United States
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Methodology for Evaluating Beneficial Uses of Industrial Non-Hazardous Secondary Materials

Office of Resource Conservation and Recovery
Office of Land and Emergency Management
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Disclaimer:

This document describes a methodology developed for evaluating the beneficial use of industrial non-hazardous secondary materials ("secondary materials") by the United States Environmental Protection Agency ("EPA" or "the Agency") Office of Land and Emergency Management. The methodology is intended to be useful to those conducting or reviewing beneficial use evaluations and other interested stakeholders, including states, local governments, tribal authorities, regulated communities, and the general public. The methodology is based on the Agency's current understanding of the range of issues and circumstances involved with the beneficial use of secondary materials. It is not intended to address the combustion of non-hazardous secondary materials for energy or use/reuse of municipal solid waste. Use of this methodology is voluntary, and the methodology does not change or substitute for any federal or state statutory or regulatory provisions or requirements. This document does not preclude the use of any other available approaches. Nothing in this document is intended to establish binding requirements on EPA or any other entity. Accordingly, EPA may revise or depart from this methodology at any time, without prior notice.

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Introduction

Industrial non-hazardous secondary materials ("secondary materials") are any materials that are not the primary products from manufacturing and other industrial sectors. Examples can include scrap and residuals from production processes and products that have been recovered at the end of their useful life. Virtually all industrial sectors generate some form of secondary material during the course of normal operations. Some of these secondary materials can be generated in large quantities. For example:

- Steam electric utilities generated nearly 130 million tons of coal combustion residuals during the 2014 calendar year (ACAA, 2014).
- The metal casting sector generates approximately 9.4 million tons of spent foundry sands each year (AFS, 2007).
- The construction and demolition sector generated approximately 530 million tons of building-related construction and demolition materials in 2013 (U.S. EPA, 2015).

Once generated, secondary materials are often sent directly for disposal, but some have the potential to be beneficially used instead. Beneficial use involves the substitution of these secondary materials, either as generated or following additional processing, for some or all of the virgin, raw materials in a natural or commercial product (an "analogous product") in a way that provides a functional benefit, meets product specifications, and does not pose concerns to human health or the environment. State, tribal and territorial regulatory bodies make the determinations whether to allow a given beneficial use under a wide variety of programs. A survey of beneficial use programs in the United States conducted by the Association of State and Territorial Solid Waste Management Officials in 2006 found that, although the number of requests for determinations is increasing, "insufficient information to determine human or ecological impacts of use rather than disposal" has been a major barrier for states when reviewing proposed beneficial uses (ASTSWMO, 2007). The United States Environmental Protection Agency ("EPA" or "the Agency") Office of Land and Emergency Management developed this document to help address this barrier.

This methodology can be used to determine whether the potential for adverse impacts to human health and the environment from a proposed beneficial use is comparable to or lower than from an analogous product, or at or below relevant health-based and regulatory benchmarks. Use of this methodology is voluntary and does not change or substitute for existing laws, regulations, or any beneficial use determinations that govern the management of individual wastes on either a federal or state level. EPA encourages those individuals or entities who use the methodology to consult with relevant regulatory bodies to ensure that the application of this methodology is scientifically sound and accounts for any additional considerations required by these regulatory bodies. While protection of human health and the environment is a critical component of beneficial use determinations, EPA recognizes that additional considerations (e.g., existing state and federal requirements, public opinion, the existence of a market) may also factor into the final determination for a particular use.

This document builds on the steps first outlined in the *Methodology for Evaluating Encapsulated Beneficial Uses of Coal Combustion Residuals* (U.S. EPA, 2013a), which underwent independent external peer review documented in *Responses to External Peer Review Comments: Methodology for Evaluating Encapsulated Beneficial Uses of Coal Combustion Residuals* (US EPA, 2013b) and was applied in *Coal Combustion Residual Beneficial Use Evaluation: Fly Ash Concrete and FGD Gypsum Wallboard* (U.S. EPA, 2014). The updated methodology presented in this document is intended to provide further clarification on the analytical steps and to ensure relevance for the widest range of secondary materials used in encapsulated and unencapsulated beneficial uses.[1] The updated methodology is divided into three phases: planning and scoping, impact analysis, and final characterization. Each beneficial use evaluation conducted using this methodology will progress through these three phases, but there is flexibility in how each is applied. This document provides an introduction to each phase and is intentionally broad in order to present a balanced discussion of the different aspects of the methodology. A summary flowchart of the three phases is presented on the following page in **Figure 1**. A more detailed discussion of the specific considerations that may arise in a particular evaluation, as well as a list of existing resources and tools that can assist with these evaluations, can be found in the *Beneficial Use Compendium: A Collection of Resources and Tools to Support Beneficial Use Evaluations* (U.S. EPA, 2016).

Many opportunities exist to beneficially use these secondary materials (e.g., coal fly ash as a replacement for cement in concrete, spent foundry sands as road subbase). Some of the potential benefits associated with the use of secondary materials include preservation of natural virgin resources, reduced air and water pollution from extraction activities, reduced greenhouse gas emissions, reduced production costs, and avoided use of landfill space. Because of the potential for numerous environmental, economic and performance benefits, the appropriate beneficial use of secondary materials can advance the goals of EPA's Sustainable Materials Management program, which emphasizes a materials management approach that aims to reduce impacts to human health and the environment associated with materials over their entire life cycle (e.g., extraction, manufacture, distribution, use, disposal).

1) Encapsulated beneficial uses are those where the secondary material is bound in a solid matrix that minimizes mobilization into the surrounding environment. Examples of encapsulated uses include, but are not limited to: aggregate in concrete; a replacement for, or raw material used in production of, cementitious components in concrete or bricks; filler in plastics, rubber, and similar products; and raw material in the manufacture of a product (e.g., wallboard).

Unencapsulated beneficial uses are those where the secondary material is used in a loose or unbound particulate or sludge form and involves the direct placement of the secondary material on the land. Examples of these applications include: structural fills; use in agriculture as a soil amendment; and aggregate.

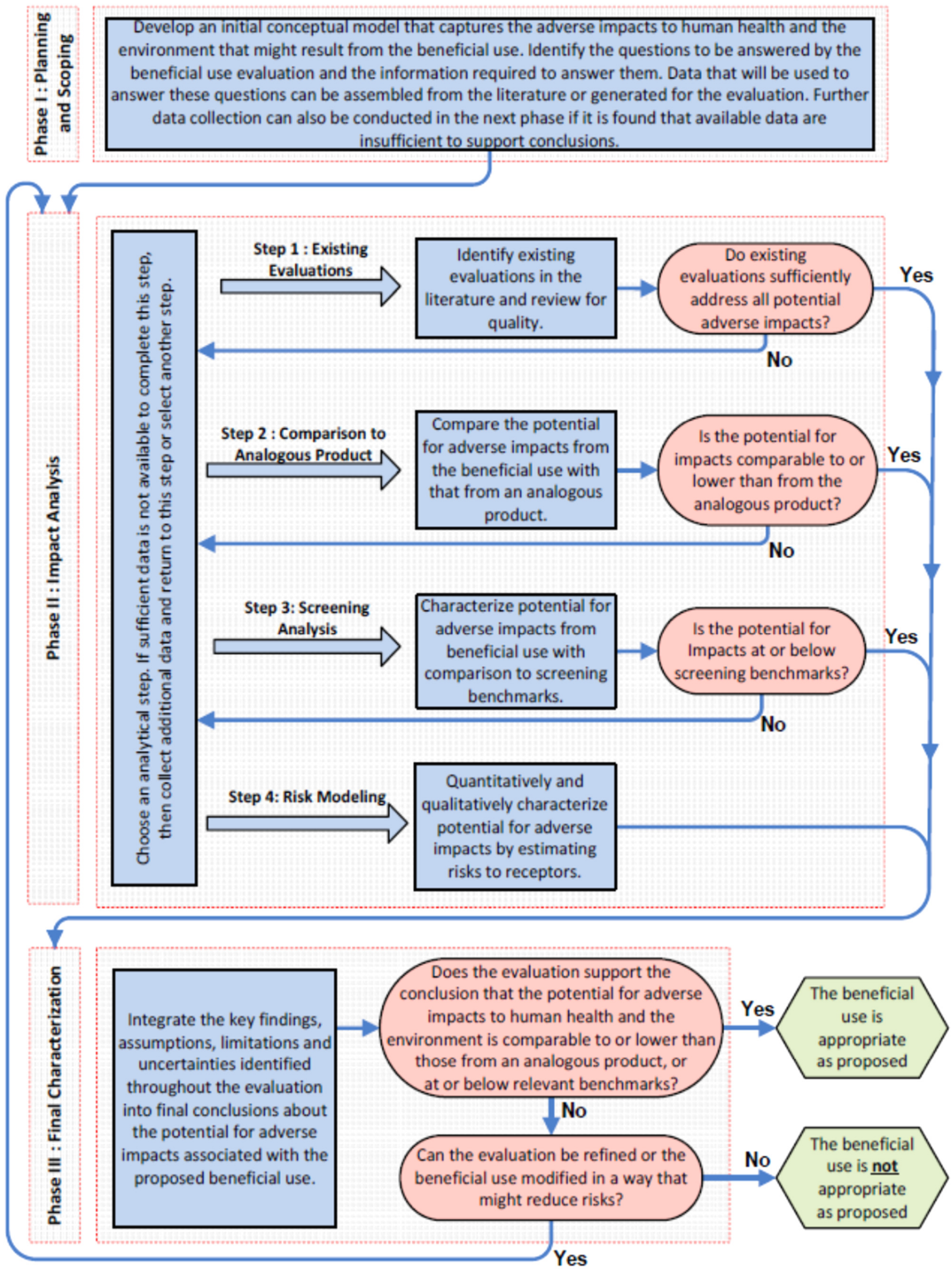

Figure 1. Summary Flowchart of the Beneficial Use Methodology

Phase I – Planning and Scoping

This is the initial phase for beneficial use evaluations conducted using this methodology. The objective is to identify the questions that will be answered by the evaluation and the information required to answer them. Because of the substantial variability in the secondary materials generated, the range of potential uses for these materials, and the data available to characterize each, there is no single structure best suited for every evaluation. Therefore, careful planning is essential to ensure that the scope of the evaluation is well-defined, realistic, and ultimately forms a sound basis for the subsequent beneficial use determination.

The scope of the evaluation is primarily defined by how widespread the intended use will be and the composition of beneficial use during the relevant stages of its life cycle. This information places bounds on the adverse impacts that may occur by defining the possible chemical constituents and other stressors (e.g., particulate matter) released, environmental media affected, and nearby receptors exposed. The scope will, in turn, dictate the data needed to answer the questions posed by the evaluation.

Data can be assembled from the existing sources or generated for the evaluation. The benefit of generating new data is that it allows the quality and quantity of data to be tailored to the specific needs of the evaluation. Yet the planning, sampling and analysis necessary to generate new data can be a resource-intensive process. Therefore, this option can be reserved until a later stage of the evaluation, if it is found that existing data are insufficient. Because it can be difficult to know the exact amount of data required before the analysis is underway, the collection and analysis of data is often an iterative process. While the evaluation may not ultimately rely on all the collected data in the analyses, it is important to provide documentation of all the data sources considered and the rationale for exclusion of any data.

The ultimate goal of the evaluation is to reduce uncertainties enough that well-substantiated conclusions can be drawn about the beneficial use. However, some uncertainty may remain, regardless of the amount of data available. There is an opportunity during planning and scoping to manage uncertainty through the selection of analytical methods that will either minimize it or deliberately bias it in a known, protective direction. The most suitable methods may not always be the most sophisticated. The added complexity of some methods might not add value when less complex methods are sufficient, and may actually exacerbate the amount of uncertainty present in the evaluation. It can be helpful to seek input from experts to help identify and implement the most suitable methods.

Hypothetical Application of Phase I

A secondary material is proposed for use as subsurface structural fill statewide as generated. One example of an adverse impact that may occur during use is an increased risk of cancer in receptors who ingest the chemical constituents released into ground water. Consideration of potential impacts during storage may also be warranted if the beneficial use will be staged outdoors in a way that is exposed to wind and rain for any considerable time prior to use.

In this hypothetical, there are few limitations placed on where this secondary material could be used. This makes it difficult to develop representative distributions for distances to residential wells, water bodies, and other receptors that would be needed for a refined, probabilistic analysis. As a result, a large-scale evaluation for this use may be limited in complexity to a screening analysis. If such a screening shows the potential for concern, then it may be more practical to refine the scope of the evaluation to pursue demonstrations on a more site-specific basis. But the actual demonstration whether this beneficial use is appropriate, either as initially proposed or with additional conditions, is accomplished in the next phase of the methodology.

Phase II – Impact Analysis

In the second phase the objective is to answer the questions posed during planning and scoping through a combination of quantitative and qualitative analysis. This phase is presented as four distinct steps of increasing complexity. There is flexibility in how these steps are applied in an evaluation. Individual steps can be omitted or used in the order that makes the best use of available data, so long as the analyses conducted are supported by sound science. If at any point during the analysis sufficient information is available to reach well-substantiated conclusions about the beneficial use, then the evaluation can proceed to the third and final phase.

Step 1 – Existing Evaluations

This step consists of a literature review to identify any existing evaluations that are of sufficient quality to rely upon in the beneficial use evaluation. The purpose of this step is to avoid duplication of effort by building on previous works. Examples of existing evaluations include previous beneficial use evaluations, peer-reviewed studies, or technical reports that have been published by government agencies, academic institutions, trade association and other sources. Many of these existing evaluations will likely be identified during other data collection efforts in planning and scoping.

Relying on the findings of other evaluations also incorporates any uncertainties present in those evaluations. Therefore, it is important to review the quality of data and analyses relied upon to ensure that the findings are valid and can be extended to the particular beneficial use under evaluation. Specifically, this review determines whether the findings are applicable to a particular secondary material and its beneficial use, supported by sound science, adequately capture sources of variability, subjected to sufficient external review, and transparently documented with enough detail and clarity to allow replication. If this review determines an existing evaluation is of sufficient quality, its findings may be used to draw conclusions about the beneficial use. The findings may be drawn from multiple existing evaluations to address different constituents or exposure routes. If an existing evaluation supports the conclusion that the potential for adverse impacts is comparable to or lower than from an analogous product, or at or below relevant regulatory and health-based benchmarks, then no further evaluation would be necessary. Potential adverse impacts that are not sufficiently addressed by these findings would warrant further consideration through additional steps.

Hypothetical Application of Step 1

A secondary material is proposed for beneficial use as generated. During review of the literature, it is discovered that an international health agency has previously studied the leaching behavior of three heavy metals from a number of materials, including the secondary material. The study found that even the highest leachate concentrations observed from the materials did not result in exposures to contaminated ground or surface water above European benchmarks. Thorough review of the study identifies no significant data gaps or other concerns and determines that exposures are also below all relevant benchmarks defined by the state government agency responsible for the beneficial use determination. Based on these findings, the leaching of these three constituents would not warrant further evaluation. However, if there are additional release routes for these three constituents other than leaching to ground and surface water, or if there are additional constituents associated with leachate from the beneficial use beyond these three, then the additional release routes and constituents would remain to be addressed in subsequent steps of the beneficial use evaluation.

Step 2 – Comparison with Analogous Product

This step consists of a comparison between the beneficial use and an analogous product made with virgin materials. The objective is to determine whether the potential for adverse impacts is comparable to or lower than from an analogous product. This comparison assumes that the same receptors will be exposed, regardless of whether the analogous product or beneficial use is present. It also assumes that the characteristics, behavior and sensitivity of these receptors do not change. Thus, any differences in exposure rates and potential for adverse impacts are driven only by changes to the stressor levels present in environmental media.

A direct comparison of concentrations at the point of exposure may involve some amount of fate and transport modeling if field data are not available. This can greatly increase the complexity of this step. However, it is often possible to use a surrogate in place of exposures in this comparison to reduce the computational burden. For the purposes of this methodology, a surrogate is data on one variable (e.g., bulk concentration, release rate) that can be used to reliably approximate the magnitude of another (e.g., exposure point concentration) and, as a result, can substitute for the other variable in the comparison. It is important to be aware of any differences in the chemical or physical composition of the beneficial use and analogous product (e.g., organic carbon content, density) because these variables can affect releases and subsequent exposures in ways that are not easily predicted based on individual surrogates. The stronger the link that can be documented between the surrogate and exposures, the greater confidence there is in the comparison results.

It is important to be aware that the processes that generate secondary materials can introduce constituents not typically found in nature. When use of a secondary material introduces chemical constituents or other stressors into the beneficial use that are wholly absent from any analogous product, this would be sufficient information to demonstrate that the beneficial use is not comparable and that further evaluation is warranted. Conversely, if there are constituents associated with the analogous product that are wholly absent from the beneficial use, this would be sufficient information to demonstrate that exposures are lower and do not require further comparison.

It is important to consider the full range of potential variability in this comparison, not only in the composition of the products, but also in environmental conditions that affect fate and transport. Statistical tests are one common and powerful tool that can be used to compare full datasets. However, statistical tests are only as accurate as available data allows them to be. The presence of small datasets, high detection limits, and other sources of uncertainty can result in erroneous conclusions. Thus, where available, other comparisons and sources of information are encouraged to corroborate statistical results. If the comparison can demonstrate that exposures to constituents that result from the beneficial use are comparable to or lower than those from an analogous product, then no further evaluation would be necessary. Any exposures found to be higher would warrant further consideration through additional steps.

Hypothetical Application of Step 2

A secondary material is proposed for use as a replacement for the clay in bricks. The secondary material contains an inorganic compound that may volatilize and escape into indoor air. Bricks also contain this compound. Thus, the same exposures are possible from both products. Available literature shows both a strong and consistent linear relationship between the concentration of this constituent in the products and the emission rate from the products. Because changes in the emission rate are driven primarily by changes in the concentration of the constituent present in the products, it is possible to conduct a comparison of bulk constituent concentrations in the two products. Controlling for the effects of temperature and other environmental factors that may influence releases, a statistical test conducted on the range of constituent concentrations reveals there is no appreciable difference between concentrations in the two products. Based on these findings, releases of this constituent to indoor air would not warrant further evaluation.

Bricks also contain an inorganic constituent that may leach out and escape into ground water. However, there is no reasonable expectation that this constituent would be present in the beneficial use based on knowledge of the generation and subsequent handling of the secondary material. Documentation of the basis for this conclusion would be sufficient to demonstrate that concentrations are lower than in the analogous product. Additional collection of data to attempt a quantitative comparison for this constituent would not typically be warranted.

Step 3 – Screening Analysis

This step characterizes the potential for adverse impacts from the beneficial use through a comparison with screening benchmarks. A screening benchmark is a discrete value, typically a concentration in environmental media, set at a level below which exposures are not anticipated to pose concern. The objective is to identify individual constituents or entire exposure pathways that can be eliminated from further consideration with a high degree of confidence prior to more intensive modeling. This is accomplished with a combination of data and simplifying assumptions on beneficial use composition, environmental conditions, and/or receptor characteristics that result in a point estimate of exposures that ranges anywhere from a reasonable upper bound to a worst case scenario.

The benchmarks that are most relevant to an evaluation will be determined by the constituents, exposure routes, and receptors present. Federal, state and non-governmental organizations develop and maintain benchmarks for various regulatory and non-regulatory purposes, which may be relevant to an evaluation. Benchmarks can also be calculated for an evaluation. This allows the screening benchmarks to capture any considerations specific to an evaluation, such as the presence or absence of specific receptors. In all cases, it is important to understand and disclose any assumptions built into the screening benchmarks to demonstrate that they are applicable and sufficiently protective.

There is flexibility in how the degree of protectiveness is incorporated into calculated exposures. At the most extreme, constituent concentrations at the point of release can be compared directly to screening benchmarks. Alternately, simplifying assumptions and screening models can be used to estimate concentrations at the point of exposure by accounting for some of the dilution and attenuation that occurs during transport through the environment. If the exposures are found to be below levels of concern based on any of these comparisons with screening benchmarks, then no further evaluation would be necessary. However, those found to be above screening benchmarks after reasonable refinement of the screening would warrant further evaluation.

Hypothetical Application of Step 3

A beneficial use is proposed for use statewide as an agricultural amendment mixed into subsurface soils. Previous steps have shown that all exposures are comparable to those from the analogous product, except for those from ingestion of impacted ground water. Of the potential receptors identified, nearby residential receptors are determined to be the highest exposed population. The constituent concentration measured at the point of release is found to exceed the screening benchmark for residential receptors. A screening model was then used to estimate dilution and attenuation during transport through both the subsurface soils and underlying aquifer. Some of the assumptions incorporated into the model to ensure that the model results do not underestimate potential exposures include that the soil is highly permeable and that the closest residential receptors live across the street from the location of the beneficial use. Initial model runs indicate that constituent concentrations are far greater than relevant benchmarks. While further incremental refinements are possible within available screening models, it is unlikely that these changes will appreciably change the estimated exposures. Therefore, it is better to carry this constituent forward to the next step. However, given that the exposures estimated in the screening are biased high, it is important to emphasize that the results of this step are not intended to be precise or even realistic. Therefore, an exceedance of screening benchmarks at this step does not necessarily mean that the beneficial use will pose concern. However, if more refined analyses cannot be performed and other sources of information are not available, this does indicate that uncertainties are too great to demonstrate whether the beneficial use is appropriate as proposed.

Step 4 – Risk Modeling

This step consists of a refined, quantitative and qualitative characterization of the potential for adverse impacts from the beneficial use. The objective is to reduce remaining uncertainties enough to permit well-substantiated conclusions about the proposed use. This is accomplished by applying more realistic data and models that refine the estimates of release, fate, transport and exposure that are used to estimate the actual risks to receptors.

Prior to calculating risks, it is recommended that the assumptions and point estimates used in the screening are updated with distributions that better reflect real-world conditions in order to generate more realistic inputs for the models. However, assumptions that reflect an upper bound or worst case can be retained where desired as a factor of safety, so long as they do not interfere with the ability to draw conclusions from model results. Once the models have been run, the media concentrations generated by the models are combined with information about potential receptors and constituent toxicity to characterize the resulting risks. Quantitative characterization of these risks provides the most useful information; however, where available data are insufficient to calculate risks, a qualitative characterization based on available information can still be helpful. If the risks associated with all the remaining exposures fall below levels of concern, then the beneficial use would be considered appropriate. However, if one or more risks exceed standards, then the beneficial use would not be considered appropriate as proposed.

Hypothetical Application of Step 4

The previous three steps of the evaluation screened out all complete exposure pathways, except for ingestion of a constituent in ground water contaminated by leachate. The fourth step begins by reviewing the data and assumptions used to calculate high-end exposures in previous steps and replacing them with probabilistic distributions that better reflect the real-world variability in beneficial use composition, environmental parameters, and receptor characteristics. The selected model is run using these updated data to generate more realistic constituent concentrations at the point of exposure. The adjusted high-end estimate of ground water concentrations at the hypothetical downgradient wells is then used to calculate the associated cancer and non-cancer risks. The resulting risks are found to all be well below levels of concern. Therefore, no additional analysis is warranted and the evaluation can proceed to the final phase of the evaluation.

Phase III – Final Characterization

This is the final phase for beneficial use evaluations conducted using this methodology. The aim is to integrate key findings, assumptions, limitations and uncertainties identified throughout the evaluation into final conclusions about the potential impacts to human health and the environment associated with the proposed beneficial use. The emphasis of this phase is on providing context for the results of the beneficial use evaluation in a transparent, clear, consistent and reasonable manner to inform decision-makers and other relevant audiences, such as the general public.

If the evaluation shows that the beneficial use may pose concern, this does not necessarily mean that the use of this secondary material is inappropriate under all circumstances. The concerns identified may be driven by a smaller subset of constituent levels, beneficial use design, environmental conditions, or other factors considered in the evaluation. This phase can be used to highlight the conditions under which risks are below levels of concern or any additional steps that can be taken to ensure that the use is appropriate. Based on these results, decision-makers may choose to allow the beneficial use, either as proposed or with some additional conditions. Such conditions might include limitations on the amount of a secondary material that can be incorporated into the beneficial use or on the constituent concentrations in the secondary material used.

Hypothetical Application of Phase III

Modeling performed in the previous phase found that the proposed use of a secondary material as fill for road embankments across a state has the potential to adversely impact the health of nearby residents. Further review of the model results shows that the identified risks are driven by a relatively small subset of the secondary materials with extremely high levels of one chemical constituent. Based on this information, the proposed use may be appropriate under the condition that this subset is isolated and excluded from use. Alternatively, if this subset can be treated prior to use to reduce the risks below levels of concern, then the beneficial use may be appropriate as proposed. If neither of these approaches is viable, the party conducting the evaluation may consider altering the composition of the beneficial use to reduce the bulk concentration or to eliminate conditions favorable for releases. However, altering the physical or chemical composition of the beneficial use may result in the need for additional data and analysis to demonstrate that the amended beneficial use no longer poses concern.

Further Information

The purpose of this document is to describe the individual phases and steps of the EPA's beneficial use methodology. This methodology is designed to be applicable to the widest range of secondary materials and associated beneficial uses possible. Further information and tools that can assist with specific evaluations can be found in the *Beneficial Use Compendium: A Collection of Resources and Tools to Support Beneficial Use Evaluations* (U.S. EPA, 2016). Those individuals or entities who rely on these two documents should also coordinate with state regulatory bodies to ensure that the application of the methodology is scientifically sound and accounts for any additional considerations required by state, tribal and territorial regulatory bodies. This coordination can help facilitate beneficial use determinations.

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