EFFECTS OF ENVIRONMENTAL FLUORIDE ON PLANTS, ANIMALS AND HUMANS

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"When fluoride exists in these natural elements [soil, water and air], every living organism is affected" (Miller, 2000). Fluorine, derived from the Latin word, "fluere," meaning "to flow," is a naturally occurring and abundant element in the halogen family. As a highly reactive and the most electronegative element on the periodic table, it is commonly found in its ionized form, fluoride (F^-) or reacted with another element. Fluoride has no biochemical function and is extremely toxic at large concentrations in plants, animals, humans and our environment. Despite this toxicity, close to two-thirds of the United States population drinks fluoridated water supplied by the municipality (CDC, 2008).

Effects on environment

It is released into the environment through both natural and anthropogenic sources. Volcanoes, ocean spray and soil dust, are all natural sources of fluorine in our atmosphere. Anthropogenic sources are generally industries that emit both gas and particulate forms of fluoride, which can dissolve in surface waters, forming hydrogen fluoride or hydrofluoric acid, toxic to all living things (CDC: Hydrogen Fluoride, 2013). Airborne fluoride exists in varied concentrations around the world. In the US, generally, airborne fluoride exists at a concentration between 0.04 and 1.2 ppb, whereas developing countries have seen levels as high as 2.14 ppb (Beijing, China). Some of the ranges of fluorine in water are noted below. Variations can be attributed to the rocks from which the water is sourced (Yu et al., 2011).

Natural Waters: 0.02-0.2 ppm
River Water: 0.0-6.5 ppm
Groundwater: 0.1-8.7 ppm
Seawater: 1.4 ppm

As one study that focused on the effect of fluoride on soil acidity found, as the amount of fluoride increased in the soil, so too did the concentration of Al, Fe, and TOC, as well as the pH (Arnesen, 1997). The pH of soil rises with the addition of fluoride as a result of an exchange with OH-, an effect that can increase the bioavailability of the element to plant roots and microorganisms (Arnesen, 1997). Another result of the increased fluoride in soil is that the fluoride can solubilize the organic material in the soil, as well as the Al and Fe, and other heavy metals (Arnesen, 1997). Detection of fluoride in the soil utilizes a fluoride specific ion electrode and a special reference electrode (Arnesen, 1997). Treatment of soils saturated with fluoride often uses lime, alum or gypsum to alleviate the alkalinity (Jacks, 2005). This results in harder water with more Ca and lowers the abundance of fluoride (Jacks, 2005).

Food also naturally contains some fluoride and between that and water, people in different locations consume a widely varied amount of fluoride, anywhere from less than 1.0 mg per day to more than 3.0 mg per day (Yu et al., 2011). A large amount of this consumed fluoride is a result of human activity, namely industrial pollution. This includes phosphate fertilizer production, aluminum and steel production and coal combustion (Yu et al., 2011).

Effect of Fluoride on Plants

Fluorine is unique chemical element which occurs naturally, but is not an essential nutrient for plants (Mackowiak, et al., 2003). The natural concentration of fluoride in dry mass of plant tissue, which had been growing on fluoride free soil, rarely exceeds 30 mg/kg (Kabata-Pendias, 2001).

There are two major ways that plants are exposed to fluoride. The first route of exposure is through the stomata, which is responsible for the transition of air into the plant cells. The fluoride moves in the transpiration stream to the tip and edges of the leaves where it accumulates and can cause physiological, biochemical and structural changes and sometimes cell death (Domingos, et al., 2003). The second route of exposure to fluoride is through uptake through the plant's roots if soil is contaminated. Fluoride uptake by plants is dependent on several parameters such as soil pH, plant species, fluoride activity and its composition (Mackowiak, et al., 2003)

A wide variety of pesticides also contain fluorine as a main chemical compounds. Thus, these pesticides are one of the largest sources of fluoride in soil contamination. The most common fluoride pesticides used in the USA in 1994-1995 were Sulfuryl fluoride and Fluometuron (EPA, 1997).

Effects on Humans

Despite the fact that fluoride is a byproduct from phosphate fertilizer manufacture (Campbell, 2013), it is commonly added to treat drinking water in the United States and a few other countries to promote dental health, such as to reduce tooth decay - one of the most prevalent chronic diseases worldwide (EPA, 2013). For this reason, fluoride is used in toothpaste at higher concentrations than would be found naturally, but causes adverse health effects and can be toxic when ingested (WHO, 2013). Effects of fluoride on human health depend on dosage and exposure to excessive amount of fluoride over a lifetime. Commonly known acute health effects include death related to binding of fluorine with serum calcium and magnesium, vomiting, nausea, chronic convulsion, necrosis of the mucosa of the digestive tract and heart failure (Yu, Tsunoda, & Tsunoda, 2011). Chronic effects include increased likelihood of bone fractures, bone pain and tenderness in adults, increased chance of developing pits in tooth enamel for children 8 years or younger and dental fluorosis (Yu, Tsunoda, & Tsunoda, 2011). Various scientific studies demonstrate both positive and negative impacts of fluoride on human health. Positive impacts of fluoride will be discussed first, followed by negative impacts of fluoride.

According to American Dietetic Association report, fluoride is considered a beneficial nutrient and an important element for body tissues mineralization (ADA, 2000). ADA concludes report noting that when fluoride is introduced in optimal amounts, it supports dental health benefits to all age groups (ADA, 2000). It plays an important role in tooth mineralization, increased bone density; promotes enamel remineralization and current research focuses on the possible role of fluoride in osteoporosis prevention (ADA, 2000). Fluoride makes a tooth a stronger and more resistant to acid attack from bacteria by binding with tooth enamel which is made up of hydroxylapatite, a crystal composed of calcium, hydrogen, oxygen and phosphate, and replaces the hydroxyl molecule in hydroxylapatite (Campbell, 2013). A recent study conducted by American Dental Association supports the important role of fluoride on its ability to reduce dental cavities by showing that minorities, immigrants, children with disabilities, homeless people, and those of lower socioeconomic status suffer from a higher number of dental caries (Zero, Fontana, & Martinez-Mier, 2009). It is therefore an important current public health issue (Campbell, 2013).

Despite a of number of studies showing positive effects of fluoride on humans, a plethora of studies and reports also provide support of fluoride having adverse health effects on humans. In contrast to the studies that show the correlation between fluoridated water and decreases in tooth decay, data from the World Health Organization demonstrates that tooth decay rates in many countries that do not fluoridate their water supply are currently lower than those of the United States (Campbell, 2013). Other studies suggest a negative correlation between fluoride and endocrine system, neurotoxicity, teeth, bone and kidney health.

One of many effects from overexposure to fluoride is dental fluorosis. Dental fluorosis is a condition where abnormal white streaks on teeth occur. According to a 2010 report by the Centers for Disease Control and Prevention (CDC), 41% of children the 12-15 year age bracket had dental fluorosis (Beltran-Aguilar, Barker, & Dye, 2010) while a recent study, which examined fluoride exposure in more than 600 children in Iowa, found no significant link between fluoride exposure and tooth decay (Warren, et al., 2009). Similarly, skeletal fluorosis, a symptom that causes bones to lose hardness and become tender and porous, is also one of the most common effects of excess exposure to fluoride (Yu, Tsunoda, & Tsunoda, 2011).

There are a great number of studies that demonstrate negative impacts of ingested fluoride on human health. The National Research Council’s 2006 report stated that it is clear that “fluoride ha[s the] ability to interfere with the functions of the brain (Doull, Poole, & Webster, 2006).” Even the Environmental Protection Agency (EPA) considers fluoride a “chemical with substantial evidence of developmental neurotoxicity (Mundy, Padilla, & Shafer, 2009).” According to the report of New Zealand Medical Association, 2013 study by Choi *et al* suggests that exposure to fluoride decreases the IQ of children (NZMA, 2013). Yet another study conducted by Klein, *et al* draws similar conclusions, stating that fluoride was used as a thyroid suppressant in the early 1960s and while knowing that fluoride can affect the thyroid, the study shows that pregnant mothers with subclinical hypothyroidism have children with lower IQs (Klein, et al., 2001). Choi, *et al* has generated a systematic review and meta-analysis of published studies on effects of increased fluoride exposure in drinking water associated with neurodevelopmental delays

(Choi, *et al*., 2012). Their study results show that children in high-fluoride areas had significantly lower IQ scores than those who lived in low-fluoride areas, and thus supports the possibility of an adverse effect when children are exposed to high fluoride quantities on their neurodevelopment. Further studies need to be conducted on detailed individual-level information on prenatal exposure, neurobehavioral performance, and covariates for adjustment (Choi, *et al*., 2012).

The EPA regulated a non-enforceable Maximum Contaminant Level Goal (MCLG) of 4.0 mg/L or 4.0 ppm at Maximum Contaminant Level (MCL) to protect against skeletal fluorosis and reference dose of 0.08 mg F/Kg/day (EPA, 2013). MCL currently equals to MCLG of 4.0 mg/L because "analytical methods and treatment technology do not pose any limitation (EPA-Fluoride Questions and Answers, 2011)," although the concentration of fluoride in water in the United States averages approximately 1.0 ppm (Campbell, 2013). The great controversial debate on whether fluoride ingestion is harmful or safe for the entire population is ongoing and further studies are being conducted.

Effects on animals

Increasing fluoride levels in water, food, and air not only threaten human health but also animal health. Known acute effects on animals include gastroenteritis, muscular weakness, pulmonary congestion, nausea, vomiting, diarrhea, respiratory and cardiac failure and eventually death. Chronic effects include dental and skeletal fluorosis (Yu, Tsunoda, & Tsunoda, 2011). Acute and chronic effects in animals appear to be fairly similar to the symptoms that occur in humans, suggesting a close relationship between toxic effects on animal and human health. Scientific studies performed on animals suggest fluoride has toxic effects in the reproductive system, thyroid hormones, learning and memory abilities, growth, blood and feed efficiency. Effects on reproduction will be discussed first followed by thyroid hormonal effects.

Alonso and Camargo, who studied short-term and long-term fluoride toxicity to aquatic snail, *Potamopyrgus antipodarum*, found that "the number of embryos with shell was reduced by the highest concentration," and behavioral activity was affected by high concentration of fluoride (Alonso & Camargo, 2011). This study concluded that fluoride is toxic. Both short- and long-term exposures can cause mortality; with adverse effects on reproduction and behavior (Alonso & Camargo, 2011). Gupta *et al* concluded that a high fluoride concentration in drinking water is associated with decreased birth rates (Gupta *et al*, 2007). Their study suggests sodium fluoride in drinking water of 2, 4, and 6 ppm concentration for 6 months to male rats associated with testicular disorders and adversely affected their fertility and reproductive system (Gupta *et al*, 2007).

Basha *et al* observed significant decreases in the serum-free thyroxin, free triiodothyronine levels, acetylcholine esterase activity in fluoride treated group (Basha, Rai, & Begum, 2011). The study suggests that change in levels of thyroid hormones might be due to inhibition of iodine absorption through fluoride interaction. The study concludes that fluoride exposure causes cumulative multigenerational effects resulting in decreased thyroid hormone which correlated to learning and memory impairments (Basha, Rai, & Begum, 2011). Studies on toxicity of fluoride on animals suggest that "biological responses of animals to fluoride are related to dosage and other factors that influence the animal's physiological and anatomical responses (Madan, Puri, & Singh, 2009)."

Conclusion

In conclusion, fluoride is a ubiquitous element, from natural and anthropogenic sources and is present in all areas on the environment. Human activity certainly has increased the availability of fluoride to plants, animals and humans which in turn has shown some positive and many negative effects for all species. Unfortunately, there has not been much research that demonstrates positive effects of fluoride on plants; the high fluoride content in the soil or air results in foliage damage (albeit at different rates for different species). While fluoride does exhibit some favorable properties for human tooth health, particularly in cavity prevention, this is mainly topical and can cause serious health effects when ingested. Similar effects are experienced by animals. With such negative physiological responses to fluorine it is curious that the US continues to chlorinate public drinking water. While it is important to recognize the topical benefits fluoride offers, it is also just as important to recognize the negative effects the element has and question the industrial emissions and addition of fluoride in municipal drinking water.

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РОЗВИТОК ЕКОЛОГІЧНО БЕЗПЕЧНОГО ВИРОБНИЦТВА В УКРАЇНІ

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Із постійним розвитком виробництва екологічна ситуація в світі з кожним роком становиться все гірше, це спричинило виникнення нового системного підходу – екологізації економіки. Реалізація принципів екологізації економіки на практиці обумовлена високим рівнем технічного виробництва та прагненням пізнати природні процеси. Якщо в майбутньому тип економіки не зміниться, то буде дуже важко уникнути погіршення навколишнього середовища. Необхідно не тільки розуміння всієї небезпеки забруднення і виснаження природного середовища, але й прийняття системи заходів про об'єднання природного середовища та економіки.

Екологізація економіки – це необхідний процес, головна складова частина екологічно збалансованого розвитку. Головна мета екологізації економіки – це зменшення природоємності всього людського господарства, економіки, техносфери.

Про процес екологізації вперше згадали у світовому масштабі на Конференції ООН в Стокгольмі в 1972 р., а потім на Конференції РІО -92, яка відбулася в столиці Бразилії.

Згідно до Кіотського протоколу про зміну клімату Україна, яка підписала і ратифікувала його в 2004 р., може застосовувати механізми, їм передбачені. Зокрема, Кіотським протоколом регламентовано використання Проектів