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## TECHNICAL BULLETIN:

### Green Chemistry as it relates to ORC® and ORC Advanced®

#### The Concept of Green Chemistry

The term “green” is used to describe processes, products, or activities that have little or no detrimental effects to the environment and human health and safety. In recent years, the American Chemical Society (ACS) and the United States Environmental Protection Agency (US EPA) have emphasized the importance of green chemistry for the chemical industry. From the EPA website on this subject, the concept is briefly defined as follows:

*“Green chemistry, also known as sustainable chemistry, is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle, including the design, manufacture, and use of a chemical product”*

- US EPA website: [www.epa.gov/gcc/](http://www.epa.gov/gcc/)

To further define the concept of green chemistry, both the US EPA and the ACS have cited the book “Green Chemistry, Theory and Practice” by Anastas and Warner,<sup>1</sup> which defines twelve principles of green chemistry. In the context of these twelve principles, we have determined the ORC and ORC-Advanced products (ORC product family) to be significantly green chemical technologies. The twelve principles of green chemistry are outlined below with descriptions of how the ORC product family complies on nearly all accounts.

#### The Twelve Principles of Green Chemistry<sup>1</sup>

*And how they are reflected in the ORC® family of products*

- 1. Prevent waste:** Design chemical syntheses to prevent waste, leaving no waste to treat or clean up.

*ORC™ and ORC-Advanced® are manufactured in a stirred reactor followed by a water-evaporation process. The final drying step removes clean water and leaves no waste to treat or clean up.*

- 2. Design safer chemicals and products:** Design chemical products to be fully effective, yet have little or no toxicity.

*ORC and ORC-Advanced have very low toxicity. The patented chemical compositions contain phosphates intercalated into magnesium peroxide and calcium oxyhydroxide/calcium peroxide, respectively.*

- 3. Design less hazardous chemical syntheses:** Design syntheses to use and generate substances with little or no toxicity to humans and the environment.

*The ORC family of products are formulated by Regenesis without the use of any toxic ingredients or formation of toxic byproducts.*

- 4. Use renewable feedstocks:** Use raw materials and feedstocks that are renewable rather than depleting. Renewable feedstocks are often made from agricultural products or are the wastes of other processes; depleting feedstocks are made from fossil fuels (petroleum, natural gas, or coal) or are mined.

*The feedstocks for ORC and ORC-Advanced are inorganic minerals that unfortunately are not considered renewable.*

- 5. Use catalysts, not stoichiometric reagents:** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once.

*The production of ORC and ORC-Advanced results in zero waste, so a catalyst is not necessary for waste minimization.*

- 6. Avoid chemical derivatives:** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.

*ORC and ORC-Advanced are formulated without the use of protecting groups or temporary chemical modifications. This minimizes waste and maximizes energy efficiency.*

- 7. Maximize atom economy:** Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms.

*The ORC family of products contain 100% of their starting ingredients, with the exception of water and oxygen gas liberated during production. These processes can be described as atom-economical.*

- 8. Use safer solvents and reaction conditions:** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals.

*Water, the most environmentally innocuous solvent available, is the solvent for the syntheses of ORC and ORC-Advanced.*

- 9. Increase energy efficiency:** Run chemical reactions at ambient temperature and pressure whenever possible.

*The reactions to form ORC and ORC-Advanced are exothermic. The heat liberated by these reactions is used to maintain the optimal elevated temperature for the reaction to proceed. This allows for energy savings as the reactor need not be heated by an external source and requires little outside input of energy.*

- 10. Design chemicals and products to degrade after use:** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.

*By design, Regensis products are made to have little or no detrimental impact on groundwater quality or the environment. The action of ORC or ORC-Advanced in the subsurface causes the destruction of harmful petroleum-based contaminants in groundwater. The residuals from this process have minimal detrimental impact on the environment compared to competing technologies. These residuals include calcium or magnesium hydroxide, and calcium or magnesium phosphates. These inorganics have very low water solubility. The end products of contaminant oxidation are simply water and carbon dioxide. The carbon dioxide is not released to the atmosphere as a waste gas, rather it is generated within the subsurface aqueous environment and sequestered largely as carbonic acid, bicarbonate and carbonate. The use of ORC and ORC-Advanced have*

- 11. Analyze in real time to prevent pollution:** Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.

*No harmful byproducts are formed in the synthesis and formulation of ORC and ORC-Advanced. To maximize energy efficiency and reaction yield the temperature, duration, and stirring parameters of these reactions are carefully controlled.*

- 12. Minimize the potential for accidents:** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment

*All chemical oxidants carry some safety risks as a result of their oxidizing nature. ORC and ORC-Advanced are engineered to release their active-oxygen very slowly in water. This makes them inherently safer to ship, transport, and handle when compared with many other oxidants and oxygen-releasing materials.*

## References

1. Originally published by Paul Anastas and John Warner in **Green Chemistry: Theory and Practice** (Oxford University Press: New York, 1998). Taken from: <http://www.epa.gov/greenchemistry/pubs/principles.html>