EPA Document No. 822D23001

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A Standardized Framework for Sewage Sludge Chemical Risk Assessment

White Paper prepared for review by the EPA Science Advisory Board

March 2023

U.S. Environmental Protection Agency
Office of Water, Office of Science and Technology
Washington, DC

Notices

This document has been reviewed in accordance with U.S. Environmental Protection Agency (EPA) policy and approved for publication for the purpose of external peer review by the EPA Science Advisory Board (SAB).

This document provides an overview of the prioritization, risk screening, and probabilistic risk assessment framework of chemical pollutants found in sewage sludge. This document is not a regulation and does not impose legally binding requirements on EPA, states, tribes, or the regulated community, and might not apply to a particular situation based on the circumstances. Based upon peer-review and/or evolving availability of information, EPA may change this document in the future.

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1. List of Acronyms and Abbreviations

AMSA	Association of Metropolitan Sewerage Agencies
BER	bioactivity-to-exposure ratio
BST	Biosolids Tool
CCTE	Center for Computational Toxicology and Exposure
CFR	Code of Federal Regulations
CWA	Clean Water Act
DSSTox	Distributed Structure-Searchable Toxicity
DTXSID	Distributed Structure-Searchable Toxicity Substance Identifier
ECHO	Enforcement and Compliance History Online
EPA	U.S. Environmental Protection Agency
ExpoCast	Exposure Forecasting
HTT	High throughput testing
HTTK	High-throughput toxicokinetic
IAM	Information Availability Metric
IVIVE	*in vitro*-to-*in vivo* extrapolation
mdmt	Million Dry Metric Tons
NACWA	National Association of Clean Water Agencies
NAMs	New Approach Methodologies
NEBRA	North East Biosolids and Residuals Association
NRC	National Research Council
OW	Office of Water
ORD	Office of Research and Development
PCB	Polychlorinated biphenyls
PFAS	Per- and polyfluoroalkyl substances
PICS	Public Information Curation and Synthesis
POD	Point of departure
POTW	Publicly Owned Treatment Works
QSAR	Quantitative Structure–Activity Relationship
RfD	Reference Dose
SDM	Scientific Domain Metric
SEEM3	Systematic Empirical Evaluation of Models
TNSSS	Targeted National Sewage Sludge Survey
TER	TTC-to-exposure ratio
TSCA	Toxic Substances Control Act
SSI	Sewage Sludge Incinerators
TTC	Threshold of Toxicological Concern
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

2. Executive Summary

The U.S. Environmental Protection Agency's (EPA's) Office of Water (OW) has the responsibility under the Clean Water Act (CWA) to protect public health and the environment from adverse effects of pollutants that may be present in sewage sludge. The following framework is meant to facilitate this goal by evaluating risk from those chemical contaminants most likely to be of concern. This document presents a framework to prioritize chemicals identified in biosolids for assessment, perform an initial screening assessment, and then, if necessary, perform a refined risk assessment to determine the risks of chemicals in biosolids or sewage sludge to human health and the environment.

EPA periodically conducts nationwide sewage sludge surveys to measure the concentrations of pollutants and performs biennial surveys of the academic literature to identify additional chemicals that have been found in sewage sludge. Chemicals that have been identified in biosolids are prioritized using EPA's Public Information Curation and Synthesis (PICS) process (USEPA, 2021a). Following prioritization, EPA proposes to screen chemicals using the Biosolids Tool (BST), which can provide high-end exposure assessments (aka screening assessments) for a farm family and nearby ecological receptors. The BST is a user interface that connects agricultural use or surface disposal (i.e., sewage sludge landfill) with a set of previously peer reviewed EPA models for transport and exposure. This allows for the identification of the exposure pathways with the highest risk associated with a chemical and provides a problem formulation for a subsequent, more refined assessment of chemicals when indicated by risk levels. The BST also allows for the identification of chemicals that are unlikely to pose risks based on their concentration in biosolids because, in a screening mode, the BST estimates high-end exposures for human and ecological receptors. The screening assessment may be followed by a more refined assessment that will involve some (or all) of the following: further assessment of hazard and exposure parameters, additional review of environmental fate models, gathering of additional concentration data in biosolids, and/or a probabilistic risk assessment. Some models in the BST may also be used in refined assessment, e.g., with less conservative input parameters.

This document describes EPA's proposed prioritization process, application of the BST tool to screen chemicals found in sewage sludge and biosolids for human health and ecological risk, and the refined risk assessment (e.g., probabilistic assessment) that may follow for chemicals with exposures of concern after screening.

3. Introduction

Biosolids are a product of the wastewater treatment process. During wastewater treatment the liquids are separated from the solids. Those solids may then be treated physically and chemically to produce a semisolid, nutrient-rich product known as biosolids. The terms 'biosolids' and 'sewage sludge' are often used interchangeably, but in this document biosolids are meant to indicate the product of treated sewage sludge that is meant for land application.

Sewage sludge must meet federal and state requirements for beneficial use or disposal. Examples of beneficial use include application to agricultural land and reclamation sites (*e.g.*, mining sites). The main methods of sewage sludge disposal are landfilling and incineration.

As required by Section 405(d) of the Clean Water Act (CWA), the EPA's Office of Water developed a regulation to protect public health and the environment from any reasonably anticipated adverse effects of pollutants that might be present in sewage sludge. This regulation, *The Standards for the Use or Disposal of Sewage Sludge,* was published on February 19, 1993 (Vol. 58, No. 32 FR 9248, also known as 40 CFR Part 503 or "Part 503").

40 CFR Part 503 establishes 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 in a sewage sludge incinerator. The standards for each end use and disposal practice consist of general requirements, numerical limits on the pollutant concentrations in sewage sludge, management practices and, in some cases, operational requirements. They also include requirements for monitoring, record-keeping, and reporting.

There are over 14,600 publicly owned treatment works, servicing over 234 million people across the U.S. (USEPA, 2016b). Additionally, more than 1 in 5 households in the U.S. have private sewage systems (septic systems).[1]

EPA collects annual biosolids reports under Part 503 from roughly 2,500 larger facilities in the U.S. These annual biosolids reports are required by Part 503 for the larger public facilities[2] that land apply, incinerate, or landfill their sewage sludge in sewage sludge only landfills[3]. Biosolids annual reports are collected from the 41 states where EPA implements the Biosolids Program. There are currently nine states (Arizona, Idaho, Michigan, Ohio, Oklahoma, South Dakota, Texas, Utah, and Wisconsin) which are authorized through the NPDES Program to be the permitting authority for biosolids. EPA will transition to electronic reporting by December 2025 for the authorized states as part of Phase 2 implementation of the NPDES eRule. Based on the EPA annual biosolids reports from 2021, approximately 4.5 million dry metric tons of biosolids were produced in the U.S. in that year. Additional information from the EPA biosolids reports can be found in Figure 1.

[1] EPA Office of Wastewater Management https://www.epa.gov/septic/about-septic-systems

[2] Facilities that must report are Class 1 management facilities (POTWs with an approved pretreatment program); major POTWs (POTWs with a design flow rate greater than or equal to one million gallons per day); that serve 10,000 people or more; or are otherwise required to report by EPA or permitting authority.

[3] In the EPA the disposal of sewage sludge in a sewage sludge only landfill has commonly been called "surface disposal" (e.g., the text of Part 503) and is regulated under the CWA. Unfortunately, "surface disposal" sounds like "surface spreading" which is another term for land application of biosolids. In this paper and in the model "surface disposal" has frequently been used to maintain consistency with historical language, but for clarity, this paper also uses the term "sewage sludge landfill" to be clearer that a disposal method is being described.

Data from EPA Annual Biosolids Program Reports in 2021

Data gleaned from 2519 Publicly Owned Treatment Works (POTWs) in states where EPA is the permitting authority representing:

(1) Class 1 management facilities (POTWs with an approved pretreatment program)
(2) Major POTWs (a design flow rate greater than or equal to one million gallons per day)
(3) POTWs that serve 10,000 people or more
(4) Facilities otherwise required to report by EPA or permitting authority.

EPA estimates:

- 4.5 Million Dry Metric Tons (mdmt) of treated sewage sludge were generated.
- 1.96 mdmt biosolids were applied to land.
    - 1.15 mdmt to agricultural land
    - 0.796 mdmt to other land (e.g., home garden, landscaping, golf courses etc.)
    - 0.035 mdmt to reclamation land
- 1.9 mdmt biosolids were landfilled.
    - 1.8 mdmt in a municipal solid waste landfill (MSW)
    - 0.095 mdmt surfaced disposed of in a sewage sludge landfill
- 0.633 mdmt biosolids were incinerated.
- 0.057 mdmt biosolids were managed via other practices (deep well injection, storage, syngas and other).

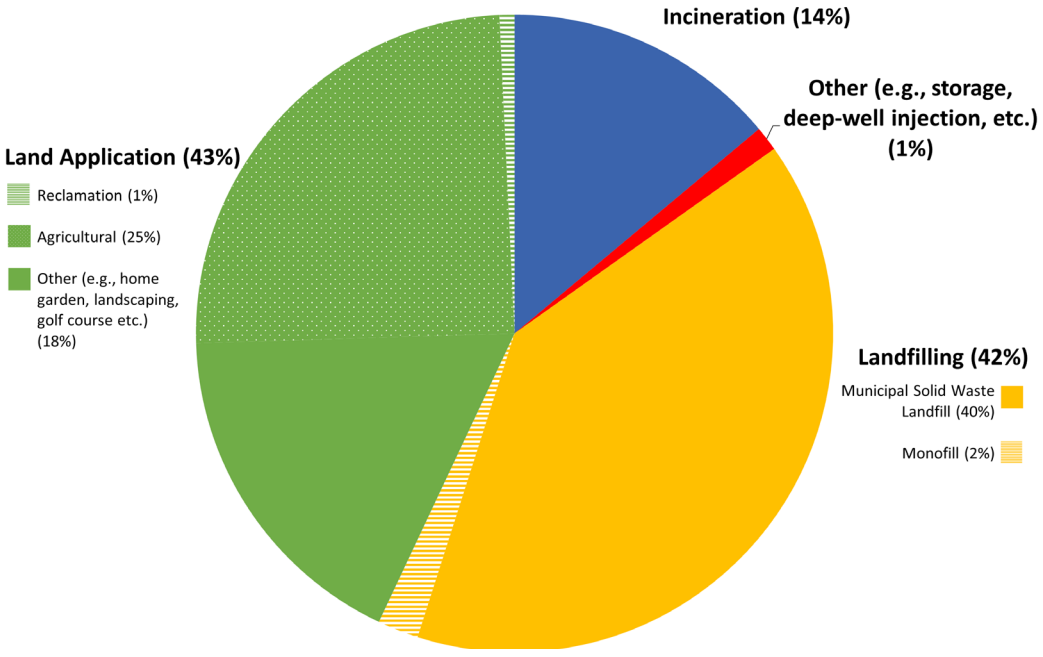

Figure 1. Distribution of biosolids beneficial use (land application) and sewage sludge disposal (landfilling and incineration) from biosolids annual reports covering available in Enforcement and Compliance History Online (ECHO)

Because EPA does not receive data from states that are authorized to implement the biosolids program, nor smaller facilities, nor facilities that send all their sewage sludge to municipal solid waste landfills,

there is no definitive source that reports the amount of biosolids produced annually in the United States. An alternate source of data collected as part of the National Biosolids Data Project conducted by the Northeast Biosolids and Residuals Association (NEBRA) survey from 2018 showed that about six million dry metric tons of treated sewage sludge are produced in the U.S. annually (Beecher, 2022). An earlier survey by NEBRA estimated that the smaller facilities not required to submit annual biosolids reports generate about eight percent of the total flow generated in the U.S. (NEBRA, 2007) These smaller treatment facilities tend to place sewage sludge in a lagoon for treatment and transport untreated solids to larger wastewater treatment plants.

Section 405(d)(2)(C) of the CWA directs EPA to review, not less than every two years, existing regulations "for the purpose of identifying additional toxic pollutants and promulgating regulations for such pollutants . . .." The biennial reviews are part of EPA's actions to meet this CWA requirement to identify pollutants in sewage sludge. One purpose of this draft risk assessment framework is to improve communication to the public about potential harm to human health and the environment from the pollutants identified in the biennial reviews or other monitoring activities.

EPA has determined that there are over 700 chemicals identified in biosolids (USEPA, 2021c). This number is based on EPA's eight biennial reviews of published literature covering 2004 through 2019 and three EPA national sewage sludge surveys.

- In 1988/89 (published in 1992), EPA conducted the first sewage sludge survey to obtain a current and reliable database on biosolids quality and management. (USEPA, 1988)
- In 2001 (published in 2007), EPA conducted a second sewage sludge survey to obtain national estimates of concentrations of dioxin and dioxin-like compounds in sewage sludge. (USEPA, 2001a)
- In 2006/07 EPA conducted a third sewage sludge survey (published in 2009 and 2021) to measure nationally representative concentrations of pollutants in sewage sludge. (USEPA, 2009a)

The over 700 chemicals identified in sewage sludge are not all found at the same time or in the same location but have been reported in at least one biosolids sample over the past 30 years. Chemicals that were found to be in biosolids based on the sewage sludge survey, particularly the 2006 survey, may have sufficient data for understanding the distribution of occurrence across the country.

Given the large number of chemicals identified in sewage sludge, EPA has updated risk assessment framework to efficiently evaluate chemicals and exposure pathways and identify those that need further review to determine chemicals that may require risk management actions. These steps are depicted graphically in Figure 2.

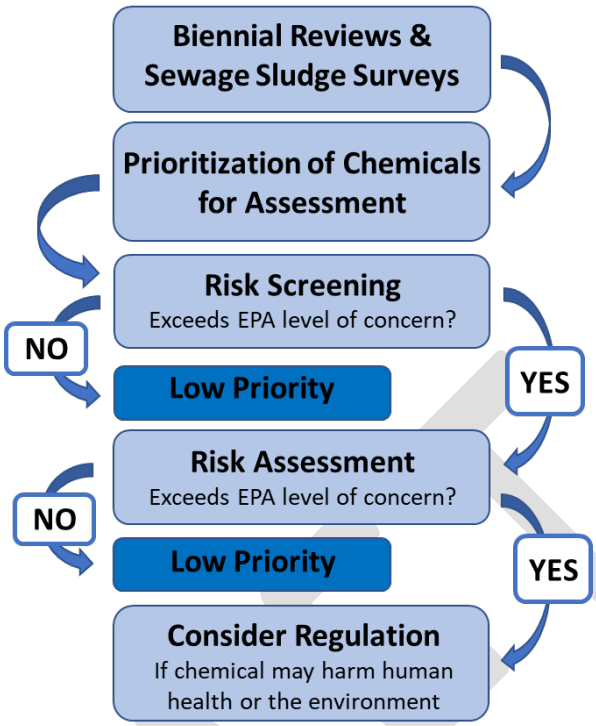

Figure 2. EPA's proposed prioritization and risk assessment framework for chemicals in sewage sludge and biosolids.

The first step in this framework is categorizing the chemicals detected in sewage sludge via EPA's biennial reviews and sewage sludge surveys. Next is prioritization, using the Public Information Curation and Synthesis (PICS) approach that provides a transparent and reproducible process that can identify high and low priority candidates among large chemical inventories for expert review.

This is followed by a screening risk assessment that is based on a high-end exposure scenario for a farm family and terrestrial and aquatic ecological receptors. Chemicals that have exposures that exceed levels of concern will move on to the fourth step which is a refined risk assessment, likely a probabilistic risk assessment. EPA will develop management practices for those chemicals that may cause harm to human health or the environment.

This updated framework should allow the EPA to prioritize and efficiently evaluate chemicals for their potential to cause harm to human health or the environment based on their concentration in biosolids. Chemicals may warrant re-assessment through this framework if hazard or exposure information change due to updates in the scientific literature or new monitoring data.

4. History of Biosolids Risk Assessment and Regulation

"Biosolids" in this paper is meant to indicate treated sewage sludge from the treatment of domestic wastewater in non-industrial treatment works. In February 1993, EPA published the standards for the Use or Disposal of Sewage Sludge (40 CFR Part 503). Part 503 provides general requirements, pollutant limits, management practices, operational standards (*i.e.*, technology requirements to reduce pathogens

and vectors) and requirements for the frequency of monitoring, record-keeping, and reporting, among others.

Ten pollutants are currently regulated in Part 503: arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, zinc, and molybdenum (USEPA, 1995a). To assess risk for these 10 chemicals EPA considered 14 exposure pathways resulting from the use and disposal of sewage sludge. Nine of the pathways assessed exposure to humans, two to animals, two to soil organisms, and one to plants. Results of the 1988/89 sewage sludge survey were used as an indication of the potential for human or environmental harm when compared with the outcome of the risk assessment. The risk assessments were summarized in "A Guide to the Biosolids Risk Assessments for EPA Part 503 Rule" (USEPA, 1995a).

In May of 1993, EPA created a candidate list of 31 pollutants for a second round of biosolids regulation (USEPA, 1996). Pollutants that were considered but not regulated under the February 1993 regulations (Round One) were again considered under Round Two (May 1993) for potential regulation. EPA conducted preliminary exposure analyses in a Comprehensive Hazard Identification process to determine which of the 31 pollutants should be on the final pollutant list for potential regulation under Round Two (USEPA, 1996). Three groups of pollutants were placed on the list for Round Two, all dioxin-like compounds: polychlorinated-p-dioxins, dibenzofurans, and dioxin-like coplanar polychlorinated biphenyls (PCBs). On December 15, 1999, EPA proposed a rule to establish numerical limits for dioxins and dioxin-like compounds (dibenzofurans, and co-planar PCBs) in sewage sludge applied to the land and proposed not to regulate them in sewage sludge disposed of in a sewage sludge landfill or fired in a sewage sludge incinerator (December 23, 1999, 64 FR 72045).

In 2000 and 2001, updated sewage sludge surveys were conducted to determine levels of these dioxin-like compounds in biosolids (sewage sludge) that are land applied (AMSA, 2000) (USEPA, 2001a) since the phase out of these compounds in commerce. These data were collected to assist EPA in developing scientifically sound assessments to inform regulatory decisions for these chemicals in land-applied biosolids.

On December 15, 2001, EPA promulgated a final notice of EPA's determination that numerical limits or management practices were not warranted for dioxins and dioxin-like compounds in sewage sludge disposed of in a sewage sludge landfill or incinerated in a sewage sludge incinerator (66 FR 66228). In October 2003, EPA promulgated in the Federal Register its decision not to regulate dioxin-like compounds in land-applied sewage sludge (66 FR 66227[4]). After five years of study, including independent external peer review, the Agency determined that dioxin-like compounds in land applied biosolids did not pose a significant risk to human health or the environment.

5. Risk Assessment Prioritization

To prioritize the chemicals identified in biosolids, EPA is proposing to use the PICS process described below. This effort aligns EPA's efforts to promote the use of new approach methodologies (NAMs) to reduce animal testing with the data needs of biosolids risk assessment (USEPA, 2020a). The goal of implementing NAMs is to increase the rigor and sophistication of Agency assessments while reducing

[4] https://www.federalregister.gov/documents/2001/12/21/01-31342/standards-for-the-use-or-disposal-of-sewage-sludge

the reliance on vertebrate animals to test chemicals. The Biosolids Program will use available data and computational toxicology tools to screen and prioritize chemical pollutants found in biosolids for risk assessment more efficiently.

5.1. Risk-based Prioritization using the Public Information Curation and Synthesis (PICS) Approach

EPA developed the Public Information Curation and Synthesis (PICS) approach (USEPA, 2020d) to support chemical risk assessment prioritization under the Toxic Substances Control Act (TSCA). The PICS approach integrates publicly available hazard, exposure, persistence, and bioaccumulation information from traditional methods and NAMs to characterize the overall degree of potential concern related to human health and the environment. PICS also describes the toxicity and exposure information available to rank chemicals based on risk and gaps in the full data set that a risk assessment would utilize. The PICS approach was designed to be readily adaptable to address prioritization needs under multiple statutes, including the biosolids regulations in Part 503.

To ensure that data for each of the over 700 chemicals identified in biosolids can be accessed, EPA's first step was to curate the list and make it available on the CompTox Chemicals Dashboard (Richard, 2004; Williams et al., 2017). EPA ensured that each chemical is identified with a CAS Registry Number and is mapped to a Distributed Structure-Searchable Toxicity (DSSTox) substance identifiers (DTXSIDs) in the ChemReg chemical registration system (Grulke, Williams, Thillanadarajah, & Richard, 2019). ChemReg is a database that underpins the CompTox Chemicals Dashboard. The chemicals EPA has identified that occur in biosolids from the past three sewage sludge surveys and biennial reviews are now tagged as part of the "Biosolids List" on EPA's CompTox Chemicals Dashboard (USEPA, 2021c).

The PICS approach utilizes metrics for prioritization in seven scientific domains:

1. human hazard-to-exposure ratio,
2. ecological hazard,
3. carcinogenicity,
4. genotoxicity,
5. susceptible populations,
6. persistence and bioaccumulation, and
7. skin sensitization and skin/eye irritation.

For each scientific domain, a workflow was developed that specifies what information is utilized and the logic of how it is integrated. The methodology underlying the individual workflows are designed to incorporate scientific advances in each discipline and differ from domain to domain. The domain-specific workflows are described in detail in the PICS White Paper (USEPA, 2020d). In general, for each domain data are prioritized from study types for which there is traditionally the most confidence in the regulatory toxicology community (*e.g.*, *in vivo*), followed by those with decreasing confidence depending on the context for use (*e.g.*, *in vitro, in silico*). The overall Scientific Domain Metric (SDM), reflecting the overall degree of potential concern related to human health and the environment, is determined by summing the results from the seven individual scientific domain workflows. The higher the SDM, the higher the chemical is prioritized for a screening assessment. A second metric, the Information Availability Metric (IAM), reflects the relative coverage of potentially relevant, publicly available human health and ecological toxicity and exposure information that could inform level of effort and resources that may be needed to evaluate the chemical. Therefore, the higher the IAM metric, the more comprehensive the available data set for that chemical.

The only domain that includes a quantitative exposure estimate is the human hazard-to-exposure ratio (HER) domain. The calculation of the human HER domain metric is based on a workflow that incorporates a tiered selection of hazard information as well as exposure estimates from the EPA model ExpoCast (Exposure Forecasting) (USEPA, 2018). The third generation ExpoCast Systematic Empirical Evaluation of Models (SEEM3) exposure model (Ring et al., 2019) is a meta-model that incorporates twelve different exposure predictors covering sources that are near[5]- and far-field[6] to estimate aggregate U.S. population median dose intake rate for a specific pollutant (USEPA, 2020d).

Points-of-departure (PODs) from dose-response curves from traditional *in vivo* toxicity studies are divided by the median ExpoCast intake rate estimate to provide a HER. When *in vivo* studies are not available, *in vitro* bioactivity estimates from ToxCast are converted into an oral dose equivalent using high throughput toxicokinetic (HTTK) approaches (Pearce, Setzer, Davis, & Wambaugh, 2017; Pearce, Setzer, Strope, Wambaugh, & Sipes, 2017). This value, called the *in vitro*-to-*in vivo* extrapolation (IVIVE) POD, is divided by the ExpoCast exposure estimate to provide a bioactivity-to-exposure ratio (BER) (Ring et al., 2019; Wetmore et al., 2015). Finally, when neither *in vivo* nor *in vitro* studies are available, the most relevant threshold of toxicological concern (TTC) value is assigned when appropriate and divided by the ExpoCast exposure estimate to provide a TTC-to-exposure ratio (TER) (Patlewicz, Wambaugh, Felter, Simon, & Becker, 2018) (USEPA, 2020d).

Although the exposure estimates from ExpoCast do not provide predictions of biosolids-specific scenarios (resulting from land application, sewage sludge landfill, or incineration of biosolids), they do simulate environmental exposure pathways from diet, water, and air that are relevant to biosolids exposure. Therefore, when combined with the available hazard information, the ExpoCast predictions allow for a ranking of chemicals in terms of the human health risk associated with known pathways, including those which may be most critical for biosolids. This approach also allows EPA to determine that some chemicals are not expected to present risk above the Agency's level of concern as a result of biosolids exposure if, for example, there are many orders of magnitude separation between the hazard and exposure values from direct exposure routes.

The remaining domains in the PICS approach account for evidence that a chemical is carcinogenic, genotoxic, persistent and bioaccumulative, and/or a skin sensitizer or skin/eye irritant. These factors can be important flags for risks of concern resulting from biosolids exposure. The susceptible population domain metric characterizes the potential for differential exposure between children and the general population. This domain is only tangentially relevant to biosolids exposure, as it quantifies evidence of a chemical's presence in media such as children's products, breastmilk, and residential dust. However, like the exposure data from ExpoCast in the human hazard-to-exposure ratio domain, it may provide context as to whether additional exposure from biosolids could be an important factor in the aggregate.

5.2. PICS Results

In February 2021, the PICS process was applied to the chemicals that have been reported in biosolids (USEPA, 2021a). A plot summarizing the scientific domain and information availability metrics for these

[5] Near-field represents exposures occuring proximal to use-field (e.g., sources inside the home, for example from consumer products).

[6] Far-field represents exposures occuring far from use or as a result of environmental emission (e.g., ambient sources outside the home, for example from industrial releases).

chemicals is in Figure 3. The full list of chemicals[7] with their scientific domain metrics and information availability metrics is in Appendix A. The currently regulated chemicals and chemicals prioritized for risk assessment in 2003 as part of the National Research Council (NRC) review in 2002 (NRC, 2002) (USEPA, 2003a) are indicated on the plot to show how they compare to the proposed PICS risk assessment prioritization process. The regulated and prioritized chemicals from 2003 have an information availability metric that is in the top half of the possible range for the metric. The scientific domain metric for these chemicals has a wider range, indicating a variability in concern for impacts on human health and/or the environment. This range is not unexpected due to the variability in the data available across chemicals, variation in prioritization approaches used previously, and depth of review between the time of the initial regulation in 1993 and more recent prioritization efforts.

A similar analysis done with TSCA chemicals in 2021 (USEPA, 2021a) showed that there is an association between information availability and scientific domain metric (*i.e.*, more information tends to produce a higher value, meaning more concern for impacts on human health and/or the environment) (USEPA, 2020d). This may be a result of testing or publication bias. Chemical substances that are expected to show or have previously shown indications of hazard can lead to more data being generated by the scientific community, while those that are not expected to show high hazard or show low hazard values in initial tests are less likely to be tested further. Additionally, there is a publication bias towards positive results as most peer-reviewed publications do not describe negative results. However, a lack of available data does not indicate a lack of toxicity, particularly for emerging contaminants and new chemicals.

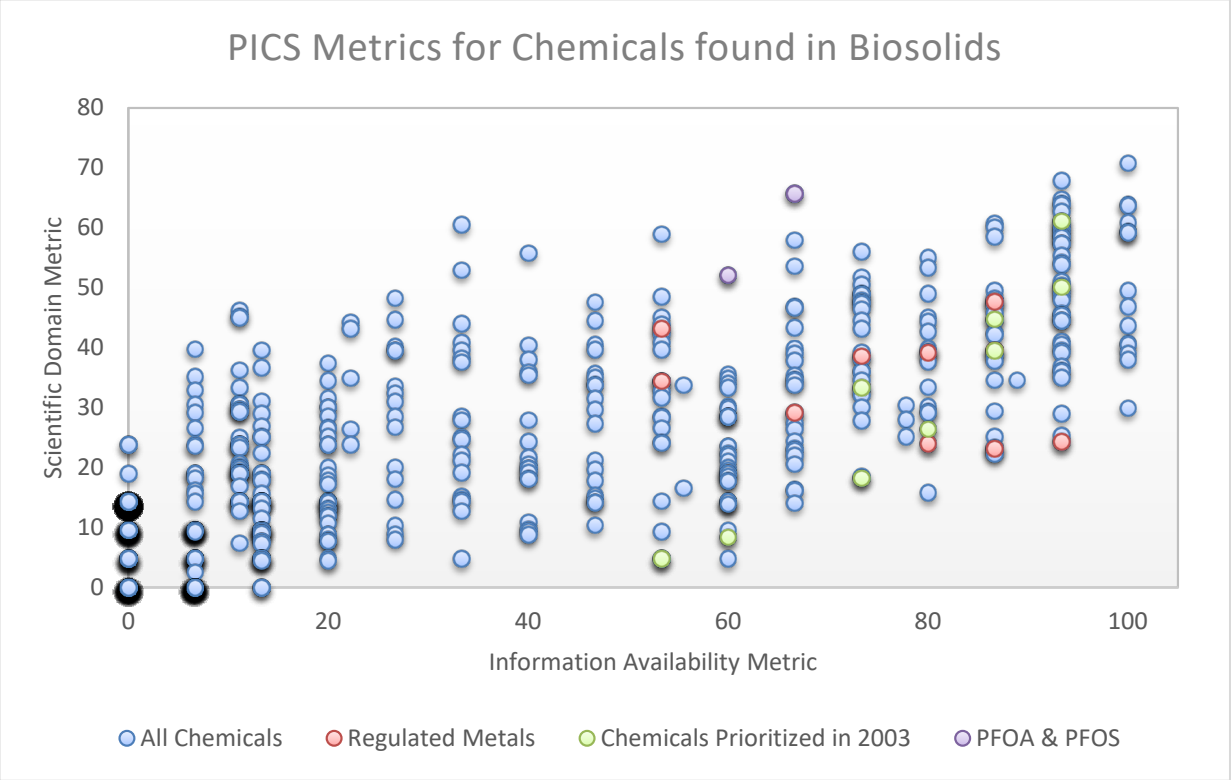

Figure 3. Plot of the information availability vs. scientific domain metrics for the master list of chemicals measured in biosolids. Each dot represents one chemical substance, with overlap indicated

[7] PICS ran the full list of chemicals as of February 2021, small changes may have taken place to the list of chemicals since then.

by a shadow. The regulated chemicals (mainly metals) are red. The chemicals prioritized for risk assessment in 2003 are yellow (note: molybdenum is on both lists and is in red on this plot).

EPA will begin by evaluating a set of chemicals from both the highest ranked chemicals by PICS for screening and a set of chemicals that were amongst the lower ranked chemicals. This should provide an indication of the performance of the PICS prioritization method and could indicate if certain factors need to be weighted more heavily in future prioritization.

5.3. Future Prioritization Methodology Improvements

EPA is planning several projects to modify biosolids exposure estimates used in screening (e.g., the human hazard-to-exposure ratio (HER)) using an exposure value specific to biosolids. EPA will identify conservative exposure parameters (e.g., biosolids application rate, weather) and exposure pathways (e.g., dietary exposure) to define a high-end human exposure dose based on the most sensitive chemical property inputs. Chemical properties will be identified using EPA's CompTox Chemicals Dashboard. The same concept can be applied to the ecological risk pathway by calculating high-end ecological exposure values for aquatic and terrestrial organisms using the BST. If the PICS ecological hazard domain identifies an *in vivo* or Quantitative Structure–Activity Relationship (QSAR)-based point of departure, EPA can compare the biosolids-specific ecological exposure estimate to the PICS ecological hazard domain to create an ecological hazard-to-exposure ratio. Together, these ratios will enable EPA to prioritize the chemicals found in biosolids for human and ecological risk using inputs that result in a tailored, high-end estimate for risks associated with chemicals in biosolids.

Additionally, EPA is working on a model for estimating concentrations of chemicals in biosolids based on existing biosolids concentrations coupled with data on releases and production volumes for those chemicals. This model will allow the Agency to calculate human health and ecological exposure estimates for chemicals on the "Biosolids List" on EPA's CompTox Chemicals Dashboard that do not have comprehensive measured concentration data (*e.g.*, chemicals identified through biennial reviews or with outdated concentration data) or for chemicals without any measured data in biosolids. This could lead to identification of chemicals that warrant being added to a future sewage sludge survey or for other monitoring efforts by the EPA or external groups.

6. Screening-level Exposure Estimation and Risk Calculations

Following risk assessment prioritization for chemicals found in biosolids, the second step is to conduct a screening-level risk assessments of the prioritized chemicals. This screening-level risk assessment is deterministic and uses point values and models to produce an estimate of exposure for a high-end exposure scenario using the BST. Deterministic assessments are relatively simple to carry out, often use readily available data, and produce results that are straightforward to interpret. Not all pollutants found in biosolids present a clear and defined risk, and EPA must be able to prioritize evaluation of chemicals that have the greatest risk to human health and the environment. The deterministic BST will allow EPA to identify chemicals that EPA should advance for refined assessment as well as those that are unlikely to present risk above EPA's levels of concern for human health and the environment, based on currently available data. EPA can then conduct more resource-intensive, refined assessments for chemicals that exceed levels of concern at the screening level.

This section presents the BST framework, conceptual models, and the selection process for the components of the model. The BST is a composite model that allows the user to enter biosolids information into an existing set of environmental transport models. (The model and User Guide describe these in greater detail and are provided separately as supporting documents for the EPA Science Advisory Board (SAB)). The selection of the chemical specific inputs is described in the appendices to the model user's guide. The human health and ecological toxicity values used in the screening process should not be viewed as final regulatory values. The results of the risk screen are used in prioritization of chemicals for refined (e.g., probabilistic) risk assessment and are not a final determination of risk. Toxicity and fate and transport values may be modified when used in refined risk assessments. In addition, pathways may be refined to focus the refined risk assessment on those most relevant to a chemical in the screening process. The BST and the refined assessment will be based on the same modeling framework, but the BST runs this framework in a deterministic mode using high-end inputs for key parameters.

6.1. Biosolids Tool Framework

Error! Reference source not found.4 provides an overview of the BST conceptual framework. This figure illustrates how source, fate and transport, and exposure and risk models are linked and how input and output data transfers are integrated to support the characterization of high-end exposures and risks. As shown in Error! Reference source not found.4, the framework has a modular design that facilitates modeling of exposures and risks associated with the range of regulated management practices or "sources" for biosolids.

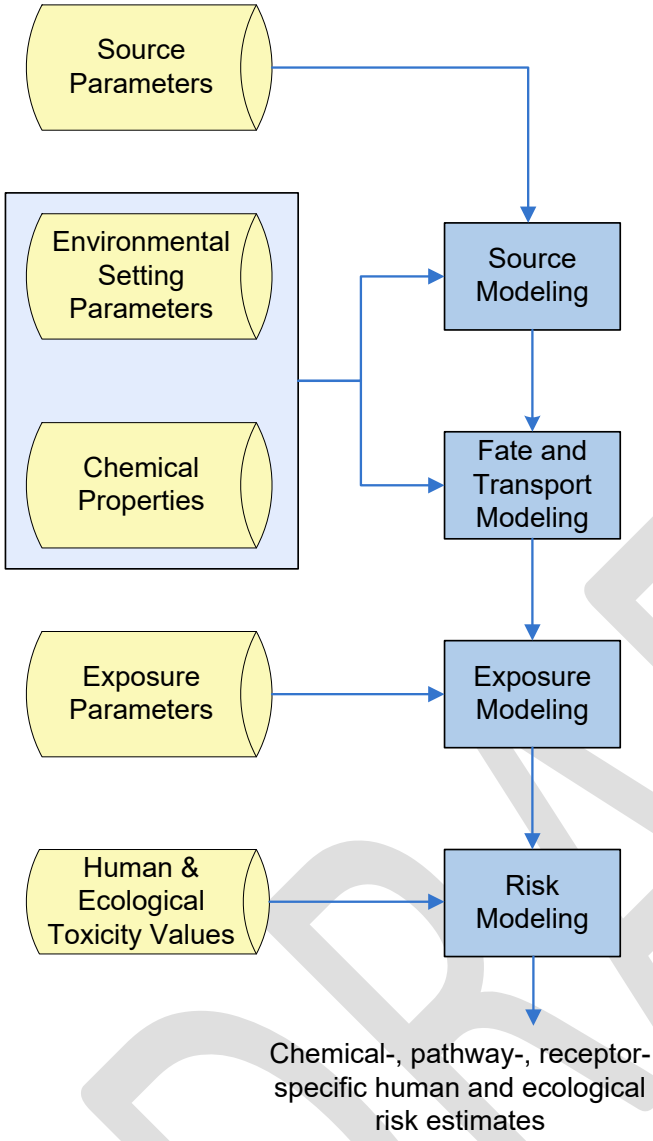

Figure 4. Overview of BST conceptual framework.

At this time, the BST model has been parametrized to screen for risks from land application of biosolids used as nutrients for fertilizing crops (agricultural land application) and for land reclamation, as well as to screen for risks from sewage sludge landfills. The agricultural land application management practice represents the most complex scenario in terms of the number of potential exposure pathways of interest.

Surface disposal of sewage sludge (i.e., sewage sludge landfill) practices regulated under Part 503 include disposal in a sewage sludge-only landfill. Municipal solid waste landfills are regulated under the Resource Conservation and Recovery Act (RCRA) and not under the CWA. The surface disposal scenario in BST includes a subset of the pathways captured by the land application scenarios.

Although the BST model is parameterized only for land application and surface disposal at this time, it does contain an air model that can be adapted to estimate incineration and would require parameterization of a scenario representing operation of a sewage sludge incinerator (SSI).

Parameterization for incineration in SSIs will requires defining operating conditions of SSIs, dispersion modeling inputs, destruction removal efficiencies, and exposures. Further collaboration with other EPA offices including the Office of Air and Radiation is needed to address these questions before the BST is operational to screen for risks associated with incineration.

6.2. Conceptual Models

Conceptual models for the BST (Figures 5, 6, and 7) represent major transport mechanisms and the primary routes of exposure that will be modeled. The four major transport mechanisms of interest are: (1) air transport (dispersion and deposition of vapor phase and dust); (2) runoff and erosion to surface water; (3) leaching to groundwater; and (4) plant uptake. The conceptual models contain exposure pathways that expand on the four transport mechanisms. Therefore, as described in Section 6, the same exposure models can be applied to each application scenario. Different exposure factors and toxicity values are applied to human versus ecological receptors for risk calculations. The land reclamation scenario exposure pathways are the same as the pasture scenario but involves a larger one-time application of biosolids at the beginning of the simulation instead of yearly applications. There is no ecological conceptual model for the surface disposal scenario because there are no ecological exposure pathways modeled for landfilling sewage sludge.

Based on the model results the significance of each exposure pathway is expected to vary by chemical. For example, chemicals with higher vapor pressures and/or Henry's law constants could be more relevant to the pathways involving volatilization, whereas leaching to groundwater will likely be important for hydrophilic chemicals. Conceptual models are presented for human and ecological exposure for land application and surface disposal.

As indicated in the figure captions, the dashed arrows and dashed box outlines indicate exposure pathways that have been added to the conceptual models since 1993, when EPA completed the risk assessments that supported the Part 503 rule. These added exposure pathways reflect the expansion of exposure modeling to the risk assessment framework. The pathway numbers 1 through 14 are also matched to the pathways modeled in the 1993 risk assessments (USEPA, 1995a). Numbers above 14 indicate pathways that have been added. The major additions are surface run-off from the farm field contaminating a pond and exposures to chemicals that deposit from the air to surface water and soil.

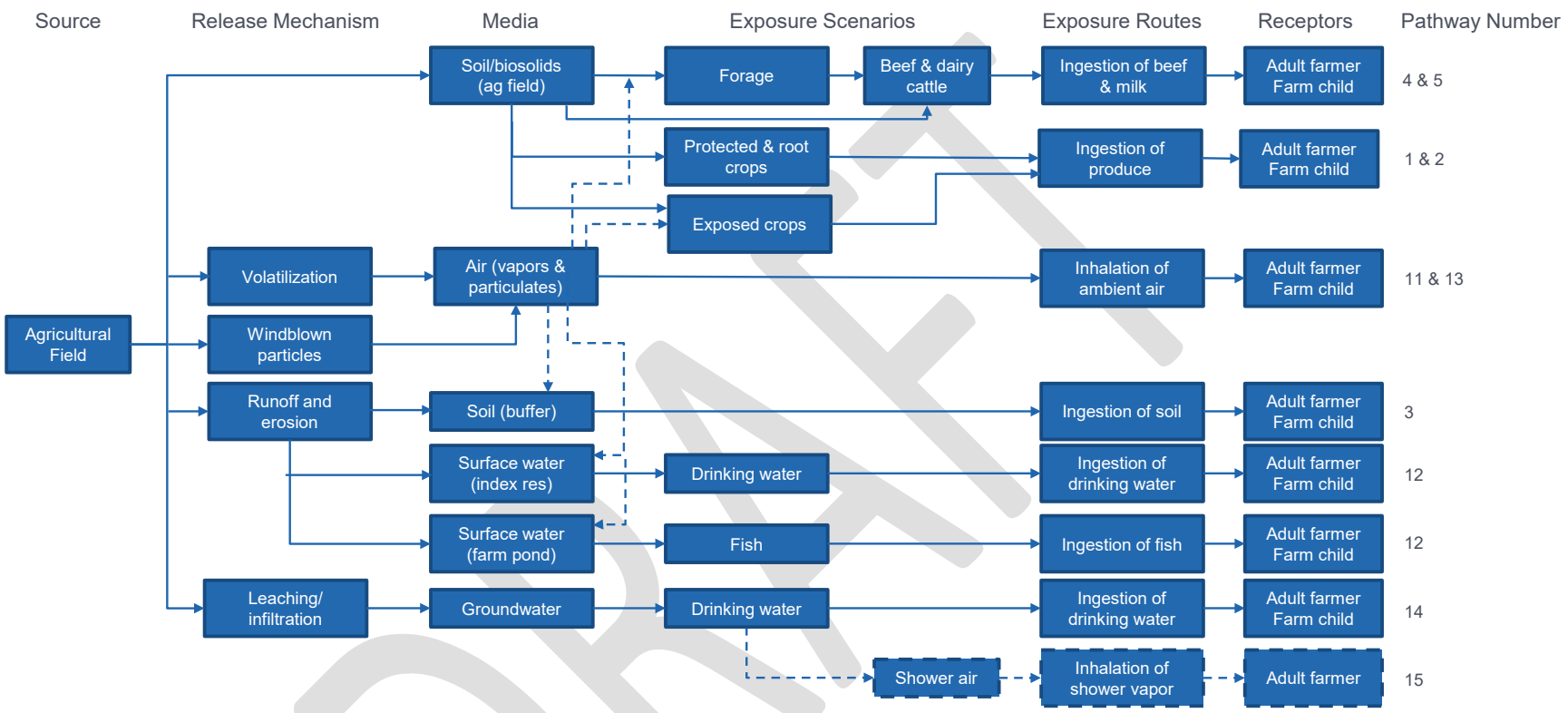

Figure 5. Conceptual model for the agricultural land application scenario and land reclamation scenario for human exposures. Dashed arrows and box outlines indicate a pathway or route that has been added since 1993 (when risk assessments that supported the Part 503 rule were completed).

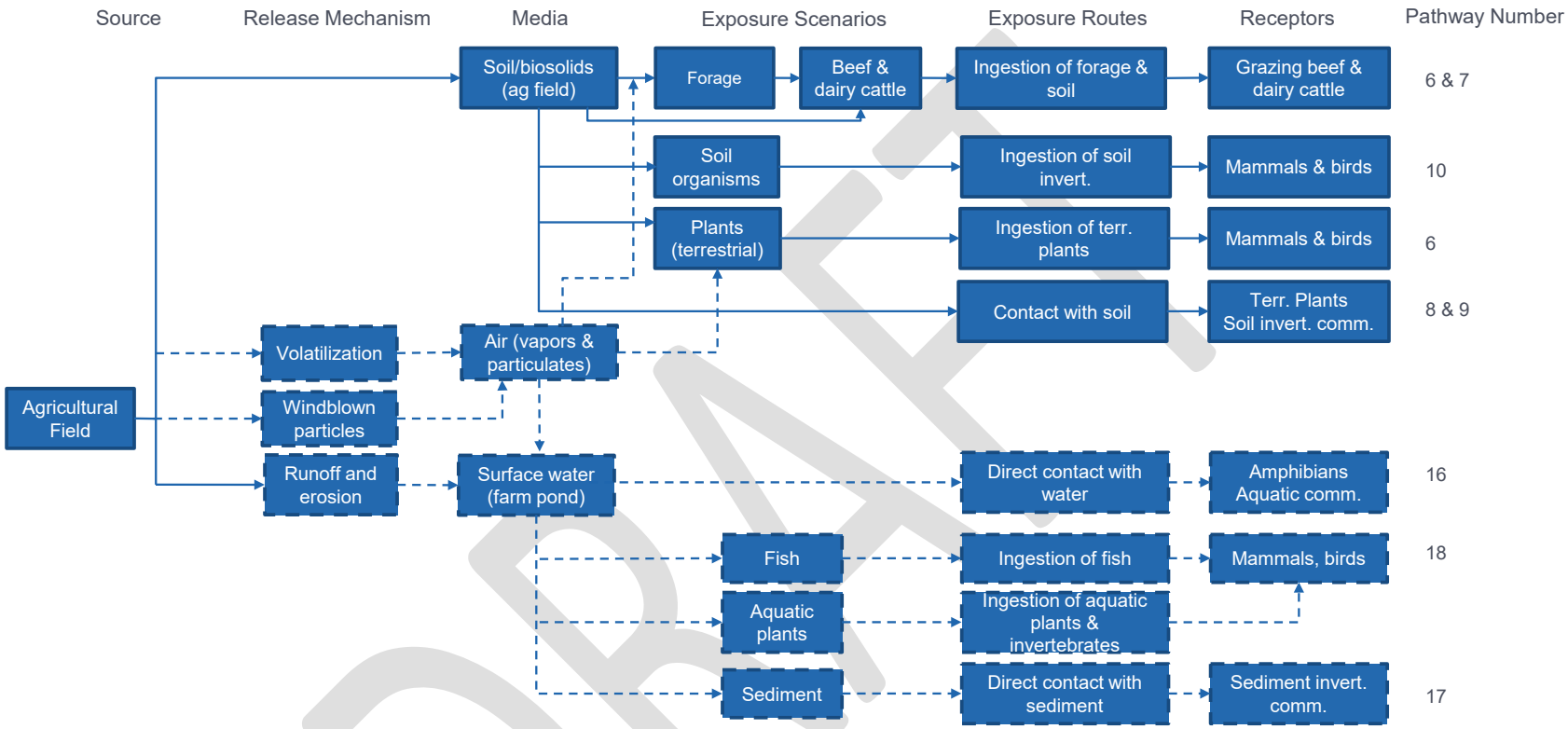

Figure 6. Conceptual model for the agricultural land application scenario and land reclamation scenario for ecological exposures. Dashed arrows and box outlines indicate a pathway or route that has been added since 1993 (when risk assessments that supported the Part 503 rule were completed).

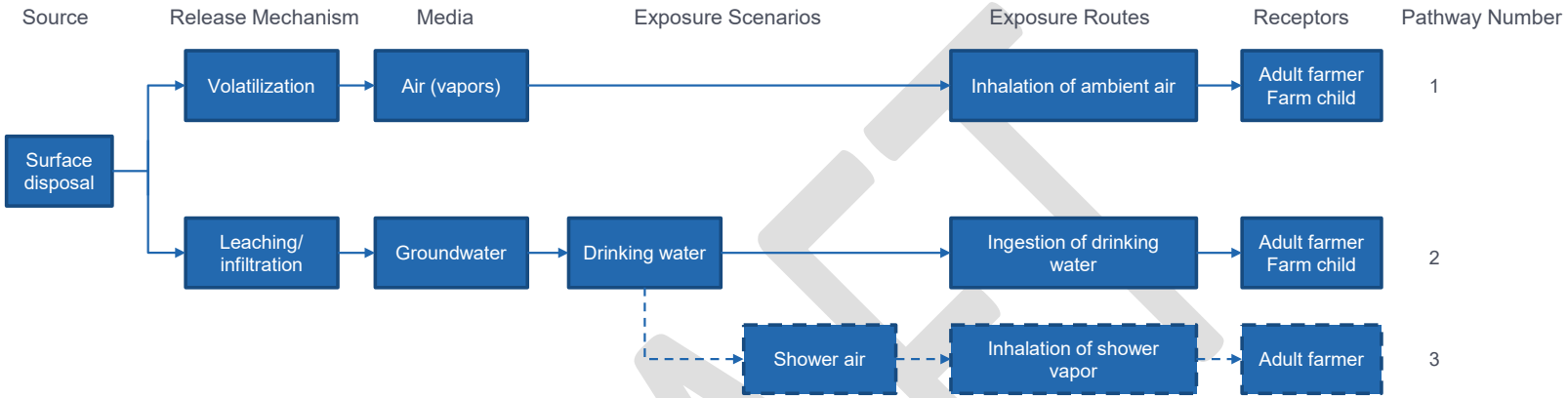

Figure 7. Conceptual model for the surface disposal scenario (i.e., sewage sludge landfill) for human exposures. Dashed arrows and box outlines indicate a pathway or route that has been added since 1993 (when risk assessments that supported the Part 503 rule were completed). Note: Ecological receptors are not included in this exposure scenario.

6.3. Models for Estimating Exposure

6.3.1. Candidate Model Identification

Models applicable to the exposure pathways identified in the conceptual models above were identified through the review of relevant modeling resources from the EPA, U.S. Department of Agriculture (USDA), and U.S. Geological Survey (USGS) and drawing from experience with EPA multimedia biosolids and waste management assessments (Table 1). In addition, the review leveraged information presented in two recently completed model reviews that focused on existing models (NCASI 2020) (MDEP, 2020)).

Using these sources, EPA identified a list of publicly available models as shown in Table 1.

Table 1. Models Identified for Review

Air Transport Models
AERMOD (American Meteorological Society (AMS)/EPA Regulatory Model) (USEPA, 2019a)
AERSCREEN (USEPA, 2016a)
Multimedia, Multipathway, and Multireceptor Risk Assessment (3MRA) Air Module (USEPA, 2003c)
US EPA, Toxics Screening Model (TSCREEN) (USEPA, 1994b)
US EPA, Industrial Waster Air Model (IWAIR) (USEPA, 2002)
Runoff, Erosion, Surface Water Models
3MRA Land Application Model (LAU) (USEPA, 2003c)
Pesticide in Water Calculator (PWC, includes Pesticide Root Zone Model (PRZM5) and Variable Volume Water Model (VVWM)), Version 2.0 (USEPA, 2019b, 2020b, 2020c)
3MRA Surface Water Module (SW) (USEPA, 2003c) Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (HHRAP) (USEPA, 2005)
Dynamic Waterbody Model (USEPA, 2003d)
Water, Energy, and Biogeochemical Model (WEBMOD) (USGS, 2018)
Soil and Water Assessment Tool (SWAT+) (USDA, 2020b)
Agricultural Policy / Environmental eXtender (APEX) model (TexasA&M, 2018)
Multimedia Contaminant Fate, Transport, and Exposure Model (MMSOILS) (USEPA, 1997b)
The Biosolids-Amended Soil Level 4 Model (BASL4) (Hughes & Mackay, 2011)
Leaching and Groundwater Models
Dilution Attenuation Factors (DAF) (USEPA, 1994a)
3MRA Vadose Zone and Aquifer Models (USEPA, 2003b)
EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) (USEPA, 2003a, 2003b)
EPA's Pesticide Root Zone Model for Ground Water (PRZM-GW) (USEPA, 2012)
Hydrus 1D (Šimůnek, Šejna, Saito, Sakai, & van Genuchten, 2013)
PEARL/SWAP (van den Berg, Tiktak, Boesten, & van der Linden, 2016)
Root Zone Water Quality Model (RZWQM) (USDA, 2020a)
Pesticide Leaching Model (PELMO) (Klein, 1995)
Variably Saturated Flow and Transport (VSAFT2) (Yeh, 2006)
CHEMFLO-2000 (D. L. Nofziger & J. Wu, 2005)
Chemical Movement in Layered Soils (CMLS) model (D.L. Nofziger & J. Wu, 2005)
STANMOD (Šimůnek, van Genuchten, Šejna, Toride, & Leij, 1999)
Vadose zone LEACHing model (VLEACH) (USEPA, 1997c)
VS2DI (USGS, 2012)
MODFLOW 6 (USGS, 2019)
MT3DMS (USGS, 2016)
Plant Uptake

HHRAP (USEPA, 2005)
3MRA Farm Food Chain (USEPA, 2003c)
Plant Uptake Model Based on Irrigation Water (Canadian Standard Association, as cited in: (National Council for Air and Stream Improvement, 2020))
Canadian Foodweb Model v2.00 (Parnis, 2006)
A partition-limited model for the plant uptake of organic contaminants from soil and water (Chiou, Sheng, & Manes, 2001)
A novel and simple model of the uptake of organic chemicals by vegetation from air and soil (Hung & Mackay, 1997)
Plant uptake of non-ionic organic chemicals from soils (Ryan, Bell, Davidson, & Oconnor, 1988)
Factors affecting the uptake of C-14-labelled organic chemicals by plants from soil (Topp, Scheunert, Attar, & Korte, 1986)
Various models of Trapp et al. (Trapp, 2004, 2007, 2009, 2015, 2017)

6.3.2. Model Evaluation

EPA characterized and evaluated the identified models using the following criteria to evaluate their ability to be used for simulating and screening human and ecological risks resulting from biosolids application fields (the most complex modeling scenario identified). Attachment A (EvaluationOfModels_20210128.xlsx) provides a detailed review of the identified models based on these evaluation criteria.

- **Inputs and outputs.** Model inputs were reviewed to ensure consistency with a screening-level assessment, where parameter values are readily available or can be estimated using standard environmental settings so that data collection is not overly burdensome. Model outputs were reviewed to ensure adequacy to support linkages with downstream models considering parameter requirements and compatibility, as well as spatial and temporal resolution. For example, aquatic ecological assessments require that the surface water model provides pollutant-specific concentration estimates in dissolved water, sediments, and porewater for averaging times of 1 day for acute exposures and 4 days for chronic exposures, consistent with exposures used in Clean Water Act ambient water quality criteria for the protection of aquatic life.
- **Chemical coverage.** As described previously, hundreds of pollutants have been reported in biosolids as part of the biennial review process and in sewage sludge surveys. These pollutants are associated with a range of chemical classifications including anions, metals, polycyclic aromatic hydrocarbons, semi-volatiles, flame retardants, pharmaceuticals, steroids, and hormones, and, more recently, PFAS. Therefore, the model review and selection process considered the models' abilities to simulate these pollutant classifications (either all or a significant subset of them).
- **Processes and mechanisms.** Each model was reviewed to identify the processes and mechanisms implemented, the mathematical formulations used, and the temporal and spatial granularity of the models. In the case of empirical methodologies, it was necessary to document and consider foundational data sets and their relevance to the BST conceptual model. For example, within the 3MRA land application unit (LAU) model, the Soil Erosion Module implements the Universal Soil Loss Equation (USLE), an empirical methodology based on measured soil losses for experimental field-scale plots in the United States. In this case, the implemented approach is considered consistent with the proposed screening conceptual model within the contiguous United States.

- **Dimensionality.** Dimensionality was reviewed to ensure compatible linkage between upstream and downstream models.
- **Ability to integrate/adapt.** Under this criterion, the accessibility of the source code, data structure format for inputs and outputs, and licensing restrictions were all considered as they relate to EPA's ability to incorporate parts or the entire model into the modeling framework. Having access to the source code will be of particular importance for emerging pollutants because the code may need to be enhanced as the body of knowledge concerning the fate and transport of these pollutants evolves.
- **Usability.** This criterion was used to characterize each model's ability to support the biosolids conceptual model, considering its ability to predict pollutant-specific concentrations in the media of interest (soil, ambient air, surface water, groundwater, and shower air associated with groundwater use) and support exposure assessments including chronic human exposures associated with inhalation and ingestion of drinking water, affected crops, fish caught in a nearby pond, and beef and dairy products obtained from pasturing cattle. For ecological receptors, acute and chronic exposures will be assessed as described above.
- **Agency consistency.** This criterion was applied to highlight model applicability and use within EPA offices and regions, states, other US federal agencies, and Canada. Canadian models and their use were also considered, given the similarity across North America regarding soils and biosolids land application management.
- **Peer review.** This criterion was included as a means for highlighting the scientific defensibility of a given model.
- **Availability.** This criterion was applied to confirm that the model is freely available with no problematic licensing restrictions.

6.3.3. Recommended Models

The reviewed models associated with each of the four major transport mechanisms are discussed briefly below with the reasons some models were eliminated from consideration and the rationale for the final recommendations. EPA recommends the following model(s) to evaluate each transport mechanism:

- **Air Transport:** AERMOD;
- **Runoff, Erosion, and Surface Water:** 3MRA LAU for runoff and erosion coupled with the Variable Volume Water Model, Revision B (VVWM, the PWC waterbody model) for surface water;
- **Leaching and Groundwater:** 3MRA LAU for leaching combined with a single conservative dilution attenuation factor (DAF); and
- **Plant Uptake:** HHRAP methodology.

Note that to best support the implementation of the BST conceptual model, EPA recommends combining models/modeling approaches to fully cover the runoff, erosion, and surface water pathways and the leaching and groundwater pathway.

Air Transport. The BST requires the ability to simulate vapor and particle dispersion and wet and dry deposition of vapors and particles (windblown dust) to support the assessment of ambient air inhalation exposures and to estimate pollutant loadings to crops, off farm soil, and surface waterbodies. As shown above in Table 1, the models identified and considered for this migration pathway included five EPA models. Of these models, AERSCREEN, TSCREEN, and IWAIR were excluded from selection given that they do not produce estimates of deposition. The EPA's 3MRA Air Module, which is based on and is

compatible with EPA's Industrial Source Complex model, version 3 (ISC3), does produce estimates for both vapor and particle dispersion and wet deposition of vapors and particles, and dry deposition of particles. However, the ISC3 version implemented for the 3MRA module does not produce estimates for dry deposition of vapors. Since the development of EPA's 3MRA Air Module, EPA's AERMOD has been developed and named as EPA's preferred dispersion model replacing ISC3. Therefore, AERMOD was selected as the recommended model.

Runoff, Erosion, and Surface Water. To assess human and ecological exposures, the BST must be able to simulate pollutant-specific runoff and erosion from 1) the agricultural field to surrounding land (the buffer) and into the farm pond and 2) the agricultural field to surrounding land and into an index reservoir. Once affected by runoff and erosion, the surface water model needs to be able to simulate pollutant-specific concentrations in total dissolved water, sediments, and porewater for averaging times of 1 day or 4 days.

As part of the model identification efforts, EPA was unable to find a single comprehensive model that could support all these migration pathway requirements including temporal requirements as defined by the framework's conceptual model. Therefore, as shown below, EPA identified 10 models that implement one or more processes associated with this migration pathway — Runoff (R), Erosion (Er), and Surface Water (SW). EPA evaluated these models to select the combination that would best support the conceptual model:

1) US EPA 3MRA LAU (R, Er)
2) US EPA, PWC, 2.0 (R, Er, SW), which includes PRZM5 (field model) and VVWM (waterbody model)
3) US EPA 3MRA Surface Water Module (SW)
4) US EPA HHRAP (R, Er, SW)
5) US EPA Dynamic Surface Waterbody Model (SW)
6) USGS WEBMOD (R, Er, SW)
7) USDA-ARS Soil and Water Assessment Tool (SWAT+) (R, Er, SW)
8) Texas A&M, Agricultural Policy / Environmental eXtender (APEX) model (R, Er, SW)
9) US EPA MMSOIL (R, Er, SW)
10) Canadian-based BASL4 (R)

Of the models listed above, seven were excluded from further consideration for the following reasons:

- The 3MRA Surface Water Module was excluded because it does not have the daily time resolution needed to support evaluation of ecological exposures.
- The Dynamic Surface Waterbody Model, although it was used in the 2003 biosolids screening assessment (USEPA, 2003d) and offers outputs on daily and annual timesteps, is a complex numerical solution and is better suited for more refined, site-specific modeling.
- USGS WEBMOD was excluded given that it only simulates and is applicable to aqueous geochemistry.
- USDA SWAT+ was eliminated given that this basin-scale model is not consistent with the framework's spatial scale.
- US EPA MMSOILS was excluded primarily given that the algorithms applied in the software did not improve on those used in the more recent 3MRA LAU.
- Lastly, both the APEX and BASL4 were excluded from consideration because of potential licensing restrictions that could hinder the distribution of the BST.

The remaining three models/methodologies we retained for closer examination (pathway component denoted in parenthesis)—US EPA 3MRA LAU (R, Er); US EPA HHRAP (R, Er, SW); and PWC (R, Er, SW), which includes PRZM5 (field model) and VVWM (waterbody model). The 3MRA LAU model, used in previous biosolids assessments, and the PRZM5 component of the PWC model offer similar runoff and erosion capabilities needed to support the conceptual model. These models also provide the ability to simulate leachate, which is of importance to the conceptual model and can ensure an integrated solution to the leaching, groundwater migration pathway discussed below. Of these two models, the LAU model offers greater consistency with the BST conceptual site layout (simulates well placement beneath the buffer land rather than well placement directly below the amended field, as is implemented in PRZM5). Given this site layout consistency, the LAU model was identified as the more preferred model. HHRAP approaches for modeling runoff and erosion are earlier, simplified versions of approaches currently used in the LAU (USDA Soil Conservation Service "curve number" procedure and USLE, respectively). When the HHRAP surface water algorithms were compared to the VVWM (waterbody model) component of the PWC, it was determined that the daily timestep implemented by VVWM would provide the ability to evaluate ecological exposures and risks more accurately; thus, it is a preferred solution. The VVWM model uses a stable, analytical solution that has been employed in screening and probabilistic environments. Our review noted one limitation associated with VVWM. Specifically, the VVWM, as currently implemented, does not accommodate air deposition as discussed above for air transport. To address this deficiency, the current deposition terms provided by the air pathway model will be converted to a mass flux to use the spray drift functionality within VVWM.

In summary, the peer-reviewed 3MRA LAU model has been coupled with the peer-reviewed VVWM to address the runoff, erosion, and surface water components of the BST. Coupling these models will provide the ability to simulate pollutant-specific runoff and erosion to the soil buffer area, farm pond, and index reservoir and, subsequently, simulate pollutant-specific concentrations in total dissolved water, sediments, and porewater for averaging times of 1 day or 4 days (consistent with CWA aquatic life criteria).

Leaching and Groundwater. **EPA identified and reviewed** the following models to support the evaluation of the leaching and groundwater pathway:

1) US EPA DAF
2) US EPA 3MRA Vadose Zone and Aquifer Models
3) US EPA, EPACMTP
4) US EPA, PRZM-GW
5) HYDRUS 1D (Šimůnek et al., 2013)
6) PEARL/SWAP (van den Berg et al., 2016)
7) USDA RZWQM
8) PELMO (Klein, 1995)
9) University of Arizona VSAFT2
10) Oklahoma State CHEMFLO-2000
11) Oklahoma State CMLS
12) USDA STANMOD
13) US EPA VLEACH
14) USGS VS2DI
15) USGS MODFLOW 6 and MT3DMS

Upon review, the following were models excluded for incompatibility with the conceptual model or for various software configurations that prohibit access to either the model or intermediate outputs:

- EPACMTP and HYDRUS 1D are complex and overly sophisticated for the BST conceptual model and better suited for site-specific analyses or probabilistic simulations where full parameterization is feasible.
- PRZM-GW soil concentrations are not readily accessible for runoff and sediment transport, and the conceptual site layout is inconsistent with the BST layout (discussed above for PRZM5, which incorporates PRZM-GW functionality; the well is assumed to be located directly below the amended field);
- PEARL/SWAP is a one-dimensional system that does not address lateral groundwater flow or transport, and the source code is not publicly available;
- RZWQM is a tailored solution for agricultural users and does not give the user access to some of the parameters relevant for contaminant transport modeling (such as solubility), and the leaching model is not accessible as a stand-alone program;
- PELMO is based on PRZM and only has limited documentation available;
- VSAFT2 is tightly integrated with a graphical user interface (GUI), making it difficult to link it within the context of the screening tool;
- CHEMFLOW-2000 is also tightly bound to a GUI, and the source code is not publicly available;
- CMLS could not be integrated with the screening tool because it is only available as a web-based tool; and
- STANMOD was designed for back-calculating site-specific transport parameters as opposed to forward simulations for exposure.
- The VLEACH model is designed for making preliminary assessments of the effects on groundwater from the leaching of volatile, sorbed contaminants through the vadose zone but is not intended for modeling metal pollutants, and the source code is not readily available.
- The USGS models, VS2DI and the combination of MODFLOW and MT3DMS, are complex, distributed parameter models that are overly sophisticated for a screening-level analysis.
- The EPA Vadose Zone and Aquifer Models are sophisticated but have more streamlined input requirements than the USGS models and would be a reasonable substitute for a single dilution attenuation factor (DAF). However, EPA recommends applying a single, conservative DAF value for addressing the subsurface pathway for the screening analysis. The use of a single DAF for screening purposes has been applied by US EPA since 1994, and a DAF of 1 is consistently applied in support of US EPA's Regional Screening Level tables (USEPA, 2020e).

For the BST, EPA recommends a conservative DAF of 1. A DAF of 1 is supported based on the results of Monte Carlo simulations conducted with EPACMTP (USEPA, 2003a, 2003b) for five representative organic pollutants with log Koc values ranging from -2.7 to 6.2 to capture a range of sorption. Simulations were conducted for each pollutant using national and location-adjusted environmental conditions for the three representative locations selected for use in the BST: Charleston, SC, representing a wet climate; Chicago, IL, a moderate climate; and Boulder, CO, a dry climate. Subsurface properties for these sites were modeled probabilistically based on the respective hydrogeologic environment (Charleston—coastal beaches; Chicago—limestone; Boulder—bedded sedimentary rocks). Well placement was consistently characterized with the BST conceptual site layout, placing the well 5 meters from the downgradient edge of the field (in the middle of a 10-meter buffer) and constraining the well depth to be within the top 10 meters of the saturated zone. An examination of the fifth and tenth percentile DAFs extracted from the Monte Carlo simulations for each pollutant and location indicates that a DAF of 1 is most appropriate to represent the groundwater pathway in the BST.

Plant Uptake. The BST requires a pollutant-specific approach but is not plant-species specific. Plants are divided into six categories: exposed fruit, exposed vegetables, protected fruit, protected vegetables, root vegetables, and forage. The models/methodologies considered for this pathway include five models presented in the literature by various research groups: two Canadian models, and US EPA's 3MRA Farm Food Chain Module and HHRAP.

- The Canadian Plant Uptake Model Based on Irrigation Water is not compatible with the conceptual model (it is based on irrigation water rather than materials applied to the soil). it is also not freely available and, therefore, was excluded.
- The models of several of two of the research groups were excluded as either too complex (Trapp, 2004, 2007, 2009, 2015, 2017) or too high level (Ryan et al., 1988). Two other models were limited in scope, covering only root uptake (Chiou et al., 2001) or aquatic receptors (Canadian Foodweb). The work of (Topp et al., 1986) is like the Briggs root concentration factor (Briggs, Bromilow, & Evans, 1982), which is incorporated in HHRAP; similarly, MacKay's research on fugacity models was considered in the development of HHRAP, and the Hung and MacKay reference that we reviewed offers no enhancements (Hung & Mackay, 1997).
- The 3MRA Farm Food Chain is like the HHRAP model, but the latter incorporates several important updates.
- The peer reviewed HHRAP model was selected for use in the BST as its methodologies can make use of plant uptake factors based on empirical correlations, as discussed in the guidance such as those of (Travis & Arms, 1988), (Briggs et al., 1982), and (Bacci, Calamari, Gaggi, & Vighi, 1990) for chemicals with log Kow within the applicable range for those correlations, or uptake factors based on literature values. The HHRAP database includes many of these data already, and the model can easily use new data as they become available, particularly for emerging chemicals for which the log Kow correlations are not well suited.

Table 2 below contains a summary of all the components of the BST used for screening assessment. The table also provides comments on models applied in the 2003 biosolids risk assessment, which was EPA's last published biosolids risk assessment (USEPA, 2003d). Inputs used in screening are described in Table 4 and compared with inputs for refined assessment.

Table 2. Summary of Models Used in BST Screening Modeling

Model Component	Model	Comparison to EPA's Prior Approach (2003)[a]
Simulation of pollutant concentrations in soil, runoff, erosion, leaching and volatile and particulate emissions		
Source	EPA's Multimedia, Multipathway, and Multireceptor Risk Assessment (3MRA) (USEPA, 2003c) • 3MRA LAU for land application • 3MRA SI for surface disposal	Both models were used in EPA's 2003 assessment.
Simulation of air dispersion and deposition		

Model Component	Model	Comparison to EPA's Prior Approach (2003)[a]
Air	AMS/EPA Regulatory Model (AERMOD) (USEPA, 2019a)	EPA's 2003 assessment used the EPA's Industrial Source Complex model, version 3 (ISC3). EPA has since replaced ISC3 with AERMOD.
Simulation of pollutant concentrations in surface water and sediments		
Surface Water	Version 2.0 of the EPA's Variable Volume Water Model (VVWM) (USEPA, 2019b)	This recent, peer reviewed model replaces the surface water model applied in the 2003 assessment.
Simulation of pollutant concentrations in groundwater and wells used for domestic use		
Groundwater	Dilution Attenuation Factor (DAF) based on EPACMTP (USEPA, 2003a, 2003b)	Same approach as EPA's 2003 assessment*.
Simulation of impacts due to plant uptake		
Human Food Chain	Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (HHRAP) (USEPA, 2005).	These models have had minor updates as compared to the 2003 assessment.

*The DAF is based on Monte Carlo simulations conducted with EPACMTP (USEPA, 2003a, 2003b) considering five representative organic pollutants capturing a range of sorption behavior.

[a] In 2003, EPA published risk assessments for the dioxin like compounds.

6.4. Model scenarios

The scenarios available for biosolids land application in the BST are:

- **Agricultural Land application scenarios:**
  - **Crop:** biosolids are applied at an agronomic rate to a tilled field used to grow crops for human consumption;
  - **Pasture:** biosolids are applied at an agronomic rate to an untilled field used to pasture beef and dairy cattle raised to produce beef and milk for human consumption; and
- **Land Reclamation:** biosolids are applied at a higher than agronomic rate suitable to a mining reclamation site. Subsequent exposures are estimated based on land use as a pasture for beef and dairy cattle.

Exposures to both human and ecological receptors will be modeled under these scenarios. The human receptors are an adult farmer and farm child; this farm family is assumed to live on a farm and consume farm-raised foods where land-applied biosolids are used as fertilizer or a soil amendment, and thus, the family is more highly exposed to biosolids than the general population. The farm family's diet consists entirely of foods from their farm, including root vegetables and above-ground exposed and protected fruits and vegetables for the crop scenarios, and beef and milk for the pasture and reclamation scenarios. Exposure pathways common to all land application scenarios include inhalation of ambient air; inhalation of indoor air while showering with groundwater; and ingestion of soil, fish caught in the farm pond, and groundwater or surface water used as drinking water sources. The aquatic and

terrestrial ecological receptors include invertebrates, vertebrate animals and birds, and plants exposed on cropland or pasture and in the farm pond.

The scenario for sewage sludge surface disposal (i.e., sewage sludge landfill) in the BST is:

- **Disposal in a surface impoundment or lagoon**. The impoundment may either be unlined or lined by a clay liner or by a composite liner with a leachate collection system.

Receptors to human receptors will be modeled in this scenario. The human receptors are residents (adult and child) living near the impoundment. Ecological receptors are not modeled. Human exposure pathways include inhalation of volatile emissions from the impoundment and exposure to groundwater contaminated by impoundment leachate used as a source of drinking water and showering.
Human health hazard values

To calculate risks in the BST human health hazard values that correspond to the exposure pathways must be entered. The suggested practice for selecting these values is described in Appendix D.1 of the BST user manual.

As a summary, the BST estimates daily doses averaged over a year for inhalation and ingestion and cancer and non-cancer values can be enter for both exposure routes. In the manual that accompanies the BST there is a listing of sources to consider for finding human health hazard values. For some of the chemicals currently on the "Biosolids List" on EPA's CompTox Chemicals Dashboard (Richman, 2022) final human health assessments with hazard values (reference doses, cancer slope factors) are or will be available from authoritative sources like federal agencies (e.g., EPA Integrated Risk Information System (IRIS), EPA Provisional Peer Reviewed Toxicity Values (PPRTVs), ATSDR toxicological profiles), state agencies, and/or international entities. In the absence of a final health assessment from an authoritative source, hazard information will be drawn from existing *in vivo* studies (i.e., traditional experimental animal assay hazard and dose-response data) and/or validated NAMs such as toxicogenomics (e.g., *in vitro* cell bioactivity) and *in silico* platforms (e.g., structure-activity, read-across).

6.5. Ecological hazard values

The BST calculates ecological exposures due to exposure to soil, water, sediment, and diet for aquatic, terrestrial and avian species. Ecological risks are calculated for the land application and reclamation scenarios.

Soil organisms, plants, and soil invertebrates are directly exposed as a result of land application of biosolids. The BST gives the user the ability to enter an ecological hazard value for soil organisms if measured data are available for these organisms. There is no existing EPA model that predicts plant toxicity values, and many chemicals have little or no plant hazard data available, except for pesticides. There may be situations where it would be appropriate for EPA to use a threshold of toxicological concern (TTC) approach to screen a pathway. The TTC approach involves determining a reasonable worst case hazard values for a receptor. It may be appropriate for EPA to employ a TTC approach to decide if further data collection or collaboration for data creation is merited.

Runoff and soil erosion lead to contamination of a farm pond in the BST and users can assess risk to any aquatic or benthic organisms by entering a hazard value representative of that organism in the field for the respective environmental compartment. In risk screening, the hazard value for the most sensitive

organism should be entered or the hazard value from an authoritative ecological assessment of the aquatic compartment (e.g., national recommended CWA aquatic life criteria, EPA ecological risk assessment for a pesticide). The aquatic compartment is the only part of the BST where acute and chronic exposures are modeled, with 1-day exposure for acute and 4-day exposures for chronic. When authoritative assessments and *in vivo* aquatic toxicity data are lacking, EPA proposes to use available models (e.g., EcoSAR, Web-ICE) to estimate hazard to aquatic species. (USEPA, 2022) (Raimondo, 2010)

Terrestrial and avian species dietary exposures are calculated with a food web model in the BST. The simplest method to calculate hazard values for these species is to use allometric scaling combined with available test data to estimate terrestrial/avian hazard values. For example, rodent data may be used as a surrogate for other species following allometric scaling adjustment. Additionally, newer methods like Web-ICE allow for better consideration of potential susceptible species and help to ensure that the risk assessment is protective of the ecosystem. In addition, Web-ICE may allow for more consistent assessments across chemicals with varying data sets by considering whether the available data address sensitive species.

The risk assessment framework accommodates assessment of a wide variety of receptors and routes of exposure: adults, children, aquatic, soil, and terrestrial organisms. The benefit is that it allows for flexibility in using a wide range of information that may be available to address the pathways and receptors most appropriate for a chemical or chemical category. However, it is inevitable that a full data set will not exist for all pathways and receptors across all the chemicals that have been and will be detected in biosolids. EPA will need to evaluate whether additional data searching or collaboration to create data for risk assessment is necessary based on estimated exposures due to concentrations in biosolids, analog data, or other information.

6.6. Evaluating Screening Model results

The BST can be used to screen out or lower the priority of chemicals, pathways, and/or receptors of low concern and to identify where additional evaluation is warranted using a refined assessment. The BST is used to estimate risk for land application and surface disposal using all scenarios, and climate conditions (*i.e.*, wet, dry, and average). From these results, any chemical–source–scenario–pathway–receptor combination that exceeds a cancer risk of 1 E-6 or a hazard quotient (HQ) of 1 (i.e., exposure exceeds hazard) for any of the three climate settings should be considered a candidate for refined assessment. (USEPA, 2000) The HQ is the exposure dose divided by the human health reference dose for non-cancer effects. EPA proposes to use the HQ approach to sum aggregate exposures across the pathways and determine whether a chemical warrants further evaluation. As evaluation progresses for a chemical it may become clear that the pathways may need to be altered to capture all the significant exposures. For example, where exposure from breastmilk is a concern, this pathway may be possible to at least qualitatively assess in a refined risk assessment.

7. Probabilistic Modeling Framework for Refined Risk Assessment

Some of the models in the BST can also be used for refined risk assessment for most pathways. A refined biosolids risk assessment will attempt to consider environmental conditions that exist across the country where biosolids are managed. At this higher tier of assessment EPA may refine the pathways to better

characterize chemical specific properties, evaluating factors that may cause variation in transport or exposure, or refine the hazard values for the receptors of concern. The groundwater model is an exception, as a more complex model would likely be warranted for a refined assessment compared to the DAF model used in the BST. If there are limited or no data on the occurrence and magnitude of a chemical in biosolids, then it may also be necessary to gain more monitoring data or use estimates based on industrial release data combined with POTW modeling to understand the likely range of concentrations in biosolids. This probabilistic assessment step replaces high-end values used in screening with distributions of chemical-, regional- and/or site-specific data to address the variability and uncertainty in input parameters that represent waste characteristics, operating practices, and environmental conditions across the country where biosolids can be applied.

7.1. Probabilistic Modeling Components

Both the screening and the proposed probabilistic modeling step rely on a common conceptual framework, shown in **Error! Reference source not found.**. The screening and probabilistic steps are also largely based on the same models. Table 3 compares the models used in each step.

Table 3. Summary of Models Used in BST for Refined assessment and Probabilistic Modeling

Model Component	Model	Comparison to the BST
Simulation of pollutant concentrations in soil, runoff, erosion, leaching and volatile and particulate emissions		
Source	EPA's Multimedia, Multipathway, and Multireceptor Risk Assessment (3MRA) (USEPA, 2003c) • 3MRA LAU for land application. • 3MRA SI for surface disposal	Both models are also used in the BST
Simulation of air dispersion and deposition		
Air	*AMS/EPA Regulatory Model (AERMOD)* (USEPA, 2019a)	Model also used in the BST
Simulation of pollutant concentrations in surface water and sediments		
Surface Water	Version 2.0 of the EPA's Variable Volume Water Model (VVWM) (USEPA, 2019b) …	Model also used in the BST
Simulation of pollutant concentrations in groundwater and wells used for domestic use		
Groundwater	EPACMTP (USEPA, 2003a, 2003b) and/or HYDRUS 1D (Šimůnek et al., 2013)	EPACMTP was used to generate the DAF used in the BST. HYDRUS is not used in the BST.
Simulation of impacts due to plant uptake		
Human Food Chain	EPA's Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (USEPA, 2005). (HHRAP)	HHRAP also used in BST

As the models are largely the same between screening and probabilistic, the conservative nature of the screening model is achieved by setting key parameters to high-end values. In both the screening and probabilistic modeling frameworks, chemical-specific parameters (e.g., physical-chemical properties, bioconcentration factors, degradation rates, human toxicity, and ecological benchmarks) as well as ecological exposure factors (*i.e.,* diet fractions, consumption rates, body weight, and exposure duration) are set to single values based on best available data. Both the screening and refined assessments utilize a risk scenario based on exposure to a farm family. Refined assessments may also consider impacts of biosolids application to other populations besides farmers, potentially including groundwater impacts and food consumption (e.g., community supported agriculture (CSA)).

The probabilistic model uses distributions for many of the inputs used in screening. Table 4 lists the set of parameters that are likely to be varied during Monte Carlo (probabilistic) assessment, although some assessments may focus on a subset of these parameters and other assessments may include additional parameters.

By contrast, in screening mode:

- **Pollutant concentrations** are set to 95th percentiles for the 145 chemicals identified from the TNSSS (USEPA, 2009a, 2009b, 2021d) 2014). If the chemical is only reported in the biennial review, then the literature will be evaluated to determine if a high-end estimate for concentration can be developed State or other governmental monitoring studies may also be considered to develop an understanding of pollution concentrations across the country.
- **Application rate** for land-applied biosolids is set to either a high-end agronomic rate applied annually over a predetermined period for the crop and pasture scenarios, or a higher than agronomic rate applied once for reclamation.
- **Operating life** is the span of time over which biosolids are applied to land or into surface disposal units; set to a maximum period of 40 years for the crop and pasture scenario, and 50 years for the surface disposal scenario. The application of biosolids for land reclamation is not considered a periodic or continuous operation, and therefore, has an operational life of 1 year.
- **Human consumption rates** of drinking water, produce, beef, dairy, and fish/shellfish are set to 90th percentiles from EPA's Exposure Factors Handbook (USEPA, 2011, 2017).
- **Other environmental setting parameters** are represented by median values selected from exposure handbook information or other literature values.

Table 4. Summary of Input Parameters for the Proposed BST and Probabilistic Models.

Input Type	BST	Probabilistic	Comments
Biosolids-specific			
Pollutant concentration	95th percentile	Distribution	The chemical-specific concentration distributions from the TNSSS (USEPA, 2009a, 2009b) are used as the basis for the screening (set to 95% concentrations) and probabilistic framework where they will be sampled and used as input to the Monte Carlo (probabilistic) analysis. For chemicals not in the TNSSS, data from the literature will be used to the extent

Input Type	BST	Probabilistic	Comments
			possible to estimate the distribution of concentrations.
Operating life	Land application: Crop and pasture: 40 years Reclamation: 1 year Surface disposal: 50 years	Distribution for all scenarios except reclamation which is fixed – 1 year	Consistent with the 2003 assessment, operating life for the crop/pasture and the surface disposal scenarios are fixed under the screening to 40 and 50 years, respectively. The operating life of these units may be varied in the Monte Carlo analysis. The operating life of the unit and the rate of application will be assumed to be independent. Under both the screening and probabilistic assessment, crop and pastureland application is assumed to occur every year at the beginning of Spring (*i.e.*, application on April 1). Biosolids are generally applied once for land reclamation (USEPA, 1995b). Therefore, the operating life for reclamation is set to 1 year reflecting a single, one-time application under both the screening and probabilistic assessments.
Land application rate	default, high-end agronomic rates that users can change. crop and pasture: Default of 10 MT dry weight/ha-application applied once a year for 40 years reclamation: Default of 40 MT dry weight/ha applied one time	distribution	A single value is applied under the screen. Under the probabilistic assessment, distributions may be developed for crop, pasture, and reclamation scenarios. Based on national-level agronomic calculations, a distribution may be developed and applied for both the crop and pasture scenarios. Under the reclamation scenario, we will develop a uniform distribution using data presented in Table 9-3 in (USEPA, 1995b) for reclamation projects up through 1993.
Environmental Setting			
Location (meteorological)	3 (wet, dry, avg)	Locations across the country	The screening scenario uses three locations (Charleston, SC = wet; Boulder, CO = dry; Chicago, IL = avg) from the conterminous US where biosolids application is known to occur to represent a range of climatological conditions (wet, dry, average). The 2003 probabilistic framework used data from 41 climate regions. Expanded meteorological files are available for the

Input Type	BST	Probabilistic	Comments
			USA that could allow for an even larger set of locations to be included for a refined assessment. This would include expanded precipitation data and soil information.
Location (soil, etc.)	3 locations corresponding to meteorological data sources	Locations across the country	In the screen, meteorologic locations are used as a basis for selecting regional soil and hydrologic parameters. For the probabilistic analysis (as described in Section 7.2.2), locations will be distributed across the country.
Farm size	Median	Distribution	The screening simulates an 80-acre farm corresponding to the national median farm size based on data from USDA, 2012 Census of Agriculture (USDA, 2014). Probabilistic simulations will sample from the 2012 USDA data for farms up to 180 acres using individual state farm size data.
Waterbodies	Standard, constant	Standard, constant	Location specific input parameters are assigned as described below in Section 7.2. The physical dimensions of the farm pond and index reservoir will remain the same under the screening and probabilistic frameworks reflecting standard parameters as provided for the VVWM model (USEPA, 2019b).
Well placement	Not applicable, DAF applied	Distribution	The DAF developed for screening assumed the farm well was in the middle of the 10-meter buffer adjacent to the field. For the probabilistic assessment, the farm water well may be located further downgradient and at varying depths.
Human Exposure Factors			
Consumption rates	90th percentile	distribution	Based on *Exposure Factors Handbook* (USEPA, 2011, 2017).
Body weight	50th percentile	distribution	
Exposure duration (number of years spent farming)	90th percentile	distribution	
Starting year of exposure (SY)	Under both the screening and probabilistic assessments, SY is assumed to occur around the time of maximum media concentrations allowing the exposure duration to be centered around the maximum concentrations.		For example, if the peak soil concentration occurs in year 30 and the adult exposure duration is assumed to be 48-years, the exposure period would be simulated for ages 6 to 54.

7.2. Probabilistic Assessment

This section describes the probabilistic modeling framework that is being proposed to support national-scale assessments that will focuses on pollutants, pathways, and receptors of interest as identified through the screening process. To address the variability in modeling exposure scenarios for a national assessment, a Monte Carlo modeling framework will be implemented that produces a distribution of risk estimates for each pollutant, management scenario, receptor, and pathway. A probabilistic assessment is particularly appropriate because biosolids can be applied to land application units and disposed in surface impoundments in many different parts of the country. The Monte Carlo simulation incorporates the variability in environmental settings (e.g., hydrology, meteorology, application rates, farm size), and exposure-related parameters, such as consumption rates capturing the range of conditions that can exist in the contiguous United States.

7.2.1. Monte Carlo Simulation

As illustrated in Figure 8, the Monte Carlo simulation will produce a distribution of exposure and hazard/risk for each pollutant/modeling scenario combination. The distribution represents the variability in hazard associated with location, waste characteristics, operating practices, and other inputs such as consumption rates.

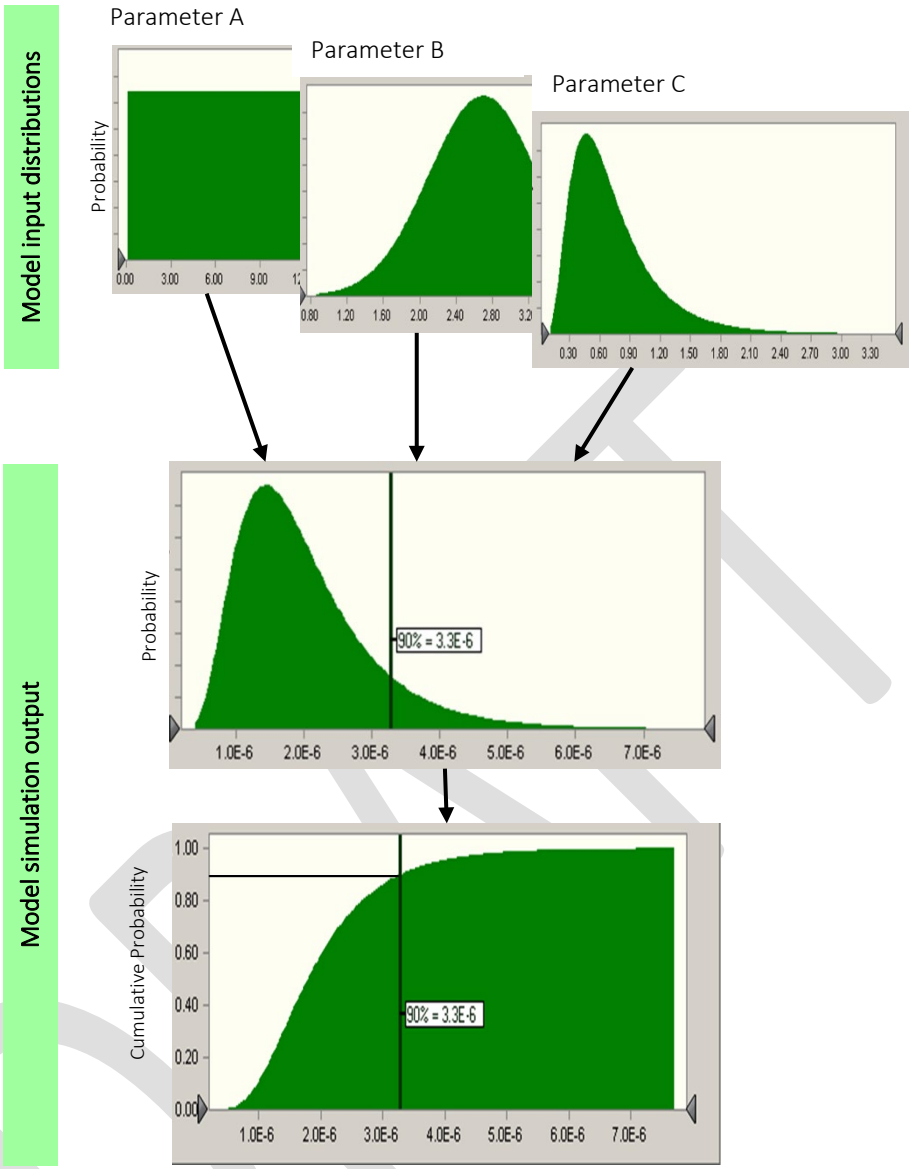

Figure 8. How the Monte Carlo framework addresses variability and uncertainty.

7.2.2. Data Development for Probabilistic Modeling

For all exposure pathways, some of the parameters are represented by distributions (e.g., the distribution of drinking water consumption rates for adults) or through sampling of location-specific input parameters (e.g., precipitation rate). However, sufficient data are not available to discern a defensible distribution of values for all input parameters required by the model (e.g., biodegradation). For these parameters, input values are selected to be representative and reasonably conservative with respect to risk/hazard. For example, data on biodegradation for organic pollutants are limited, and rather than assuming that no biodegradation occurs, EPA will select biodegradation values from the low end of the range simulating conditions under which only minimal biodegradation would occur. For other parameters, such as human health hazard, the EPA has developed point estimates to characterize the cancer slope factor and noncancer hazard that may result from exposure to pollutants in biosolids.

To support the Monte Carlo simulation, EPA will apply a variety of data sources. EPA will first seek to use information collected and developed for other EPA analyses, especially those that have gone through a formal peer-review process. The probabilistic modeling step and data development generally follow major Agency guidance documents, including, for example, the Risk Assessment Guidance for Superfund Volume 3 Part A: Process for Conducting Probabilistic Risk Assessment (RAGS 3A) (USEPA, 2001b) and the Guiding Principles for Monte Carlo Analysis (USEPA, 1997a), as well as Probabilistic Techniques in Exposure Assessment: A Handbook for Dealing with Variability and Uncertainty in Models and Inputs (Cullen & Frey, 1999). It is important to note that EPA will attempt to make direct use of input data that have previously undergone extensive review. For example, data distributions for exposure factors are based on EPA's Exposure Factors Handbook (USEPA, 2011, 2017).

Because the probabilistic modeling framework may need to capture the variability in environmental conditions across the contiguous United States, special care is taken to ensure that the parameters describing the environmental setting are internally consistent. The development of the input data set to support a location-based Monte Carlo simulation begins with the selection of agricultural land application and surface disposal locations. Once a location has been determined, regional data are used to capture the variability in environmental conditions including meteorological station region, soil polygon grid, hydrographic region, and hydrogeologic environment. The following section provides an overview of the environmental characterization applied for each modeling scenario.

7.2.3. Land Application Scenarios

For the land application scenarios, including agricultural use and reclamation, climate and soil data are needed to characterize the environmental setting. These data include the meteorologic data used for air modeling, and the soil and climate data used to estimate fate and transport of the pollutants in the soil, surface waterbody, and groundwater. The probabilistic assessment will utilize meteorologic and geologic data sets that have been developed by other EPA offices to parametrize the Monte Carlo assessments.

Distribution of Farm Sizes

Agricultural field size (for the agricultural land application scenario) is proposed to be jointly associated with distributions of state farm sizes from the 2012 Census of Agriculture (USDA, 2014) and agricultural resource regions in **Error! Reference source not found.** (USDA, 2000) but not directly linked to climate or soil conditions. The range of farm sizes to be used would not exceed 180 acres, an upper bound identified by (Hoppe et al., 2001).

Site Layout

A hypothetical site configuration including either cropland or pastureland and two waterbodies are used to model the land application scenarios. The first waterbody is a farm pond that is located immediately adjacent to the biosolids-amended land and receives runoff and erosion directly from the biosolids-amended land (no buffer). Based on the standard farm pond (1 hectare in area and 2 meters deep) described in the VVWM documentation (USEPA, 2019b), the farm pond is the site of all ecological receptor exposures and is used for recreational fishing by the farm family. The second waterbody is an "index reservoir." The index reservoir is represented by Shipman City Lake in Shipman, Indiana. This

reservoir has an area of approximately 13 acres, a depth of 9 ft, and a watershed area of 427 acres. These values remain constant, and the same index reservoir is assumed to occur at each farm location. The 427-acre watershed is assumed to contain other farms (in addition to the modeled farm) that also apply biosolids. These farms are assumed to occupy 10 to 80 percent of the 427-acre watershed (USEPA, 2003d). Drinking water exposures are assessed using this index reservoir, which receives runoff from agricultural land to which biosolids was applied as a fertilizer or soil amendment. Drinking water exposures are also assessed using groundwater as a drinking water source. When aggregating exposure via the ingestion pathway, only the drinking water source associated with higher concentration is considered.

7.2.4. Surface Disposal Scenario (i.e., Sewage Sludge Landfill)

For this scenario, EPA expects that sewage sludge is typically managed in a nonaerated surface disposal lagoon. The lagoon in this analysis is represented by nonaerated surface impoundments with retention times greater than 2 years. These impoundments are modeled under three liner scenarios: no liner, clay liner, and composite liner. The lined lagoons are also assumed to have a leachate collection system. Predicted leachate concentrations and infiltration rates from the modeled lagoons are provided to the probabilistic groundwater model EPACMTP (USEPA, 2003a, 2003b) to conduct groundwater flow and transport simulations to predict pollutant concentrations in the nearby residential well from the leachate concentration. A resident family is assumed to live near a facility with a sewage sludge surface disposal unit and breathe the air at that location. In addition, the family is assumed to have a residential well that supplies tap water to the household for use as drinking water.

For the surface disposal scenario, meteorologic data used for air modeling, and soils and hydrogeologic data for groundwater modeling are needed to characterize the environmental setting. The meteorologic parameterization consists of the following elements:

- Regional meteorological data are used to capture the variability across the United States.
- A hypothetical site layout is used to represent the hazards to rural residents living at various distances from disposal impoundments.
- Soils and hydrogeologic data corresponding to impoundment locations.

These elements are discussed in more detail in the following sections.

Regional Data

The regional data represent the variability in climate attributable to the variety of geographic locations for surface impoundments throughout the United States. The surface impoundments used in this analysis were selected from a national distribution of nonaerated, non-hazardous surface impoundments based on a representative sample of surface impoundments developed by the EPA Office of Solid Waste as part of the Surface Impoundment Study (USEPA, 2001c). These surface impoundments are modeled using the locations reported in the survey. Meteorological data from the nearest, most representative meteorological stations are used.

Site Layout Data

Surface disposal units are assumed to be located in a rural industrial setting where rural residents may (1) live within a distribution of distances relatively close to the lagoon, (2) be exposed to ambient air contaminated by sewage sludge pollutants, and (3) consume drinking water from residential groundwater wells.

7.2.5. Risk Characterization

Modeling of the management scenarios (*i.e.*, crop and pastureland application, surface disposal, and reclamation land application) will be performed for each pollutant, pathway, and receptor of interest to estimate national distributions of noncancer HQ and cancer risk for human receptors, and HQs for ecological receptors. EPA will use the 95th percentile of the distributions to evaluate if a level of concern has been exceeded, indicating a risk to human health and the environment. If, after a probabilistic risk assessment, risks are found then EPA may take additional steps to establish limits and best management practices, as appropriate to ensure there are no adverse effects on human health or the environment from land application or surface disposal.

Human Receptors

- For pollutants that cause noncancer health effects, the level of concern is defined as a ratio of predicted intake levels to safe intake levels—the HQ—above 1.
- For carcinogenic (cancer-causing) pollutants, the level of concern is defined as an excess lifetime cancer risk to individuals above 1 chance in 1,000,000 (=10^{-6}).

Ecological Receptors

For ecological species, the level of concern is defined as a ratio between the environmental concentration and the critical concentration, or a ratio between the receptor dose and the critical dose—the HQ—above 1.

8. Summary:

As detailed in this White Paper, following SAB review, EPA is proposing the following three-step process as a standardized approach to biosolids chemical risk assessment:

1. Prioritize chemicals using the state-of-the-science, peer reviewed PICS process.

2. Use the BST to conduct a screening-level risk assessment for the chemicals identified as highest concern in the PICS process.

3. Conduct refined assessments, potentially probabilistic assessments, for those chemicals that pose the greatest risk to human health and/or the environment.

4. If needed, take steps to manage risks for these chemicals in biosolids from land application and/or the surface disposal of sewage sludge.

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10. Appendix A. PICS Results for the Preliminary Ranking of Chemicals Found in Biosolids

DTXSID	CASRN	Chemical Name	Regulated (R) or Previously Prioritized Chemical (PC)	Scientific Domain Metric	Information Availability Metric
DTXSID2020139	50-32-8	Benzo(a)pyrene		71	100
DTXSID3039242	71-43-2	Benzene		68	93
DTXSID8031865	335-67-1	Perfluorooctanoic acid	PC	66	67
DTXSID0020442	94-75-7	2,4-Dichlorophenoxyacetic acid		65	93
DTXSID0020448	78-87-5	1,2-Dichloropropane		64	93
DTXSID0021383	79-01-6	Trichloroethylene		64	93
DTXSID9020376	1163-19-5	1,1'-Oxybis[2,3,4,5,6-pentabromobenzene]		64	100
DTXSID4020375	50-29-3	Dichlorodiphenyltrichloroethane		64	100
DTXSID1020439	120-83-2	2,4-Dichlorophenol		63	93
DTXSID9020295	106-47-8	4-Chloroaniline	PC	61	93
DTXSID7020182	80-05-7	Bisphenol A		61	93
DTXSID5021124	108-95-2	Phenol		61	100
DTXSID6020143	65-85-0	Benzoic acid		61	87
DTXSID8021060	100-75-4	N-Nitrosopiperidine		61	33
DTXSID7021869	106-44-5	p-Cresol		60	93
DTXSID8020913	91-20-3	Naphthalene		60	87
DTXSID0020868	75-09-2	Dichloromethane		60	93
DTXSID1020431	106-46-7	1,4-Dichlorobenzene		60	93
DTXSID9020243	133-06-2	Captan		59	100
DTXSID8021808	95-48-7	o-Cresol		59	100
DTXSID5020607	117-81-7	Di(2-ethylhexyl) phthalate		59	100
DTXSID5020154	120-32-1	Clorophene		59	53
DTXSID4020298	108-90-7	Chlorobenzene		59	93
DTXSID2020216	128-37-0	Butylated hydroxytoluene		59	87
DTXSID2020686	58-89-9	Lindane		59	93
DTXSID3020596	100-41-4	Ethylbenzene		58	93
DTXSID7021029	62-75-9	N-Nitrosodimethylamine		58	67
DTXSID8020250	56-23-5	Carbon tetrachloride		57	93
DTXSID2021284	100-42-5	Styrene		57	93
DTXSID1020778	5989-27-5	D-Limonene		56	73
DTXSID8031863	375-95-1	Perfluorononanoic acid		56	40
DTXSID8021482	67-64-1	Acetone		55	93
DTXSID4021975	122-39-4	Diphenylamine		55	80
DTXSID0021965	120-82-1	1,2,4-Trichlorobenzene		54	93
DTXSID5021411	115-96-8	Tris(2-chloroethyl) phosphate		54	93
DTXSID2026602	96-76-4	2,4-Di-tert-butylphenol		54	67
DTXSID5020152	100-51-6	Benzyl alcohol		53	80
DTXSID8021062	930-55-2	N-Nitrosopyrrolidine		53	33
DTXSID3031864	1763-23-1	Perfluorooctanesulfonic acid	PC	52	60
DTXSID4039231	107-05-1	Allyl chloride		52	73
DTXSID7020479	60-51-5	Dimethoate		51	93
DTXSID8024864	4170-30-3	Crotonaldehyde		51	73
DTXSID7021360	108-88-3	Toluene		50	93
DTXSID3024104	206-44-0	Fluoranthene	PC	50	93
DTXSID2021781	84-74-2	Dibutyl phthalate		50	100
DTXSID5032498	3380-34-5	Triclosan		49	87
DTXSID1020306	67-66-3	Chloroform		49	93
DTXSID0023878	120-12-7	Anthracene		49	80
DTXSID0021834	100-02-7	4-Nitrophenol		49	73
DTXSID4022529	99-76-3	Methylparaben		49	73
DTXSID6022056	541-73-1	1,3-Dichlorobenzene		49	73
DTXSID3020209	94-26-8	Butylparaben		49	53
DTXSID9020407	333-41-5	Diazinon		48	93
DTXSID2021028	55-18-5	N-Nitrosodiethylamine		48	27
DTXSID7021106	87-86-5	Pentachlorophenol		48	87
DTXSID6020430	95-50-1	1,2-Dichlorobenzene		48	93
DTXSID1031040	7440-48-4	Cobalt		48	73

DTXSID	CASRN	Chemical Name	Regulated (R) or Previously Prioritized Chemical (PC)	Scientific Domain Metric	Information Availability Metric
DTXSID4023886	7440-38-2	Arsenic	R	48	87
DTXSID6026080	100-21-0	Terephthalic acid		48	87
DTXSID6024254	85-01-8	Phenanthrene		48	47
DTXSID1020302	75-00-3	Chloroethane		48	73
DTXSID7026368	69-72-7	Salicylic acid		47	73
DTXSID6020802	108-78-1	Melamine		47	87
DTXSID5023902	56-55-3	Benz(a)anthracene		47	100
DTXSID7020215	25013-16-5	Butylated hydroxyanisole		47	67
DTXSID1021403	512-56-1	Trimethyl phosphate		47	67
DTXSID2021315	1746-01-6	2,3,7,8-Tetrachlorodibenzo-p-dioxin		46	73
DTXSID8052693	207122-16-5	2,2',3,4,4',5',6-Heptabromodiphenyl ether		46	11
DTXSID3021516	78-93-3	Methyl ethyl ketone		46	87
DTXSID5020528	606-20-2	2,6-Dinitrotoluene		46	93
DTXSID0021381	71-55-6	1,1,1-Trichloroethane		45	93
DTXSID9022360	140-66-9	4-(1,1,3,3-Tetramethylbutyl)phenol		45	93
DTXSID4052685	182346-21-0	2,2',3,4,4'-Pentabromodiphenyl ether		45	11
DTXSID1026081	79-94-7	3,3',5,5'-Tetrabromobisphenol A		45	80
DTXSID4022527	94-13-3	Propylparaben		45	53
DTXSID3052692	207122-15-4	2,2',4,4',5,6'-Hexabromodiphenyl ether		45	11
DTXSID3024289	129-00-0	Pyrene	PC	45	87
DTXSID8026195	108-70-3	1,3,5-Trichlorobenzene		45	27
DTXSID5021388	93-76-5	2,4,5-Trichlorophenoxyacetic acid		45	87
DTXSID5021758	78-51-3	Tris(2-butoxyethyl) phosphate		45	47
DTXSID2021319	127-18-4	Tetrachloroethylene		45	93
DTXSID2021995	134-62-3	DEET		45	73
DTXSID4020533	123-91-1	1,4-Dioxane		45	93
DTXSID6021030	86-30-6	N-Nitrosodiphenylamine		44	80
DTXSID3032179	57465-28-8	3,3',4,4',5-Pentachlorobiphenyl		44	22
DTXSID4059916	375-22-4	Perfluorobutanoic acid		44	33
DTXSID3026645	99-87-6	p-Cymene		44	53
DTXSID0022432	218-01-9	Chrysene		44	100
DTXSID9021847	101-84-8	Diphenyl oxide		43	67
DTXSID7024031	156-60-5	(E)-1,2-Dichloroethylene		43	73
DTXSID3031022	7440-47-3	Chromium	R	43	53
DTXSID4038899	35958-30-6	Tetrabutyl ethylidenebisphenol		43	22
DTXSID6021828	98-86-2	Acetophenone		43	80
DTXSID0021389	52-68-6	Trichlorfon		42	87
DTXSID5033836	104-40-5	4-Nonylphenol		42	53
DTXSID0021759	78-83-1	2-Methyl-1-propanol		42	87
DTXSID8020044	107-18-6	Allyl alcohol		41	93
DTXSID0041307	1464-53-5	2,2'-Bioxirane		41	33
DTXSID5020732	15687-27-1	Ibuprofen		41	53
DTXSID9030048	60348-60-9	2,2',4,4',5-Pentabromodiphenyl ether		41	100
DTXSID2021105	82-68-8	Pentachloronitrobenzene		41	93
DTXSID3030056	5436-43-1	2,2',4,4'-Tetrabromodiphenyl ether		41	100
DTXSID6025690	81-14-1	Musk ketone		41	47
DTXSID9026974	120-95-6	2,4-Di-tert-pentylphenol		40	40
DTXSID4023622	63-74-1	Sulfanilamide		40	27
DTXSID1024176	126-98-7	Methacrylonitrile		40	80
DTXSID9026261	13674-87-8	Tris(1,3-dichloro-2-propyl) phosphate		40	67
DTXSID40872703	147217-75-2	2,2',4-Tribromodiphenyl ether		40	7
DTXSID8025383	25637-99-4	Hexabromocyclododecane		40	47
DTXSID9021899	109-06-8	2-Methylpyridine		40	53
DTXSID1023940	7440-43-9	Cadmium	R	40	87
DTXSID4022600	300-62-9	Amphetamine		40	27
DTXSID3031860	335-76-2	Perfluorodecanoic acid		40	33
DTXSID9022526	94-18-8	Benzylparaben		40	13
DTXSID3021986	126-73-8	Tributyl phosphate		40	93
DTXSID1021405	81-15-2	2,4,6-Trinitro-1,3-dimethyl-5-tert-butylbenzene		40	27

DTXSID	CASRN	Chemical Name	Regulated (R) or Previously Prioritized Chemical (PC)	Scientific Domain Metric	Information Availability Metric
DTXSID4024305	7440-22-4	Silver	PC	39	87
DTXSID4021717	59-50-7	4-Chloro-3-methylphenol		39	80
DTXSID0021337	148-79-8	Thiabendazole		39	73
DTXSID6027052	128-39-2	2,6-Di-tert-butylphenol		39	93
DTXSID1024172	7439-97-6	Mercury	R	39	80
DTXSID8026193	87-61-6	1,2,3-Trichlorobenzene		39	67
DTXSID4030047	68631-49-2	2,2',4,4',5,5'-Hexabromodiphenyl ether		39	100
DTXSID4024359	95-95-4	2,4,5-Trichlorophenol		39	87
DTXSID2020925	7440-02-0	Nickel	R	39	73
DTXSID0020737	120-72-9	Indole		38	33
DTXSID8027373	1222-05-5	Cyclopenta[g]-2-benzopyran, 1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethyl-		38	73
DTXSID4020161	92-52-4	Biphenyl		38	100
DTXSID5026625	98-55-5	alpha-Terpineol		38	40
DTXSID7034672	7553-56-2	Iodine		38	67
DTXSID8026228	78-40-0	Triethyl phosphate		38	87
DTXSID5021889	108-10-1	4-Methyl-2-pentanone		38	80
DTXSID8029315	17540-75-9	4-(Butan-2-yl)-2,6-di-tert-butylphenol		38	33
DTXSID3022370	57-83-0	Progesterone		37	20
DTXSID0020232	58-08-2	Caffeine		37	93
DTXSID7044130	68-35-9	Sulfadiazine		37	13
DTXSID30451985	437701-79-6	BDE-207		36	11
DTXSID3020205	85-68-7	Benzyl butyl phthalate		36	93
DTXSID3020964	98-95-3	Nitrobenzene		36	93
DTXSID0021541	74-87-3	Chloromethane		36	73
DTXSID4020878	91-57-6	2-Methylnaphthalene		36	73
DTXSID6021824	97-23-4	Dichlorophen		36	40
DTXSID0038883	1843-03-4	Phenol, 4,4',4''-(1-methyl-1-propanyl-3-ylidene)tris 2-(1,1-dimethylethyl)-5-methyl-		36	47
DTXSID4021341	96-69-5	4,4'-Thiobis(6-tert-butyl-m-cresol)		36	60
DTXSID2021311	732-26-3	2,4,6-Tris(tert-butyl)phenol		35	40
DTXSID7020970	1836-75-5	Nitrofen		35	67
DTXSID7040150	355-46-4	Perfluorohexanesulfonic acid		35	7
DTXSID2021993	132-64-9	Dibenzofuran		35	47
DTXSID1021952	115-86-6	Triphenyl phosphate		35	93
DTXSID30881107	63387-28-0	1,2,3,4,5-Pentabromo-6-(2,3,4,5-tetrabromophenoxy)benzene		35	22
DTXSID2021868	106-42-3	p-Xylene		35	60
DTXSID1021956	117-84-0	Di-n-octyl phthalate		35	67
DTXSID5020108	50-78-2	Aspirin		35	73
DTXSID0021414	78-42-2	Tris(2-ethylhexyl) phosphate		35	87
DTXSID6024913	124-18-5	Decane		35	89
DTXSID8031861	307-55-1	Perfluorododecanoic acid		35	20
DTXSID2020006	103-90-2	Acetaminophen		35	67
DTXSID2024161	7439-92-1	Lead	R	34	53
DTXSID3021857	25154-52-3	n-Nonylphenol		34	53
DTXSID7021607	142-62-1	Hexanoic acid		34	53
DTXSID6026298	108-38-3	m-Xylene		34	60
DTXSID8022371	58-22-0	Testosterone		34	47
DTXSID2052732	84852-53-9	1,1'-Ethane-1,2-diylbis(pentabromobenzene)		34	56
DTXSID1027134	298-07-7	Bis(2-ethylhexyl) phosphate		34	67
DTXSID8026064	723-46-6	Sulfamethoxazole		34	47
DTXSID7030066	57117-31-4	2,3,4,7,8-Pentachlorodibenzofuran		34	27
DTXSID4034609	120068-37-3	Fipronil		33	80
DTXSID3021807	95-47-6	o-Xylene		33	60
DTXSID4023913	7440-41-7	Beryllium	PC	33	73
DTXSID4052689	189084-64-8	2,2',4,4',6-Pentabromodiphenyl ether		33	11
DTXSID1024126	1024-57-3	Heptachlor epoxide B		33	73
DTXSID3059921	376-06-7	Perfluorotetradecanoic acid		33	7

DTXSID	CASRN	Chemical Name	Regulated (R) or Previously Prioritized Chemical (PC)	Scientific Domain Metric	Information Availability Metric
DTXSID4022367	53-16-7	Estrone		33	53
DTXSID4021212	99-50-3	3,4-Dihydroxybenzoic acid		32	27
DTXSID1025300	1241-94-7	2-Ethylhexyl diphenyl phosphate		32	73
DTXSID5020576	57-63-6	17alpha-Ethinylestradiol		32	53
DTXSID9022811	57-62-5	Chlortetracycline		32	20
DTXSID7041544	21145-77-7	7-Acetyl-1,1,3,4,4,6-hexamethyltetraline		32	47
DTXSID8026068	72-14-0	Sulfathiazole		31	13
DTXSID0047741	132-65-0	Dibenzothiophene		31	27
DTXSID1024627	37853-59-1	1,2-Bis(2,4,6-tribromophenoxy)ethane		31	11
DTXSID9074775	117964-21-3	BDE-197		31	11
DTXSID1037303	375-85-9	Perfluoroheptanoic acid		31	7
DTXSID3074789	446255-39-6	BDE-196		31	11
DTXSID7022411	118-82-1	4,4'-Methylenebis(2,6-di-t-butylphenol)		30	78
DTXSID5029055	84852-15-3	4-Nonylphenol, branched		30	60
DTXSID3026647	99-96-7	4-Hydroxybenzoic acid		30	80
DTXSID5024267	1336-36-3	Polychlorinated biphenyls		30	20
DTXSID6062599	2706-90-3	Perfluoropentanoic acid		30	20
DTXSID4026214	101-20-2	Triclocarban		30	73
DTXSID1024128	87-82-1	Hexabromobenzene		30	100
DTXSID0020652	25812-30-0	Gemfibrozil		30	60
DTXSID0052706	38380-08-4	2,3,3',4,4',5-Hexachlorobiphenyl		30	11
DTXSID2038314	32774-16-6	3,3',4,4',5,5'-Hexachlorobiphenyl		30	11
DTXSID8040698	126-71-6	Triisobutyl phosphate		30	47
DTXSID3040728	107-66-4	Phosphoric acid, dibutyl ester		29	87
DTXSID6023947	75-15-0	Carbon disulfide		29	80
DTXSID4032116	31508-00-6	2,3',4,4',5-Pentachlorobiphenyl		29	11
DTXSID8038306	32598-14-4	2,3,3',4,4'-Pentachlorobiphenyl		29	11
DTXSID2023985	7440-50-8	Copper	R	29	67
DTXSID9020299	510-15-6	Chlorobenzilate		29	80
DTXSID1048207	838-85-7	Diphenyl phosphate		29	7
DTXSID6067331	27619-97-2	6:2 Fluorotelomer sulfonic acid		29	13
DTXSID7024873	108-80-5	Cyanuric acid		29	93
DTXSID0022068	591-78-6	2-Hexanone		29	67
DTXSID3031862	307-24-4	Perfluorohexanoic acid		29	20
DTXSID8028000	38051-10-4	Phosphoric acid, 2,2-bis(chloromethyl)-1,3-propanediyl tetrakis(2-chloroethyl) ester		29	53
DTXSID0020311	150-68-5	Monuron		29	33
DTXSID4020373	72-54-8	p,p'-DDD		29	60
DTXSID4021395	1582-09-8	Trifluralin		29	60
DTXSID9020374	72-55-9	p,p'-DDE		29	60
DTXSID9020453	60-57-1	Dieldrin		29	60
DTXSID2021026	924-16-3	N-Nitrosodibutylamine		29	27
DTXSID9034941	7704-34-9	Sulfur		28	53
DTXSID1027267	629-59-4	Tetradecane		28	78
DTXSID3022401	57-88-5	Cholesterol		28	33
DTXSID9020740	53-86-1	Indomethacin		28	40
DTXSID2020684	319-84-6	alpha-1,2,3,4,5,6-Hexachlorocyclohexane		28	73
DTXSID7026811	108-98-5	Benzenethiol		27	47
DTXSID7020685	319-85-7	beta-Hexachlorocyclohexane		27	67
DTXSID9049748	7440-09-7	Potassium		27	13
DTXSID0021836	100-25-4	1,4-Dinitrobenzene		27	27
DTXSID5024506	89-57-6	5-Aminosalicylic acid		27	20
DTXSID2052281	611-59-6	1,7-Dimethylxanthine		27	7
DTXSID0044236	36443-68-2	Triethylene glycol bis(3-tert-butyl-4-hydroxy-5-methylphenyl)propionate		27	53
DTXSID9050484	7440-70-2	Calcium		26	20
DTXSID5063364	4221-80-1	Benzoic acid, 3,5-bis(1,1-dimethylethyl)-4-hydroxy-, 2,4-bis(1,1-dimethylethyl)phenyl ester		26	22
DTXSID0020573	50-28-2	17beta-Estradiol		26	67

DTXSID	CASRN	Chemical Name	Regulated (R) or Previously Prioritized Chemical (PC)	Scientific Domain Metric	Information Availability Metric
DTXSID8023894	7440-39-3	Barium	PC	26	80
DTXSID3021774	83-32-9	Acenaphthene		25	93
DTXSID3022455	131-11-3	Dimethyl phthalate		25	87
DTXSID0026913	112-40-3	Dodecane		25	78
DTXSID8021775	83-34-1	3-Methylindole		25	20
DTXSID0064046	5875-45-6	Phenol, 2,5-bis(1,1-dimethylethyl)-		25	13
DTXSID70274236	615-22-5	2-(Methylthio)benzothiazole		25	13
DTXSID7074165	52663-72-6	2,3',4,4',5,5'-Hexachlorobiphenyl		25	11
DTXSID7029871	23593-75-1	Clotrimazole		25	33
DTXSID5030030	375-73-5	Perfluorobutanesulfonic acid		25	33
DTXSID0027195	544-76-3	Hexadecane		24	67
DTXSID7035012	7440-66-6	Zinc	R	24	93
DTXSID3029869	41859-67-0	Bezafibrate		24	40
DTXSID2040282	7440-62-2	Vanadium		24	53
DTXSID1021879	107-12-0	Propionitrile		24	53
DTXSID9021261	7782-49-2	Selenium	R	24	80
DTXSID70858838	59080-40-9	2,2',4,4',5,5'-Hexabromobiphenyl		24	22
DTXSID5022934	20830-75-5	Digoxin		24	20
DTXSID6021373	396-01-0	Triamterene		24	20
DTXSID2032180	35065-27-1	2,2',4,4',5,5'-Hexachlorobiphenyl		24	11
DTXSID50865989	40186-72-9	2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl		24	11
DTXSID6038299	35065-29-3	2,2',3,4,4',5,5'-Heptachlorobiphenyl		24	11
DTXSID8038300	35065-28-2	2,2',3,4,4',5'-Hexachlorobiphenyl		24	11
DTXSID1049774	7440-23-5	Sodium		24	7
DTXSID60872265	182677-30-1	2,2',3,4,4',5'-Hexabromodiphenyl Ether		24	0
DTXSID9052688	189084-61-5	2,3',4,4'-Tetrabromodiphenyl ether		24	0
DTXSID9022528	120-47-8	Ethylparaben		24	60
DTXSID8023971	91-58-7	2-Chloronaphthalene		24	60
DTXSID3060950	645-92-1	1,3,5-Triazin-2(1H)-one, 4,6-diamino-		24	7
DTXSID5023879	7440-36-0	Antimony		23	87
DTXSID8060955	646-31-1	Tetracosane		23	11
DTXSID1024207	7439-98-7	Molybdenum	R & PC	23	87
DTXSID3024861	26444-49-5	Cresyl diphenyl phosphate		23	67
DTXSID3023922	7440-42-8	Boron		23	87
DTXSID0023909	207-08-9	Benzo(k)fluoranthene		23	67
DTXSID6021290	57-68-1	Sulfamethazine		22	13
DTXSID0049658	7439-95-4	Magnesium		22	60
DTXSID5026259	13674-84-5	Tris(2-chloroisopropyl)phosphate		22	87
DTXSID6032192	78-30-8	Tri-o-cresyl phosphate		22	33
DTXSID4027862	25322-68-3	Polyethylene glycol		22	60
DTXSID1027184	541-02-6	Decamethylcyclopentasiloxane		22	67
DTXSID5020364	50-18-0	Cyclophosphamide		22	40
DTXSID6022923	15307-86-5	Diclofenac		21	47
DTXSID0051441	7440-21-3	Silicon		21	33
DTXSID5021384	75-69-4	Trichlorofluoromethane		21	60
DTXSID4074144	39635-31-9	2,3,3',4,4',5,5'-Heptachlorobiphenyl		21	11
DTXSID9037539	959-98-8	Endosulfan I		21	40
DTXSID7027750	13560-89-9	Bis(hexachlorocyclopentadieno)cyclooctane		21	67
DTXSID6074205	69782-90-7	2,3,3',4,4',5'-Hexachlorobiphenyl		20	11
DTXSID5022481	83-46-5	beta-Sitosterol		20	27
DTXSID4021391	1330-78-5	Tris(methylphenyl) phosphate		20	60
DTXSID4043937	67-71-0	Dimethyl sulfone		20	20
DTXSID8037540	33213-65-9	Endosulfan II		20	40
DTXSID50867160	65510-44-3	2',3,4,4',5-Pentachlorobiphenyl		20	11
DTXSID9074226	74472-37-0	2,3,4,4',5-Pentachlorobiphenyl		20	11
DTXSID9023380	68-22-4	Norethindrone		20	40
DTXSID7023645	60-54-8	Tetracycline		20	47
DTXSID3040273	7429-90-5	Aluminum		19	60
DTXSID6074209	70362-50-4	3,4,4',5-Tetrachlorobiphenyl		19	11

DTXSID	CASRN	Chemical Name	Regulated (R) or Previously Prioritized Chemical (PC)	Scientific Domain Metric	Information Availability Metric
DTXSID6023525	525-66-6	Propranolol		19	40
DTXSID5023243	61-68-7	Mefenamic acid		19	33
DTXSID2024246	32534-81-9	Pentabromodiphenyl ether		19	60
DTXSID0023907	205-99-2	Benzo(b)fluoranthene		19	60
DTXSID8020040	309-00-2	Aldrin		19	60
DTXSID0023824	57653-85-7	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin		19	13
DTXSID5036767	7440-46-2	Cesium		19	13
DTXSID7021156	13171-21-6	Phosphamidon		19	13
DTXSID0022513	2437-79-8	2,2',4,4'-Tetrachlorobiphenyl		19	11
DTXSID3038305	35693-99-3	2,2',5,5'-Tetrachlorobiphenyl		19	11
DTXSID3051466	78-33-1	Tris(4-tert-butylphenyl) phosphate		19	11
DTXSID4047753	198-55-0	Perylene		19	11
DTXSID5022514	32598-13-3	3,3',4,4'-Tetrachlorobiphenyl		19	11
DTXSID2038310	7012-37-5	2,4,4'-Trichlorobiphenyl		19	7
DTXSID3040300	2051-62-9	4-Chlorobiphenyl		19	7
DTXSID7022596	88150-42-9	Amlodipine		19	7
DTXSID4052710	41318-75-6	2,4,4'-Tribromodiphenyl ether		19	0
DTXSID0022353	92-04-6	2-Chloro-4-phenylphenol		19	20
DTXSID5043710	7439-89-6	Iron		19	60
DTXSID8020620	55-38-9	Fenthion		19	73
DTXSID3047764	7440-32-6	Titanium		18	40
DTXSID2024169	7439-96-5	Manganese	PC	18	73
DTXSID7020504	58-15-1	4-Dimethylaminoantipyrine		18	7
DTXSID4020406	439-14-5	Diazepam		18	40
DTXSID4022949	58-73-1	Diphenhydramine		18	27
DTXSID1044699	598-02-7	Diethyl hydrogen phosphate		18	13
DTXSID6021117	60-80-0	Phenazone		18	20
DTXSID2069155	57117-44-9	1,2,3,6,7,8-Hexachlorodibenzofuran		18	13
DTXSID4022991	114-07-8	Erythromycin		18	60
DTXSID2022628	29122-68-7	Atenolol		18	47
DTXSID1034260	79-57-2	Oxytetracycline		18	60
DTXSID1023607	122-11-2	Sulfadimethoxine		17	20
DTXSID7047063	629-97-0	Docosane		17	11
DTXSID8069197	57583-54-7	Resorcinol bis(diphenyl phosphate)		17	56
DTXSID1025227	112-95-8	Eicosane		16	67
DTXSID7061433	1066-40-6	Trimethylsilanol		16	7
DTXSID9047172	593-45-3	Octadecane		16	67
DTXSID6023991	57-12-5	Cyanide		16	80
DTXSID4025799	3268-87-9	Octachlorodibenzo-p-dioxin		16	13
DTXSID3052062	39001-02-0	Octachlorodibenzofuran		16	7
DTXSID1040661	882-09-7	Clofibric acid		15	47
DTXSID8052720	5945-33-5	Phosphoric acid, P,P'-[(1-methylethylidene)di-4,1-phenylene] P,P,P',P'-tetraphenyl ester		15	33
DTXSID8024523	63-05-8	4-Androstene-3,17-dione		15	47
DTXSID2036035	7440-28-0	Thallium		15	33
DTXSID5024134	319-86-8	delta-Hexachlorocyclohexane		15	27
DTXSID3025465	29761-21-5	Isodecyl diphenyl phosphate		14	53
DTXSID0021387	93-72-1	2-(2,4,5-Trichlorophenoxy)propionic acid		14	60
DTXSID1024209	300-76-5	Naled		14	60
DTXSID3020679	76-44-8	Heptachlor		14	60
DTXSID6021032	621-64-7	N-Nitrosodipropylamine		14	60
DTXSID0021256	599-79-1	Sulfasalazine		14	33
DTXSID0037237	10238-21-8	Glybenclamide		14	20
DTXSID0037653	564-25-0	Doxycycline		14	20
DTXSID3043996	1401-69-0	Tylosin		14	20
DTXSID4020458	2921-88-2	Chlorpyrifos		14	20
DTXSID6020771	22071-15-4	Ketoprofen		14	20
DTXSID0020814	72-33-3	Mestranol		14	13
DTXSID1052036	360-68-9	Coprosterol		14	13

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DTXSID3023429	87-08-1	Penicillin V		14	13
DTXSID5023908	191-24-2	Benzo(g,h,i)perylene		14	13
DTXSID6023319	22916-47-8	Miconazole		14	13
DTXSID7022594	50-48-6	Amitriptyline		14	13
DTXSID801009891	474-62-4	Campesterol		14	13
DTXSID8041117	80214-83-1	Roxithromycin		14	13
DTXSID9021398	137-17-7	2,4,5-Trimethylaniline		14	13
DTXSID9023914	141-66-2	Dicrotophos		14	13
DTXSID0074184	56558-16-8	2,2',4,6,6'-Pentachlorobiphenyl		14	11
DTXSID2074243	76842-07-4	2,3,3',4',5'-Pentachlorobiphenyl		14	11
DTXSID3040302	33979-03-2	2,2',4,4',6,6'-Hexachlorobiphenyl		14	11
DTXSID4047541	2051-24-3	Decachlorobiphenyl		14	11
DTXSID50858932	38380-07-3	2,2',3,3',4,4'-Hexachlorobiphenyl		14	11
DTXSID8038304	37680-73-2	2,2',4,5,5'-Pentachlorobiphenyl		14	11
DTXSID3036525	53-41-8	Androsterone		14	7
DTXSID0065983	15968-05-5	2,2',6,6'-Tetrachlorobiphenyl		14	0
DTXSID0073536	52663-60-2	2,2',3,3',6-Pentachlorobiphenyl		14	0
DTXSID0073538	52663-64-6	2,2',3,3',5,6,6'-Heptachlorobiphenyl		14	0
DTXSID0074132	2136-99-4	2,2',3,3',5,5',6,6'-Octachlorobiphenyl		14	0
DTXSID0074134	33091-17-7	2,2',3,3',4,4',6,6'-Octachlorobiphenyl		14	0
DTXSID0074136	33284-54-7	2,3,5,6-Tetrachlorobiphenyl		14	0
DTXSID0074138	35694-06-5	2,2',3,4,4',5-Hexachlorobiphenyl		14	0
DTXSID0074186	59291-64-4	2,2',3,4,4',6'-Hexachlorobiphenyl		14	0
DTXSID0074188	60145-20-2	2,2',3,3',5-Pentachlorobiphenyl		14	0
DTXSID0074211	70424-68-9	2,3,3',4',5-Pentachlorobiphenyl		14	0
DTXSID0074213	70424-70-3	2,3',4',5,5'-Pentachlorobiphenyl		14	0
DTXSID0074215	73575-53-8	2,3',4,5-Tetrachlorobiphenyl		14	0
DTXSID0074217	73575-55-0	2,2',3,5,6'-Pentachlorobiphenyl		14	0
DTXSID0074219	73575-57-2	2,2',3,4,6'-Pentachlorobiphenyl		14	0
DTXSID00867918	70362-46-8	2,2',3,5-Tetrachlorobiphenyl		14	0
DTXSID1040299	2051-61-8	3-Chlorobiphenyl		14	0
DTXSID1073496	38380-01-7	2,2',4,4',5-Pentachlorobiphenyl		14	0
DTXSID1073498	38380-04-0	2,2',3,4',5',6-Hexachlorobiphenyl		14	0
DTXSID1073608	68194-05-8	2,2',3,4',6-Pentachlorobiphenyl		14	0
DTXSID1074171	52663-78-2	2,2',3,3',4,4',5,6-Octachlorobiphenyl		14	0
DTXSID1074173	52704-70-8	2,2',3,3',5,6-Hexachlorobiphenyl		14	0
DTXSID1074175	52712-05-7	2,2',3,4,5,5',6-Heptachlorobiphenyl		14	0
DTXSID1074177	54230-22-7	2,3,4,6-Tetrachlorobiphenyl		14	0
DTXSID1074179	55312-69-1	2,2',3,4,5-Pentachlorobiphenyl		14	0
DTXSID1074200	68194-13-8	2,2',3,4',5,6-Hexachlorobiphenyl		14	0
DTXSID1074202	68194-15-0	2,2',3,4,5,6'-Hexachlorobiphenyl		14	0
DTXSID1074204	68194-17-2	2,2',3,3',4,5,5',6-Octachlorobiphenyl		14	0
DTXSID1074206	70362-41-3	2,3,3',4,5'-Pentachlorobiphenyl		14	0
DTXSID1074208	70362-49-1	3,3',4,5-Tetrachlorobiphenyl		14	0
DTXSID10865965	39635-34-2	2,3,3',4',5,5'-Hexachlorobiphenyl		14	0
DTXSID10867525	68194-06-9	2,2',4,5,6'-Pentachlorobiphenyl		14	0
DTXSID2073481	35065-30-6	2,2',3,3',4,4',5-Heptachlorobiphenyl		14	0
DTXSID2073510	41464-51-1	2,2',3,4',5'-Pentachlorobiphenyl		14	0
DTXSID2074160	52663-63-5	2,2',3,5,5',6-Hexachlorobiphenyl		14	0
DTXSID2074162	52663-67-9	2,2',3,3',5,5',6-Heptachlorobiphenyl		14	0
DTXSID2074164	52663-70-4	2,2',3,3',4,5',6'-Heptachlorobiphenyl		14	0
DTXSID2074166	52663-73-7	2,2',3,3',4,5,6,6'-Octachlorobiphenyl		14	0
DTXSID2074168	52663-75-9	2,2',3,3',4,5,5',6'-Octachlorobiphenyl		14	0
DTXSID2074241	74472-53-0	2,3,3',4,4',5,5',6-Octachlorobiphenyl		14	0
DTXSID20866044	41411-62-5	2,3,3',4,5,6-Hexachlorobiphenyl		14	0
DTXSID3038301	38379-99-6	2,2',3,5',6-Pentachlorobiphenyl		14	0
DTXSID3038307	38380-03-9	2,3,3',4',6-Pentachlorobiphenyl		14	0
DTXSID3038309	32598-11-1	2,3',4',5-Tetrachlorobiphenyl		14	0
DTXSID3073472	32598-10-0	2,3',4,4'-Tetrachlorobiphenyl		14	0

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DTXSID3073474	33025-41-1	2,3,4,4'-Tetrachlorobiphenyl		14	0
DTXSID3073503	38444-93-8	2,2',3,3'-Tetrachlorobiphenyl		14	0
DTXSID3073509	41464-41-9	2,2',5,6'-Tetrachlorobiphenyl		14	0
DTXSID3074151	41411-64-7	2,3,3',4,4',5,6-Heptachlorobiphenyl		14	0
DTXSID3074153	41464-43-1	2,3,3',4'-Tetrachlorobiphenyl		14	0
DTXSID3074155	41464-48-6	3,3',4,5'-Tetrachlorobiphenyl		14	0
DTXSID3074157	42740-50-1	2,2',3,3',4,4',5,6'-Octachlorobiphenyl		14	0
DTXSID3074159	52663-58-8	2,3,4',6-Tetrachlorobiphenyl		14	0
DTXSID3074230	74472-41-6	2,2',3,4',5,6'-Hexachlorobiphenyl		14	0
DTXSID3074232	74472-43-8	2,3,3',4,5',6-Hexachlorobiphenyl		14	0
DTXSID3074234	74472-45-0	2,3,3',4',5',6-Hexachlorobiphenyl		14	0
DTXSID3074236	74472-48-3	2,2',3,4,4',6,6'-Heptachlorobiphenyl		14	0
DTXSID3074238	74472-50-7	2,3,3',4,4',5',6-Heptachlorobiphenyl		14	0
DTXSID30867845	69782-91-8	2,3,3',4',5,5',6-Heptachlorobiphenyl		14	0
DTXSID4030045	35694-04-3	2,2',3,3',5,5'-Hexachlorobiphenyl		14	0
DTXSID4058657	33284-52-5	3,3',5,5'-Tetrachlorobiphenyl		14	0
DTXSID4073540	52663-71-5	2,2',3,3',4,4',6-Heptachlorobiphenyl		14	0
DTXSID4074142	38411-25-5	2,2',3,3',4,5,6'-Heptachlorobiphenyl		14	0
DTXSID4074146	39635-35-3	2,3,3',4,5,5'-Hexachlorobiphenyl		14	0
DTXSID4074148	40186-71-8	2,2',3,3',4,5',6,6'-Octachlorobiphenyl		14	0
DTXSID4074190	60145-22-4	2,2',4,4',5,6'-Hexachlorobiphenyl		14	0
DTXSID4074192	60233-24-1	2,3',4,6-Tetrachlorobiphenyl		14	0
DTXSID4074194	62796-65-0	2,2',4,6-Tetrachlorobiphenyl		14	0
DTXSID4074196	68194-07-0	2,2',3,4',5-Pentachlorobiphenyl		14	0
DTXSID4074198	68194-10-5	2,3,3',5',6-Pentachlorobiphenyl		14	0
DTXSID4074221	74338-24-2	2,3,3',4-Tetrachlorobiphenyl		14	0
DTXSID4074223	74472-34-7	2,3,4',5-Tetrachlorobiphenyl		14	0
DTXSID4074227	74472-38-1	2,3,4,4',6-Pentachlorobiphenyl		14	0
DTXSID4074229	74472-40-5	2,2',3,4,6,6'-Hexachlorobiphenyl		14	0
DTXSID40864820	18259-05-7	2,3,4,5,6-Pentachlorobiphenyl		14	0
DTXSID40866046	41464-47-5	2,2',3,6'-Tetrachlorobiphenyl		14	0
DTXSID5052832	52663-68-0	2,2',3,4',5,5',6-Heptachloro-1,1'-biphenyl		14	0
DTXSID5073535	52663-59-9	2,2',3,4-Tetrachlorobiphenyl		14	0
DTXSID5073537	52663-61-3	2,2',3,5,5'-Pentachlorobiphenyl		14	0
DTXSID5073539	52663-66-8	2,2',3,3',4,5'-Hexachlorobiphenyl		14	0
DTXSID5074133	32598-12-2	2,4,4',6-Tetrachlorobiphenyl		14	0
DTXSID5074135	33284-53-6	2,3,4,5-Tetrachlorobiphenyl		14	0
DTXSID5074139	35694-08-7	2,2',3,3',4,4',5,5'-Octachlorobiphenyl		14	0
DTXSID5074183	56030-56-9	2,2',3,4,4',6-Hexachlorobiphenyl		14	0
DTXSID5074185	56558-17-9	2,3',4,4',6-Pentachlorobiphenyl		14	0
DTXSID5074187	59291-65-5	2,3',4,4',5',6-Hexachlorobiphenyl		14	0
DTXSID5074189	60145-21-3	2,2',4,5',6-Pentachlorobiphenyl		14	0
DTXSID5074210	70424-67-8	2,3,3',5-Tetrachlorobiphenyl		14	0
DTXSID5074214	73575-52-7	2,3',4,5'-Tetrachlorobiphenyl		14	0
DTXSID5074216	73575-54-9	2,2',3,6,6'-Pentachlorobiphenyl		14	0
DTXSID5074218	73575-56-1	2,2',3,5,6-Pentachlorobiphenyl		14	0
DTXSID50865964	39635-32-0	2,3,3',5,5'-Pentachlorobiphenyl		14	0
DTXSID50866577	56558-18-0	2,3',4,5',6-Pentachlorobiphenyl		14	0
DTXSID60274189	52663-62-4	2,2',3,3',4-Pentachlorobiphenyl		14	0
DTXSID6040298	2051-60-7	2-Chlorobiphenyl		14	0
DTXSID6073497	38380-02-8	2,2',3,4,5'-Pentachlorobiphenyl		14	0
DTXSID6073499	38411-22-2	2,2',3,3',6,6'-Hexachlorobiphenyl		14	0
DTXSID6073609	68194-12-7	2,3',4,5,5'-Pentachlorobiphenyl		14	0
DTXSID6074170	52663-77-1	2,2',3,3',4,5,5',6,6'-Nonachlorobiphenyl		14	0
DTXSID6074172	52663-79-3	2,2',3,3',4,4',5,6,6'-Nonachlorobiphenyl		14	0
DTXSID6074174	52712-04-6	2,2',3,4,5,5'-Hexachlorobiphenyl		14	0
DTXSID6074178	55215-17-3	2,2',3,4,6-Pentachlorobiphenyl		14	0
DTXSID6074201	68194-14-9	2,2',3,4,5',6-Hexachlorobiphenyl		14	0
DTXSID6074203	68194-16-1	2,2',3,3',4,5,6-Heptachlorobiphenyl		14	0

DTXSID	CASRN	Chemical Name	Regulated (R) or Previously Prioritized Chemical (PC)	Scientific Domain Metric	Information Availability Metric
DTXSID6074207	70362-47-9	2,2',4,5-Tetrachlorobiphenyl		14	0
DTXSID60867919	70362-48-0	2,3',4',5'-Tetrachlorobiphenyl		14	0
DTXSID7074161	52663-65-7	2,2',3,3',4,6,6'-Heptachlorobiphenyl		14	0
DTXSID7074163	52663-69-1	2,2',3,4,4',5',6-Heptachlorobiphenyl		14	0
DTXSID7074167	52663-74-8	2,2',3,3',4,5,5'-Heptachlorobiphenyl		14	0
DTXSID7074169	52663-76-0	2,2',3,4,4',5,5',6-Octachlorobiphenyl		14	0
DTXSID7074240	74472-52-9	2,2',3,4,4',5,6,6'-Octachlorobiphenyl		14	0
DTXSID7074242	74487-85-7	2,2',3,4',5,6,6'-Heptachlorobiphenyl		14	0
DTXSID70867526	68194-09-2	2,2',3,5,6,6'-Hexachlorobiphenyl		14	0
DTXSID8038302	41464-39-5	2,2',3,5'-tetrachlorobiphenyl		14	0
DTXSID8073473	32690-93-0	2,4,4',5-Tetrachlorobiphenyl		14	0
DTXSID8073504	39485-83-1	2,2',4,4',6-Pentachlorobiphenyl		14	0
DTXSID8073508	41464-40-8	2,2',4,5'-Tetrachlorobiphenyl		14	0
DTXSID8073554	55215-18-4	2,2',3,3',4,5-Hexachlorobiphenyl		14	0
DTXSID8073631	74472-46-1	2,3,3',5,5',6-Hexachlorobiphenyl		14	0
DTXSID8074150	41411-63-6	2,3,4,4',5,6-Hexachlorobiphenyl		14	0
DTXSID8074152	41464-42-0	2,3',5,5'-Tetrachlorobiphenyl		14	0
DTXSID8074154	41464-46-4	2,3',4',6-Tetrachlorobiphenyl		14	0
DTXSID8074156	41464-49-7	2,3,3',5'-Tetrachlorobiphenyl		14	0
DTXSID8074158	51908-16-8	2,2',3,4',5,5'-Hexachlorobiphenyl		14	0
DTXSID8074231	74472-42-7	2,3,3',4,4',6-Hexachlorobiphenyl		14	0
DTXSID8074233	74472-44-9	2,3,3',4',5,6-Hexachlorobiphenyl		14	0
DTXSID8074235	74472-47-2	2,2',3,4,4',5,6-Heptachlorobiphenyl		14	0
DTXSID8074237	74472-49-4	2,2',3,4,5,6,6'-Heptachlorobiphenyl		14	0
DTXSID8074239	74472-51-8	2,3,3',4,5,5',6-Heptachlorobiphenyl		14	0
DTXSID8074780	61798-70-7	PCB 131		14	0
DTXSID80873557	36559-22-5	2,2',3,4'-Tetrachloro-1,1'-biphenyl		14	0
DTXSID9073541	52744-13-5	2,2',3,3',5,6'-Hexachlorobiphenyl		14	0
DTXSID9073599	65510-45-4	2,2',3,4,4'-Pentachlorobiphenyl		14	0
DTXSID9074141	38380-05-1	2,2',3,3',4,6'-Hexachlorobiphenyl		14	0
DTXSID9074145	39635-33-1	3,3',4,5,5'-Pentachlorobiphenyl		14	0
DTXSID9074147	40186-70-7	2,2',3,3',4,5',6-Heptachlorobiphenyl		14	0
DTXSID9074191	60145-23-5	2,2',3,4,4',5,6'-Heptachlorobiphenyl		14	0
DTXSID9074193	60233-25-2	2,2',3,4',6'-Pentachlorobiphenyl		14	0
DTXSID9074195	68194-04-7	2,2',4,6'-Tetrachlorobiphenyl		14	0
DTXSID9074197	68194-08-1	2,2',3,4',6,6'-Hexachlorobiphenyl		14	0
DTXSID9074199	68194-11-6	2,3,4',5,6-Pentachlorobiphenyl		14	0
DTXSID9074220	74338-23-1	2,3',5',6-Tetrachlorobiphenyl		14	0
DTXSID9074222	74472-33-6	2,3,3',6-Tetrachlorobiphenyl		14	0
DTXSID9074224	74472-35-8	2,3,3',4,6-Pentachlorobiphenyl		14	0
DTXSID9074228	74472-39-2	2,3',4',5',6-Pentachlorobiphenyl		14	0
DTXSID9074779	70362-45-7	PCB 045		14	0
DTXSID1049801	7440-31-5	Tin		14	47
DTXSID8047553	2058-94-8	Perfluoroundecanoic acid		14	20
DTXSID4040686	22204-53-1	Naproxen		14	47
DTXSID3038939	754-91-6	Perfluorooctanesulfonamide		14	20
DTXSID3024312	7440-24-6	Strontium		14	67
DTXSID1024382	7723-14-0	Phosphorus		14	60
DTXSID7052234	57117-41-6	1,2,3,7,8-Pentachlorodibenzofuran		13	13
DTXSID8041030	42017-89-0	Fenofibric acid		13	20
DTXSID2023309	51384-51-1	Metoprolol		13	20
DTXSID3022829	81103-11-9	Clarithromycin		13	33
DTXSID6058639	630-02-4	Octacosane		13	11
DTXSID9049617	16984-48-8	Fluoride		12	20
DTXSID3052147	51207-31-9	2,3,7,8-Tetrachlorodibenzofuran		12	20
DTXSID5021255	18559-94-9	Albuterol		12	20
DTXSID1045033	10118-90-8	Minocycline		11	13
DTXSID7023067	54910-89-3	Fluoxetine		11	40
DTXSID9022366	50-27-1	Estriol		11	20

DTXSID	CASRN	Chemical Name	Regulated (R) or Previously Prioritized Chemical (PC)	Scientific Domain Metric	Information Availability Metric
DTXSID4022731	298-46-4	Carbamazepine		10	47
DTXSID8052067	39227-28-6	1,2,3,4,7,8-Hexachlorodibenzodioxin		10	27
DTXSID0058641	7440-45-1	Cerium		10	40
DTXSID7022174	2104-64-5	EPN		10	60
DTXSID1052034	35822-46-9	1,2,3,4,6,7,8-Heptachlorodibenzodioxin		10	13
DTXSID2020341	76-57-3	Codeine		10	13
DTXSID3020122	86-50-0	Azinphos-methyl		10	13
DTXSID3040279	21609-90-5	Leptophos		10	13
DTXSID3065740	14260-97-0	Ethanol, 2-butoxy-, hydrogen phosphate		10	13
DTXSID40883258	80-97-7	Cholestan-3-ol, (3.beta.,5.alpha.)-		10	13
DTXSID7021782	85-22-3	2,3,4,5,6-Pentabromoethylbenzene		10	13
DTXSID8051835	19466-47-8	Stigmastanol		10	13
DTXSID0023612	127-79-7	Sulfamerazine		10	7
DTXSID0074180	55702-46-0	2,3,4-Trichlorobiphenyl		10	7
DTXSID10878676	313-04-2	Desmosterol		10	7
DTXSID2020391	2303-16-4	Diallate		10	7
DTXSID3020912	389-08-2	Nalidixic acid		10	7
DTXSID30212316	6303-30-6	Diisobutyl hydrogen phosphate		10	7
DTXSID3034957	107-49-3	Tetraethyl pyrophosphate		10	7
DTXSID3037044	26787-78-0	Amoxicillin		10	7
DTXSID4022602	69-53-4	Ampicillin		10	7
DTXSID40865913	38444-88-1	3,4',5-Trichlorobiphenyl		10	7
DTXSID50184485	3040-56-0	Bis(2-chloroethyl) phosphate		10	7
DTXSID6029915	70648-26-9	1,2,3,4,7,8-Hexachlorodibenzofuran		10	7
DTXSID6073491	37680-65-2	2,2',5-Trichlorobiphenyl		10	7
DTXSID7073482	35693-92-6	2,4,6-Trichlorobiphenyl		10	7
DTXSID8052350	67562-39-4	1,2,3,4,6,7,8-Heptachlorodibenzo[b,d]furan		10	7
DTXSID80883752	1804-93-9	Phosphoric acid, dipropyl ester		10	7
DTXSID0022511	34883-43-7	2,4'-Dichlorobiphenyl		10	0
DTXSID0022515	2050-68-2	4,4'-Dichlorobiphenyl		10	0
DTXSID0073405	15862-07-4	2,4,5-Trichlorobiphenyl		10	0
DTXSID0073409	16605-91-7	2,3-Dichlorobiphenyl		10	0
DTXSID0074182	55720-44-0	2,3,5-Trichlorobiphenyl		10	0
DTXSID00865914	38444-90-5	3,4,4'-Trichlorobiphenyl		10	0
DTXSID1073492	37680-66-3	2,2',4-Trichlorobiphenyl		10	0
DTXSID10863067	2974-90-5	3,4'-Dichlorobiphenyl		10	0
DTXSID10872790	25038-59-9	Polyethylene terephthalate		10	0
DTXSID3073501	38444-78-9	2,2',3-Trichlorobiphenyl		10	0
DTXSID3073557	55702-45-9	2,3,6-Trichlorobiphenyl		10	0
DTXSID3074024	25569-80-6	2,3'-Dichlorobiphenyl		10	0
DTXSID4036304	7727-37-9	Nitrogen		10	0
DTXSID4044533	13029-08-8	2,2'-Dichlorobiphenyl		10	0
DTXSID4074140	37680-68-5	2,3',5'-Trichlorobiphenyl		10	0
DTXSID4074778	38444-81-4	PCB 026		10	0
DTXSID5074137	34883-41-5	3,5-Dichlorobiphenyl		10	0
DTXSID5074181	55712-37-3	2,3',4-Trichlorobiphenyl		10	0
DTXSID50858937	38444-87-0	3,3',5-Trichlorobiphenyl		10	0
DTXSID6073310	2974-92-7	3,4-Dichlorobiphenyl		10	0
DTXSID6074176	53555-66-1	3,4,5-Trichlorobiphenyl		10	0
DTXSID60865879	37680-69-6	3,3',4-Trichlorobiphenyl		10	0
DTXSID7038313	33146-45-1	2,6-Dichlorobiphenyl		10	0
DTXSID7073480	34883-39-1	2,5-Dichlorobiphenyl		10	0
DTXSID70872817	2050-67-1	3,3'-Dichloro-1,1'-biphenyl		10	0
DTXSID7091549	38444-85-8	2,3,4'-Trichlorobiphenyl		10	0
DTXSID8040301	33284-50-3	2,4-Dichlorobiphenyl		10	0
DTXSID8040303	38444-86-9	2',3,4-Trichlorobiphenyl		10	0
DTXSID8073500	38444-77-8	2,4',6-Trichlorobiphenyl		10	0
DTXSID8073502	38444-84-7	2,3,3'-Trichlorobiphenyl		10	0
DTXSID9073410	16606-02-3	2,4',5-Trichlorobiphenyl		10	0

DTXSID	CASRN	Chemical Name	Regulated (R) or Previously Prioritized Chemical (PC)	Scientific Domain Metric	Information Availability Metric
DTXSID9074143	38444-76-7	2,3',6-Trichlorobiphenyl		10	0
DTXSID9074777	38444-73-4	2,2',6-Trichlorobiphenyl		10	0
DTXSID90868151	72629-94-8	Perfluorotridecanoic acid		9	13
DTXSID6023577	79617-96-2	Sertraline		9	40
DTXSID3037208	15307-79-6	Diclofenac sodium		9	53
DTXSID6024701	56803-37-3	tert-Butylphenyl diphenyl phosphate		9	7
DTXSID2023270	657-24-9	Metformin		9	13
DTXSID3023425	61869-08-7	Paroxetine		9	13
DTXSID8029868	134523-00-5	Atorvastatin		9	27
DTXSID7037680	70458-96-7	Norfloxacin		9	20
DTXSID5043974	14798-03-9	Ammonium		9	20
DTXSID3023712	738-70-5	Trimethoprim		9	40
DTXSID5024219	14797-65-0	Nitrite	PC	8	60
DTXSID3023215	154-21-2	Lincomycin		8	20
DTXSID3041085	82419-36-1	Ofloxacin		8	27
DTXSID3023342	42200-33-9	Nadolol		8	20
DTXSID4040680	98079-51-7	Lomefloxacin		8	20
DTXSID4020329	51481-61-9	Cimetidine		8	13
DTXSID8045191	66357-35-5	Ranitidine		8	13
DTXSID7060883	630-01-3	Hexacosane		7	11
DTXSID5037072	1069-66-5	Sodium valproate		7	13
DTXSID0049816	7440-65-5	Yttrium		5	13
DTXSID6020561	72-20-8	Endrin		5	60
DTXSID5024217	14797-55-8	Nitrate	PC	5	53
DTXSID5020100	11097-69-1	Aroclor 1254		5	53
DTXSID1045619	93106-60-6	Enrofloxacin		5	33
DTXSID8022824	85721-33-1	Ciprofloxacin		5	20
DTXSID00108550	1079184-43-2	Ethanaminium, 2-hydroxy-N-(2-hydroxyethyl)-N,N-dimethyl-, esters with C16-18 and C18-unsatd. fatty acids, chlorides		5	13
DTXSID1021089	14698-29-4	Oxolinic acid		5	13
DTXSID4022577	28981-97-7	Alprazolam		5	13
DTXSID6023735	137862-53-4	Valsartan		5	13
DTXSID8030760	83905-01-5	Azithromycin		5	13
DTXSID1023524	469-62-5	Propoxyphene		5	7
DTXSID2032683	7786-34-7	Mevinphos		5	7
DTXSID3052276	60851-34-5	2,3,4,6,7,8-Hexachlorodibenzo[b,d]furan		5	7
DTXSID5023407	76-42-6	Oxycodone		5	7
DTXSID6020648	54-31-9	Furosemide		5	7
DTXSID6023781	19408-74-3	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin		5	7
DTXSID6043913	6804-07-5	Carbadox		5	7
DTXSID7046700	516-92-7	(3alpha,5beta)-Cholestan-3-ol		5	7
DTXSID9022998	50-50-0	Estradiol benzoate		5	7
DTXSID9052216	55673-89-7	1,2,3,4,7,8,9-Heptachlorodibenzofuran		5	7
DTXSID0020101	11096-82-5	Aroclor 1260		5	0
DTXSID1047576	486-56-6	Cotinine		5	0
DTXSID2022836	18323-44-9	Clindamycin		5	0
DTXSID4023884	12672-29-6	Aroclor 1248		5	0
DTXSID40880080	11006-76-1	Virginiamycin		5	0
DTXSID7023518	60-87-7	Promethazine		5	0
DTXSID7039672	14265-44-2	Phosphate		5	0
DTXSID8023131	125-29-1	Hydrocodone		5	0
DTXSID9052347	67035-22-7	Dimethyl 2,6-dimethyl-4-(2-nitrophenyl)-3,5-pyridinedicarboxylate		5	0
DTXSID90897481	67554-50-1	n-Octylphenol		5	0
DTXSID9043809	27986-36-3	Ethylene glycol nonylphenyl ether		4	13
DTXSID9041152	52-53-9	Verapamil		4	20
DTXSID9045265	80-32-0	Sulfachloropyridazine		3	7
DTXSID1022893	127-33-3	Demeclocycline		0	13

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DTXSID4064686	7440-17-7	Rubidium		0	13
DTXSID6073524	50585-41-6	2,3,7,8-Tetrabromodibenzo-p-dioxin		0	13
DTXSID00192353	39108-34-4	8:2 Fluorotelomer sulfonic acid		0	7
DTXSID0047874	4640-01-1	Methyl triclosan		0	7
DTXSID0052702	31107-44-5	1,2,3,4,6,7,8,9,10,10,11,11-dodecachloro-1,4,4a,5a,6,9,9a,9b-octahydro-1,4:6,9-dimethanodibenzofuran		0	7
DTXSID0060935	638-68-6	Triacontane		0	7
DTXSID0073794	110999-45-6	1,2,3,6,7,8-Hexabromodibenzo-p-dioxin		0	7
DTXSID1032355	81777-89-1	Clomazone		0	7
DTXSID10704805	446255-30-7	1,2,3,5-Tetrabromo-4-(3,4,5-tribromophenoxy)benzene		0	7
DTXSID20301804	2150-43-8	Methyl 3,4-dihydroxybenzoate		0	7
DTXSID2074245	110999-47-8	1,2,3,4,6,7,8-Heptabromodibenzo-p-dioxin		0	7
DTXSID20873415	943913-15-3	6:2/8:2 Fluorotelomer phosphate diester		0	7
DTXSID20873793	14206-58-7	4-epi-Oxytetracycline		0	7
DTXSID20874028	914637-49-3	2H,2H,3H,3H-Perfluorooctanoic acid		0	7
DTXSID30408651	5136-34-5	STK368415		0	7
DTXSID30936606	161880-49-5	1,2,3,7,8,9-Hexabromodibenzo[b,d]furan		0	7
DTXSID40873795	79-85-6	Epitetracycline		0	7
DTXSID50448655	117948-63-7	Benzene, 1,2,3,5-tetrabromo-4-(2,4,6-tribromophenoxy)-		0	7
DTXSID50561590	57677-95-9	6:2 Fluorotelomer phosphate diester		0	7
DTXSID5073793	110999-44-5	1,2,3,4,7,8-Hexabromodibenzo-p-dioxin		0	7
DTXSID5073795	110999-46-7	1,2,3,7,8,9-Hexabromodibenzo-p-dioxin		0	7
DTXSID5073870	131166-92-2	2,3,4,7,8-Pentabromodibenzofuran		0	7
DTXSID50869644	120067-83-6	Fipronil sulfide		0	7
DTXSID50936608	161880-51-9	1,2,3,4,7,8,9-Heptabromodibenzo[b,d]furan		0	7
DTXSID6073605	67733-57-7	2,3,7,8-Tetrabromodibenzofuran		0	7
DTXSID6073784	109333-34-8	1,2,3,7,8-Pentabromodibenzo-p-dioxin		0	7
DTXSID6073861	129880-08-6	1,2,3,4,7,8-Hexabromodibenzofuran		0	7
DTXSID60869478	107555-93-1	1,2,3,7,8-Pentabromodibenzo[b,d]furan		0	7
DTXSID60892443	2806-15-7	Sodium perfluorodecanesulfonate		0	7
DTXSID70153436	1219-99-4	4,4'-Dichlorocarbanilide		0	7
DTXSID70176089	2170-45-8	Octabromodibenzo-p-dioxin		0	7
DTXSID7073779	107555-95-3	1,2,3,4,6,7,8-Heptabromodibenzofuran		0	7
DTXSID7074244	107555-94-2	1,2,3,6,7,8-Hexabromodibenzofuran		0	7
DTXSID8037128	537-46-2	Methamphetamine		0	7
DTXSID8060082	492-22-8	Thioxanthone		0	7
DTXSID80866540	83891-03-6	Norfluoxetine		0	7
DTXSID90145919	103582-29-2	Dibenzofuran, 1,2,3,4,6,7,8,9-octabromo-		0	7
DTXSID90218051	678-41-1	8:2 Fluorotelomer phosphate diester		0	7
DTXSID9032329	741-58-2	Bensulide		0	7
DTXSID9059757	217-59-4	Triphenylene		0	7
DTXSID90860791	42542-10-9	MDMA		0	7
DTXSID90936607	161880-50-8	2,3,4,6,7,8-Hexabromodibenzo[b,d]furan		0	7
DTXSID001026176	-	-		0	0
DTXSID001026564	-	-		0	0
DTXSID0043719	205650-65-3	Fipronil-desulfinyl		0	0
DTXSID00873791	7518-17-4	4-Epianhydrotetracycline		0	0
DTXSID00948190	25344-86-9	Sulfuric acid--6'-methoxycinchonan-9-ol (1/1)		0	0
DTXSID101026567	-	-		0	0
DTXSID10214757	645-93-2	Ammelide		0	0
DTXSID1046689	6981-18-6	Ormetoprim		0	0
DTXSID10873621	25429-29-2	Pentachloro-1,1'-biphenyl		0	0
DTXSID201016171	-	-		0	0
DTXSID201027532	-	-		0	0
DTXSID2038443	50-36-2	Cocaine		0	0
DTXSID2052156	517-09-9	Equilenin		0	0

DTXSID	CASRN	Chemical Name	Regulated (R) or Previously Prioritized Chemical (PC)	Scientific Domain Metric	Information Availability Metric
DTXSID20872428	-	-		0	0
DTXSID20873798	514-53-4	Isochlortetracycline		0	0
DTXSID301026563	-	-		0	0
DTXSID30108225	13560-92-4	1,4:5,8:9,10-Trimethanoanthracene, 1,2,3,4,5,6,7,8,12,12,13,13-dodecachloro-1,4,4a,5,8,8a,9,9a,10,10a-decahydro-		0	0
DTXSID3042425	14808-79-8	Sulfate		0	0
DTXSID3047477	6533-00-2	dl-Norgestrel		0	0
DTXSID30992969	-	-		0	0
DTXSID401026566	-	-		0	0
DTXSID4052712	513-08-6	Tripropyl phosphate		0	0
DTXSID4064767	-	-		0	0
DTXSID50860237	-	-		0	0
DTXSID50881104	-	-		0	0
DTXSID50912301	4497-08-9	Anhydrochlortetracycline		0	0
DTXSID601026562	-	-		0	0
DTXSID6025648	832-69-9	1-Methyl phenanthrene		0	0
DTXSID6037514	7700-17-6	Crotoxyphos		0	0
DTXSID6074750	120068-36-2	Fipronil Sulfone		0	0
DTXSID60873414	-	-		0	0
DTXSID60873419	205650-69-7	Fipronil amide		0	0
DTXSID60873792	14297-93-9	4-Epichlortetracycline		0	0
DTXSID60873797	86408-45-9	N-Desmethyldiltiazem		0	0
DTXSID701026565	-	-		0	0
DTXSID7022120	786-19-6	Carbophenothion		0	0
DTXSID7046758	519-09-5	Benzoylecgonine		0	0
DTXSID7047433	474-86-2	Equilin		0	0
DTXSID7052078	40321-76-4	1,2,3,7,8-Pentachlorodibenzo-p-dioxin		0	0
DTXSID70873788	651-55-8	?-Dihydroequilin		0	0
DTXSID70957173	-	-		0	0
DTXSID801015733	-	-		0	0
DTXSID801026568	-	-		0	0
DTXSID8022377	57-91-0	17alpha-Estradiol		0	0
DTXSID8023056	5250-39-5	Floxacillin		0	0
DTXSID8048494	98105-99-8	Sarafloxacin		0	0
DTXSID80873799	67018-85-3	Norverapamil		0	0
DTXSID9022659	86-13-5	Benztropine		0	0
DTXSID90274172	-	-		0	0
DTXSID9040132	-	-		0	0
DTXSID9052470	72918-21-9	1,2,3,7,8,9-Hexachlorodibenzo[b,d]furan		0	0
DTXSID9052682	1576-67-6	3,6-Dimethylphenanthrene		0	0
DTXSID90873785	1159-82-6	10-Hydroxyamitriptyline		0	0
DTXSID90878679	57-87-4	ERGOSTEROL		0	0