Chapter 12: Benefit Overview

INTRODUCTION

Part III of the EEBA assesses the benefits to society from the reduced effluent discharges that will result from the proposed MP&M industry regulations. EPA expects that benefits will accrue to society in several broad categories, including reduced health risks, enhanced environmental quality, and increased productivity in economic activities that are adversely affected by MP&M industry discharges.

The benefit chapters assess the national benefits expected to accrue from the regulation. This chapter provides a discussion of the ***pollutants of concern*** **(POCs)**, their effect on human health, their environmental effects, a framework for understanding the benefits likely to be achieved by the MP&M regulation, and a qualitative discussion of those benefits. The following chapters quantify and estimate the economic value of these benefit categories. Appendices E and G provide further information on environmental effects of MP&M pollutants and water quality models used to assess these effects.

CHAPTER CONTENTS:

12.1 MP&M POLLUTANTS

EPA defines three general categories of pollutants: priority or toxic pollutants; nonconventional pollutants; and conventional pollutants. ***Priority pollutants*** **(PPs)** are defined as any of 126 named pollutants.[1] Conventional pollutants include ***biological oxygen demand*** **(BOD)**, ***total suspended solids*** **(TSS)**, ***oil and grease*** **(O&G)**, ***pH***, and anything else the Administrator defines as a conventional pollutant. Nonconventionals are a catch-all category that includes everything that is not in the two previously described categories. The naming system is somewhat confusing in that some nonconventional pollutants may be as "toxic" as, or more "toxic" than some of the PPs.

MP&M effluents contain a variety of priority, nonconventional, and conventional pollutants. The release of these pollutants to our nation's surface water degrades aquatic environments, alters aquatic habitats, and affects the diversity and abundance of aquatic life. It also increases the health risks to humans who ingest contaminated surface waters or eat contaminated fish and shellfish (U.S. EPA, 1997). A number of the pollutants commonly found in MP&M effluents also inhibit biological wastewater treatment systems or accumulate in sewage sludge or sediment.

Metals are a particular concern because of their prevalence in MP&M effluents. Metals are inorganic compounds, generally non-volatile (with the notable exception of mercury), and cannot be broken down by biodegradation processes. Metals can accumulate in biological tissues, sequester into sewage sludge in ***publicly owned treatment works*** **(POTWs)**, and contaminate soils and sediments when released to the environment. Sediments contaminated with metals become resuspended by dredging, boat propellers, water currents or wave action, and storm events, releasing metals back into the water column. Metals can also become biologically available and enter terrestrial food chains once the sludge is applied on land. Sludges with high concentrations of metals are therefore unsuitable for land application. Some metals are quite toxic even when present at relatively low levels.

Human and ecological exposure and risk from environmental releases of MP&M pollutants depend on chemical-specific properties, the mechanism and medium of release, and site-specific environmental conditions.

[1] The Agency started with 129 PPs, but 3 have been dropped from the list.

Chemical-specific properties include toxicological effects on living organisms, ***hydrophobicity/lipophilicity***, reactivity and persistence. These properties are described in sections 12.1.1 through 12.1.4.

12.1.1 Characteristics of MP&M Pollutants

EPA sampled MP&M facilities nationwide to assess the concentrations of pollutants in MP&M effluents. The Agency collected samples of raw wastewater from MP&M facilities and applied standard water analysis protocols to identify and quantify the pollutant levels in each sample. EPA used these analytical data, along with selection criteria, to identify 132 contaminants of potential concern.[2]

EPA then evaluated the potential environmental fate and transport of these pollutants and their toxicity to humans and aquatic receptors.

Fate of the MP&M pollutants was estimated based on the propensity of those pollutants to volatilize, adsorb onto sediments, bioconcentrate, and biodegrade. Table E.1 in Appendix E lists MP&M pollutants and provides data on human health concerns, and fate and effects.

Some of the inorganic POCs found in MP&M effluents are also natural constituents of water, including potassium, calcium, magnesium, iron, chlorine, fluoride, sulfate, phosphates, silica, and a number of trace metals such as copper and zinc.

EPA used various data sources to evaluate pollutant-specific fate and toxicity. To evaluate potential human health effects, the Agency relied on ***reference doses* (RfDs)** and ***cancer potency slope factors* (SFs)**, ***human health-based water quality criteria* (WQC)**, ***maximum contaminant levels* (MCLs)** for drinking water protection and other drinking water related criteria, and ***hazardous air pollutant* (HAP)** and PP lists. Appendix E.1.1 provides short descriptions and definitions for each of these measures of human health effects.

To evaluate potential fate and effects in aquatic environments, the Agency relied on measures of ***acute*** and ***chronic toxicity*** to aquatic species, bioconcentration factors for aquatic species, ***Henry's Law constants*** (to estimate volatility), ***adsorption coefficients* (Koc)** (to estimate association with bottom sediments), and ***biodegradation half-lives*** (to estimate the removal of chemicals via ***microbial metabolism***).

[2] EPA identified 150 POCs. Of these 150 POCs, the Agency estimated loadings for 132 pollutants. The benefits analysis presented in this chapter and the following chapters addresses the 132 pollutants for which loadings are available.

The data sources used in the assessment include EPA ***Ambient Water Quality Criteria* (AWQC)** documents and updates, ***EPA's ASsessment Tools for the Evaluation of Risk* (ASTER)**, the ***AQUatic Information REtrieval System* (AQUIRE)**, and the ***Environmental Research Laboratory-Duluth fathead minnow database***, EPA's ***Integrated Risk Information System* (IRIS)**, ***EPA's Health Effects Assessment Summary Tables* (HEAST)**, EPA's 1991 and 1993 ***Superfund Chemical Data Matrix* (SCDM)**, Syracuse Research Corporation's ***CHEMFATE*** and ***BIODEG*** databases, EPA and other government reports, scientific literature, and other primary and secondary data sources.

To ensure that the assessment is as comprehensive as possible, EPA also obtained data on chemicals for which physical-chemical properties and/or toxicity data were not available from the sources listed above. To the extent possible, EPA estimated values for the chemicals using the ***quantitative structure-activity relationship* (QSAR)** model incorporated in ASTER, and for some physical-chemical properties, used published linear regression correlation equations.

12.1.2 Effects of MP&M Pollutants on Human Health

Individuals are potentially exposed to MP&M pollutants released to the aquatic environment via consumption of contaminated fish. Populations served by drinking water utilities located downstream of effluent discharges from MP&M facilities are also exposed to MP&M pollutants via contaminated drinking water. Many of these pollutants may increase risks to human health.

Based on the available human health toxicity data for the 132 POCs presented in Table E.1 (Appendix E), EPA found that:

- 77 pollutants are human ***systemic toxicants***;
- 13 pollutants with published SFs are classified as known, probable, or possible human carcinogens when ingested via drinking water or food. Lead is also classified as a possible human carcinogen in IRIS but EPA has not developed a SF for it;
- 36 pollutants have drinking water criteria (27 with enforceable health-based MCLs, 7 with ***secondary MCLs*** for taste or aesthetics, and 2 with action levels for treatment);
- 35 pollutants are designated as HAPs in wastewater;
- 43 pollutants are identified as PPs; and

- 77 pollutants have human-health based water quality criteria (WQC) to protect against the ingestion of water and organisms or organisms only (see Chapter 13, Table 13.3).

The carcinogens identified by EPA in MP&M effluent samples include known (A), probable (B1 and B2) and possible (C) human carcinogens. These pollutants are associated with the development of cancers in the spleen, liver, kidney, lung, bladder, and skin, among others. These pollutants and target organs are shown in Table 12.1.

Table 12.1: Human Carcinogens Evaluated, Weight-of-Evidence Classifications, and Target Organs

CAS Number	Carcinogen	Weight-of-Evidence Classification	Target Organs
62533	Aniline	B2	Spleen
7440382	Arsenic	A	Liver, kidneys, lungs, bladder and skin
117817	Bis(2-ethylhexyl) phthalate	B2	Liver
75003	Chloroethane [a]		
75092	Dichloromethane	B2	Liver, lungs
123911	Dioxane, 1,4-	B2	Liver, nasal cavity, gall bladder
78591	Isophorone	C	Preputial gland
62759	Nitrosodimethylamine, N-	B2	Liver, lungs, skin, seminal vesicle, lymphatic/hematopoetic system
86306	Nitrosodiphenylamine, N-	B2	Bladder tumors, reticulum cell sarcomas
127184	Tetrachloroethene	B2	Liver
79016	Trichloroethene [a]		
67663	Trichloromethane	B2	Kidneys

A = Human Carcinogen
B1 = Probable Human Carcinogen (limited human data)
B2 = Probable Human Carcinogen (animal data only)
C = Possible Human Carcinogen
a. Pollutant has been withdrawn from the IRIS database for additional study.
Source: U.S. Environmental Protection Agency verified (IRIS) or provisional (HEAST) (U.S. EPA (1998/99d), U.S. EPA (1997)).

Noncarcinogenic hazards associated with pollutants in MP&M effluent include systemic effects (e.g., impairment or loss of neurological, respiratory, reproductive, circulatory, or immunological functions), organ-specific toxicity (e.g., kidney, small intestines, blood, testes, liver, stomach, thyroid), fetal effects (e.g., increased fetal mortality, decreased birth weight), other effects (e.g., lethargy, cataracts, weight loss, hyperactivity), and mortality. These effects are listed by pollutant in Table 12.2.

Table 12.2: MP&M Pollutants Exhibiting Systemic and Other Non-Cancer Human Health Effects[a]

CAS Number	Toxicant	RfD Target Organ and Effects
83329	Acenaphthene	Liver, hepatotoxicity
67641	Acetone	Increased liver and kidney weights, nephrotoxicity
98862	Acetophenone	General toxicity
107028	Acrolein	Cardiovascular toxicity[c]
7429905	Aluminum	Renal failure, intestinal contraction interference, adverse neurological effects[d]
120127	Anthracene	General toxicity
7440360	Antimony	Longevity, blood glucose, cholesterol
7440382	Arsenic	Hyperpigmentation, keratosis and possible vascular complications
7440393	Barium	Increased kidney weight
65850	Benzoic acid	General toxicity
100516	Benzyl alcohol	Forestomach, epithelial hyperplasia
7440417	Beryllium	Small intestinal lesions
92524	Biphenyl	Kidney damage
117817	Bis(2-ethylhexyl) phthalate	Increased relative liver weight
7440428	Boron	Testicular atrophy, spermatogenic arrest
85687	Butyl benzyl phthalate	Significantly increased liver-to-body and liver-to-brain weight
7440439	Cadmium	Significant proteinuria (protein in urine)
75150	Carbon disulfide	Fetal toxicity, malformations
108907	Chlorobenzene	Histopathologic changes in liver
75003	Chloroethane	General toxicity
7440473	Chromium	Renal tubular necrosis (kidney tissue decay)[d]
18540299	Chromium-hexavalent	Reduced water consumption
7440484	Cobalt	Heart effects[d]
7440508	Copper	Gastrointestinal effects, liver necrosis[d]
95487	Cresol, o-	Decreased body weight and neurotoxicity
106445	Cresol, p-	Central nervous system hypoactivity and respiratory system distress
57125	Cyanide	Weight loss, thyroid effects and myelin degeneration
75354	Dichloroethene, 1,1-	Toxic effects on kidneys, spleen, lungs[d]; hepatic lesions
75092	Dichloromethane	Liver toxicity
68122	Dimethylformamide, N,N-	Liver and gastrointestinal system effects
105679	Dimethylphenol, 2,4-	Clinical signs (lethargy, prostration, and ataxia) and hematological changes
84742	Di-n-butyl phthalate	Increased mortality
51285	Dinitrophenol, 2,4-	Cataract formation
606202	Dinitrotoluene, 2,6-	Mortality, central nervous system neurotoxicity, blood heinz bodies and methemoglobinemia, bile duct hyperplasia, kidney histopathology
117840	Di-n-octyl phthalate	Kidney and liver increased weights, increased liver enzymes
122394	Diphenylamine	Decreased body weight, and increased liver and kidney weights

Table 12.2: MP&M Pollutants Exhibiting Systemic and Other Non-Cancer Human Health Effects[a]

CAS Number	Toxicant	RfD Target Organ and Effects
100414	Ethylbenzene	Liver and kidney toxicity
206440	Fluoranthene	Nephropathy, increased liver weights, hematological alterations, clinical effects
86737	Fluorene	Decreased red blood cell count, packed cell volume and hemoglobin
16984488	Fluoride	Objectionable dental fluorosis (soft, mottled teeth)
591786	Hexanone, 2-	Hepatotoxicity and nephrotoxcity[c]
7439896	Iron	Liver pathology, diabetes mellitus, endocrine disturbance, and cardiovascular effects[c]
78831	Isobutyl alcohol	Hypoactivity and ataxia
78591	Isophorone	Kidney pathology
7439965	Manganese	Central nervous system effects
78933	Methyl ethyl ketone	Decreased fetal birth weight
108101	Methyl isobutyl ketone	Lethargy, increased liver and kidney weights and urinary protein
80626	Methyl methacrylate	Increased kidney to body weight ratio
91576	Methylnaphthalene, 2-	
7439987	Molybdenum	Increased uric acid
91203	Naphthalene	Decreased body weight
7440020	Nickel	Decreased body and organ weights
100027	Nitrophenol, 4-	
59507	Parachlorometacresol	
108952	Phenol	Reduced fetal body weight
129000	Pyrene	Kidney effects (renal tubular pathology, decreased kidney weights)
110861	Pyridine	Increased liver weight
7782492	Selenium	Clinical selenosis (hair or nail loss)
7440224	Silver	Argyria (skin discoloration)
100425	Styrene	Red blood cell and liver effects
127184	Tetrachloroethene	Liver toxicity, weight gain
7440280	Thallium	Liver toxicity, gastroenteritis, degeneration of peripheral and central nervous system[c]
7440315	Tin	Kidney and liver lesions
7440326	Titanium	Considered to be physiologically inert[c]
108883	Toluene	Changes in liver and kidney weights
79016	Trichloroethene	Bone marrow, central nervous system, liver, kidneys[4]
75694	Trichlorofluoromethane	Histopathology and mortality
67663	Trichloromethane	Fatty cyst formation in liver
7440622	Vanadium	Kidney and central nervous system effects[b]
108383	Xylene, m-	Central nervous system hyperactivity, decreased body weight
179601231	Xylene, m- & p- (c)	
95476	Xylene, o-	Central nervous system hyperactivity, decreased body weight

Table 12.2: MP&M Pollutants Exhibiting Systemic and Other Non-Cancer Human Health Effects[a]

CAS Number	Toxicant	RfD Target Organ and Effects
136777612	Xylene, o- & p- (c)	
7440666	Zinc	47% decrease in erythrocyte superoxide dismutase (ESOD) concentration in adult human females after 10 weeks of zinc exposure
137304	Ziram \ Cymate	

Notes:
a. Chemicals with EPA verified (IRIS) or provisional (HEAST, or other Agency document)) human health-based RfDs, referred to as "systemic toxicants" (U.S. EPA (1998/99d), U.S. EPA (1997)).
b. RfD based on a no-observed-adverse-effect level (NOAEL). Health effects summarized from Amdur, M.O., Doul, J., and Klaassen, C.D., eds. *Cassarett and Doul's Toxicology*, 4th edition, 1991.
c. Target organ and effects summarized from Klaassen, C.D., ed. *Cassarett and Doul's Toxicology*, 5th edition, 1996.
d. Target organ and effects summarized from Wexler, P., ed. *Encyclopedia of Toxicology*, Volumes 1-3, 1998.

12.1.3 Environmental Effects of MP&M Pollutants

Ecological impacts of MP&M pollutants include acute and chronic toxicity to aquatic receptors by dozens of pollutants present in MP&M effluents, ***uptake*** of certain pollutants into aquatic food webs, sublethal effects on metabolic and reproductive functions, habitat degradation from turbidity, eutrophication, dissolved oxygen depletion, and loss of prey organisms. Metals are of particular concern to this regulation because they (1) do not volatilize, (2) do not biodegrade, (3) can be toxic to plants, invertebrates and fish, (4) adsorb to sediments and (5) bioconcentrate in biological tissues.

EPA obtained the environmental fate and toxicity information for the 132 MP&M POCs. Table E.1 in Appendix E shows the environmental fate and toxicity of each MP&M pollutant.[3] EPA found that:

- 56 pollutants are not volatile or are only slightly volatile (all metals were assumed to be non-volatile except for mercury);
- 57 pollutants have moderate to high adsorption potentials (all metals were assumed to have high adsorption potential except for nickel);
- 42 pollutants have moderate to high bioconcentration factors;
- 62 pollutants biodegrade slowly or are resistant to biodegradation altogether (all metals were assumed to be resistant to biodegradation);
- For freshwater environments, 32 pollutants have acute toxicities to aquatic life that range from moderate to high, and 33 pollutants have chronic toxicities that range from moderate to high;
- For saltwater environments, 20 pollutants have acute toxicities to aquatic life that range from moderate to high, and 23 pollutants have chronic toxicities that range from moderate to high.

The available information shows that dozens of the MP&M POCs have the potential to pose significant hazards to the aquatic environment when released to receiving waters. A number of pollutants are of particular concern because of their combined toxicity and fate. These include several polyaromatic hydrocarbons (acenaphthene, anthracene, 3,6-dimethyl-phenanthrene, fluoranthene, phenanthrene, and pyrene), several metals (aluminum, cadmium, copper, mercury, and selenium) and several phthalates (di-n-octyl phthalate, butyl benzyl phthalate, and di-n-butyl phthalate). Other pollutants are of concern chiefly because of their toxicity (arsenic, cyanide, chromium, lead, nickel, silver, and zinc) or their fate (bis(2-ethylhexyl)phthalate, bromo-2-chlorobenzene, bromo-3-chlorobenzene, dibenzofuran, dibenzothiophene, diphenylamine, long-chained petroleum hydrocarbons, 1-methylfluorene, N-nitrosodiphenylamine, and several metals).

The available fate and toxicity data indicate that many MP&M pollutants tend to (1) be "toxic", (2) not readily volatilize from the water column, (3) adsorb to sediments, (4) bioconcentrate in aquatic organisms, and (5) do not biodegrade. Such pollutants accumulate in sediments and reach concentrations which can impair ***benthic*** communities. Pollutants that have accumulated in sediments can be released back into the water column

[3] Note that EPA was unable to obtain fate or toxicity data for a substantial number of POCs.

because sediments act as long-term sinks. The pollutants can also enter soils and reach high levels over time if present in sewage sludge that is applied to land. The tendency of these pollutants to resist biodegradation and to bioconcentrate in biological tissue also causes them to be taken up into aquatic food chains where they can affect predators or humans who consume fish and shellfish (U.S. EPA, 1998).

The toxicity data also indicate that a sizable number of the POCs in MP&M effluents have toxicities that result in lethal or sub-lethal responses in aquatic receptors, including algae, ***vascular plants***, invertebrates, fish and amphibians. Responses include death, which may occur within a matter of hours to days, or longer-term sublethal responses (such as reproductive failure or growth impairment) that manifest themselves over weeks, months, or even years. The effects of toxic chemicals are not shared equally among exposed species: sensitive species are typically more affected than species that are more resistant. Hence, toxic conditions could selectively remove sensitive species from receiving waters. Such a pattern is of particular concern to ***threatened and endangered* (T&E)** species, which may already be close to extinction. Aquatic receptors are exposed to many different toxicants at the same time, which may have additive effects. The EPA assessment is based on a chemical-by-chemical approach and therefore does not consider additive effects. This approach may understate the benefits of the rule.

EPA also did not evaluate the potential fate and effects of the four conventional pollutants (BOD, pH, O&G, TSS) and several other pollutants, including ***Total Petroleum Hydrocarbon* (TPH)**, ***Total Kjeldahl Nitrogen* (TKN)**, phosphorus, and ***chemical oxygen demand* (COD)**, which may nonetheless adversely affect aquatic environments.[4,5]

- Effluents with high levels of BOD or COD consume large amounts of dissolved oxygen in a short time, causing surface waters to become oxygen-depleted, thereby killing or excluding aquatic life (U.S. EPA, 1986). At current discharge levels, MP&M facilities discharge 414 million pounds of BOD per year.
- Low pH (high acidity) water can be lethal to aquatic organisms; sensitive species of fish and invertebrates are eliminated from surface waters at pH's between 6.0 and 6.5 (U.S. EPA, 1999).
- O&G and TPH can have lethal effects on fish by coating gill surfaces and causing asphyxia, depleting dissolved oxygen levels due to excessive BOD, and impairing stream re-aeration due to the presence of surface films. Compounds present in O&G or TPH can also be detrimental to waterfowl by affecting the buoyancy and insulating capacity of their feathers (U.S. EPA, 1998). At current discharge levels, MP&M facilities discharge 221 million pounds per year of O&G, including 73 million pounds a year of TPH.
- TSS increases the turbidity of surface water and impairs underwater visibility and transparency, thereby inhibiting photosynthesis by diminishing the amount of sunlight that reaches algae or submerged aquatic plants. TSS also causes a general degradation of aquatic habitats by increasing the rate of sedimentation, which smothers eggs, covers aquatic plants, and affects benthic invertebrates (U.S. EPA, 1998).
- High input of nitrogen in estuarine and marine systems or phosphorus in freshwater systems can increase primary productivity and result in eutrophication. Such a process overloads surface waters with algae and reduces the transparency of the water column. The excess algae sink to the bottom and decompose at the end of their life cycle. This process consumes large amounts of dissolved oxygen and can turn surface waters anoxic (U.S. EPA, 1998; U.S. EPA, 1999).

12.1.4 Effects of MP&M Pollutants on Economic Productivity

Releases of large quantities or high concentrations of toxic pollutants in MP&M effluents may interfere with POTW processes (e.g., inhibiting microbial degradation), reduce the treatment efficiency or capacity of POTWs, and reduce disposal options for the sludge. In addition, toxic pollutants present in the effluent discharges may pass through a POTW and adversely affect receiving water quality, or may contaminate sludges generated during primary or secondary wastewater treatment. EPA expects that the proposed regulation will reduce interferences of operations and contamination of sewage sludge at POTWs receiving effluent discharges from MP&M facilities.

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[4] TKN is defined as the total of organic and ammonia nitrogen. It is determined in the same manner as organic nitrogen, except that the ammonia is not driven off before the digestion step.

[5] EPA, however, considered environmental effects of TKN in the Ohio case study. EPA evaluated the impact of in-stream TKN concentrations on recreational value of fishing, boating, swimming, and wildlife viewing sites. For detail see Chapter 22 of this report.

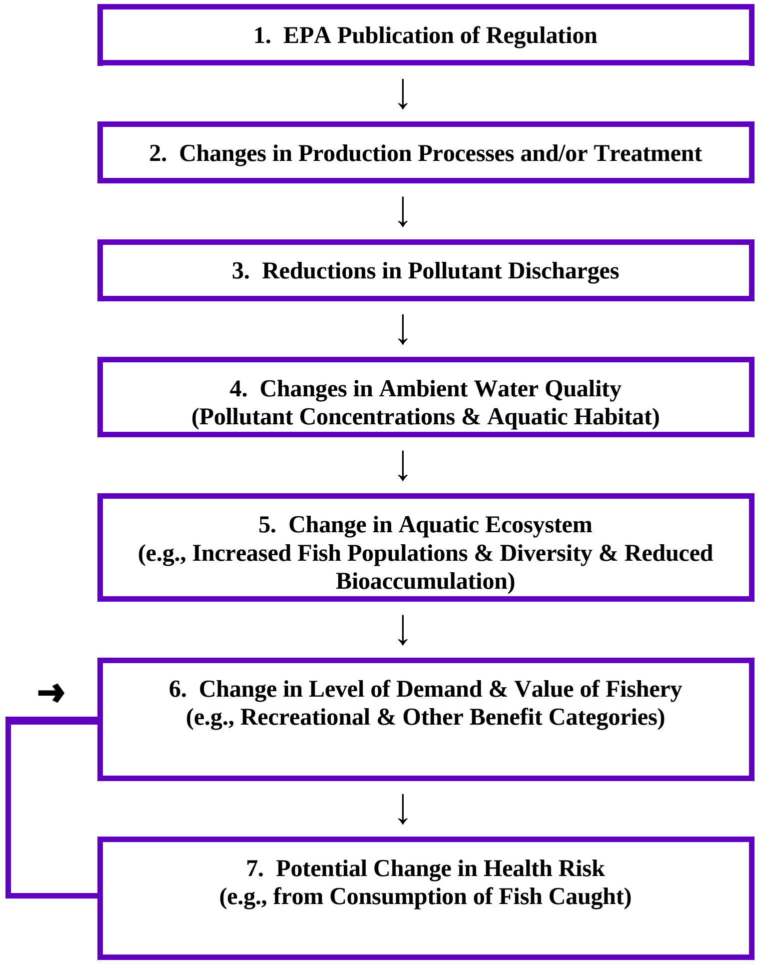
Because most MP&M pollutants associated with adverse health effects are subject to drinking water criteria, MP&M discharges to surface water can increase the cost of municipal water treatment by requiring investment in chemical treatment and filtration. Public water treatment systems must comply with drinking water criteria MCLs and secondary standards. Compliance may require treatment to reduce the levels of regulated pollutants below their MCLs. Capital investment and operating and maintenance (O&M) costs associated with treatment technologies can be substantial. To the extent that the proposed regulation reduces the concentration of MP&M pollutants in source waters to values that are below pollutant-specific drinking water criteria, public drinking water systems will accrue benefits in the form of reduced water treatment costs.

Releases of MP&M pollutants to surface waters may also increase treatment costs of irrigation water and industrial water.

12.2 Linking the Regulation to Beneficial Outcomes

This section describes the linkages between promulgation of a regulation and the expected benefits to society. As indicated in Figure 12.1, the benefits of the proposed regulation occur from a chain of events. These events include: (1) Agency publication of the regulation, (2) industry changes in production processes and/or treatment systems, (3) reductions in pollutant discharges, (4) changes in water quality, (5) changes in ecosystem attributes and sewage sludge quality, (6) changes in human responses, and (7) changes in human health and ecological risk. The first two events reflect the institutional and technical aspects of the regulation. The benefit analysis begins with the third event, the changes in the pollutant content of effluent discharges.

Figure 12.1: Chain of Events in a Benefits Analysis



Source: U.S. EPA analysis.

In event four, changes in pollutant discharges translate into improvements in water and sludge quality. In event five, these improvements in turn affect in-stream and near-stream biota (e.g., increased diversity of aquatic species and size of species populations) and sludge disposal options. Finally, human effects and the related valuation of benefits occur in events six and seven. For example, improvements to recreational fisheries and enhanced enjoyment by recreational anglers is connected to improved water quality and the value of reduced risk to human health. These linkages are the basis of the benefits analysis presented in this and the following chapters.

12.3 Qualitative and Quantitative Benefits Assessment

A benefit assessment defines and quantifies the types of improvements to human health and ecological receptors that can be expected from reducing the amount of MP&M pollutants released to the environment. The following sections provide an overview of the concepts and analytic approaches involved in the benefits assessment. The first section describes the general categories of benefits expected to result from the regulation and the level of analysis undertaken for them. The following three sections review, within the broad categories of benefits likely to be achieved by the MP&M regulation, the specific benefits that are evaluated in this analysis. Finally, Section 12.3.5 summarizes methods for attaching values to some of the benefit measures. Chapters 13 through 16 present the quantitative assessment of benefits.

12.3.1 Overview of Benefit Categories

The benefits of reduced MP&M discharges may be classified in three broad categories: human health, ecological, and economic productivity benefits. Table 12.3 summarizes the different types of benefits that fall in each of these categories. Each category is comprised of a number of more narrowly defined benefit categories. EPA expects that the MP&M regulation will provide benefits to society in all of these categories. EPA was not able to bring the same depth of analysis to all of these categories, however, because of imperfect understanding of the link between discharge reductions and benefit categories, and how society values some of the benefit events. EPA was able to quantify and monetize some benefits, quantify but not monetize other benefits, and assess still other benefits only qualitatively.

In addition to the national level benefits analysis, the Agency conducted a case study in the State of Ohio to provide in-depth analysis of the regulation's expected benefits. The Ohio case study improves on the national analysis in two ways. First, the analysis uses improved data and methods to address co-occurrence of MP&M facility benefits and other-source contributions of MP&M pollutants in the same locations. Second, the analysis of recreational benefits is based on original travel cost models of resource valuation in a random utility framework. The analysis values changes in the value of water resources for four recreational activities -- fishing, boating, swimming, and near-water recreation. Due to data limitations, only three of these four activities were valued at the national level benefits analysis.

To provide perspective on the extent to which this regulatory impact assessment was able to comprehensively analyze the benefits, Table 12.3 summarizes the specific benefits within each of the three broad benefit categories that are expected to accrue from the MP&M regulation and the level of analysis applied to each category. As shown in Table 12.3, only a few of the relevant benefit categories can be both quantified and monetized.

Table 12.3: Level of Analysis Performed for Specific Benefit Categories

Benefit Category	Quantified and Monetized	Quantified but Not Monetized	Qualitative
Human Health Benefits			
Reduced cancer risk due to ingestion of chemically-contaminated fish and unregulated pollutants in drinking water	X		
Reduced systemic health hazards (e.g. reproductive, immunological, neurological, circulatory, or respiratory toxicity) due to ingestion of chemically-contaminated fish and unregulated pollutants in drinking water		X	
Reduced systemic health hazards from exposure to lead from consumption of chemically-contaminated fish	X		
Reduced cancer risk and health hazards from exposure to unregulated pollutants in chemically-contaminated sewage sludge			X
Reduced health hazards from exposure to contaminants in waters used recreationally (e.g., swimming)			X
Ecological Benefits			
Reduced risk to aquatic life		X	
Enhanced water-based recreation including fishing, near-water recreation, and boating	X		
Other enhanced water-based recreation such as swimming, waterskiing, and white water rafting			X
Increased aesthetic benefits such as enhancement of adjoining site amenities (e.g. residing, working, traveling, and owning property near the water)			X
Nonuser value (i.e., existence, option, and bequest value)	X		
Reduced contamination of sediments			X
Reduced non-point source nitrogen contamination of water if sewage sludge is used as a substitute for chemical fertilizer on agricultural land			X
Satisfaction of a public preference for beneficial use of sewage sludge[a]			X
Economic Productivity Benefits			
Reduced sewage sludge disposal costs	X		
Reduced management practice and record-keeping costs for users of sewage sludge that meets exceptional quality criteria			X
Reduced interference with POTW operations		X	
Benefits to tourism industries from increased participation in water-based recreation			X
Improved commercial fisheries yields			X
Addition of fertilizer to crops (nitrogen content of sewage sludge is available as a fertilizer when sludge is land applied)[a]			X
Improved crop yield (the organic matter in land-applied sewage sludge increases soil's water retention)[a]			X
Avoidance of costly siting processes for more controversial sewage sludge disposal methods (e.g., incinerators) because of greater use of land application			X
Reduced water treatment costs for municipal drinking water, irrigation water, and industrial process and cooling water			X

a. Some of these benefit categories are accounted for and quantified under the "reduced sewage sludge disposal costs."

Source: U.S. EPA analysis.

Each category of benefits and the level of analysis applied to this category are discussed in greater detail below.

12.3.2 Human Health Benefits

Reduced pollutant discharges to the nation's waterways will generate human health benefits by several mechanisms. The most important and readily analyzed benefits stem from reduced risk of illness associated with the consumption of water, fish or other food that is taken from waterways affected by MP&M discharges. Human health benefits are typically analyzed by estimating the change in the expected number of adverse human health events in the exposed population resulting from a reduction in effluent discharges. While some health effects such as cancer are relatively well understood and thus may be quantified in a benefits analysis, others are less well characterized and cannot be assessed with the same rigor or at all.

EPA analyzed the following direct measures of change in risk to human health: incidence of cancer from fish and water consumption; reduced risk of non-cancer toxic effects from fish and water consumption; and lead-related health effects to children and adults. EPA was able to monetize only two of the three measures (cancer-related and lead-related health risks). Incidence of cancer was translated into an expected number of avoided mortality events and, on that basis, monetized. Lead impacts to children were evaluated in terms of potential intellectual impairment as measured by estimated changes in IQ. Changes in adverse health effects to adults from lead exposure were measured in terms of reduced risk of hypertension, non-fatal coronary heart disease, non-fatal strokes, and mortality.

EPA also quantified but did not monetize the expected reduction of pollutant concentrations in excess of health-based AWQC limits. This benefit measure was obtained by comparing in-waterway pollutant concentrations to toxic effect levels.

In concept, the value of these health effects to society is the monetary value that society is willing to pay to avoid the health effects, or the amount that society would need to be compensated to accept increases in the number of adverse health events. ***"Willingness-to-pay"*** **WTP** values are generally considered to provide a fairly comprehensive measure of society's valuation of the human and financial costs of illness associated with the costs of health care, losses in income, and pain and suffering of affected individuals and of their family and friends.

In some cases, available economic research provides little empirical data for society's WTP to avoid certain health effects. One component of the cost of an illness estimates the direct medical costs of treating a health condition (e.g., hypertension), and can be used to value changes in health risk from reduced exposure to toxic pollutants such as lead. These estimates represent only one component of society's WTP to avoid adverse health effects and therefore produce a partial measure of the value of reduced exposure to MP&M pollutants. Employed alone, these monetized effects will significantly underestimate society's WTP.

12.3.3 Ecological Benefits

EPA expects that the ecological benefits from the regulation will include protection of fresh- and saltwater plants, invertebrates, fish, and amphibians, as well as terrestrial wildlife and birds that prey on aquatic organisms exposed to MP&M pollutants. The regulation will reduce the presence and discharge of various pollutants and will enhance or protect aquatic ecosystems currently under stress. The drop in pollutant loading is expected to reestablish productive ecosystems in damaged waterways and to protect resident species, including T&E species. EPA also expects that the regulation will enhance the general health of fish and invertebrate populations, increase their propagation to waters currently impaired, and expand fisheries for both commercial and recreational purposes. Improvements in water quality will also favor increased recreational activities such as swimming, boating, and water skiing. Finally, the Agency expects that the regulation will augment nonuse values (e.g., option, existence, and bequest values) of the affected water resources.

It is frequently difficult to quantify and attach economic values to ecological benefits. The difficulty results from imperfect understanding of the relationship between changes in effluent discharges and the specific ecological changes, lack of water quality monitoring data for most locations, and time lags between water quality changes and changes in species population and composition. In addition, it is difficult to attach monetary values to these ecological changes because they often do not occur in markets in which prices or costs are readily observed. As such, ecological benefits may be loosely classified as nonmarket benefits. This classification can be further divided into nonmarket *use* benefits and nonmarket *nonuse* benefits.

Nonmarket use benefits stem from improvements in ecosystems and habitats, which in turn lead to enhanced human use and enjoyment of these areas. For example, reduced discharges may lead to increased recreational use and enjoyment of affected waterways in such activities as fishing, swimming, boating, hunting or near water activities such as bird watching. In some cases, it may be possible to quantify and attach partial economic values to ecological benefits using market values (e.g., an increase in tourism or boat rentals associated with improved recreational fishing opportunities); in this case, these benefit events might better be classified as economic productivity related events, which are discussed below. Economic markets, however, do not provide enough information to fully capture the value of these benefits. Such markets capture only related expenditures made by recreationists (e.g., food and lodging) and do not capture the value placed on the experience itself. A variety of nonmarket valuation techniques can be used to capture the value placed on the resource in question. These techniques include hedonic valuation (wage-risk studies) and ***travel cost methods*** **(TCM)**, stated preferences methods (i.e., ***contingent valuation*** **(CV)**, ***contingent rating*** **(CR)**, ***contingent activity*** **(CA)**), benefits transfer, and averting behavior models.

Nonmarket nonuse benefits are not associated with current use of the affected ecosystem or habitat, but rather arise from (1) the *realization* of the improvement in the affected ecosystem or habitat resulting from reduced effluent discharges and (2) the value that individuals place on the *potential for use* sometime in the future. Nonmarket nonuse benefits may also be manifested by other valuation mechanisms, such as cultural valuation, philanthropy, and bequest valuation. It is often extremely difficult to quantify the relationship between changes in discharges and the improvements in societal well-being associated with such valuation mechanisms. That these valuation mechanisms exist, however, is indisputable, as evidenced, for example, by society's willingness to contribute to organizations whose mission is to purchase and preserve lands or habitats to avert development.

12.3.4 Economic Productivity Benefits

Reduced pollutant discharges may also benefit economic productivity. First, economic productivity gains may occur through reduced costs to public sewage systems (POTWs) for managing and disposing of the sludge (i.e., biosolids) from treating effluent discharges. For example, higher quality sludge may be applied to agricultural land or otherwise beneficially used rather than being incinerated or disposed of in landfills. POTWs may also incur lower costs because of lower record keeping requirements.

Economic productivity benefits may also accrue from reduced treatment costs of drinking water, irrigation water, and industrial use water. Reduced pollutant concentrations in public water systems source water to levels at or below MCLs or secondary standards could reduce ongoing treatment costs and avoid the need to invest in treatment technologies in the future. Reduced pollutant discharges may also reduce sediment dredging costs. Contaminated sediments may contribute substantially to contamination of aquatic biota and human exposure to human health toxicants. Controlling point source discharges of toxic pollutants can prevent sediment contamination and eliminate the need for future remediation (i.e., dredging) of contaminated sediments.

Other economic productivity gains may result from improved tourism opportunities in areas affected by MP&M discharges. Improved aquatic species survival may contribute to increased commercial fishing yield. When such economic productivity effects can be identified and quantified, they are generally straightforward to value because they involve market commodities for which prices or unit costs are readily available.

Although some of these improvements can be seen as cost savings (i.e., reduced treatment and disposal costs), and could be included in the economic cost analysis rather than in the benefits analysis, they are treated in this analysis as a benefit of the proposed effluent guideline and not included in the cost analysis.

12.3.5 Methods for Valuing Benefit Events

Some of the benefits expected from the MP&M regulation will manifest themselves in economic markets through changes in price, cost, or quantity of market-valued activities. For benefits endpoints traded in markets, such as increased yields from commercial fisheries, benefits can be measured by market prices or market-based factor pricing. Competitive prices can be also used to measure ***avoided cost*** type of benefits. For example, reduced pollutant loadings to public water supplies may lower costs of drinking treatment. Similarly, improved sludge quality resulting from the MP&M regulation would translate into an observable reduction in sludge disposal costs for some POTWs (see Chapter 16). Finally, market prices can be used to value direct medical costs of illnesses associated with exposure to pollutants. For this analysis, we used medical costs associated with treating hypertension, coronary heart disease, and stroke to estimate benefits from reduced exposure to lead (see Chapter 14). The estimated values can be used as minimum measures of the benefits associated with reduced cases of these illnesses.

In other cases, benefits involve activities or sources of value that either do not involve economic markets or involve them only indirectly. Methods used to value such benefits are described briefly below:

a. Wage-risk approach.

The wage-risk approach uses regression estimates of the wage premium associated with greater risks of death on the job to estimate the amount that persons are willing to pay to avoid death. Benefit values based on this approach are used as part of the basis for valuing reduced cancer cases due to fish consumption in Chapter 13.

b. Travel cost method

The TCM uses information on the costs that people incur in traveling to and using a particular site to estimate a demand curve for that site. The demand curve is then used to estimate the "consumer surplus" associated with the use of the site, that is, the value that consumers receive from the site over and above the costs that they incur in using it. Consumer surplus is an estimate of the net benefits of the resource to the people using that resource. For example, if the resource is a recreational fishing site, the TCM can be used to value the recreational fishing experience. TCM is one of the approaches used to value recreational benefits in Chapter 15. The Agency also used an original travel cost study to value benefits from enhanced water-based recreation in Ohio (see Part IV: Chapter 21).

c. Contingent valuation

In the CV method, surveys are conducted to elicit individuals' WTP for a particular good, such as a fishery, or clean water. CV is more broadly applicable than TCM. Like TCM, CV can be used to estimate the consumer surplus associated with recreational fisheries. CV can also be used to estimate less tangible values, such as how much people care about a clean environment. Values from both the CV approach and the wage-risk approach support the estimated value of avoided death that is used to monetize reduced cancer cases from consumption of contaminated fish (Chapter 13). In addition, the analysis of recreational benefits in Chapter 15 uses a baseline value of the fishery that is derived from CV analysis.

d. Benefits transfer

When time and resource constraints preclude primary research, benefit assessment based on benefit transfer from existing studies is used. This approach involves extrapolating benefit findings for one analytic situation to another. The relevant study situations are defined by type of environmental resource (e.g., fishery), policy variable(s), and the characteristics of user populations. The benefits transfer approach is used to monetize several benefit categories, including changes in the incidence of cancer cases (Chapter 13) and the national-level benefits from enhanced water-based recreation (Chapter 15).

The techniques described above form the basis of the benefits methodologies described in Chapters 13,14 and 15.

GLOSSARY

acute toxicity: the ability of a substance to cause severe biological harm or death soon after a single exposure or dose. Also, any poisonous effect resulting from a single short-term exposure to a toxic substance. (See: chronic toxicity, toxicity.) (http://www.epa.gov/OCEPAterms/aterms.html)

adsorption coefficients (Koc): represents the ratio of the target chemical absorbed per unit weight of organic carbon in the soil or sediment to the concentration of that same chemical in solution at equilibrium.

ambient water quality criteria (AWQC): AWQC present scientific data and guidance of the environmental effects of pollutants which can be useful to derive regulatory requirements based on considerations of water quality impacts; these criteria are not rules and do not have regulatory impact (U.S. EPA. 1986. Quality Criteria for Water 1986. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, DC. EPA 440/5-86-001).

AQUatic Information REtrieval System (AQUIRE): a web-based ecotoxicity database maintained by EPA's Mid-Continent Ecology Division (MED) which summarizes ecotoxicity data retrieved from the literature. (http://www.epa.gov/med/databases/databases.html#aquire).

ASsessment Tools for the Evaluation of Risk (ASTER): an ecological risk assessment tool developed by EPA's Mid-Continent Ecology Division (MED); ASTER integrates information from the AQUIRE toxic effects database and the QSAR system (a structure activity based expert system) to estimate ecotoxicity, chemical properties, biodegradation and environmental partitioning. (http://www.epa.gov/med/databases/aster.html)

avoided cost: costs that are likely to be incurred in the future if current conditions still prevail at the time, but which will be avoided if particular actions are taken now to change the status quo.

benthic: relating to the bottom of a body of water; living on, or near, the bottom of a waterbody.

BIODEG: a web-based biodegradation database developed by Syracuse Research Corporation (http://esc.syrres.com/efdb/BIODGSUM.HTM).

biodegradation half-lives: represents the number of days a compound takes to be degraded to half of its starting concentration under prescribed laboratory conditions.

biological oxygen demand (BOD): the amount of dissolved oxygen consumed by microorganisms as they decompose organic material in an aquatic environment.

cancer potency slope factor (SF): a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen.

CHEMFATE: a web-based chemical fate database developed by Syracuse Research Corporation (http://esc.syrres.com/efdb/Chemfate.htm).

chemical oxygen demand (COD): A measure of the oxygen required to oxidize all compounds, both organic and inorganic, in water. (http://www.epa.gov/OCEPAterms/cterms.html)

chronic toxicity: the capacity of a substance to cause long-term poisonous health effects in humans, animals, fish, and other organisms. (http://www.epa.gov/OCEPAterms/cterms.html)

contingent activity: is one of the stated preference methods (see: contingent valuation and contingent activity). Survey respondents are asked how their behavior would change in response to a proposed change in one or more attributes of an activity (e.g., cost of the activity, site accessibility, or site attractiveness). Given responses to this type of question, and given information about incremental travel costs and value of time, a revealed preference method can be used to estimate the value of change.

contingent rating: is one of the stated preference methods (see: contingent valuation and contingent activity). Survey respondents are asked to rate several alternatives on an ad hoc utility scale (e.g., 1 to 10). The choice set of alternatives usually includes the environmental effect to be valued, substitutes for the effect, and a good with a monetary price to act as a threshold. Based on the respondent's rating of the environmental effect and the threshold good, and the monetary price of the threshold good, the value of the environmental effect can be determined.

contingent valuation (CV): a method used to determine a value for a particular event, where people are asked what they are willing to pay for a benefit and/or are willing to receive in compensation for tolerating a cost. Personal valuations for increases or decreases in the quantity of some good are obtained contingent upon a hypothetical market. The aim is to elicit valuations or bids that are close to what would be revealed if an actual market existed. (http://www.damagevaluation.com/glossary.htm)

Environmental Research Laboratory-Duluth fathead minnow database: a data base developed by EPA's Mid-Continent Ecology Division (MED) which provides data on the acute toxicity of hundreds of industrial organic compounds to the fathead minnow. (http://www.eoa.gov/med/databases/fathead_minnow.html)

hazardous air pollutant (HAP): compounds that EPA believes may represent an unacceptable risk to human health if present in the air.

Health Effects Assessment Summary Tables (HEAST): a comprehensive listing of provisional human health risk assessment data relative to oral and inhalation routes for chemicals of interest to EPA. Unlike data in IRIS, HEAST entries have received insufficient review to be recognized as high quality, Agency-wide consensus information (U.S. EPA. 1997. Health Effects Assessment Table; FY 1997 Update. EPA-540-R-97-036).

Henry's Law constant: a numeric value which relates the equilibrium partial pressure of a gaseous substance in the atmosphere above a liquid solution to the concentration of the same substance in the liquid solution.

human health-based water quality criteria (WQC): human health-based criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes (see AWQC). http://www.epa.gov/OCEPAterms/wterms.html)

hydrophobicity: having a strong aversion to water (http://www.epa.gov/OCEPAterms/hterms.html)

Integrated Risk Information System (IRIS): IRIS is an electronic data base with information on human health effects of various chemicals. IRIS provides consistent information on chemical substances for use in risk assessments, decision-making and regulatory activities.

lipophilicity: having a strong attraction to oils

maximum contaminant levels (MCLs): the maximum permissible level of a contaminant in water delivered to any user of a public system. MCLs are enforceable standards. (http://www.epa.gov/OCEPAterms/mterms.html)

metals: inorganic compounds, generally non-volatile, and which cannot be broken down by biodegradation processes. They are a particular concern because of their prevalence in MP&M effluents. Metals can accumulate in biological tissues, sequester into sewage sludge in POTWs, and contaminate soils and sediments when released to the environment. Some metals are quite toxic even when present at relatively low levels.

microbial metabolism: biochemical reactions occurring in living microorganisms such as bacteria, algae, diatoms, plankton, and fungi. POTWs make use of bacterial metabolism for wastewater treatment purposes. This process is inhibited by the presence of toxics such as metals and cyanide because these pollutants kill bacteria.

oil and grease (O&G): organic substances that may include hydrocarbons, fats, oils, waxes, and high-molecular fatty acids. Oil and grease may produce sludge solids that are difficult to process. (http://www.epa.gov/owmitnet/reg.htm)

pH: An expression of the intensity of the basic or acid condition of a liquid; Natural waters usually have a pH between 6.5 and 8.5. (http://www.epa.gov/OCEPAterms/pterms.html)

pollutants of concern (POCs): are the 150 contaminants identified by EPA as being of potential concern for this rule and which are currently being discharged by MP&M facilities.

priority pollutant (PP): 126 individual chemicals that EPA routinely analyzes when assessing contaminated surface water, sediment, groundwater or soil samples.

publicly-owned treatment works (POTWs): a treatment works, as defined by section 212 of the Act, that is owned by a State or municipality. This definition includes any devices or systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature. It also includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW Treatment Plant. (http://www.epa.gov/owm/permits/pretreat/final99.pdf)

quantitative structure-activity relationship (QSAR) model: an expert system which uses a large database of measured physicochemical properties such as melting point, vapor pressure and water solubility to estimate the fate and effect of a specific chemical based on its molecular structure. (http://www.epa.gov/med/databases/aster.html)

reference doses (RfDs): chemical concentrations expressed in mg of pollutant/kg body weight/day, that, if not exceeded, are expected to protect an exposed population, including sensitive groups such as young children or pregnant women.

secondary MCLs: human health-based drinking water criteria to assess the health hazards associated with the presence of certain toxic chemicals in drinking water. SMCLs are established for taste or aesthetic effects.

Superfund Chemical Data Matrix (SCDM): a source for factor values and benchmark values applied when evaluating potential National Priorities List (NPL) sites using the Hazard Ranking System (HRS). (http://www.epa.gov/superfund/resources/scdm/index.htm).

suspended solids: small particles of solid pollutants that float on the surface of, or are suspended in, waterbodies. (http://www.epa.gov/OCEPAterms/sterms.html)

systemic toxicants: chemicals that EPA believes can cause significant non-carcinogenic health effects when present in the human body above chemical-specific toxicity thresholds.

threatened and endangered (T&E): animals, birds, fish, plants, or other living organisms threatened with extinction by anthropogenic (man-caused) or other natural changes in their environment. Requirements for declaring a species endangered are contained in the Endangered Species Act.

Total Petroleum Hydrocarbon (TPH): a general measure of the amount of crude oil or petroleum product present in an environmental media (e.g., soil, water, or sediments). While it provides a measure of the overall concentration of petroleum hydrocarbons present, TPH does not distinguish between different types of petroleum hydrocarbons.

Total Kjeldahl Nitrogen (TKN): the total of organic and ammonia nitrogen. TKN is determined in the same manner as organic nitrogen, except that the ammonia is not driven off before the digestion step.

total suspended solids (TSS): a measure of the suspended solids in wastewater, effluent, or water bodies, determined by tests for "total suspended non-filterable solids." (See: suspended solids.) (http://www.epa.gov/OCEPAterms/tterms.html)

total suspended particles (TSP): a method of monitoring airborne particulate matter by total weight. (http://www.epa.gov/OCEPAterms/tterms.html)

travel cost method (TCM): method to determine the value of an event by evaluating expenditures of recreators. Travel costs are used as a proxy for price in deriving demand curves for the recreation site. (http://www.damagevaluation.com/glossary.htm)

uptake: the movement of one or more chemicals into an organism via ingestion, inhalation, and or trough the skin.

vascular plants: plants that are composed of, or provided with vessels or ducts that convey fluids. (www.infoplease.com)

willingness to pay (WTP): maximum amount of money one would give up to buy some good. (http://www.damagevaluation.com/glossary.htm)

ACRONYMS

AQUIRE: AQUatic Information REtrieval System
ASTER: ASsessment Tools for the Evaluation of Risk
AWQC: ambient water quality criteria
BIODEG: biodegradation
BOD: biological oxygen demand
CA: contingent activity
CHEMFATE: chemical fate
CR: contingent rating
CV: contingent valuation
COD: chemical oxygen demand
HAP: hazardous air pollutant
HEAST: Health Effects Assessment Summary Tables
IRIS: Integrated Risk Information System
Koc: adsorption coefficient
MCL: maximum contaminant level
O&G: oil and grease
POC: pollutant of concern
POTW: publicly owned treatment work
PP: priority pollutant
QSAR: quantitative structure-activity relationship
RfD: reference dose
SCDM: Superfund Chemical Data Matrix
SF: cancer potency slope factor
T&E: threatened and endangered
TCM: travel cost method
TKN: Total Kjeldahl Nitrogen
TPH: Total Petroleum Hydrocarbon
TSS: total suspended solids
WQC: human health-based water quality criteria
WTP: willingness-to-pay

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