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Biennial Review of 40 CFR Part 503 As Required Under the Clean Water Act Section 405(d)(2)(C)

Reporting Period
2005 Biennial Review

EPA-822-R-06-014

Biennial Review of 40 CFR Part 503
As Required Under the Clean Water Act Section 405(d)(2)(C)

Reporting Period Biennial Review 2005

U.S. Environmental Protection Agency
Office of Water
Office of Science and Technology
Health and Ecological Criteria Division
Ecological and Health Processes Branch
Washington, D.C.

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NOTICE

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http://www.epa.gov/waterscience/biosolids/

EXECUTIVE SUMMARY

In 1993, the Environmental Protection Agency (EPA) promulgated regulations in 40 CFR Part 503 as amended, setting numerical standards for certain metals in sewage sludge, requiring vector attraction reduction (e.g., reducing birds, rodents and insects) for pathogens, and establishing operational standards for emissions from sewage sludge incinerators. Section 405(d)(2)(C) of the Clean Water Act (CWA) states that EPA shall review the sewage sludge regulations not less often than every two years for the purpose of identifying additional toxic pollutants and promulgating regulations for such pollutants consistent with the requirements of section 405(d).

In fulfilling this commitment for the 2005 Biennial Review Cycle, EPA collected and reviewed publicly available information. The Agency searched databases with articles published in English and in refereed journals for information on occurrence, fate and transport in the environment, human health and ecological effects, as well as other relevant information for pollutants that may occur in U.S. sewage sludge. If such data are available for pollutants that may occur in sewage sludge, the agency is able to characterize the potential risk associated with exposure to such pollutants when sewage sludge is applied to land as a fertilizer or soil amendment, placed in a surface disposal site, or incinerated.

The data search identified 137 pollutants for which some data were available for 118 pollutants, but the data were not sufficient to allow the Agency to either conduct exposure and hazard assessments or determine what, if any, regulatory action may be needed. For the remaining 19 pollutants, data are available to enable EPA to evaluate exposure and hazard. This evaluation will use existing data, data collected during the 2005 Biennial Review, and results from the recent Targeted National Sewage Sludge Survey. When EPA evaluates potential risk for these pollutants, EPA will be able to determine what, if any, regulatory action may be needed pursuant to Section 405(d) of the CWA. However, at this time EPA has not identified additional toxic pollutants for regulation under Section 405(d)(2)(C) of the CWA.

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Introduction

This document summarizes the U.S. Environmental Protection Agency's (EPA) activities related to the 2005 biennial review of pollutants pursuant to the Clean Water Act (CWA) Section 405(d)(2)(C). That section requires EPA to review existing sewage sludge regulations at least every two years to identify additional pollutants for possible regulation. The biennial review covered by this report summary – the 2005 Biennial Review – obtained biosolids-related literature through March 2005. This document summarizes the analysis of that literature (a more detailed report is included in Attachment 1). In this document, we use the term "biosolids" interchangeably with "sewage sludge," which is defined in the regulations and used in the statute.

History of the Standards for Use or Disposal of Sewage Sludge

In Section 405 of the CWA, Congress set forth a comprehensive program designed to reduce potential health and environmental risks associated with using or disposing of sewage sludge. Under Section 405(d), EPA establishes numeric limits and management practices that protect public health and the environment from the reasonably anticipated adverse effects of chemical and microbial pollutants in sewage sludge. Section 405(d) prohibits any person from using or disposing of sewage sludge from publicly owned treatment works (POTWs) or other treatment works treating domestic sewage, unless the use or disposal complies with regulations promulgated under section 405(d).

On February 19, 1993, EPA identified pollutants which, on the basis of available information on their toxicity, persistence, concentration, mobility, or potential for exposure, were present in sewage sludge in concentrations which may adversely affect public health or the environment. At that time, the Agency promulgated regulations (58 *FR* 9248) - CFR 40 Part 503 *Standards for the Use or Disposal of Sewage Sludge* - specifying acceptable management practices, numeric standards for ten metals (see Table 1) and operational standards for microbial organisms.

The 1993 rule established requirements for the final use or disposal of sewage sludge when it is: (1) applied to land as a fertilizer or soil amendment; (2) placed in a surface disposal site, including sewage sludge-only landfills; or (3) incinerated. These requirements apply to

publicly and privately owned treatment works that generate or treat domestic sewage sludge and to anyone who uses or disposes of sewage sludge. The rule also requires monitoring, record keeping, and reporting of specific information regarding sewage sludge management.

Table 1: Metals Regulated in 40 CFR 503

Metal	Land Application	Incineration[2]	Surface Disposal
Arsenic	X	X	X
Cadmium	X		X
Chromium	X[1]	X	X
Copper	X		
Lead	X		X
Mercury	X		
Molybdenum	X[1]		
Nickel	X	X	X
Selenium	X		
Zinc	X		

[1/] Minor amendments published in 1994 and 1995 improved clarity and responded to the results of judicial review resulting in changes in land application limits for chromium (deleted all limits) and molybdenum (deleted limits in Tables 2, 3, and 4 of Section 503.13).

[2/] Mercury emissions are regulated as limits to air emissions either by monitoring the exhaust air from the incinerator or the ambient air around the incinerator. In either case, the concentration in the air must meet the National Emission Standards for Hazardous Air Pollutants (NESHAPs, 40 CFR Part 61). Total hydrocarbons (THC) or carbon monoxide (CO) is monitored to represent all organic compounds in the exhaust gas that are covered by the Part 503 Rule. See Subpart E, Section 503.43 for other incineration requirements.

Section 405(d)(2)(C) of the CWA also requires the Agency to review from time to time, but not less often than every 2 years (i.e., biennial reviews), the regulations for the purpose of identifying additional toxic pollutants and promulgating regulations for such pollutants (the Agency uses the term pollutant as defined in the CWA). The purpose of reviewing information on pollutants, or potential pollutants, is to assess the availability and sufficiency of the data to conduct exposure and hazard assessments. Such exposure and hazard assessments, where sufficient data exist, allow the Agency to determine the potential for harm to public health or the environment following use or disposal of biosolids. To inform the exposure and hazard assessments of pollutants in biosolids, EPA typically collects the following data:

- Toxicity to human and ecological receptors (e.g., toxicity defined in terms of reference dose, reference concentrations, cancer slope factor, lethal dose, lethal concentration, or chronic endpoints related to fecundity).
- Acceptable concentration data in sewage sludge. Both the ability to detect a given pollutant in sewage sludge and the concentrations at which that pollutant is present are highly dependent on the existence of acceptable analytical methods for that pollutant in the sewage sludge matrix. Analytical methods for water, effluent, or soil may not necessarily be appropriate for detecting pollutants in biosolids.
- Fate and transport data for pollutants that may be present in sewage sludge. These data are necessary for assessing exposure. Chemical and physical properties that are developed for a given pollutant in sewage sludge should generally include:

Parameter
Molecular weight
Solubility
Vapor pressure
Henry's law constant
Soil-water partitioning coefficient
Soil adsorption coefficient (K_d and K_{oc})
Degradation rates in various media
Log octanol-water partition coefficient (Log K_{ow})
Diffusivity in air
Diffusivity in water

Air-to-plant transfer factor
Root uptake factor for above ground vegetation
Root concentration factor
Bioconcentration factors for animal products

The Agency evaluates the sufficiency of such data for pollutants having acceptable analytical methods, source concentration values, human health benchmarks, and other pertinent data for two general purposes:

1. To conduct sewage sludge exposure and hazard assessments for humans and the environment.
2. To support potential rulemaking under 40 CFR Part 503.

EPA did not meet the timetable in section 405(d) for promulgating the first round of regulations, and a citizen's suit was filed (*Gearhardt v. Reilly* (Civ. No. 89-6266-HO (D. Ore.)) to require EPA to fulfill this mandate. A consent decree was entered by the court in that case, establishing schedules for two rounds[1] of sewage sludge rules. To comply with the consent decree, EPA was required to:

- Identify toxic pollutants in sewage sludge (not identified pursuant to 33 U.S.C. Section 1345(d)(2)(A)(i) and (ii)) that may adversely affect public health and the environment. In compliance, on February 19, 1993, EPA promulgated the first rule codified at 40 CFR Part 503 (58 *FR* 9248) (”Round One”)[1].
- Sign a notice for publication proposing Round Two[1] regulations no later than December 15, 1999, and to sign a notice taking final action on the proposal no later than December 2001. In compliance, on December 21, 2001 EPA published in the Federal Register (66 *FR* 66228) its determination not to regulate dioxin and

[1/] The terms “Round One” and “Round Two” were used by the consent decree. EPA uses the term “Biennial Review” to refer to subsequent reviews of Part 503 pursuant to Section 405(d) of the CWA.

dioxin-like compounds [i.e., polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and dioxin-like coplanar polychlorinated biphenyls (PCBs)] in sewage sludge that is incinerated or placed in sludge landfills or containment ponds. EPA based its decision on an evaluation of the risk of exposure for people most likely to be exposed to dioxin from these sources. EPA concluded that existing regulations for incinerators, landfills or containment ponds adequately protect human health and the environment by limiting exposure to pollutants, including dioxins in sewage sludge that is disposed of at a surface disposal site or incinerated in a sewage sludge incinerator.

- The consent decree (as amended) required EPA to take final action on the land application Round Two rulemaking from the original date of December 15, 2001, to a new date of October 17, 2003. In compliance, on October 24, 2003 EPA announced its final decision not to regulate dioxins in land-applied sewage sludge, concluding that dioxins from land-applied sewage sludge do not pose a significant risk to human health or the environment. (68 *FR* 61084).

Biennial Reviews

2003 Biennial Review

Consistent with the consent decree mentioned above, EPA agreed to publish a notice in the Federal Register describing how the Agency intends to respond to the National Research Council (NRC) report (http://www.epa.gov/waterscience/biosolids/nas/complete.pdf) recommendations and to seek public comment on its planned response. EPA also agreed to review publicly available information to identify additional toxic pollutants in sewage sludge and to publish a notice and seek public comment on the results of the review. Fulfilling these commitments, EPA published a notice in the Federal Register on December 31, 2003 (68 FR 75531).

For its 2003 Biennial Review, EPA assessed available data on chemical pollutants that had been detected in sewage sludge and that had not been regulated or previously assessed. The Agency collected and reviewed publicly available information published between 1990 and 2003

on the occurrence of chemicals in sewage sludge; data on environmental properties such as mobility and persistence; and available human health benchmarks (HHBs). Following this review, EPA made preliminary determinations regarding sufficiency of information for conducting an exposure and hazard-based screening assessment. That literature review identified 803 chemicals reported to occur in sewage sludge. Sufficient data for evaluation were available for 40 of these 803 pollutants. EPA conducted a human health and an ecological hazard screening assessment for these 40 pollutants. Of the 40 pollutants evaluated, EPA determined that 15 pollutants presented a potential risk to human health and/or the environment. EPA further reduced the 15 pollutants to nine pollutants based on an updated biosolids exposure and hazard assessment. The results of EPA's review do not mean that EPA has concluded that these nine pollutants in sewage sludge adversely affect human health or the environment. EPA will use the results from the recently completed Targeted National Sewage Sludge Survey (TNSSS) (www.epa.gov/waterscience/biosolids) to complete its risk evaluation for these 9 pollutants. EPA will use that evaluation to inform what action, if any, to take under section 405(d) of the CWA.

2005 Biennial Review

The remainder of this document presents the 2005 Biennial Review. In conducting its 2005 Biennial Review, EPA again collected and reviewed publicly available information on pollutants for evaluating potential harm to human health or the environment following use or disposal of sewage sludge.

Ecological Assessment

EPA conducted a literature search through March 2005. EPA searched databases and the published literature to capture available information needed to conduct ecological and environmental risk evaluations (e.g., occurrence, fate and transport in the environment, and ecological effects) for pollutants in U.S. sewage sludge. The Agency used articles published in English in peer-reviewed journals, databases such as ECOTOX, Aquatic Sciences and Fisheries Abstracts, Biological Sciences Database, and the Environmental Sciences and Pollution Management Database, as well as secondary sources of data for eco-toxicity benchmarks (e.g., the recent Ecological Soil Screening Level documentation for certain metals). The Agency assessed whether data were sufficient to conduct an ecological exposure and hazard assessment.

Human Health Assessment

To conduct human health risk evaluations, EPA did a literature search from 2003 through March 2005. EPA searched databases and the published literature, such as PubMed, TOXLINE, and the Environmental Sciences and Pollution Management Database for information such as occurrence, fate and transport in the environment, and human health effects for pollutants in U.S. sewage sludge.

The Agency followed the same methodology as for the 2003 Biennial Review to determine whether the identified data were sufficient for proceeding with an exposure and hazard screening assessment. This methodology involved identifying the pollutants for which EPA peer-reviewed final human health benchmarks (HHBs) had been developed by the Agency's Office of Pesticide Programs Programs (OPP) for Reregistration Eligibility Decisions (REDs), or by EPA's Office of Research and Development for Integrated Risk Information System (IRIS) health assessments. For this biennial review, EPA did not include pollutants for which the scientific basis of HHBs was being reassessed at the time of review. For future biennial reviews, the Agency is re-evaluating which HHBs to be used for assessment purposes.

Results of the 2005 Biennial Review

During the Agency's search of known databases and the open literature during 2005 Biennial Review, the Agency collected reviewed publicly available information for pollutants listed in Tables 2 and 3. The Agency evaluated the availability and acceptability of data addressing toxicity to human and ecological receptors, pollutant concentrations in sewage sludge based on acceptable analytical methods, physical and chemical properties, and fate and transport in the environment in order to be able to conduct an exposure and hazard assessment.

For its 2005 Biennial Review, EPA identified articles published since the 2003 Biennial Review as potential sources of information on pollutants in biosolids. The Agency evaluated the articles as potentially relevant sources containing new information that was not previously available or evaluated for pollutants in a prior biennial review, as well as previously collected information. Two criteria were established for selecting a pollutant for an exposure and hazard evaluation if relevant data were available: 1) the pollutant has either an OPP or IRIS HHB and that the HHB study was not undergoing reevaluation, and (2) the pollutant has nationally representative or otherwise acceptable measured concentrations in U.S. sewage sludge based on

acceptable analytical methodology that can be used to detect and quantify such concentrations.

EPA compiled a list of 137 chemical pollutants for which some information was found. The Agency divided the list of pollutants identified into two major groups:

1. For pollutants listed in Table 2 (i.e., 19 pollutants), the Agency updated any information that may have been made available since 2003. Where sufficient data exist, EPA will be able to evaluate these pollutants using results from the TNSSS to evaluate potential risk and determine what, if any, regulatory action may be needed pursuant to Section 405(d) of the CWA. The Agency also continues to evaluate certain pollutants according to the following reasons:
    - Barium, beryllium, manganese, silver, fluoranthene, pyrene, 4-chloroaniline, nitrate and nitrite were previously identified during the 2003 Biennial Review based on a human health and ecological risk evaluation (68 *FR* 75531). When updated occurrence and concentration data are available from the Targeted National Sewage Sludge Survey (TNSSS) (www.epa.gov/waterscience/biosolids), EPA plans to evaluate these nine pollutants and conduct a risk evaluation to determine whether to propose regulating any of these pollutants under Section 405(d) of the CWA.
    - The EPA-Integrated Risk Information System (IRIS) recently issued human health benchmarks for antimony, barium, and 2-methylnaphthalene.
    - Thallium, benzo(a)pyrene, bis (2-ethylhexyl) phthalate, and fluoride were included based on comparison of theoretical hazard quotients to exposure and hazard screening results. These compounds are currently undergoing a human health benchmark reevaluation.
    - The U.S. Department of Agriculture (USDA) and EPA are evaluating cobalt and iron during re-vegetation and remediation of soils with biosolids.
    - The Agency is interested in obtaining information about phosphate levels in the sewage sludge; such knowledge may help the Agency and states address nutrient management during the application of sewage sludge.

- The Agency is reevaluating molybdenum for a revised numerical standard based on updated sewage sludge concentration and other data.

2. Pollutants listed in Table 3 (i.e., 118 pollutants) represent those for which EPA searched published literature for the availability of relevant data aimed at identifying other pollutants to evaluate pursuant to Section 405(d) of the CWA. Currently there are significant data gaps for pollutants listed in Table 3. EPA does not have sufficient information on these pollutants to evaluate even a minimal number of exposure pathways. Examples of missing information include environmental properties, adequate human health and eco-toxicity benchmarks, and acceptable concentration data in sewage sludge. Therefore, there is not sufficient information at this time on these pollutants to conduct exposure and hazard assessment for deriving scientifically supportable numerical standards.

Table 2. Selected Chemicals Evaluated in the Literature Search

Chemical	CAS Registry Number
Metals	
Antimony[1]	7440-36-0
Barium* [1]	7440-39-3
Beryllium*	7440-41-7
Cobalt[3]	7440-48-4
Iron[3]	7439-89-6
Manganese*	7439-96-5
Molybdenum[5]	7439-98-7
Silver*	7440-22-4
Thallium[2]	7440-28-0
Polycyclic Aromatic Hydrocarbon	
Benzo(a)pyrene[2]	50-32-8
Fluoranthene*	206-44-0
2-Methylnaphthalene[1]	91-57-6
Pyrene*	129-00-0
Semi-volatiles	
Bis(2-ethylhexyl)phthalate[2]	117-81-7
4-Chloroaniline*	106-47-8
Inorganic Ions	
Fluoride[2]	16984-48-8
Nitrate*	14797-55-8
Nitrite*	14797-65-0
Phosphate (total)[4]	14265-44-2

** Chemicals evaluated during BR 2003 (68 FR 75531).*

(1) EPA-Integrated Risk Information System (IRIS) recently issued or retained human health benchmarks.

(2) Included based on comparison of theoretical hazard quotients to exposure and hazard screening results. These compounds are currently ongoing human health benchmark assessments.

(3) USDA and EPA are evaluating during re-vegetation and remediation of soils with biosolids.

(4) Included based on concerns surrounding P loading to soils and runoff.

(5) Reevaluating pollutant for a revised numerical standard based on updated sewage sludge concentration and other data.

Table 3. Literature Search Chemicals

Chemical	CASRN	Evaluated Previously
Metals		
Aluminum	7429-90-5	A
Boron	7440-42-8	A
Cerium	7440-45-1	A
Rubidium	7440-17-7	A
Tin	7440-31-5	A
Vanadium	7440-62-2	A
Yttrium	7440-65-5	A
Organics		
Carbon tetrachloride	56-23-5	A
Chloroform	67-66-3	A
Cyanide	57-12-5	A
Dimethyl phthalate	131-11-3	A
Di-n-octyl phthalate	117-84-0	A
Ethylbenzene	100-41-4	A
Nitrophenol, p-	100-02-7	A
Octylphenol	67554-50-1	A
Polyethylene glycol	25322-68-3	A
Styrene	100-42-5	A
Tetrabromobisphenol A	79-94-7	A
Tris(2-chloroethyl) phosphate	115-96-8	A
Trichlorobenzene, 1,3,5-	108-70-3	A
Organics / disinfectants, antiseptics		
Triclosan	3380-34-5	A
Organics / surfactants		
Nonylphenol	25154-52-3	A
Nonylphenol (branched), 4-	84852-15-3	A
Nonylphenol, 4-	104-40-5	A
Organics / odorants		
Dimethyl-3,5-dinitro-4-tert-butylacetophenone, 2,6-	81-14-1	A
Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta-g-2-benzopyran, 1,3,4,6,7,8-	1222-05-5	A
Musk Xylene	81-15-2	A
Organics / pesticides		
Cresol,p- (4-methylphenol)	106-44-5	A
Dichlorobenzene, 1,3-	541-73-1	A
1,4-Dichlorobenzene	106-46-7	A

Chemical	CASRN	Evaluated Previously
Dimethoate	60-51-5	A
Endosulfan alpha	959-98-8	A
Endosulfan beta	33213-65-9	A
Fenthion	55-38-9	A
Heptachlor epoxide	1024-57-3	A
Monuron	150-68-5	A
Nitrofen (TOK)	1836-75-5	A
Pentachloronitrobenzene	82-68-8	A
Trichlorofon	52-68-6	A
Triphenyl phosphate	115-86-6	A
Organics / pharmaceuticals		
17 (alpha)-estradiol	57-91-0	A
17 (alpha)-ethynyl estradiol	57-63-6	A
17 (beta)-estradiol	50-28-2	A
19-norethisterone	68-22-4	A
Acetaminophen	103-90-2	A
Albuterol	18559-94-9	A
Aspirin	50-78-2	A
Bezafibrate	41859-67-0	A
Benzenesulfonic acid,2,2’- (1,2-ethenediyl)bis[5-amino]	42615292	A
Butylated hydroxy toluene	128-37-0	A
Caffeine	58-08-2	A
Carbamazepine	298-46-4	A
Carbadox	6804-07-5	A
Cholesterol	57-88-5	A
Cimetidine	51481-61-9	A
Ciprofloxacin	85721-33-1	A
Clofibric acid	882-09-7	A
Codeine	76-57-3	A
Cotinine	486-56-6	A
Cyclophosphamide	50-18-0	A
Diazepam	439-14-5	A
Diclofenac sodium	15307-79-6	B
Digoxin	20830-75-5	A
Diltiazem	42399-41-7	A
Dimethylaminophenazone	58-15-1	B
Dimethylxanthine, 1,7-	611-59-6	A
Di-tert-butylphenol, 2,6-	128-39-2	A

Chemical	CASRN	Evaluated Previously
Doxycycline	564-25-0	A
Equilin	474-86-2	A
Erythromycin	114-07-8	A
Estriol	50-27-1	A
Estrone	53-16-7	A
Fenofibric acid	26129-32-8	B
Floxacillin	5250-39-5	A
Fluoxetine	54910-89-3	A
Gemfibrozil	25812-30-0	A
Ibuprofen	15687-27-1	A
Indometacine	53-86-1	B
Ketoprofen	22071-15-4	A
L-Norgestrel (levonorgestrel)	797-63-7	A
Mefenamic acid	61-68-7	A
Mesalazine	89-57-6	A
Mestranol	72-33-3	A
Metoprolol	37350-58-6	A
N,N-diethyltoluamide (DEET)	134-62-3	A
Nadolol	42200-33-9	A
Naproxen	22204-53-1	A
Norfloxacin	70458-96-7	A
Oxytetracycline	79-57-2	A
Phenazone	60-80-0	A
Phenoxymethylpenicyllin	87-08-1	A
Progesterone	57-83-0	A
Propranolol	525-66-6	A
Quinine sulfate	7778-93-0	A
Ranitidine	66357-35-5	A
Salicylic acid	69-72-7	A
Sodium valproate	1069-66-5	A
Sulfamerazine	127-79-7	A
Sulfamethazine	57-68-1	A
Sulfasalazine	599-79-1	A
tert-butyl-4-hydroxy anisole, 3-	25013-16-5	A
Trimethoprim	738-70-5	A
Tylosin	1401-69-0	A
Virginiamycin	11006-76-1	A
Organics / plasticizers		

Chemical	CASRN	Evaluated Previously
Ethanol, 2- butoxy-phosphate	78-51-3	A
Di-n-butyl phthalate	84-74-2	A
Polybrominated biphenyls (PBBs)		
Hexabromobiphenyl, 2,2',4,4',5,5'-	59080-40-9	A
Organics / solvents		
Tetrachloroethylene	127-18-4	A
Toluene	108-88-3	A
Xylene, m-	108-38-3	A
Xylene, o-	95-47-6	A
Xylene, p-	106-42-3	A
Polychlorinated naphthalenes (PCNs)		
Chloronaphthalene, 2-	25586430	A
Polychlorinated aromatic hydrocarbons (PAHs)		
Benzo(a)anthracene	56-55-3	A
Benzo(b)fluoranthene	205-99-2	A
Benzo(k)fluoranthene	207-08-9	A
Chrysene	218-01-9	A
Naphthalene	91-20-3	A

A = Evaluated during 2003 Biennial Review (68 *FR* 75531)
B = No previous evaluation

The Agency will continue to assess the availability of sufficient information for these and other pollutants during subsequent biennial reviews pursuant to Section 405(d)(2)(C) of the CWA. In addition, the Agency is evaluating its process for how future biennial reviews will be conducted. For example, for future biennial reviews, the Agency is re-evaluating its process of only relying solely on IRIS or OPP HHBs.

Additional Information

For more information about EPA's Biosolids program, contact Rick Stevens in the Health and Ecological Criteria Division, 1200 Pennsylvania Avenue, N.W., Washington, DC 20460 (telephone: 202-566-1135 or e-mail: stevens.rick@epa.gov).

Attachment 1

Literature Search Results and Database Update

Technical Background Report

Literature Search Results and Database Update

Technical Background Document

U.S. Environmental Protection Agency
Office of Water
Ariel Rios Building
1200 Pennsylvania Avenue, NW
Washington, DC 20460

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Table **Page**

Introduction

This technical report constitutes an RTI International (RTI) deliverable under U.S. Environmental Protection Agency (EPA) Contract No. 68-C-04-006, Work Assignment 1-20. Sections 1 through 4 of this report present information that updates the results of the literature search for physical and chemical properties conducted under previous work assignments and considers papers from November 2004 through April 2005. Because previous literature reviews included only a limited review of data on bioconcentration/biotransfer factors and ecotoxicity benchmarks, EPA included papers, reports, and journal articles from 2000 through April 2005 for these parameters. The literature search focused on the open literature, as well as chemicals listed in Table 1 (i.e., chemicals identified in EPA's 2003 Biennial Review). The literature search followed the search strategy described in the memorandum submitted to EPA on April 25, 2005. To augment that search strategy, EPA conducted an independent literature search and review focused exclusively on biosolids-related literature (e.g., identified from biosolids Web sites such as Cornell University) and key authors in this field of study (e.g., Dr. M.B. McBride, Dr. G.A. O'Connor). This independent search and review was designed as a quality assurance (QA) step to ensure that the literature search strategy captured all relevant data sources and articles. The results presented below include information gleaned from the primary literature survey, review, and the biosolids-specific review.

Section 5 of this report presents information pertinent to the identification of additional pollutants in U.S. sewage sludge and, in particular, examines the availability of human health benchmarks on cancer and non-cancer endpoints. The purpose of this section was to provide information on the suitability for modeling and potential rulemaking for pollutants that have been identified in sewage sludge but have not yet been included in the exposure and hazard modeling conducted by EPA.

Table 1. Chemicals and Chemical Abstract Service (CAS) Registry Numbers Considered in Data Collection

Chemical	CAS	In 2003 Screening Assessment
Antimony	7440-36-0	
Barium	7440-39-3	✓
Benzo(a)pyrene	50-32-8	
Beryllium	7440-41-7	✓
Bis(2-ethylhexyl)phthalate	117-81-7	
4-Chloroaniline	106-47-8	✓
Cobalt	7440-48-4	
Fluoranthene	206-44-0	✓
Fluoride	16984-48-8	
Iron	7439-89-6	
Manganese	7439-96-5	✓
2-Methylnaphthalene	91-57-6	
Molybdenum	7439-98-7	
Nitrate	14797-55-8	✓
Nitrite	14797-65-0	✓
Pyrene	129-00-0	✓
Silver	7440-22-4	✓
Thallium	7440-28-0	

1.0 Physical-Chemical Property Data

For this task, EPA retrieved all available data for the selected chemicals from an internal physical-chemical properties database using the same hierarchy established for the 2003 screening assessment (U.S. EPA, 2003a). The database contains data from known public databases, EPA, peer-reviewed and other published literature, and estimation software. Appendix A provides a list of all these existing sources. For the chemicals that are new to this analysis, the available data from those sources are presented in Appendix B (for others the data are the same as used in the 2003 assessment). With the exception of fluoride, EPA identified a relatively complete data set for all of the chemicals shown in Table 1. Significant data gaps included the following:

- **Soil -water partition coefficients (Kd)** was not found for iron.

- **Hydrolysis rates (Kh)** were not found for 2-methylnaphthalene and bis (2-ethylhexyl) phthalate.

- **Fish bioconcentration factors (BCFs)** were not found for iron.

EPA focused on filling data gaps for the newly added constituents and identifying additional data for existing constituents. On average, the search returned 25 papers per chemical with more than 200 papers identified for some chemicals. These papers were initially screened by reading titles and abstracts to determine relevancy (papers on marine systems were excluded), and EPA retained the references shown in Appendix C. Due to the volume of papers that were produced by the literature search and screen, the investigation was limited to a review of abstracts. No additional data were identified in the abstracts that could be used in the environmental fate and transport modeling.

2.0 Bioconcentration Data

Based on the 2003 screening analysis, the following methodology was used for obtaining bioaccumulation factors (BAFs) and bioconcentration factors (BCFs) for the new constituents listed in Table 1. These values are presented in Appendix B for terrestrial plants and in Appendix D for terrestrial vertebrates, invertebrates, and aquatic plants.

- ***Terrestrial vertebrates (small mammals, small birds, small herps, omnivorous vertebrates, and herbivorous vertebrates)***

For metals, BAF values were collected from the U.S. Army Risk Assessment Modeling System (ARAMS) (ERDC and USACHPPM, 2004); these sources rely heavily on Sample et al., 1998, which provides data on bioaccumulation in small mammals. The small mammal BAFs were applied to all other terrestrial prey items due to the lack of other data. ARAMS did not contain data for any of the new organic constituents.

- ***Terrestrial invertebrates (worms and other soil invertebrates***)

Earthworm BAFs were also obtained from ARAMS for most of the new metals and for benzo(a)pyrene.

- ***Terrestrial plants (exposed vegetables, exposed fruits, forage, silage, grains, and roots)***

For organics, values were calculated for the human ingestion pathway using the Travis and Arms regression (Travis and Arms, 1988). These values were obtained from RTI's internal chemical-physical properties database. For metals, values were identified in Baes et al., 1984.

- ***Aquatic Fauna (TL3 fish, TL4 fish, and benthic filter feeders)***

For metals and organics, Estimations Programs Interface for Windows (EPIWIN) BCFs were used for fish. The same BCFs were also used for benthic filter feeders (Bffs) in the absence of other data. These values were obtained from RTI's internal chemical-physical properties database.

- ***Aquatic plants (aquatic plants and algae)***

EPIWIN BCFs were used for metals and organics.

EPA conducted a literature search to fill the remaining data gaps. Table 2 summarizes the data availability for the new constituents listed in Table 1. Due to the large number of abstracts (more than 200), the primary literature review was restricted to screening the abstracts for useful data rather than reviewing the entire article (although EPA did obtain and review the entire text for key references, such as McBride et al., 2004). Based on this review, the abstracts were divided into three groups:

Group 1: Number of abstracts with readily available data. These abstracts contain actual data, but the full articles would require additional technical review to verify the applicability of these values.

Group 2: Number of abstracts suggesting applicable data. These abstracts contain summary information or language that suggests applicable data might be available in the full document.

Group 3: Number of articles with no indication of applicable data. These abstracts do not contain any information that suggests that useful quantitative data may have been reported by the study.

Table 2. Results of Abstract Screening for Bioaccumulation and Bioconcentration Factors

Constituent	Total Abstracts Obtained	Number of Abstracts		
		with readily available data	suggesting applicable data	no indication of applicable data
Antimony	14	0	5	9
Benzo(a)pyrene	96	2	6	88
Bis-(2-ethylhexyl)phthalate	2	0	0	2
Cobalt	71	2	2	67
Fluoride	19	0	0	19
Iron	124	0	2	122
Manganese	103	1	4	98
Molybdenum	14	0	4	10
Thallium	7	1	4	2

The references for the papers under Groups 1 and 2, as well as all other relevant references, are presented in Appendix E. The abstracts in Group 1 contained the following information.

- *Benzo(a)pyrene*: Klosterhaus, S.L., et al. (2002) presents BAFs for aquatic plants. Samsoee- Peterson, L. et al. (2002) lists BCF values for vegetables. Overcash, M., et al. (2005) lists an uptake range for crops that could be useful.

- *Cobalt*: In two separate abstracts, Kahle, J. and G-P. Zauke (2003) list BCFs for aquatic fauna. The article by Perez-Espinosa et al. (2005) can be used to calculate soil-to-plant bioconcentration factors.

- *Manganese*: El-Shenawy, NS (2004) lists a minimum BCF for aquatic fauna.

- *Molybdenum*: The data presented in McBride et al. (2004) are based on extracted metal concentrations from soil and sludge. A methodology would need to be developed to quantify the relationship between total metal concentrations in soil (required by the model) and the extracted metal concentrations reported in the study. Because the study approach used by authors may gain wide acceptance, EPA may want to investigate the use of extracted concentrations in the future. In addition, three articles were reviewed on plant uptake that did not contain adequate information to derive quantitative values (O'Connor et al., 2001a; O'Connor et al., 2001b; and O'Connor et al., 2001c).

- *Thallium*: Borgmann, U. et al. (2004) presents aquatic plant BCFs. McBride, M.B. (2003) lists crop uptake factors for thallium.

3.0 Ecotoxicity Data from Secondary Sources of Information

For each of the chemicals listed in Table 1, EPA searched primary and secondary sources for benchmarks for surface water, sediment, and soil, as well as benchmarks in units of dose for mammals and birds in the 2003 screening assessment (U.S. EPA, 2003a). Table 3 presents the data quality hierarchy established for the 2003 screening assessment and presents the list of secondary sources that we reviewed.

Table 3. Secondary Sources for Ecological Benchmarks

Benchmark Type	Secondary Data Sources
Water	1. U.S. EPA, 2004 (NAWQC) 2. Suter and Tsao, 1996 3. Canadian Council of Ministers of the Environment, 2003 4. U.S. EPA, 2003b (EFED Database) 5. California EPA, 2003
Soil	1. U.S. EPA, 2005 (ECO-SSL) 2. Effroymson et al., 1997 3. Canadian Council of Ministers of the Environment, 2003

(continued)

Table 3. (continued)

Benchmark Type	Secondary Data Sources
Sediment	1. Jones et al., 1997 2. Canadian Council of Ministers of the Environment, 2003
Mammals and Birds	1. U.S. EPA, 2005 (ECO-SSL) 2. BTAG, 2002 3. Sample et al., 1996 4. U.S. EPA, 2003 (EFED Database)

The data from secondary sources were entered to the corresponding modeling database as illustrated in Appendix F, Ecotoxicity Data from Secondary Sources. Appendix F also presents the benchmark values that were used in the 2003 screening assessment for comparative purposes whenever a new value was identified. In instances when there is more than one value for the same combination chemical/benchmark/receptor concentration, the recommended value was flagged according to the following criteria:

1. The Table 3 hierarchy for secondary data is used; for primary data, studies must come from a peer-reviewed source.

2. Chronic effects data are preferred over acute data.

3. Study reports should include test species, test species body weight, and study duration.

4. Reproductive or developmental effects are preferred over other endpoints.

5. For ingestion benchmarks, only ingestion exposures may be used with feeding studies preferred to gavage (i.e., orally induced) studies.

6. For two or more values satisfying the above criteria, the most current value was preferred.

7. For two or more values satisfying the above criteria, the most conservative (i.e., lowest) value was preferred.

Table 4 shows the availability of data coming from secondary sources. Overall, EPA identified new values for one or more ecological benchmarks except for 4-chloroaniline, pyrene, and silver for which 2003 screening assessment data already exist.

Table 4. Ecological Benchmarks Availability in Secondary Sources

Chemical	CASRN	Ecological Benchmarks Availability				
		Dose				
		Mammals	Birds	Water	Sediment	Soil
Antimony	7440-36-0	✓		✓		✓
Barium	7440-39-3	✓	✓			✓
Benzo(a)pyrene	50-32-8	✓		✓	✓	✓
Beryllium	7440-41-7	✓				✓
Bis(2-ethylhexyl)phthalate	117-81-7	✓	✓	✓	✓	
4-Chloroaniline	106-47-8					
Cobalt	7440-48-4	✓	✓	✓		✓
Fluoranthene	206-44-0			✓	✓	
Fluoride	16984-48-8	✓	✓			✓
Iron	7439-89-6			✓		
Manganese	7439-96-5	✓	✓			
2-Methylnaphthalene	91-57-6				✓	
Molybdenum	7439-98-7	✓	✓	✓		✓
Nitrate	14797-55-8			✓		
Nitrite	14797-65-0			✓		
Pyrene	129-00-0					
Silver	7440-22-4					
Thallium	7440-28-0	✓		✓		✓

4.0 Ecotoxicity Data from Primary Sources of Information

Primary sources of ecotoxicy data were also considered. EPA searched the following databases: MEDLINE, PubMed, Toxline, Aquatic Sciences and Fisheries Abstracts, Biological Sciences Database, and the Environmental Sciences and Pollution Management Database and retrieved the abstracts of papers from year 2000 to present using a previously defined list of keywords (see technical memorandum submitted to EPA on April 25, 2005). Because of the large volume of references produced by this search, we further screened the results by reading the titles and abstracts to include only the most relevant papers (see Appendix G).

Table 5 summarizes the availability of ecotoxicity benchmarks identified during the review of hundreds of article abstracts; however, additional technical review will be required to determine the quality and applicability of the benchmarks presented in these papers before they can be used for biosolids risk modeling. Information about the receptors and endpoints, as well as the key papers that were identified, is presented in the following paragraphs (organized around benchmark type).

Table 5. Ecological Benchmarks Availability in Primary Sources

Chemical	CASRN	Ecological Benchmarks Availability				
		Dose				
		Mammals	Birds	Water	Sediment	Soil
Antimony	7440-36-0					
Barium	7440-39-3			*		
Benzo(a)pyrene	50-32-8		✓			
Beryllium	7440-41-7			*		
Bis(2-ethylhexyl)phthalate	117-81-7					✓
4-Chloroaniline	106-47-8			*		
Cobalt	7440-48-4				✓	
Fluoranthene	206-44-0					✓
Fluoride	16984-48-8			✓		
Iron	7439-89-6					
Manganese	7439-96-5			✓	✓	✓
2-Methylnaphthalene	91-57-6					
Molybdenum	7439-98-7					
Nitrate	14797-55-8	*				
Nitrite	14797-65-0				✓	
Pyrene	129-00-0			✓	*	✓
Silver	7440-22-4			✓		*
Thallium	7440-28-0					

Shaded cells correspond to previously found data from secondary sources.
* Data is available from the 2003 screening assessment.

Dose Benchmarks

- *Benzo(a)pyrene*: Stoncius and Lazutka (2003) present threshold values considering effects in spleen and liver function in advanced developmental stages of the black-headed gull embryo.

Water Concentration Benchmarks

- *Fluoride*: Two studies were identified that could potentially provide data. Metcalfe-Smith et al. (2003) present LC_{50} values for different aquatic invertebrates. Saxena et al. (2001) studied the freshwater fish *Channa punctatus* exposed to different concentrations of fluoride and evaluated the 96-hour median lethal concentration (LC_{50}).

- *Pyrene*: Two studies were identified. Landrum et al. (2003) present LC_{50} and EC_{50} values considering immobility (failure to swim on prodding) for the amphipod, *Diporeia spp*. Weinstein and Polk (2001) present LC_{50} and LD_{50} values for the freshwater mussel *Utterbackia imbecillis* exposed to water concentrations of photoactivated pyrene.

- *Manganese*: Three studies were identified. Barnhoorn et al. (2001) presents LC_{50} values considering haematological and osmoregulation effects on a fish species (*Oreochromis mossambicus*). Soltan and Rashed (2003) present threshold values from studying the survival and behavior of water hyacinth (*Eichhornia crassipes*) under varying conditions of manganese concentrations. Lasier et al. (2000) presents LC_{50} and chronic IC_{50} values for the crustaceans *Ceriodaphnia dubia* and *Hyalella azteca*.

- *Silver*: Five studies were identified. Mann et al. (2004), Morgan and Wood (2004), Van Genderen et al. (2003), and Bury et al. (2003) present LC_{50} values for juvenile rainbow trout, *Pimephales promelas*, and aquatic invertebrates. Peng et al. (2004) presents LC_{50} values for *Crustacea dubia*.

Sediment Concentration Benchmarks

- *Cobalt*: Two studies were identified that could potentially provide data. Dave and Nilsson (2004) present threshold values from both acute and chronic tests that were made with the crustacean *Ceriodaphnia dubia* considering reproductive effects. Borgmann et al. (2004) presents threshold effect concentrations obtained from chronic tests performed in amphipods.

- *Manganese*: One study was identified. Dave and Nilsson (2004) presented sediment toxicity values for cobalt and manganese that could potentially be used.

- *Nitrite*: Neumann et al. (2001) present lethality concentration values after studying the complete larval development until eclosion, larval mortality, and morphological modifications of the abdominal appendages (ventral tubules and anal papillae) in benthic organisms *(Chironomus piger* and *Ch. riparius*).

Soil Concentration Benchmarks

- *Bis(2-ethylhexyl)phthalate*: Two studies were identified with potential data. Jensen et al. (2001) presents EC_{10} and EC_{50} values considering effects in survival and reproduction of a soil invertebrate (collembolan *Folsomia fimetaria*). Van Wezel et al. (2000) is a review document that presents ER-L values for survival, growth, and reproduction.

- *Fluoranthene*: Three studies were identified that could potentially serve as data sources, Sverdrup et al. (2002a, 2002b, and 2001). These studies present EC_{10} values and threshold values derived using a QSAR methodology. They consider survival and reproduction effects on soil invertebrates.

- *Pyrene*: Five studies were identified. Herbert et al. (2004) presents LC_{50}, EC_{50} (juvenile), and NOEC values for the invertebrate *Folsomia candida*. Jensen and Sverdrup (2004) present EC_{50} and EC_{10} values that consider survival and reproduction of the collembolan *Folsomia fimetaria*. Sverdrup et al. (2002a and 2002b) presents EC_{10} values considering survival and reproduction of the enchytraeid worm *Enchytraeus crypticus* and *Folsomia fimetaria*, respectively. Sverdrup et al. (2002c) measured toxic effects on the collembolan *Folsomia fimetaria* as reductions in survival and reproductive output after three weeks of exposure.

- *Manganese*: Kuperman et al. (2004) presents EC_{20} and EC_{50} values obtained from tests measuring reproductive effects on the earthworm (*Eisenia fetida*) cocoon, the enchytraeid (*Enchytraeus crypticus*), and the collembolan (*Folsomia candida*).

5.0 Data Search and Identification of Additional Pollutants

EPA examined pollutant data available from previous work assignments (2002-2004) and newly reviewed literature (November 2004 – present). The search for new data was based on the strategy developed under the previous work assignment (Contract 68-C-04-006, Work Assignment #B-20); results from bibliographic databases were limited to articles published in English in refereed journals. The bibliographic databases included MEDLINE, PubMed, Toxline, Aquatic Sciences and Fisheries Abstracts, Biological Sciences Database, and the Environmental Sciences and Pollution Management Database. The data search key words included:

Topic/Keyword:	Sewage sludge, biosolids, pollutants, toxicants, treated sewage, sludge treatment, sewage treatment, land application

From well over 100 articles, we identified the 72 articles shown in Appendix H as sources of information on pollutants in biosolids (Appendix H includes abstracts when available). We divided the list of pollutants identified in these articles into two major groups; (1) pollutants that have not previously been modeled but have readily available health benchmarks and (2) pollutants that have been identified in recent studies on biosolids for which health benchmarks were not identified in a major reference.

Pollutants with Health Benchmarks

Table 6 lists the chemicals (n=30) with health benchmarks (not limited to IRIS or OPP) that fit the following criteria: (1) identified in the National Sewage Sludge Survey- NSSS (1989), (2) not currently on EPA's list of potential candidates for addition to the Part 503 standards, and (3) not previously regulated for sewage sludge. The chemicals are organized by analyte groups defined by similarity in structure as well as typical uses when appropriate.

Table 6. List of Pollutants with Health Benchmarks

Constituent Name	CASRN
Metals	
Aluminum	7429-90-5
Boron*	7440-42-8
Tin	7440-31-5
Vanadium	7440-62-2
Organics	
Carbon tetrachloride*	56-23-5
Chloroform*	67-66-3
Cyanide*	57-12-5
Di-n-octyl phthalate	117-84-0
Ethylbenzene*	100-41-4
Styrene*	100-42-5
Organics/ desinfectants, antiseptics	
Tetrachloroethylene*	127-18-4
Organics/ pesticides	
1,4-Dichlorobenzene	106-46-7
Cresol, p- (4-methylphenol)	106-44-5
Dimethoate*	60-51-5
Endosulfan I*	959-98-8
Endosulfan II*	33213-65-9
Heptachlor epoxide*	1024-57-3
Nitrofen (tox)	1836-75-5
Pentachloronitrobenzene*	82-68-8
Organics/ plasticizers	
Di-n-butyl phthalate*	84-74-2
Organics/ solvents	
Toluene*	108-88-3
Xylene, —	108-38-3
Xylene, o-	95-47-6
Xylene, p-*	106-42-3

(continued)

Table 6. (Continued)

Constituent Name	CASRN
Polychlorinated Aromatic Hydrocarbons (PAHs)	
Benz(a)anthracene	56-55-3
Benzo(b)fluoranthene	205-99-2
Benzo(k)fluoranthene	207-08-9
Chrysene	218-01-9
Naphthalene*	91-20-3
Polychlorinated Naphthalenes (PCNs)	
Chloronaphthalene, 2- (beta)*	91-58-7

* Oral benchmark is available in IRIS and/or OPP.

Pollutants without Health Benchmarks

Based on a review of abstracts and selected articles in Appendix H, Xia et al. (2005) emerged as the most comprehensive article on pollutants that may be present in biosolids that were *not* identified specifically in our literature reviews under previous work assignments covering the years 2002 to 2004. Table 7 lists a large number of additional pollutants of concern (e.g., pharmaceuticals, pesticides) in sewage sludge that do not have human health benchmarks available in any of the sources reviewed under this work assignment. We identified toxicity data that may support development of human health benchmarks for most of these pollutants except those presented in shaded, bold rows in the table below. The table also flags pollutants reported in Xia et al. (2005) as being found in wastewater treatment plant influents. This document reports different percent removals of the pollutants (30-90%) and states that it is uncertain whether this removal is due to solids partitioning or degradation; therefore, the pollutants could potentially accumulate in the sewage sludge.

Table 7. List of Pollutants without Health Benchmarks

Constituent Name	CASRN
Metals	
Cerium	7440-45-1
Rubidium	7440-17-7
Sulfur	7704-34-9
Yttrium	7440-65-5

(continued)

Table 7. (Continued)

Constituent Name	CASRN
Organics	
Dimethyl-3,5-dinitro-4-tert-butylacetophenone,2,6-	81-14-1
Dimethylphthalate	131-11-3
Nitrophenol, p-	100-02-7
Octylphenol	67554-50-1
Poly(ethylene glycol)s	25322-68-3
Tetrabromobisphenol A	79-94-7
Tri(2-chloroethyl) phosphate	115-96-8
Trichlorobenzene, 1,3,5-	108-70-3
Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta-g-2-benzopyran, 1,3,4,6,7,8-	1222-05-5
Organics/ conditioners	
Ferrous sulfate	7720-78-7
Organics/ desinfectants, antiseptics	
Triclosan*	**3380-34-5**
Organics/ surfactants	
Nonylphenol*	25154-52-3
Nonylphenol (branched), 4-*	84852-15-3
Nonylphenol, 4-*	104-40-5
Organics/ odorants	
Musk Xylene	81-15-2
Organics/ pesticides	
Dichlorobenzene, 1,3-	541-73-1
Fenthion	55-38-9
Monuron	150-68-5
Trichlorofon	52-68-6
Triphenyl phosphate	115-86-6

(continued)

Table 7. (Continued)

Constituent Name	CASRN
Organics/ pharmaceuticals	
17 (alpha)-estradiol	57-91-0
17 (alpha)-ethynyl estradiol*	57-63-6
17 (beta)-estradiol	50-28-2
19-norethisterone	68-22-4
Acetaminophen	103-90-2
Albuteral	18559-94-9
Aspirin	50-78-2
Bezalibrate*	41859-67-0
bis[(4-anilino-6-morpholino-1,3,5-triazin-2-yl)-amino]stilbene-2,2'-disulfonate (DAS), 4,4'-	81-11-8
Butylated hydroxy toluene	128-37-0
Caffeine*	58-08-2
Carbamazepine*	298-46-4
Carbodox	6804-07-5
Cholesterol	57-88-5
Cimetidine	51481-61-9
Ciprofloxacin*	85721-33-1
Clofibric acid	**882-09-7**
Codeine	76-57-3
Cotinine	486-56-6
Cyclophosphamide*	50-18-0
Diazepam	439-14-5
Diclofenac sodium*	**15307-79-6**
Digoxin	20830-75-5
Diltiazem	42399-41-7

(continued)

Table 7. (Continued)

Constituent Name	CASRN
Dimethylaminophenazone*	**58-15-1**
Dimethylxanthine, 1,7-	611-59-6
Di-tert-butylphenol, 2,6-	128-39-2
Doxycycline	564-25-0
Equilin	474-86-2
Erythromycin-H2O	114-07-8
Estradiol (estriol)	50-27-1
Estrone	53-16-7
Fenofibric acid	26129-32-8
Flucoxacillim sodium	5250-39-5
Fluoxetine	54910-89-3
Gemfibrozil*	25812-30-0
Ibuprofen*	15687-27-1
Indometacine*	**53-86-1**
Ketoprofen*	22071-15-4
Levonorgestrel	797-63-7
Mefenamic acid	61-68-7
Mesalazine	89-57-6
Mestranol	72-33-3
Metoprolol*	37350-58-6
N,N-diethyltoluamide	134-62-3
Nadolol	42200-33-9
Naproxen*	**22204-53-1**
Norfloxacin	70458-96-7
Oxytetracycline	79-57-2

(continued)

Table 7. (Continued)

Constituent Name	CASRN
Phenazone*	**60-80-0**
Phenoxymethylpenicyllim	87-08-1
Progesterone	57-83-0
Propranolol *	525-66-6
Quinine sulphate	7778-93-0
Ranitidine	66357-35-5
Salicylic acid	69-72-7
Sodium valproate	1069-66-5
Sulfamerazine	127-79-7
Sulfamethazine	57-68-1
Sulphasalazine	599-79-1
tert-butyl-4-hydroxy anisole, 3-	25013-16-5
Trimethoprim	738-70-5
Tylosin	1401-69-0
Virginiamycin	21411-53-0
Organics/ plasticizers	
Butoxy-phosphate ethanol, 2-	78-51-3
Polybrominated Biphenyls (PBBs)	
Hexabromobiphenyl, 2,2',4,4',5,5'-	59080-40-9

*Pollutants listed in Xia et al. (2005)

6.0 Conclusions

For new pollutants and selected pollutants that were identified by EPA for further data collection efforts, EPA retrieved physical-chemical property data from existing internal databases as well as in the open literature. Based on a review of the open literature, we identified a number of additional pollutants that have not been modeled and investigated the availability benchmarks and toxicological data from multiple sources (EPA-approved sources such as IRIS as well as alternate sources of benchmarks such as the Agency for Toxic Substances and Disease Registry reports). In addition, we: (1) obtained or calculated parameter values for BAFs and BCFs for terrestrial vertebrates, invertebrates, plants, and fish and aquatic plants, and (2) evaluated the availability of ecological benchmarks and identified new values for surface water, sediment, soil, mammals, and birds from primary and secondary sources. These data often represent information gleaned from studies conducted during the past few years, particularly

studies conducted in the previous six months; however, for some chemical pollutants that were not previously evaluated, EPA expanded its search and collected data from a wide range of sources dating back to the early 1980's. EPA did not identify any sources or references presenting chemical concentration data in biosolids. Despite the collection of data on other input parameters and the availability of EPA-approved health benchmarks, we lack sufficient information on pollutant concentrations in biosolids to support running the exposure and hazard assessment model.

7.0 References

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