



Massachusetts
Department
of
ENVIRONMENTAL
PROTECTION

technical update

Expressing the Precision of Exposure Point Concentrations and Risk Estimates in MCP Risk Characterizations

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1.0 Summary

This Technical Update provides guidance on expressing the level of precision in calculated values, such as Exposure Point Concentrations (EPCs) and risk estimates used in MCP risk characterizations. This update describes several acceptable ways to address this issue, varying by the level of documentation and justification necessary to support each approach.

Alternative 1: The risk characterization may use the Absolute Method, wherein the calculated EPCs and risk estimates are compared to the promulgated standards and risk limits without rounding. *No additional documentation or justification of the approach is required.*

Alternative 2: The risk characterization may use the Rounding Method, with a minimum of two significant figures. *No additional documentation or justification of the approach is required.*

Alternative 3: The risk characterization may use the Rounding Method with one significant figure.

- *Under Risk Characterization Methods 1 and 2, supporting documentation should include an analysis of case-specific QA/QC data, with the result rounded up to provide a conservative estimate of the Exposure Point Concentration.*
- *Under Risk Characterization Method 3, supporting documentation should reference the specific input parameters that justify a single significant figure in the risk estimate.*

2.0 Introduction

This issue has generally been couched in terms of “significant figures,” to the extent that the precision of calculations has been addressed at all. The Department has published general guidance on the topic of significant figures and rounding.¹ In the absence of more specific guidance on expressing the precision of EPCs and risk estimates, standard practice has been limited to simply identifying the appropriate number of significant figures in each estimate.

¹ Guidance for Disposal Site Risk Characterization (Policy #WSC/ORS-95-141), Section 2.5

The number of figures presented in a measured or observed value indicates the precision inherent in the value and, conversely, the associated error range. The use of significant figures is one means of expressing both the nominal value and the precision in a single value. The error range around a value can also be expressed with error bars (denoting the error as +/- a certain amount). Further, the distribution of potential values within (and beyond) the error range can be expressed with a probability function.

Since measurements, such as groundwater concentrations, have limited precision, any calculations using these values – such as to generate EPCs or risk estimates – will also have limited precision. When using significant figures to convey precision, the use of too many figures in a calculation implies a greater level of precision (“superfluous precision”) than may be justified by the input data. Using too few figures may reduce the accuracy of the result (“roundoff error”).

The approach to expressing the precision of an EPC or risk estimate must take into account technical, regulatory and policy considerations within the context of the MCP.

3.0 Technical, Regulatory and Policy Considerations

3.1 MCP Language and Implications

This guidance considers the implications of the language and intent of several relevant sections of the MCP.

- First, most MCP Method 1 Standards are rounded, either up or down using standard procedures, to one digit². While the rounding considered the uncertainty inherent in the calculation of the standards, MassDEP did not explicitly consider the implications of rounding on how the standards would be used.
- Second, the MCP quantitatively defines the concept of “No Significant Risk” to mean no exposures “*greater than*” the applicable standard (Method 1, 310 CMR 40.0973(7)) or risk limit (Method 3, 310 CMR 40.0993(7)).
- Third, the MCP requires (at 310 CMR 40.0926(3)) that in estimating the Exposure Point Concentration (“EPC”), the objective shall be to identify a conservative estimate of the average concentration contacted by a receptor at the Exposure Point over the period of exposure. In other words, when there is uncertainty around a calculated result, the regulations require that the risk assessment err on the side of caution rather than simply provide the “best estimate”. This is consistent with other MCP regulatory imperatives to take a conservative, health-protective approach to site assessment and risk assessment.

The standard approach to rounding when using the significant figures approach to expressing precision, combined with the first two MCP items bulleted above, can produce a *non-conservative* result that is contrary to bullet three. While the process of rounding is assumed to be inherently unbiased, the regulations, as written, create a

² Many Method 1 groundwater standards were adopted directly from MMCLs and were not rounded. Some GW-1 standards are, therefore, expressed with two digits (e.g., the GW-1 standard for lead is 15 µg/L).

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non-conservative bias that can only change the results of the risk characterization in one direction: from “*exceeds a standard*” to “*doesn’t exceed a standard*.”³

As an example, consider the effect of rounding on a calculated hazard index of 1.44:

- If two significant figures were used, the result would be rounded to 1.4, leading to the conclusion that the risk *exceeds* the MCP hazard index limit of 1.
- If one significant figure were used, the result would be rounded to 1, leading to a conclusion that the risk *does not exceed* the MCP hazard index limit of 1.

The same rounding effect occurs when comparing site concentrations with values of 1.4, 14, 140 or 1400 to Method 1 Standards with values of 1, 10, 100, or 1000 respectively.

The implication of the MCP language described above does not change the need to correctly express the precision of the MCP risk calculations. It does underscore the importance of careful consideration of this issue, particularly when using the significant figures approach. The incorrect use of significant figures, including the use of over-simplified rounding rules, can have a disproportionate effect of the conclusions of the risk characterization.

3.2 Regulatory Standards as Exact Values

While the MCP standards are often (not always) expressed with a single digit, this does not determine or influence the number of significant figures that should be used in the calculation of EPC’s or risk estimates. The MCP does not specifically address the question of significant figures.

As noted in ASTM’s Standard Practice for Using Significant Digits in test data to Determine Conformance with Specifications (E29-06b), “*the unqualified statement of a numerical limit, such as [comparison to a standard or risk limit], cannot, in view of different established practices and customs, be regarded as carrying a definite operational meaning concerning the number of digits to be retained in an observed or calculated value for purposes of determining conformance with the [standard].*”

In other words, since there are so many different ways to approach the issue and the Department has not specifically addressed *how* significant figures should be used with the standards, nothing can or should be read into the presentation of the standards as one digit. The format of the standards themselves cannot be used to justify the use of a single significant figure in the calculation of EPC’s or risk estimates. The promulgated standards, whether they are Method 1 soil and groundwater standards or the Method 3 Risk Limits, are considered absolute (exact) values similar to constants for the purposes of determining the appropriate number of significant figures.

3.3 Absolute and Rounding Methods to Determine Compliance with a Standard

The ASTM E29-06b standard practice describes two approaches that can be taken to describe conformance with standards: the *Absolute Method* and the *Rounding Method*. Either approach can be applied, but the Method to be used must be specified to avoid confusion and ambiguity.

³ “Rounding up”, such as from a Hazard Index of 0.957 to a Hazard Index of 1, can never change the results of a risk characterization from “doesn’t exceed a standard” to “exceeds a standard”, since a value has to be “*greater than*” the standard to exceed it.

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Absolute Method (ASTM E29-06b, Section 5.). The Absolute Method applies where it is the intent that all digits in an observed value or a calculated value are to be considered significant for purposes of determining compliance with a standard. Applied this way, the standards would be considered “absolute limits.” In the MCP context, an EPC or risk estimate would not be rounded, but would be compared directly with the standard.

Rounding Method (ASTM E29-06b, Section 6.) The Rounding Method applies where it is the intent that a limited number of digits in an observed value are to be considered significant for purposes of determining compliance with a standard. An observed or measured value would be rounded (using a specified process) to the nearest unit in the designated place of figures in the standard. In the MCP context, an EPC or risk estimate would be rounded to a specific percent error, number of significant figures or other appropriate expression.

MassDEP has not specified in regulation whether the Absolute Method or the Rounding Method applies to the Method 1 standards, Method 2 standards and the Method 3 risk limits. In the absence of a specific requirement, either the Absolute or Rounding Methods may be appropriate. If the Rounding Method is chosen, then the rounding process and final expression of the EPC and risk estimates must be conducted considering relevant MCP requirements.

3.4 Approaches to Rounding

ASTM (E29-06b, Section 7.1) notes that “*Any approach to retention of significant digits of necessity involves some loss of information; therefore, the level of rounding should be carefully selected considering both planned and potential uses for the data.*”

There are no absolute rules for retaining significant figures and rounding, and the available approaches range in complexity from simple to statistical. “*Too few significant digits cause information to be lost and too many are considered bad style in numerical reporting — showing a lack of understanding of precision*”⁴.

The standard rounding rules, such as those described in MassDEP risk assessment guidance (Section 2.5), are approximations of, and substitutes for, more complex analyses, such as the use of the standard deviation of the samples to determine the rounding interval. Alternative approaches have been identified that add a significant digit to a calculation in order to minimize data lost through rounding, either under specific conditions, across the board or based on magnitude of the percent error. For example, ASTM (E29-06b, Section 7.6) suggests an addition digit be used when averaging “large” datasets⁵.

In short, there is no absolute “right” way to retain significant figures or round values. There are numerous alternative approaches designed to address the balance between data loss and misinterpretation of precision.

⁴ *Reporting Test Results, Determining Significant Digits and Rounding Properly*
http://www.astm.org/SNEWS/SO_2008/datapoints_so08.html

⁵ The definition of “large” is variable, dependent upon the lead digit of the standard deviation: the smaller the standard deviation, the smaller the data set need for an “additional” significant figure.

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3.5 *Method 3 Risk Characterizations*

The appropriate number of significant figures for Method 3 risk estimates should consider the factors that enter into the risk calculations, including the uncertainty about the toxicity values and exposure factors. Many of the toxicity and exposure factors employed in risk calculations may be reasonably considered to include only one significant figure.

3.6 *Method 1 and Method 2 Risk Characterizations*

The precision of measured contaminant concentrations is the primary consideration in determining the appropriate number of significant figures for an Exposure Point Concentration.

Analytical results for environmental media are dependent on the specific analytical method and the precision attained for each analysis. Laboratories are generally reporting analytical data with at least two digits, although this practice may be as much by convention as resulting from an analysis of the measurement precision. MassDEP believes it is not appropriate to draw broad conclusions about the precision of an analytical method or any specific result without evaluating the QA/QC data. Case-by-case decisions about the precision of analytical results and appropriate number of significant figures may be impractical. Such an approach would necessitate additional efforts to evaluate QA/QC information, possibly reporting of additional material from laboratories, likely at additional cost. Laboratories do not follow one consistent practice when reporting results, and often do not report measured concentrations with the issue of significant figures foremost in mind. It is not the Department's intent to create additional reporting requirements or modify laboratory operations to address this issue.

4.0 Conclusions

In the absence of specific regulatory language for the number of significant figures, the Department recognizes several approaches that meet the requirements and performance standards for MCP risk characterizations:

Alternative 1 – Using the Absolute Method.

For risk characterizations using the Absolute Method, the calculated EPCs and risk estimates are compared to the promulgated standards and risk limits without rounding. No additional documentation or justification of the approach is required.

Alternative 2 – Rounding to 2 or More Digits

In all cases, the Department will accept Exposure Concentrations and risk estimates rounded to two or more digits. No additional documentation or justification of the approach is required.

While the presentation of data with several digits may imply a level precision inconsistent with the calculation inputs, the inconsistency is more philosophical than substantive. This approach is consistent with the MCP charge to provide a conservative estimate of the potential exposures and risks at a site. LSPs and PRPs wishing to adopt a simple, clear approach may choose to round to two or more digits. An informal review of historic practice indicates that this approach is consistent with the majority of the risk characterizations submitted to MassDEP.

Alternative 3 - Rounding to 1 Significant Figure

The use of one significant figure to express an Exposure Point Concentration or risk estimate may be justified on a case-by-case basis. The approach taken and the level of documentation required will depend on the Method of risk characterization employed.

- **Method 1 and Method 2 Risk Characterizations**

The MCP contains requirements to conservatively calculate the EPC, which is the site-specific factor in a Method 1 or Method 2 Risk Characterization. These requirements include:

- The identification of “*a conservative estimate of the average concentration contacted by a receptor at the Exposure Point over the period of exposure*” (310 CMR 40.0926(3));
- The use of maximum of 95% UCL values when the data are “*likely to be insufficient for the simple arithmetic average to estimate the true value with reasonable confidence and there is a considerable probability of substantially underestimating the mean*” (310 CMR 40.026(3)(c); and
- The development of an Exposure Point Concentration “*representative of the actual concentration of oil or hazardous materials at the Exposure Point, unmodified by other exposure assumptions*” (310 CMR 40.0973(4)(b)).

A case-specific analysis of QA/QC data may be used to justify a single significant figure and detailed supporting documentation included in the risk characterization. In such cases, the EPC estimate should be *rounded up* to provide an upper bound estimate of the EPC consistent with the regulatory mandate to provide a conservative estimate.

- **Method 3 Risk Characterizations**

The appropriate number of significant figures for risk estimates calculated for a Method 3 Risk Characterization should be determined by the precision of the factors that go into the risk estimate, including the analytical data used to calculate the EPC (discussed above) and toxicity factors that are typically, although not universally, expressed as one significant figure. MassDEP expects that most Method 3 risk estimates should be expressed as one significant figure, based on the standard input parameters used in the calculations. However the Department recommends that the risk assessor review such inputs to confirm that the use of one significant figure is appropriate and include a short summary of that review in the risk characterization.

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