted Residential Medications in the United States," *Environ. Internat.*, 2009, 35(3): 566-572; doi:10.1016/j.envint.2008.10.007

Medication use and sustainability: introductory chapter in first book devoted to sustainability and pharmaceutical usage [2009]

Daughton CG and Ruhoy IS. "Pharmaceuticals and Sustainability: Concerns and Opportunities Regarding Human Health and the Environment," In: *A Healthy Future - Pharmaceuticals in a Sustainable Society*, collaborative publication of Apoteket AB, MistraPharma, and Stockholm County Council, Sweden; Chapter 1, pp 14-39, 2009; ISBN: 2184-01.

<http://www.epa.gov/nerlesd1/bios/daughton/Pharmaceuticals-Sustainability-2009.pdf>

Co-organized the first national conference on drug disposal [2005]

U.S. EPA Workshop: Pharmaceuticals in the Environment, Office of Research and Development, National Exposure Research Laboratory, Las Vegas, NV, 23-25 August 2005

First presentation for Drug Enforcement Administration on science behind PPCPs [2006]

Daughton, C.G. "Pharmaceuticals as Environmental Contaminants: An Overview of the Science," invited presentation for: End User Drug Disposal Conference, organized by the Drug Enforcement Administration, Seattle Field Division, Portland District Office, Portland, OR, 25-26 April 2006

Emerging Contaminants

"Emerging pollutants": one of the first papers published on this topic; first working definition presented for "emerging pollutants" [2001]

Daughton, C.G. "Emerging Pollutants, and Communicating the Science of Environmental Chemistry and Mass Spectrometry: Pharmaceuticals in the Environment," *J. Am. Soc. Mass Spectrom.* 2001, 12(10), 1067-1076.

http://www.epa.gov/nerlesd1/bios/daughton/book_jasma.pdf

A perspective on "emerging contaminants" [2009]

Daughton CG. "Peering into the Shadows of Chemical Space. Emerging Contaminants and Environmental Science: Is either being served by the other?" Opening address for the *2nd International Conference on Occurrence, Fate, Effects, and Analysis of Emerging Contaminants in the Environment (EmCon09)*, 4-7 August 2009, Fort Collins, Colorado.

extended abstract:

<http://www.epa.gov/nerlesd1/bios/daughton/Daughton-abstract-EmCon09.pdf>

slide presentation:

<http://www.epa.gov/nerlesd1/bios/daughton/Daughton-slides-EmCon09.pdf>

Additional perspectives on emerging and non-regulated contaminants [2004, 2005, 2006]

Daughton, C.G. "Non-Regulated Water Contaminants: Emerging Research," In (A. Steinemann and J Tickner, eds.): *Environment and Health - New Answers, New Questions* (special issue), *Environmental Impact Assessment Review* 2004, 24(7-8):711-732.

<http://www.epa.gov/nerlesd1/bios/daughton/EIAR.pdf>

Daughton, C.G. "'Emerging' Chemicals as Pollutants in the Environment: a 21st Century Perspective," *Renewable Resources Journal*, 2005, 23(4):6-23.

http://www.epa.gov/nerlesd1/bios/daughton/emerging_contaminants.pdf

Daughton, C.G. "'Emerging Pollutants' — Questions, Challenges, and the Future," guest editorial, *Norman Newsletter*, Network of Reference Laboratories for Monitoring of Emerging Environmental Pollutants, EU, inaugural issue, June 2006.

http://www.norman-network.net/newsletters/newsletter_norman_1.pdf