Several groups of organic compounds have been found in trace amounts in surface waters and fish tissue due to improved analytical and biomarker detection capabilities. These trace organic compounds (ToRCs) include pharmaceuticals, personal care products, surfactants, pesticides, flame retardants, and other organic chemicals, some with unknown modes of action or effects. Identifying or predicting ecological effects of ToRCs in typical aquatic multi-stressor situations is challenging. It often requires a variety of epidemiological tools that together, can diagnose effects at multiple scales of ecological organization.

The objective of WERF’s ToRCs Knowledge Area research is to provide essential frameworks, tools, and information to wastewater treatment managers, to ensure that they are making scientifically sound and appropriate treatment decisions to guarantee healthy aquatic ecosystems in receiving waters. The goal of this particular WERF project, Diagnostic Tools to Evaluate Impacts of Trace Organic Compounds, was to provide information on ToRCs to help the water quality community make scientifically defensible and cost effective decisions that are appropriately protective of aquatic populations and communities.

Five objectives were addressed in this research:
1) Develop and apply a procedure to prioritize which ToRCs are of most concern.
2) Develop and test a conceptual diagnostic framework to identify ToRC by source type.
3) Develop exposure-response models for high priority ToRCs.
4) Develop and populate a relational database of ToRC exposure and effects data.
5) Foster partnerships and transfer knowledge gained to the water quality community.

The final report summarizes approaches used and results obtained. It discusses critical data gaps and other uncertainties, and provides testable hypotheses and recommendations for Phase 2 testing and analyses. There are companion pieces to this research. They include a ToRC prioritization framework, a report on diagnostic approaches and types of analyses used to identify causes of ecological impairments in aquatic systems, seven case studies, and a web-based database (traceorganicscetool.werf.org) to help users search and evaluate ToRC data.

Which ToRCs Should I Monitor? A Framework for Prioritizing
The development of screening and diagnostic tools presented in this report could benefit end users by helping them prioritize which sites most require monitoring and assessment of ToRCs and whether ToRCs are a factor of concern at their site.
Figure 1. Flowchart Summarizing the Approach Used in Phase 1 of the Research Regarding Ecological Effects of Trace Organic Compounds.

Figure 1 shows the general conceptualization of this research and the context of screening and diagnostic tools discussed by the investigators.

Sites (e.g., a waterbody receiving treated effluent) should first be screened to determine whether they are low risk, high risk, or the risk is unknown for TOrC effects. If it can be demonstrated that a given site is low risk for TOrC effects, further monitoring and assessment of TOrCs is probably not warranted. If the site could have a high risk (or unknown risk) due to TOrCs, monitoring may be warranted. In this case effluent or receiving waters could be screened using the priority TOrC lists developed to determine if high risk chemicals are present.

Researchers developed three types of approaches for prioritizing TOrCs that may be high risk and that might be considered for monitoring.

- **Risk-based**: Max concentration divided by most sensitive predicted effects threshold (toxicity or estrogenicity). Quotient ≥ 0.10 considered high priority.

- **Risk-based and fate-based**: Sum of effect, bioaccumulation, and persistence scores; effect score based on quotient as in Approach #1; quotient ≥ 0.10 = score of 3 (highest priority); log $K_{ow}$ ≥ 5.0 = score of 3; half-life in water ≥ 180 d = score of 3. Total score ≥ 7 is high priority TOrC.

- **Tox and fate-based**: Sum of toxicity, bioaccumulation, and persistence scores; toxicity score based on predicted chronic toxicity; bioaccumulation and persistence scores same as in Approach #2.

Each approach has its advantages and limitations as described in the report (See page 2.5 of CEC5R08 and Chapter 4.0 of CEC5R08a) and is summarized below.

TOrCs identified as high priority differed among approaches: steroids, hormones, pharmaceuticals, and surfactants comprised most of the high priority TOrC based on a risk approach, while pesticides, industrial chemicals, and PAHs comprised most of the high priority TOrCs based on a persistent, bioaccumulative, and toxic chemical (PBT) approach.

The risk-based approach resulted in the fewest number of high priority TOrCs (41) while the PBT approach resulted in the greatest number of high priority TOrCs (108). A total of 23 TOrCs were identified as high priority using all three approaches and a total of 126 TOrCs were identified as high priority using any one of the approaches.

**What Types of Wastewater-Influenced Sites Are at Most Risk Due to TOrCs?**

The research team developed a framework and tools for use by the water quality community to screen sites for TOrC risks to aquatic biota. If a site could have a high risk (or unknown risk) due to TOrC, monitoring may be needed. The TOrC listed as high priority in Table 2-3 on page 2-6 of the report could serve as a guide to what type of TOrC to monitor. The framework could be used both prospectively and retrospectively depending on the end-user’s objective.

The screening approach developed in this research focuses on wastewater discharge sources and is a first step toward developing an effective screening tool.

Figure 2 and Table 1 present hypothesized risk factors used in the screening process and characteristics are grouped as:
1) wastewater influent characteristics, 2) wastewater treatment characteristics, 3) receiving system characteristics, and 4) site ecological and TOrC concentration data (measured or predicted). Using the guidance from information gathered for Table 1, one can further categorize sites to determine if a specific site warrants further investigation for TOrC impairments. Sites are likely to range from low risk to high risk and can be categorized as shown in Table 1.

### Diagnosing Potential or Actual Ecological Effects Due to TOrCs

A demonstration application of the screening approach was conducted in a retrospective assessment of available data from wastewater-influenced sites in the Drift Plain ecoregion of Ohio (See Chapter 4.0 of CECSRO8 report or Case Study report, CECSRO8c). Sites of particular interest for TOrC risk had high risk criteria for both the associated wastewater treatment facility and receiving water characteristics; had predicted TOrC exposure (household chemicals and/or pharmaceuticals) identified as a potential stressor by quantitative analysis; and were either simple (TOrCs were the only predicted stressor) or complex (multiple stressors) risk scenarios (Table 2). This categorization of risk scenarios was used in several other case studies examined in this research.

Two sites in Ohio that were screened as high risk for TOrCs and five other sites from different geographic locations were examined further to demonstrate the use of different diagnostic tools and to identify critical gaps in terms of diagnosing risks due to TOrCs. The use of these various lines of evidence in this screening assessment effectively used readily available data to screen high priority sites before devoting more resources in assessment and diagnostics at the site level.

One of the critical challenges in diagnosing risks due to TOrCs is that at higher levels of organization (population, community), there may not be “diagnostic” impacts that are attributable only to specific TOrCs (or classes of TOrCs). A decline in fish growth

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### Table 1. Draft Criteria for Screening Waste Water Treatment Plant Effluent-Influenced Sites for Potential Aquatic Ecological Effects Due to Trace Organic Chemicals.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Lower Risk</th>
<th>Higher Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WWTP Input Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry/hospital-related influents</td>
<td>None or very minor</td>
<td>&gt;5% of influent</td>
</tr>
<tr>
<td>Population served</td>
<td>&lt; 10,000</td>
<td>&gt; 1M</td>
</tr>
<tr>
<td>Average age of population</td>
<td>&lt; 30</td>
<td>&gt; 50</td>
</tr>
<tr>
<td><strong>WWTP Treatment Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of treatment</td>
<td>Tertiary, advanced secondary</td>
<td>Secondary or Primary</td>
</tr>
<tr>
<td>Sludge retention time (SRT)</td>
<td>&gt; 15d</td>
<td>&lt; 5d</td>
</tr>
<tr>
<td>Treatment effectiveness/uniformity</td>
<td>Low (near reference condition) nutrient concentrations; TSS</td>
<td>High (relative to reference conditions) nutrient levels; TSS</td>
</tr>
<tr>
<td>WWTP upsets</td>
<td>None</td>
<td>Several</td>
</tr>
<tr>
<td>Uniformity of influent flow and water quality</td>
<td>Relatively uniform most of the time</td>
<td>Very inconsistent in terms of flow and/or quality</td>
</tr>
<tr>
<td><strong>Receiving Waterbody</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent Effluent Instream (low flow)</td>
<td>&lt; 1%</td>
<td>&gt; 70%</td>
</tr>
<tr>
<td>Waterbody size and/or habitat diversity</td>
<td>Large (e.g., &gt; 5th order) waterbody; abundant refuges</td>
<td>Small waterbody; refuges few or non-existent</td>
</tr>
<tr>
<td>Waterbody openness/barriers</td>
<td>No barriers to fish movement</td>
<td>Dams or other barriers preventing fish movement</td>
</tr>
<tr>
<td>Threatened, endangered, or species of concern present</td>
<td>None</td>
<td>At least 1</td>
</tr>
<tr>
<td>Presence of other potential sources of TOrCs</td>
<td>None</td>
<td>Agricultural (CAFOs, row crops, orchards) sources present upstream or nearby urban stormwater?</td>
</tr>
<tr>
<td><strong>Site Observations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing EDC effects present</td>
<td>None</td>
<td>Significantly higher vtg induction in male fish; abnormal frequency of intersex in fish</td>
</tr>
<tr>
<td>TOrC concentration &gt; screening threshold level (from literature values)</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### Table 2. TOrC Risk Scenario Categories Used in Screening Sites.

<table>
<thead>
<tr>
<th>Site Risk Classification</th>
<th>WWTP Facility</th>
<th>Receiving Waterbody</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEVEL I (Lowest)</td>
<td>Low risk</td>
<td>Low risk</td>
</tr>
<tr>
<td>LEVEL II</td>
<td>Low risk</td>
<td>High risk</td>
</tr>
<tr>
<td>LEVEL III</td>
<td>High risk</td>
<td>Low risk</td>
</tr>
<tr>
<td>LEVEL IV (Highest)</td>
<td>High risk</td>
<td>High risk</td>
</tr>
</tbody>
</table>
rate, for example, could be due to a decline in availability of food resources, as much as to impaired physiology associated with chronic TOrC exposure. Therefore, the diagnostic approach must use multiple lines of evidence and look for patterns of responses that are not attributable to other stressors.

WERF TOrC Database

The research team compiled TOrC fate, effects, and occurrence data in a database for over 500 organic chemicals based on over 100 published studies representing more than 50 organizations and 700 sites. A web-based relational database was developed (traceorganicsecoTool.werf.org) using an easy-to-use Microsoft platform which the water resource community could store, query, and search TOrC data, as well as biological and aquatic life habitat information for sites in the U.S. This could be a useful tool for the water quality community to help track and analyze spatial and temporal trends in TOrC and associated ecological information at various locations.

Where Do We Go From Here?

While uncertainties and data gaps still exist, the investigators advise that those utilities and other organizations managing water resources do not need to wait for Phase 2 to be completed in order to obtain useful information for assessing and managing TOrC. The site screening tool developed in this research, while simple, is a useful first step to decide whether TOrC are a potential cause for concern at a site. The prioritization approaches developed are a useful starting point for deciding which TOrC should be monitored in the receiving waterbody or effluent. Partitioning the ecological effects of trace level organic compounds on aquatic populations and communities will be a long-term process. Nevertheless, the Phase 1 research has provided tools for gathering information relating to population and community effects of TOrC and laid a solid foundation for the Phase 2 and future research.

Recommendations regarding future monitoring and assessment activities that should be considered in Phase 2 of this project are discussed in full detail in Chapter 6.0 of the report.

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