ARTIFICIAL SWEETENERS - AN IGNORED ENVIRONMENTAL THREAT?

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ABSTRACT

Artificial sweeteners are produced, consumed and released into the environment in large quantities. In 2005, the respective global consumption of acesulfame (ACE), saccharin (SAC), and Cyclamate (CYC) were reported to be 5, 37 and 47 KT (Kilo Tons) respectively. In 2013, almost 2 KT of sucralose (SUC) was consumed in the United States and Europe alone. After consumption of several of these sweeteners they pass mainly unchanged through the human body. Artificial sweeteners are spread with waste water, weather and wind. The long degradation time allows such substances potentially to have long-lasting effects in the environment; therefore, they have been identified as new pollutants. In German wastewater treatment plants they found that cleansing was only successful in a limited degree, but that SAC and CYC were almost eliminated (94%). It was not the case with ACE and SUC. In addition to the four artificial sweeteners, eco-toxicological effects of the natural sweetener Stevia (Steviol glycosides) derived from Stevia plant (Stevia Rebaudiana Bertoni) have been examined and has been found to be 100% biodegradable unlike its other counterparts. From an environmental standpoint, Steviol glycosides should be preferred as sweetener. Study carried out by researchers from Environmental Science and Technology, New York indicates that sweeteners (ACE, SAC, CYC) can damage the plants' ability to perform photosynthesis (via contact with infected water), also Sucralose (SUC) has a negative environmental impact on aquatic species. This can result in less food for the animals that depend on the plants, giving the ripple effect that has consequences for humans. The focus of our investigation is the artificial sweeteners' influence in terms of pollution in nature and the environment.

1.1 INTRODUCTION

For decades the food industry has used artificial sweeteners (intense) as sugar free, or low-calorie sugar replacement. In addition to lower calorie content, artificial sweeteners have been able to help control blood sugar levels in diabetics, reduce the risk of tooth decay and for some; they have been able to extend the shelf life of food products. They are also used in sanitary products such as toothpaste and as a flavor enhancer in drugs (sweetening). Our Case Study for this research will be about 5 artificial sweeteners namely; Acesulfame (ACE), Saccharin (SAC), Sucralose (SUC) and Cyclamate (CYC).

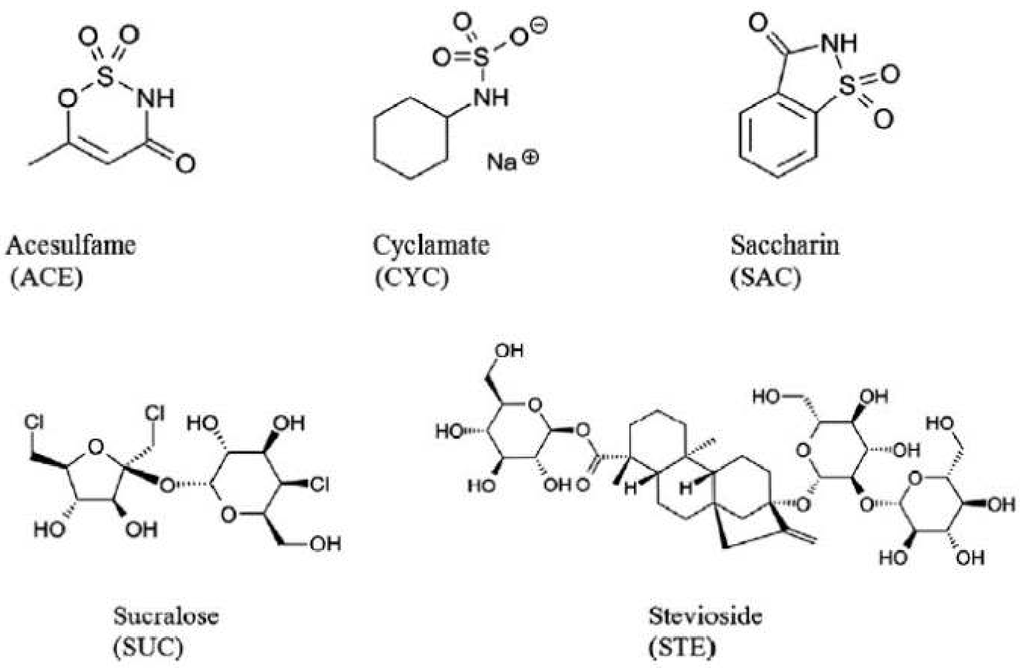

Fig 1

Chemical sweetening like Sucralose (SUC), Aspartame (ASP), Cyclamate (CYC), and others has been approved and is considered by European Food Safety Authority (EFSA) as safe from humans, as long as one stays under the limit for daily intake. Although a substance is considered harmless to the human body, it does not necessarily mean that it is harmless, or without impact for fish, birds, plants and other life in the nature. Artificial sweeteners are widely used as additives in various food products because they are extremely sweet, without calories. But "does not contain calories" means in other words that the sweetener is very resistant to decomposition both in the human body and in the environment (nature). A product that does not break down in the human body neither will be broken down in nature. At best, it will be watered down, but long-term use will provide increasingly higher concentrations, which eventually lead to unforeseen consequences.

Artificial sweeteners are spread with waste water, dust and contaminated soil. The long degradation time allows such substances to potentially have long-lasting negative effects in the environment. Several studies have confirmed widespread distribution of ACE, CYC, SAC and SUC in the water cycle at levels that are among the highest for known man-made pollution. In German wastewater treatment plants (Scheurer et al., 2009) the researchers found that cleansing was only successful in a limited degree, but that SAC and CYC were almost eliminated (94%). It was not the case with ACE and SUC. Current knowledge of the trace analysis of these connections, their incidence in water, the environment in addition to the breakdown and transformation of the environment is summarized in (Lange et al., 2012). Water samples from 25 different treatment systems in Sweden shows extensive spread of sucralose (SUC) in nature. Rough calculations from 2006 shows that five to six million tons of sucralose is spread in Sweden each year and other synthetic sweeteners as well. A screening made in the Nordic countries, by Aarhus University, shows that the water from wastewater treatment plants contains Aspartame, Sucralose and Cyclamate, with the presumed origins from soft drinks and food products. With more advanced treatment systems will, however, they may be able to eliminate more than 94% of the released Saccharin and Cyclamate.

In addition to the four artificial sweeteners, eco-toxicological effects of the natural sweetener Stevia have been examined. This sweetener belongs to the group Steviol glycosides, which gives the sweet taste of the leaves from Stevia plant (Stevia Rebaudiana Bertoni). For several decades (used for more than 1000 years by the indigenous), Stevia sweeteners have been utilized and been commercially available in Japan, China and South America .Quite recently, the cleansed steviol glucosides was "generally recognized as safe (GRAS)" by the US Food and Drug Administration (FDA) and approved for Europe by the European Food Safety Authority (EFSA).From an environmental standpoint, Steviol glycosides should be preferred as sweetener since these are considered to be 100% biodegradable (Expert Group for Technical advice on organic production, EGTOP, 2012).For sweeteners such as Aspartame (ASP) it is not found occurrences equal to SUC, related to emissions in nature, but they exist (Environmental Science and Technology). From an environmental perspective, however, the sweetener could pose an even greater environmental threat, since genetically modified ingredients and bacteria are part of the manufacturing process. In the subsequent chapters, two sweeteners will be examined; detailing their individual properties, how they are manufactured and their effect directly on the environment. We will also dive into the toxicological effects of artificial sweeteners on the environment (water, dust, soil and human race directly).

2.1 PROPERTIES OF SOME CHEMICAL SWEETENERS, THEIR MANUFACTURING PROCESS AND TOXOCOLOGICAL EFFECTS

1) Aspartame

Aspartame is produced through fermentation by combining b. flavum and c. glutamicum, with nutrients like carbohydrates, vitamins and amino acids. When sufficient amino acids are available, they will be separated and purified. Then mixed with methanol to form phenylalanine L-phenylalanine methyl. Aspartic acid is also being changed, and then the two amino acids are mixed, heated and cooled, resulting in the formation of crystals. The crystals react chemically with acetic acid to create aspartame. The last part of the process is the distillation and filtration, and aspartame is finally manufactured.

Aspartame is made by fermenting of corn and soy, two products from the group of genetically modified crops in the American Agriculture, this has raised concerns in the minds of environmentalists regarding unexpected and potentially disastrous results in the future. The bacterial culture used, b. flavum and c. glutamicum, are Genetically Modified (GMO) and the corn & soy used in production are also Genetically Modified (GMO). Studies have shown that pesticide-producing crops (GMO) pollute nearby streams, and possibly affect the aquatic life. BT toxin that is produced by these GMO crops are far stronger than anything found in nature.GMO agriculture can harm beneficial insects. And it has been determined that the former insignificant insects not targeted by the GMO varieties evolved into a "plague". Then the farmers would have to resort to spraying of pesticides again, on top of the potential for build-up of the extra strong BT toxin in soil. Such cases were reported in China, India as well as in the United States.

Products with aspartame are rarely just aspartame. The sweetener is often mixed with acesulfame K*, and/or cyclamate, so even if the sweetener, isolated, are broken down into amino acids and methanol in the body, the products with aspartame as sweetener do contribute to the environmental polluting emissions which is not always caught in wastewater treatment plants. However, Acesulfame-K (aka "Ace-K") is a potassium salt that contains methylene chloride, a known carcinogen. Long term exposure of methylene chloride can cause nausea, headaches, mood problems, impairment of the liver and kidneys, with sight problems and possibly cancer. Acesulfame-K can contribute to hypoglycemia. Aspartame is an excitotoxin, a toxin which is usually amino acids, such as glutamate and aspartate. Excitotoxicity is a process in the central nervous system which leads to the death of nerve cells and is sometimes considered to be the explanation of certain degenerative diseases such as Parkinson's and Alzheimer's.

2) Sucralose

To make Sucralose, chlorine is used. Chlorine can be harmless but can also be extremely dangerous. When chlorine is combined with sodium, chlorine forms a harmless "ionic bond" that resembles normal table salt.

Sucralose is made by adding three chlorine ions to a sugar molecule. In combination with carbon, the chlorine atom of sucralose forms a "covalent" bond. The result is organochlorine; a historically fatal compound.

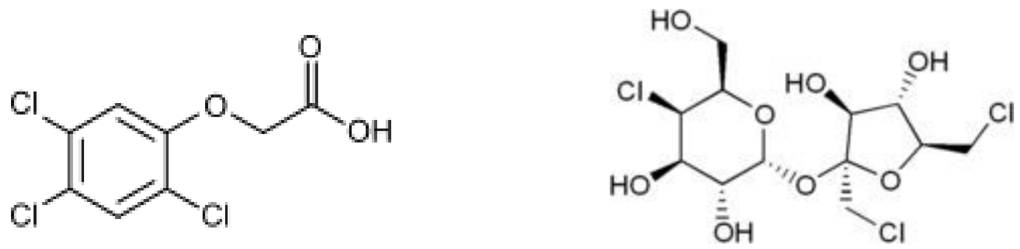

Fig 2

One of the molecules in the illustration above is sucralose. The other is "Agent Orange", which was one of the United States chemical weapons during the Vietnam War. The substance removed leaves on trees in the woods where Vietnamese soldiers and civilians fled or hid.

The structure looks quite similar and sucralose can demonstrably stop photosynthesis for several types of plants, so they both exhibit similar structure and effect, making the difference between the two compounds quite thin. Other known organochlorines are DDT, PCB, and chloroform.

According to the report: "Sucralose metabolism and pharmacokinetics in man", sucralose has nearly twice as long half-life in the body (18.8t) as radioactive plasma (13t) and no living organism in nature has enzymes to break down covalently bound chloride.

3.0 DISCUSSION

3.1 EFFECT ON AIR, DUST AND WATER

A nationwide survey in terms of artificial sweeteners was conducted by taking 98 outdoor dust and soil samples from mainland China. Soil samples showed concentrations up to 6450 ng/g in the dust and 1280 ng/g in soil.

Sources for, the proliferation and of concentrations and seasonal variations of artificial sweeteners in Tianjin were examined, with air, soil, and water samples. The levels were significantly higher on the river Haihe, at a test site in the city center, in the winter, while no obvious seasonal trends were found by another site near a factory and in the area around a wastewater treatment plant.

Saccharin, cyclamate and acesulfame K was the dominant sweeteners in both air and dust particles, with concentrations varying from 0.02 to 1940 PG/M3. Usually were concentrations of artificial sweeteners in the air relatively higher in the summer, while the opposite was the case for dust particles.

Fig 3

It appears as the artificial sweeteners best filtered in the water treatment plant is the most occurring in the air, dust and soil.

A possible source of artificial sweeteners in air and soil can be animal food, sweeteners for flavor adjustment, having gone through animal feces are used to as a fertilizer, and urine that find its way to the field, either directly, or through water treatment plants that are not capabilities to filter out the artificial sweetener.

Toxicological Risk For Fish At Relevant Concentrations

A study that aimed to evaluate possible toxicological risk in the blood, brain, gills, liver and muscle of "Cyprinus Carpio" (fish) with oxidative stress biomarker.

Carp was exposed to two different environmentally relevant concentrations (0.05 and 155 µg L − 1) of sucralose (SUC), with various exposure times (12, 24, 48, 72 and 96 h). The following biomarkers were evaluated: lipid peroxidation (LPX), hydroperoxide content (HPC) and protein carbonyl (PCC), as well as the activity of superoxide dismutase, antioxidant enzyme (SOD) and catalase (CAT).

The results show a significant increase in the static LPX, HPC, the PCC ($P < 0.05$), especially in the gills, brain and muscles, as well as significant changes in the activity of antioxidant enzyme in the gills and muscle. Sucralose have an environmental impact on aquatic species.

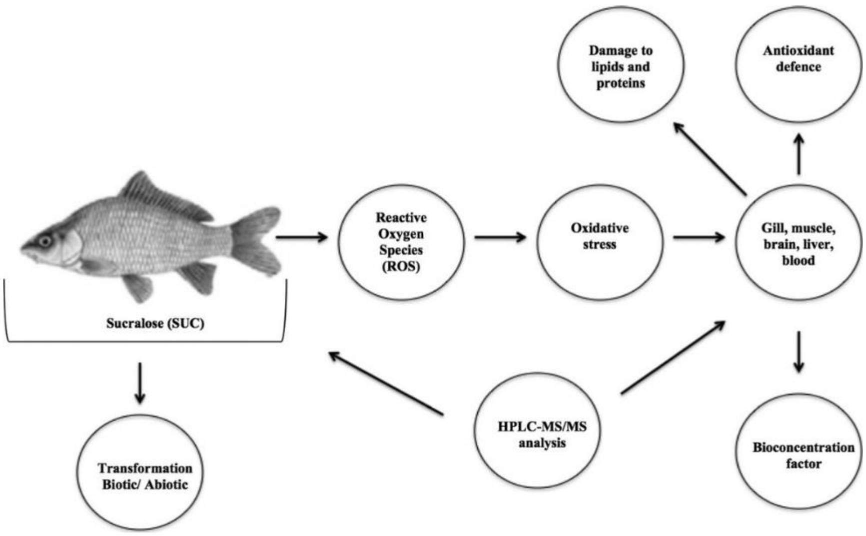

Fig 4

Sweetness – A Biological Property

Sweetness is a biological property of importance, for including animal food search and the ability to orient themselves. Thus, one can assume about the types of impacts artificial sweeteners may have in the nature.

With a type of Arctic copepod researchers found that chronic exposure to sucralose could influence the development of eggs and fresh-water crayfish that were exposed to the sucralose got faster heartbeat.

It is a scientifically accepted fact that sweeteners can also influence other animals. Effects one cannot detect in the investigations of the biological damage. Also, that certain fish species navigate their way to the spawn locations by using your taste senses, which of course will be able to disrupt a thing as winter cod migrating to Lofoten to spawn. In that case, the oil drilling and the potential pollution from such an industry be a trifle in comparison.

3.2 EFFECT ON HUMAN

Great Potential For A Domino Effect

In a study published by Environmental Science and Technology, researchers also found large amounts of sucralose, saccharin, aspartame and acesulfame close to a wastewater treatment plant in New York State. The study indicates that the sweetener can damage the plants' ability to perform photosynthesis.
This can result in less food for the animals that depend on the plants, giving the ripple effect that has consequences for humans.

Sucralose binds to vitamin B12

According to the Norwegian Health Informatics: "Vitamin B12-kobalamin-is a vitamin that is vital and important for normal nerve function and the formation of blood cells-especially red blood cells and some types of white blood cells. The vitamin cannot be made in the body and must therefore be provided through diet. Meat, fish, sea food, eggs and dairy products-are the main dietary sources for vitamin B12"

Research shows that sucralose binds to vitamin B12, and thus prevent the absorption of the vitamin. Not just for living organisms in the sea and the ocean. This property can also affect people who get little B12, especially those who are vegans.

Effect of Artificial Sweeteners on Human Metabolism

According to UNC: Sucralose cannot be effectively broken down by the bacteria in the human digestive system. The body absorbs little or no calories and 90 percent of the chemical leaves the body through urine and faeces and enters the drainage systems. The rest is thought to be accumulated in the body or end up as food for unwanted bacteria. Israeli research has indicated that some of the synthetic sweeteners act as nutrition for the bad unwanted intestinal bacteria, and negatively affect the good ones. In the presence of bad bacteria, antibiotics are used to eradicate the bacterial flora.

4.0 RESULTS

4.1 Fate of Artificial Sweeteners in Wastewater Treatment Plants in New York State, U.S.A.

Two researchers Bikram Subedi (Wadsworth Center, New York State Department of Health, and Department of Environmental Health Sciences) and Kurunthachalam Kannan (Biochemistry Department, Faculty of Science and Experimental Biochemistry Unit, King Fahd Medical Research Center, King Abdulaziz University) carried out a study on wastewater from the Wastewater Treatment Plants in New York to test for the presence of these artificial sweeteners. In this study, mass calculation, purification efficiency, and the environment in relation to emissions of sucralose, saccharin, aspartame, and acesulfame were measured in wastewater, in the primary wastewater purification, in plumbing, and sludge collected from two wastewater treatment plants in the Albany area in New York State, USA. All artificial sweeteners were detected in the wastewater. Influence, 0,49 (Aspartame) to 27,7 µg/l (Sucralose) In the primary influence, 0,11 (Aspartame) to 29,6 µg/l (Sucralose) In the wastewater. There was a significant removal of aspartame (68,2%) and saccharin (90,3%). However, sucralose and acesulfame were less effectively removed (< 2,0%).

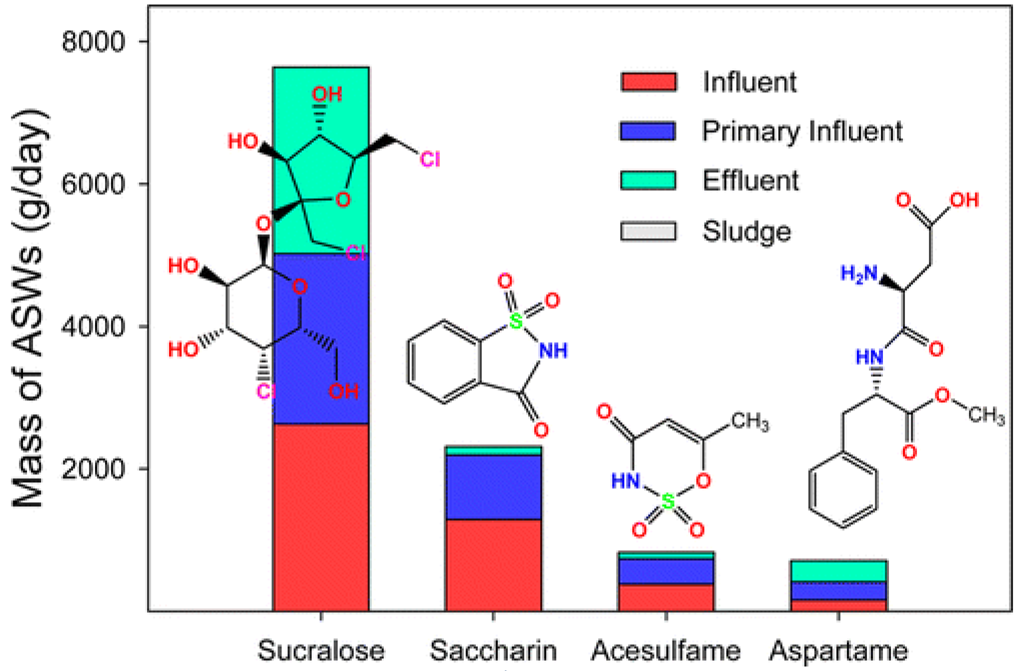

Fig 5

4.2 Artificial Sweeteners in Drinking Water

According to the report «Artificial Sweetener Sucralose in U.S. Drinking Water Systems» (Environ. Sci. Technol., 2011, 45 (20), pp 8716–8722); The artificial sweetener Sucralose has been proven to be a widespread contamination in wastewater, surface water, and groundwater. To understand its occurrence in drinking water systems, water samples from 19 US (US) treatment plants for drinking water, which supply more than 28-million people, were analyzed for sucralose. The sweetener was found to be present in the source water for 15 of 19 water supply systems (47 – 2900 ng/L), and for purified water in 13 of 17 water purifiers (49-2400 ng/L) and 8 of the 12 water pipelines (48 – 2400 ng/L) that was tested.

Presence of sucralose was monitored at one drinking water treatment plant over an 11-month period from March 2010 to January 2011, and on average, measured at 440 ng/L in the source water and to the 350 ng/L in the finished Cleaned Water. The results of this study confirm that the sucralose will work well as an indicator of man-made contamination of water sources, finished drinking water and water in pipe systems in the U.S.

Fig 5

4.3 Presence of Artificial Sweeteners in Rivers, Lakes and Falls

In the water flowing through Ontario's Grand River, for which Expires in Lake Erie, the University of Waterloo and the Environment Canada found that the amount of sugar substitutes in the water flowing through the 300-kilometre long river each day match 81-190 thousand cans of artificially sweetened soda.

Study tested for sucralose, cyclamate, saccharine and acesulfame used in soft drinks, other beverages, in dairy products, in foods all over the world. Researchers found these types of sweetener in the tap water in the Canadian city Brantford, which implies that the sweeteners in the drinking water sources is not filtered out totally by the treatment plants. Agriculture watering the fields with the same water may run the risk where the photosynthesis of the crop will be "disturbed", which will reduce food production.

For every liter of water, 0.15 micrograms of the sweetener was found, which means that it could be 72 tons of sweetener floating around in Lake Erie. Now, years after the survey, with a growing number of consumers of easy products are there may be reasonable that it is long since this number passed 100 tons, considering that sweeteners are not broken down, and that since the time the estimation was done, more supplies of the same sweeteners has been flushed out in the water systems.

In Waterloo News, published in November 2017; shown in Journal of Environmental Quality, describes how scientists tested private groundwaters wells around the Nottawasaga river for four artificial sweeteners, as a method to discover if the groundwater is affected by human wastewater.

Artificial sweeteners are ideal trace elements for waste water, because when they leave the human body, they remain the same, and cannot be cleaned in most processes for wastewater treatment. Wastewater contains relatively high concentrations of artificial sweeteners.

The research team also tested the groundwater brought out by the banks of the Nottawasaga river and found that 32 percent of the samples tested positive for sweeteners.

A study published in 2013 by researchers from the University of North Carolina (UNC) confirmed that most of the sucralose used around the world ends up in the Gulf Stream. The ocean currents that start in the Gulf of Mexico and end up in Norwegian and Arctic waters. Since artificial sweeteners cannot be broken down into the body, of water treatment systems, it ends up in the oceans, where long-term effects remain unknown.

5.1 SUMMARY

When our descendants look at what our environmentalists were occupied in 2018, they might recognize that they had overlooked our greatest environmental problem today. Emissions of environmental pollutants and artificial sweeteners can be an environmental problem, regardless of whether they are harmless in the human body in the short term.

The alternative is natural low calorie, or zero-calorie sweetener like stevia (steviol) that comes from plants and like all other herbal substances are biodegradable. Some Medical Professionals, and others claim that it is not necessarily better with natural sweeteners compared to artificial, but obviously synthetic sweeteners are an environmental poison (Soil, Water, Animals and Human Metabolism), non-biodegradable and that their long-term consequences are unknown.

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