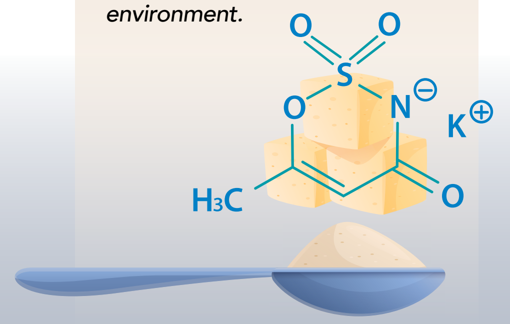
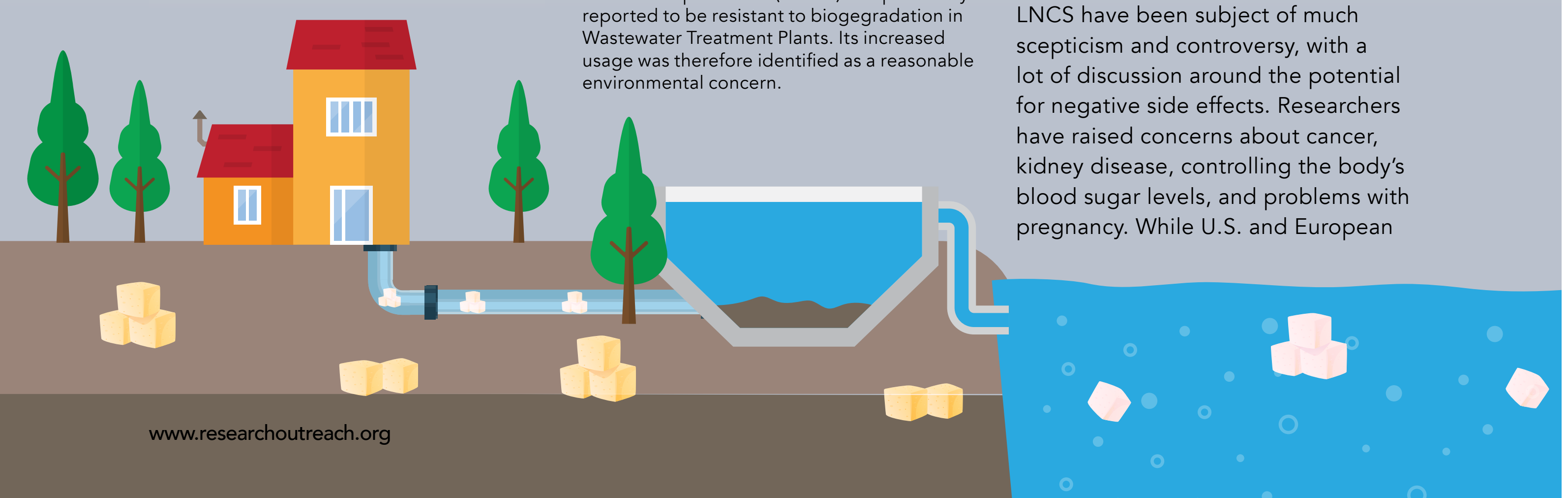
Could acesulfame potassium be leaving the bittersweet taste of a toxic environment?

Our modern sewage is defined by many potential toxic threats from new chemical compounds we use in our daily lives. One potentially unexpected entrant for this phenomenon is acesulfame potassium (ACE-K), a calorie-free sweetener. As it is not digested by the body, ACE-K is excreted straight into the toilet, arriving in our wastewater and surface water. Dr Patrick Guiney, Principal Scientist at ECOTOX-Guiney Consulting, leads the first systematic review to examine whether ACE-K's increasing presence in our wastewater might make it the latest chemical that could be toxic to the environment. He found that, thankfully, ACE-K has a negligible impact on the environment.





In recent decades, our society has become more and more preoccupied with waste. As metropolises expand and the population of the planet continues to grow, more waste needs to be managed. This includes an increase in sewage and wastewater. Having more people means more toilets and taps to flush away the various water-based waste we produce, from excretions being flushed to the cooking oils washed off from pans.

It isn't surprising that the sewage contains a cocktail of chemicals that require the water to be treated at wastewater plants. Even with the modern and sophisticated sewage and water treatment systems that exist in some countries, some chemicals and pollutants can survive the treatment process. This may pose a threat to people and animals, by contributing to environmental contamination. Endocrine disruptor chemicals from pharmaceuticals, pesticides, and personal care products are an example of a class of chemicals suspected to be changing the reproductive sex of aquatic animals.

Figure 1. The calorie-free sweetener acesulfame potassium (ACE-K) was previously reported to be resistant to biogegradation in Wastewater Treatment Plants. Its increased usage was therefore identified as a reasonable environmental concern.

A perhaps unexpected wastewater chemical is acesulfame potassium (ACE-K). ACE-K is one of several low- and no-calorie sweeteners (LNCS) used as a healthy alternative to sugar. Serendipitously discovered by Karl Clauss in 1967, ACE-K was approved by the U.S. Food and Drug Administration (FDA) as a food/drink sweetener in 1988. It has become a popular calorie-free alternative to sugar, perhaps because it is 200 times sweeter than sucrose and therefore, less is needed in order to achieved the desired level of sweetness in food and beverage products.

ACE-K is sold directly in Sweet One and Sunett sweeteners, and is used to flavour many products, including (but not limited to) baking products, sodas, fruit juices, desserts, and toothpaste. In the last few decades, LNCS have become much more widely used as a less caloric alternative to sugar. Whereas sugar is absorbed at a caloric cost, ACE-K isn't even absorbed by the body. Instead, ACE-K is excreted out of the body unchanged. But what if there is a price to pay for a calorie-free sweetness?

AN ARTIFICIALLY BITTERSWEET TASTE?

LNCS have been subject of much scepticism and controversy, with a lot of discussion around the potential for negative side effects. Researchers have raised concerns about cancer, kidney disease, controlling the body's blood sugar levels, and problems with pregnancy. While U.S. and European regulatory agencies have stated such sweeteners are safe, research has begun to identify a different potential concern with ACE-K: possible environmental problems associated with wastewater contamination.

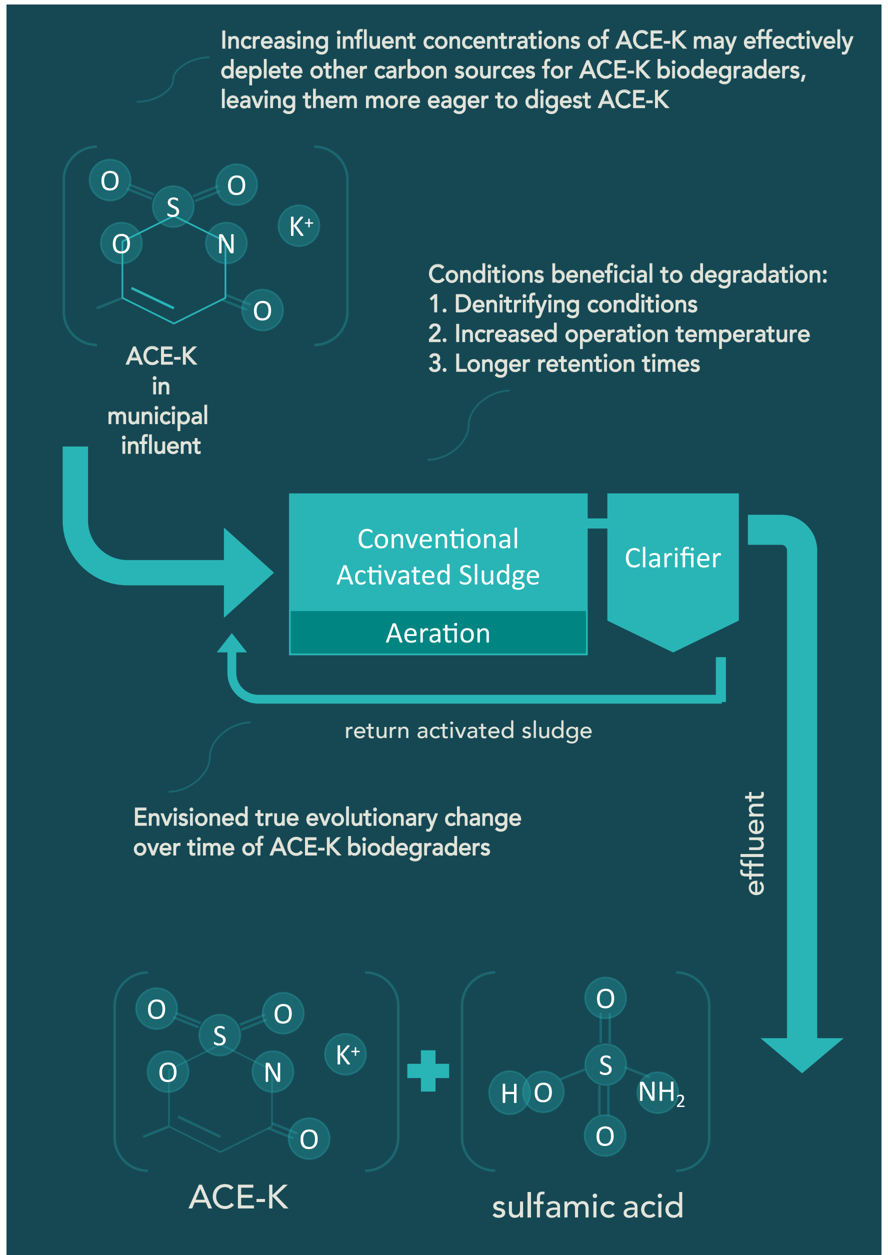


Figure 2. Conceptualised fate of ACE-K in a wastewater treatment plant.

As ACE-K isn't absorbed by the body, it is excreted into the toilet, where it makes its way to the local sewage wastewater treatment system. Ultimately, if the wastewater treatment plant cannot biodegrade it, ACE-K can potentially enter the environment, including various water bodies. Traditionally, the life of ACE-K outside of the body has been ignored. It's only in recent years that new environmental research has begun to probe the question of environmental health. As its concentration in surface water has increased, researchers have recently grown concerned that it could be the latest in a list of potentially toxic pollutants to be manufactured by man and released into the aquatic environment.

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One of the consequences of it being a new research topic is that there has yet to have been any systematic review of the research into ACE-K's possible environmental impacts, and no way to discern a clear agreement on the topic. This is problematic for anyone who needs an accessible and reliable assessment on the scientific literature around ACE-K, like risk managers and policymakers who are tasked to create policy to stop environmental damage.

Dr Patrick Guiney, President of ECOTOX-Guiney Consulting and Adjunct Professor at the University of Wisconsin-Madison, has led the publication of a review paper on the environmental risks of ACE-K. Dr Guiney and his team have, for the first time, collated and evaluated the totality of available environmental data on ACE-K based on reliable and relevant data for an environmental risk assessment from published scientific papers as well as the gray literature. They used expert scientific judgment to assess, review and integrate all of the data to form a meaningful conclusion on the predicted environmental impacts of ACE-K.

Dr Guiney and his colleagues began by looking to focus on surface water, referring to any natural water that has not penetrated much below the surface of the ground which are part of the water cycle. This includes the ocean, rivers, lakes, and wetlands. By carefully evaluating the scientific literature surrounding ACE-K's chemical structure and properties, they were able to predict where it should partition in the environment. The chemical structure of ACE-K lends itself to being absorbed eagerly in water, which is unsurprising given that it has been detected in wastewater and surface water generally in the lower parts per billion (ppb) range.

REVIEWING ACE-K IN THE ENVIRONMENT

Fortunately, though, soil doesn't absorb ACE-K with the same enthusiasm as water (i.e., parts per trillion [ppt] in sludge and

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groundwater), meaning it won't have a major impact on soils or river/ocean sediment beds. Furthermore, its chemical structure also shows that ACE-K is unable to accumulate in the bodies of aquatic organisms and this has been confirmed in published studies.

But the question remained, could ACE-K still be toxic to aquatic animals if its concentration in surface water exceeds a non-toxic exposure? Dr Guiney was able to collect data from papers which had recorded the concentration of ACE-K within water bodies from around the world. His team also evaluated studies which determined the concentration at which ACE-K becomes toxic either short term or long term, to a wide variety of aquatic organisms including fish and invertebrates, fish embryos, freshwater plants, as well as toxicity to domestic sludge microorganisms.

Combining this data to conduct a probabilistic exposure analysis, Dr Guiney and his collaborators found that there was currently a very low risk of aquatic organisms being exposed to a toxic concentration level of ACE-K. The data showed that there wasn't enough ACE-K in surface water to harm any of the studied aquatic organisms. Even in a worst-case scenario, the concentration of ACE-K would still be 3.5 orders of magnitude less than the minimum concentration of toxicity needed to cause harm.

The probabilistic exposure models used in this study were USA-centric, but Dr Guiney ensured his review had global relevance by creating an 'exposure index' which calculates and compares ACE-K concentrations in USA waters to the rest of the world. It confirmed that the ACE-K concentrations in the USA were similar to other parts of the world with high ACE-K consumption, and the findings of this review are applicable throughout the world.

BIODEGRADABILITY OF ACE-K
Another point of interest in this scientific investigation was the reported rates of biodegradability of ACE-K, which is the process by which organic substances are decomposed by microorganisms into simpler substances such as carbon dioxide, water and ammonia, without harming the environment. If ACE-K is not readily degraded, either in Wastewater Treatment Plants (WWTPs) or in the outside environment, then it could create a long-term build-up of ACE-K (or a toxic by-product) in the water. Eventually, this build-up could reach toxic concentrations and begin harming animals. For a while, scientists were concerned by this scenario as the research was showing that ACE-K was not readily biodegradable.

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Interestingly, Dr Guiney notes a recent shift in the literature, with research after 2014 reporting that ACE-K, in fact, is quite biodegradable in several WWTPs around the world. However, it's not fully clear as to why this is the case. The cause for this shift could be higher, more efficient operating temperatures found in some WWTPs, or the evolution and establishment of populations of new bacteria that can more easily metabolise ACE-K – quite literally eat it for breakfast. Regardless of the mechanism in motion, it does mean that ACE-K isn't at risk of a stealthy long-term build-up towards toxic concentrations. On the contrary, we might even anticipate measurable decreases in the concentration of ACE-K in surface waters as has been reported in some rivers in Germany, where reductions of ACE-K concentrations of between 70% and 80% have been observed for the studied period of 2013 to 2016 (Kahl et al., 2018).

MOVING FORWARD WITH ACE-K RESEARCH
While this preliminary ACE-K environmental risk assessment is encouraging, we should not assume our work is done. Researchers can still do useful work to identify the degrading enzymes in bacteria on an ACE-K diet and sequence their genomes to understand how it can break down ACE-K. There is also a need for increased efforts to isolate and characterise ACE-K degrading bacteria from different regions. Other issues, such as the impact of sunlight on ACE-K degradation, is another area where there is a lack of clarity in current research. Despite these clouds within our knowledge, the broader positive messages are now apparent to everyone.

ACE-K has a negligible impact on the environment, posing little threat to the aquatic life that the planet depends upon. This information, while not the headline-catching drama that often captivates the general public's interest, is equally important as we continue to evaluate the resources we consume, and what that consumption leaves behind. As we continue to flush away more wastewater, with an increasingly varied cornucopia of new chemical compounds, it's more important than ever to be vigilant about the professional values and applications we use when developing and describing the science of environmental risk assessment that ensure transparency, reliability, and reduction of bias related to the potential impacts of these chemicals on our wastewaters and aquatic ecosystem.

It's vital that we know what we are flushing down the toilet or putting down the drains of our sinks, as well as the impact it has once it leaves our bodies and homes.

Dr Guiney's review shows that ACE-K has a negligible impact on aquatic organisms. Still, it's important we continue to evaluate the resources we consume and the effect of our consumption.

Behind the Research

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Research Objectives

Dr Patrick Guiney investigates the environmental fate and effects of low-and no-calorie sweeteners and applies ecological risk assessment methods to establish their environmental safety profiles.

Detail

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Bio
Dr Guiney has 42 years of experience in human health and ecological risk assessments. He is an Adjunct Professor at the University of Wisconsin- Madison where he teaches toxicology and risk assessment. He is President and Principal Scientist at ECOTOX-Guiney Consulting, LLC. He was also previously the Director of Environmental Safety at S.C. Johnson & Son, Inc. and President of the Society of Environmental Toxicology and Chemistry. His research focuses on the toxicity, bioaccumulation, and fate of toxic substances at various levels of biological organisation (molecular/ biochemical to field studies).

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- The Grocery Manufacturers Association (GMA), now the Consumer Brands Association (CBA)

Collaborators
- Edward Schaefer, Director of Environmental Fate at Eurofins-EAG Agrosciences
- Kerry Belton, former toxicologist at The Grocery Manufacturers Association (now Consumer Brands Association)

References

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Personal Response

From an environmental risk assessment perspective, what do you feel is the significance of the recent published findings of enhanced biodegradation of ACE-K around the world?

"Published studies prior to around 2014 tended to conclude that ACE was resistant to biodegradation, often only being biodegraded to relatively minor extents (typically ranging between 5-41%). This limited metabolism of ACE-K was thought to be associated with co-metabolic processes, and led to the suggestion that this low-calorie sweetener might be used as a wastewater input tracer in surface waters. The more recent findings that significantly higher ACE-K biodegradation (as high as >97%) have been observed in multiple WWTPs around the world suggest that the idea of using ACE-K as an environmental wastewater tracer has fallen into disuse. We now know that bacterial degradation of ACE-K is a catabolic process which leads to complete mineralisation and incorporation of the carbon-yielding part of the ACE-K molecule back to the environment. The other important feature of this observed enhanced biodegradation of ACE-K is the assurance that the current large margins of safety established in our review should remain in effect for a long-time despite the increasing usage of ACE-K."