GREEN AMERICA
CLEAN ELECTRONICS PRODUCTION NETWORK
A project of the Center for Sustainability Solutions

Clean Electronics Production Network

CEPN Alternatives Assessment Guide

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1. Introduction

This document is a concise, high-level guide for identifying and evaluating potential substitutions for Chemicals of High Concern (CoHCs) used in electronics manufacturing processes. It is intended to provide companies with a tool for thoroughly assessing and implementing safer alternatives to identified CoHCs and avoiding regrettable substitutions. A safer alternative may include a chemical substitute or a change in materials or design that eliminates the need for a chemical alternative. The alternatives assessment process laid out herein includes guidance for evaluating human health and environmental impacts, technical feasibility, lifecycle thinking, social impacts, availability, and cost of potential alternatives. There are several comprehensive alternative assessment frameworks that can be referenced if more detailed guidance is needed (National Academy of Sciences (NAS) Framework to Guide Selection of Chemical Alternatives, Interstate Chemicals Clearinghouse (IC2) Alternatives Assessment Guide, and California Department of Toxic Substances Control (DTSC) Alternatives Analysis Guide). The Clean Electronics Production Network (CEPN) also has developed several resources to aid in this analysis.

This guide may be useful to a number of actors - including brands doing an internal review of chemicals used to produce their products, brands and suppliers working together to find alternatives to a chemical the brand wishes the supplier to eliminate, and suppliers who wish to proactively replace chemicals that create large risk of worker health and/or environmental impact.

Each of these entities might use the procedure slightly differently - for example a brand might have already identified a chemical it would like a supplier to eliminate, in which case the supplier using this document could skip the "Identify Chemicals of High Concern" section.

The most robust and effective alternatives assessment process will involve relevant stakeholders in data gathering and decision-making. For example, personnel from environmental health & safety (EHS), waste management, procurement, line management, product engineering and product design may all have useful information and perspectives to contribute to discussions and decision making as various alternative candidates are identified and evaluated. In addition, line workers may have valuable insights on possible process change solutions, effectiveness of substitutes, or health and safety concerns. We encourage all users of the process to involve a broad range of stakeholders from within their organization, at best for involvement during the whole procedure, and at least for the final evaluation step.

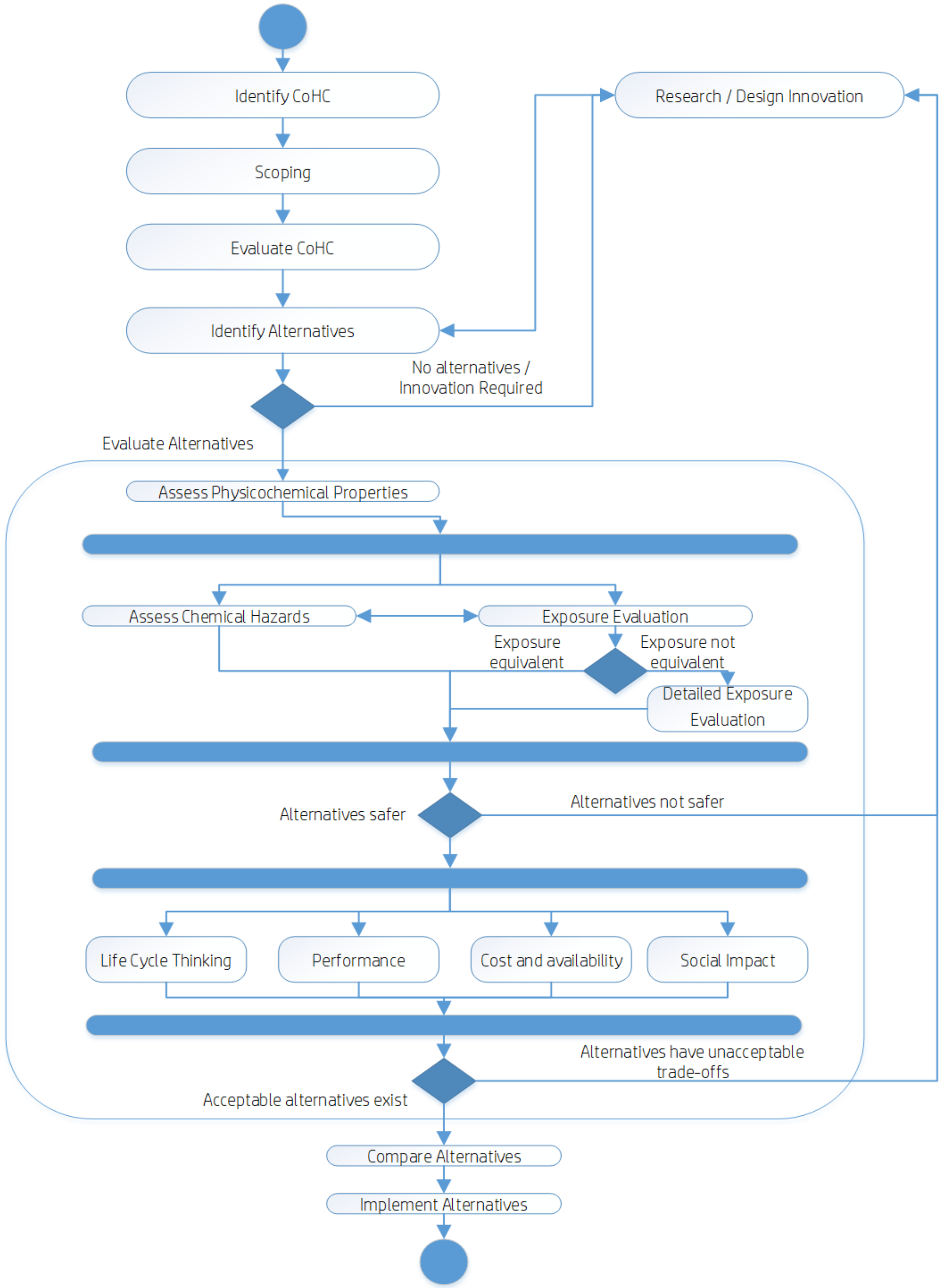
Many of the areas of evaluation will require additional information and analysis beyond the scope of this document. Some users, such as large brands, may have considerable expertise within their organizations and be able to execute the procedure using internal resources. Where possible, we encourage such brands to also provide support to their suppliers undertaking an Alternatives Assessment process - perhaps by convening meetings periodically to consider the information the supplier has discovered at each step of the evaluation process.

For those organizations with less industrial hygiene, toxicology, or chemistry knowledge, and without access to brand resources, we have provided links to documents and other resources that may provide useful guidance. In addition, it may make sense to engage with outside experts at various decision points where expert evaluation is needed. Use of the procedure should enable effective concentration of such outside help on summary decisions rather than on the information gathering steps an internal team can execute.

This process consists of six main steps as shown below: Identify Chemical of High Concern; Scoping; Evaluate Chemical of High Concern; Identify & Evaluate Alternative(s); Compare Alternative(s); and Implement Alternative. The assessment is done on a relative basis. This means that absolute values in each step are not as important as results relative to the CoHC or the alternatives being compared. Performing an alternatives assessment is also an iterative process, so some modules will need to be done at a basic level when first identifying alternatives, then more in-depth when evaluating alternatives.

Each of the steps are described in detail in the following sections and shown in the flowchart in Figure 1. This flowchart is adapted from the NAS "A Framework to Guide Selection of Chemical Alternatives." A Microsoft Excel-based "Alternatives Assessment Worksheet" is provided to document the data gathered throughout this process.

Figure 1. Alternatives Assessment Process Overview



2. Identify Chemical of High Concern

A determination that a chemical has a negative or potentially negative impact to human health or the environment can result in regulatory use restrictions, internal company reduction policies, or market demands for phase out. The detailed CoHC selection process is out of the scope of this document. The hazards and exposure potential of the CoHCs will be compared to the potential alternatives to ensure a safer material is selected.

CEPN has developed a Chemical Priority List, which includes chemicals that have already been prioritized for elimination by the CEPN member organizations due to their hazard properties and potential exposures in electronics manufacturing. This list should be referenced as a starting point for determining chemicals to eliminate, and also to ensure that chemicals on this list are not chosen as alternatives.

The CoHCs can be prioritized based on regulations or requirements that are relevant for your organization. The prioritization criteria are typically derived from the following inputs:

- Emerging legislation
- Environmental Health and Safety (EHS) requirements
- Alternatives made available by suppliers
- Customer requests
- Competitor action
- Non-governmental organization (NGO) pressure

It may be useful to weigh these inputs to develop a score based on your organization's priorities. Some potential approaches include:

- Emerging legislation - rating dependent on the effective date is (e.g. High: < 6 years out; Medium: 8-10 years out; Low: 11 or more years out)
- Environmental Health & Safety (EHS) - rating based on hazard scoring schemes (e.g. High: GreenScreen® Benchmark 1; Low: GreenScreen® Benchmark 2 or higher)
- Customer inquiries - rating based on number of customer inquiries about a CoHC (e.g. High: one or more major customers inquired about the chemical; Low: inquiry from an individual).

3. Scoping

To scope the alternatives assessment an organization should describe the level of stakeholder engagement, and the goals, principles, and decision rules. Scoping decisions are typically driven by an organization's priorities and values, however it is recommended to adopt The Commons Principles for Alternatives Assessment, which constitute an overarching chemical management approach to establish the governing principles and constraints when performing a chemical assessment. The Common Principles for Alternatives Assessment include:

- Reduce hazards
- Minimize exposure
- Use best available information
- Require disclosure and transparency
- Resolve trade-offs
- Take action

The steps for planning the assessment are as follows:

1. Determine appropriate involvement from internal and external stakeholders. Create a table to show which stakeholders should be contacted for each type of assessment.
2. Align on the goals and principles of the assessment.
3. Choose which steps within this process you will use and the appropriate tools. The Organization for Economic Cooperation and Development (OECD) has worked with stakeholders to create a Substitution and Alternative Assessment Tool Selector that is designed to help an organization choose tools that suits their competence level and requirements.
4. Decide how to manage data gaps and uncertainty since chemicals lacking important data can't be assumed safer. See section 5.2 for more information on how to manage data gaps.
5. Make a checklist of the minimum performance criteria

The main objective should be to reduce hazards by either eliminating the need for the chemical of concern with a design or process change, or replacing the chemical with a safer alternative. However, there are other considerations to ensure an alternative is selected that meets established criteria and does not cause burden shifting. The priorities among different lifecycle factors, such as water usage and carbon footprint need to be established and approved by stakeholders. Ensure that there is a clear articulation of the rationale for the priorities and a plan for dealing with trade-offs up front.

Once the project scoping is done, document the constraints of an assessment and review with internal stakeholders to make sure that the constraints of the alternatives assessment are in line with the goals and principles established.

4. Evaluate Chemical of High Concern

In this section, document relevant information about the CoHC that will aid in determining a suitable replacement. When evaluating the CoHC, one should consider impacts throughout the lifecycle, including manufacturing, use phase, and end of life. It is important to understand and document why a chemical was determined to be of concern since potential future inquiries could depend on this information being readily available. Information on the CoHC needs to be gathered, such as:

- The chemical identity and functional use
- Potential human health and environmental impacts
- Description of the application(s) in the manufacturing process
- Known or potential chemical reaction byproducts or environmental transformation products created during the use or disposal of the CoHC
- Known or potential worker exposure pathways
- Known or potential environmental discharges or impacts
- Known waste streams created during use of the CoHC

There are several resources for gathering the information needed to evaluate the CoHC. Some resources have information on the chemical identity and functional class only, whereas others also include the human health and environmental impacts. For a complete list, refer to the OECD Substitution and Alternative Assessment Tool Selector. Some examples of resources include:

- Chemical Book – chemical properties and safety information
- EPA CompTox Chemicals Dashboard – chemical properties, toxicity, and exposure information
- eChemPortal – chemical properties, toxicity, exposure information, and government reports on chemicals
- toxnot – chemical properties, hazard information based on GreenScreen List Translator™, regulation and hazard lists, and restricted substances lists
- chemsec SIN list – regulation and hazard lists, and hazard classifications

- P2OASys – chemical properties, hazard evaluation, exposure assessment, life-cycle impacts, and comparison of alternatives
- SciveraLENS® Chemical Assessment Platform – restricted substance list review, hazard evaluation, exposure assessment and risk assessment over the life of the product, and identification of preferred alternatives.

Chemical functional classes provide information regarding how a chemical may be used (such as a colorant, a surfactant, for cleaning, etc.). For example, important functional parameters for cleaning chemicals include:

- The material of the part to be cleaned (for example, copper, glass, plastics, etc.)
- Characteristics of the parts to be cleaned (size, geometry, perforation, temperature sensitivity, etc.)
- Type of contaminant to be cleaned (for example, flux residue, oil, glue, etc.)
- Have parts been treated prior to cleaning?
- The degree of contamination
- Description of the current cleaning process used
- Operations performed after cleaning
- Quality expectations of cleaning

Other sources for this information include test data and chemical disclosure information from suppliers. CEPN has developed a standardized Process Chemicals Data Collection (PCDC) tool that can be used to gather information from suppliers on the chemicals used in manufacturing.

Lastly, understanding the known exposure pathways for the chemical is part of this initial evaluation. This should include exposure during line operations, exposure during maintenance activities, potential exposure due to accidental leak/release, and exposure during waste removal. The exposure pathways should be documented in the original chemical listing or regulation. It is not expected that exposure modeling be performed at this stage, which will be covered in section 5.3. Questions that should be asked include:

- What are the identified exposures related to the use of this chemical?
- Where are the exposures happening in the manufacturing process?
- Who would be potentially exposed and how?

5. Identify & Evaluate Potential Alternative(s)

The search for alternatives should start with technology mapping to determine what types of alternatives are available. When searching for alternatives, one should consider changes to the production process or product redesign to eliminate a particular chemical, alternative materials, and chemical substitutions. First ask if the function is needed. If yes, then ask if the chemical is needed. An example of a non-chemical alternative is mechanical polishing instead of using a solvent to clean a residue.

The criteria for acceptable alternatives need to be determined based on the guiding principles and constraints that were established in section 3Error! Reference source not found.. For e xample, you may decide that potential alternative chemicals that are not acceptable for consideration are those with characteristics that present a high concern for one or more critical human or environmental health characteristics. There are several accepted frameworks available that classify chemicals for human and environmental health hazard (i.e. "chemical hazard assessment"). Examples of frameworks that indicate chemicals of high concern include a hazard rating based on a GreenScreen® assessment of Benchmark 1, or chemicals assessed with a score of Hazard Category Red in the SciveraLENS® GHS+ framework, or chemicals assigned a Global Harmonization System (GHS) hazard classification of Category 1 for key endpoints. Chemicals that are on the CEPN Priority List due to their hazard properties and potential exposures in electronics manufacturing also should not be selected as alternatives.

If a potential alternative chemical does not currently have a clear assessment score using an accepted framework, there are several options available to individuals and organizations for generating a chemical hazard assessment (refer to section 5.2).

Focusing on a chemical product, mixture, or specific ingredients are all viable approaches to alternatives assessment. To fully evaluate alternatives, one needs to assess the physicochemical properties, the chemical hazards, exposure, lifecycle impacts, social impact, performance, cost and availability. Performing an alternatives assessment is an iterative process, so some sections will need to be done at a basic level when first identifying alternatives, then more in-depth when evaluating alternatives.

There are many resources available to identify and assess alternatives. As mentioned in section 4, the OECD Substitution and Alternative Assessment Tool Selector has a comprehensive list of available tools and data sources, which can be filtered based on many options, including tool capabilities, hazard attributes, exposure, life-cycle impacts, social impacts, expertise needed to use the tools, and the cost of the tools. To perform the initial identification of potential alternatives, it is often helpful to start with a web search. You can also perform a literature search for peer-reviewed work on potential alternatives via Scifinder or Google scholar. Collaborations with chemical companies or formulators, especially those that focus on finding safer alternatives to hazardous chemicals, is also a good way to identify acceptable alternatives.

Some helpful resources to identify potential alternatives are as follows:

- Clean Electronics Production Network – Substitution case studies for priority chemicals
- CleanerSolutions database – Toxics Use Reduction Institute (TURI) database for cleaners and solvents where you can search for replacements that include key parameters (e.g. the contaminant and substrate)
- chemsec Marketplace - a website where buyers and sellers of alternatives to hazardous chemicals can interact
- EPA's Safer Chemicals Ingredients List - a list of chemical ingredients, arranged by functional-use class, that the Safer Choice Program has evaluated and determined to be safer than traditional chemical ingredients
- SUBSPORT – Substitution Support Portal (SUBS PORT) has information to support efforts in substituting hazardous substances, including case studies

When finished, organize all the potential alternatives into a matrix to be fully assessed in the following sections. This list should include non-chemical alternatives as well, which will not be subject to certain assessment steps. If applicable, the potential chemical byproducts and environmental transformational chemicals created during the use and disposal of the alternative materials should also be included in the matrix as they could cause significant human health or environmental impacts.

5.1 Assess Physicochemical Properties

It is important to have knowledge of the physicochemical properties of potential chemical alternatives when performing an alternatives assessment process for two reasons:

- The health hazard of a chemical (e.g. its capacity to interfere with normal biological processes) and its physical hazards and environmental fate (degradation, persistence) are determined by its physicochemical properties and the system with which it is interacting
- Physicochemical properties can be used to eliminate potential alternative chemicals that are likely to exhibit certain physical or toxicological hazards

To assess the physicochemical properties of alternatives, obtain the datasheet from the formulators and use the resources listed in Section 4. The IC2 Alternatives Assessment Guide exposure module also has helpful information on how to assess and evaluate the physicochemical properties. Determine if the chemical properties for the chemical of concern and alternative are materially similar or have differences. Here is a summary of physicochemical properties that may be important, however only evaluate pertinent criteria for the alternatives:

- Volatility/vapor pressure

- Molecular weight
- Molecular size
- Solvent properties
- Phase partitioning (Log K_{ow})
- Solubility
- Boiling point
- Melting point
- Density/specific gravity
- pH
- Corrosivity
- Environmental Partitioning (dissociation or phase partition constant)
- Use characteristics (binding properties such as pKa) or synergistic effects

5.2 Assess Chemical Hazards

Hazard is defined as the set of inherent properties of a substance or mixture of substances that can cause adverse effects to humans and the environment. To assess the chemical hazards, there are three evaluation levels that may be needed. This will depend on the outcome of the hazard list screening and the level of substantiation needed. For more detailed guidance, refer to the hazard section of the IC2 Alternatives Assessment Guide. For a comprehensive list of hazard assessment tools, refer to the OECD Substitution and Alternative Assessment Tool Selector.

1. Screen against priority chemical lists of known chemicals of concern
2. Screen against positive chemical lists of known safer alternatives. If the potential alternative chemical is not present on either of the above lists, go to step 3
3. Perform a comprehensive hazard assessment ("CHA") using an accepted hazard assessment framework, service, or tool

There are several automated tools available to screen the potential alternative against priority chemical lists. List translator tools based on the GreenScreen List Translator™ include toxnot by toxnotPBC and Chemical Hazard Data Commons and Pharos by Healthy Building Network. GreenScreen List Translator™ can be used to efficiently screen chemicals against restricted substance lists (RSLs) and hazard screening lists, and then translate the data to GreenScreen® hazard endpoint(s), hazard level(s), and an overall List Translator score. Scivera has also developed Screened Chemistry, which is a method of assessing, scoring, and certifying chemicals for human and environmental health characteristics.

Completion of a comprehensive hazard assessment may be needed, depending on the output from the screening steps (for example if the alternative chemical is List Translator 1 there is no need to complete a comprehensive hazard assessment). Comprehensive hazard assessment tools include the GreenScreen® for Safer Chemicals and SciveraLENS® Chemical Assessment Platform. The Quick Chemical Assessment Tool (QCAT) was developed by the Washington Department of Ecology to help companies with limited resources or expertise evaluate the hazards of chemical ingredients and compare alternatives. QCAT is a good introduction to the hazard assessment process, but is not intended to replace more thorough assessment methods.

The GreenScreen® and SciveraLENS assessment processes both include a review of all relevant and feasible environmental transformation products. In some cases, an assessment for a chemical formulation may be determined by the hazards associated with product impurities or transformation products. Impurities can sometimes be addressed by setting appropriate purchasing specifications.

The lack of data is a common problem when assessing alternatives, especially for newer chemicals. While some data gaps may be acceptable, an important long-term goal is to influence chemical suppliers to generate data to fill in the gaps. There are a few ways to manage data gaps:

- It is possible, with the proper training, to predict hazard characteristics for a chemical lacking experimental data based on its molecular structure. The most popular methodology for this is called Quantitative Structure-Activity Relationship (QSAR), but this requires chemistry expertise and training. Chemsec has developed a tool called SINimilarity, where you can enter a chemical's CAS Registry Number and find out if this chemical is structurally similar to any of the substances on the SIN List. If so, it is possible that the chemical has similar properties.
- Another way to manage data gaps is to set minimum data requirements. For example, the GreenScreen® for Safer Chemicals combines estimation with data requirements. If after using estimation the data gap remains, the final Benchmark score of the chemical is determined both by the known hazards as well as the completeness of the data. More data are required to achieve a higher Benchmark score. You can adopt GreenScreen data requirements or create your own by considering the specific manufacturing and use of this chemical.
- It is important to recognize that the acceptability of data gaps and uncertainty may be different depending on the application of the CoHC. For example, a chemical used in an eye wash solution must not have a data gap for eye irritation.

5.3 Exposure Evaluation

Exposure evaluation should be done after the hazard assessment to reduce risk, since selecting alternatives with the lowest hazard will ensure risk is reduced even if the exposure level increases at a later date. However, assessing alternatives is an iterative process and understanding the known exposure pathways for the alternatives is part of the hazard assessment. The IC2 Alternatives Assessment Guide exposure assessment module provides useful guidance for assessing exposures.

Assessing the exposure pathways should include exposure during line operations, exposure during maintenance activities, potential exposure due to accidental leak/release, and exposure during waste removal. Questions that should be asked include:

- What are the identified exposures related to the use of this chemical?
- Where are the exposures happening in the manufacturing process?
- Who would be potentially exposed and how?
- How should hazard data be prioritized based on exposure scenarios?

The hierarchy of exposure controls has been used to protect workers from exposure to hazardous chemicals and are summarized as follows:

1. Elimination
2. Substitution
3. Engineering Controls
4. Administrative Controls
5. Personal Protective Equipment (PPE)

The priority should be to eliminate the need for a chemical or substitute the chemical for a safer alternative. If this is not possible due to a lack of viable alternatives or the chemical being critical to current manufacturing processes, then implementing engineering controls, administrative controls, or PPE is necessary.

Qualitative Exposure Assessment (QEA) is a workplace exposure risk assessment based on integration of information and judgement, and not based on a rigorous quantitative analysis of workplace sampling/analytical data. Qualitative assessments use professional judgment to assess and manage occupational exposure to chemical agents based on information regarding physical and toxicological properties of the chemicals being utilized and the workplace conditions or practices involving the use of the chemicals. Qualitative assessments allow preliminary decisions to be made concerning potential occupational exposures without necessarily performing a Quantitative Exposure Assessment. Quantitative Assessments require a rigorous analysis of actual, quantitative measurements of workplace exposure utilizing air sampling and analysis techniques. CEPN has developed a Qualitative Exposure Assessment tool to aid in this analysis.

A comparative exposure assessment can be used to determine if the alternatives would result in approximately equivalent exposures. Data required for a comparative qualitative assessment include key physicochemical properties (refer to section 5.1), known exposure pathways, and hazard properties to determine whether differences in exposure exist between the chemical of concern and potential alternative(s).

If the exposures of the chemicals being compared are approximately equivalent, then the assessment can be mainly hazard based and a detailed exposure assessment is not necessary. If an alternative is deemed to have a higher potential exposure than the CoHC, then a more detailed exposure assessment is needed.

To perform a detailed exposure assessment, determine if there have been any bio- or environmental monitoring studies or scientific studies related to the persistence, bioaccumulative, and toxic properties of the alternative. Compare accepted industrial hygiene exposure levels if they exist. Determine if this exposure assessment is adequate. If not, then it may be necessary to have a third-party toxicology expert perform a complete assessment.

5.4 Life Cycle Thinking

Life cycle thinking (LCT) should be part of an alternatives assessment to ensure that no significant new burdens are created elsewhere in the lifecycle. The IC2 Alternatives Assessment Guide life cycle module provides helpful guidance for performing LCT. LCT determines whether environmental impacts throughout the lifecycle – extraction, manufacturing, use, and end-of-life – of the selected alternative(s) is likely to be less than, the same, or greater than the CoHC. For instance, the environmental impact of electricity use is strongly related to energy sources, such as coal, and LCT can inform the impact of burning coal based on electricity usage. To apply LCT, one needs to consider all the material and energy inputs and outputs (chemicals, materials, water, energy, etc.) for each stage of the life cycle. An example is a case in which a CoHC is used to clean a residue from a substrate via a one-step ultrasonic cleaning process. However, to achieve an acceptable level of cleanliness with the alternative, a waterjet step needs to be added. This extra step will require more energy and water than the original process. This may be an acceptable tradeoff, depending on the organizational priorities established in the scoping section.

It may not be necessary to perform a detailed Life Cycle Assessment (LCA) for the purposes of selecting an acceptable alternative. The LCA methodology has been formalized and regulated by the ISO 14040 series standards and there are several tools available. Some are more appropriate to evaluate the impacts during the manufacturing phase, such as ReCiPe.

5.5 Performance

A key consideration in finding an acceptable alternative is if the alternative meets the minimum level of performance required to achieve the necessary functionality. There are different levels of performance verification that can be done:

1. Basic Performance Evaluation – Uses qualitative information available from manufacturers and other sources (web search for reports or case studies) to evaluate alternatives
2. Extended Performance Evaluation – Determines if the alternative will perform the required function for the specific application by gathering information from technical experts (e.g. process engineers, scientists, academic researchers, end users, etc.)
3. Detailed Performance Evaluation – Uses quantitative information to evaluate alternatives based on tests and validation by technical experts

Important questions include:

- What are the performance needs?
- What do the current users like or dislike about the CoHC?
- Has the alternative already been identified as technically favorable?
- Has testing been performed?
- Would the alternative have an adverse impact on reliability, quality, or customer experience?
- Would the alternative affect the efficiency or throughput of the production process?
- Are process changes required to meet the required level of performance?
- What kind of qualification is needed?

5.6 Cost and Availability

When determining costs, costs throughout the life cycle and externalized costs should be considered. A chemical that has lower upfront costs, but requires extensive worker exposure controls and waste containment due to its hazard properties, can end up costing more. And although an alternative may be costlier due to lack of scale, it could become a viable alternative if more companies adopt the same solution.

You will need to request the following information from your suppliers to determine cost and availability of the alternatives:

- Cost per weight (for example, kg)
- Cost trends and projections
- Other costs (for example, qualification, additional processing required, etc.)
- Number of suppliers offering the alternative(s)
- Availability (e.g. are alternative materials available from qualified supplier in geographical location of manufacturing?)

5.7 Social Impact

Evaluate any relevant social aspects of the alternatives as part of decision-making since it is important to understand the wider implications of a selection to ensure that the chemical alternatives do not result in unduly shifting a burden from one community of people to another, or creating a new social dilemma.

The evaluation of social impacts of chemical alternatives includes the workers, communities, and societies involved in its extraction, manufacture, transport, use, and disposal.

To evaluate and contrast the potential social impacts of the chemical alternatives, the following research approach should be used:

- Perform an internet search on the chemical alternatives to understand their origin
- Find out where and how the chemical alternatives are recovered and processed
- Research should also include what workplace considerations are or may become problematic as a result of the production of these chemicals. Impacts on local communities and workers from production of a given alternative may involve:
    - Forced or child labor
    - Health & Safety concerns
    - Local economic impacts from shifting sourcing to an alternate region
    - Environmental deterioration of land, forests, water, etc. from manufacturing
    - Depletion of natural resources due to new manufacturing process requiring more water, energy, etc. (may affect human right to water, etc.)
    - Physically demanding work and occupational safety issues due to new manufacturing processes, affecting difficulty of work
- Locate potential NGO reports that characterize the industry, chemical and region of origin.

6. Compare Alternative(s)

After the alternatives are identified and the relevant information is documented, compare the CoHC that is being replaced with the alternatives. Alternatives may be ranked in any number of ways. The ranking must reflect the governing principles and constraints that were set in section 3. To rank the alternatives, the following methods can be used:

- Categorize – acceptable, preferred, and not acceptable
- List the pros and cons of each alternative
- Qualitative analysis – matrix format with red, yellow, green coding
- Quantitative analysis – weight the factors by importance (using Multi Criteria Decision Analysis or other methods)

Out of this process, at least one acceptable alternative needs to be identified, but having more alternatives is ideal in order to provide options for implementation. If the alternatives have unacceptable tradeoffs related to hazard, exposure, lifecycle, performance, cost, availability, or social impact, then more research is needed (refer to section 8).

The outcome of this process is to create a recommendation for alternatives and share this with the relevant stakeholders. The recommendation can be documented using the "Alternatives Assessment Worksheet" provided, but other documentation may be created, depending on the extent of the analysis and what is needed by the business teams and suppliers. The other types of documentation that may be created are a white paper, training materials, testing or parameter limits, implementation plan, and procurement plan or guidance.

7. Implement Alternative

To implement an alternative one needs to carefully think through and support the transition since there can be many unexpected challenges, both social and technical. The detailed steps required to implement alternatives is out of scope of this document. However, the high level steps to implement an alternative are as follows:

1. Develop a qualification plan for testing the alternative
2. Procure a small amount of the alternative chemical for testing
3. Test the alternative to ensure it works in the process application(s)
4. Update the manufacturing processes to accommodate the new chemical, if necessary (for example, equipment changes, new tools, or procedural changes)
5. Provide training for the management and workers at the factory
6. Procure the chemical for manufacturing

8. Research

If no viable alternatives can be identified, then development of alternatives must occur through research. This will likely be done far upstream of the supply chain by chemical formulators or material manufacturers. Another source for research and development is collaboration with non-profit or academic research entities. The goal of this research would be to develop viable alternatives for the CoHC that would then be evaluated as part of the entire alternatives assessment process.

If there are no viable alternatives, the hierarchy of controls (refer to section 5.3) should be followed to ensure reduce or eliminate worker and environmental exposure (for example, installation of enclosed parts wash machine for hazardous cleaning solvents) until alternatives can be developed.