Removal of Per/Polyfluoroalkyl substances (PFAS) From Landfill Leachate and other Wastewater Streams

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Abstract:

Per- and Polyfluoroalkyl substances (PFAS) are a group of durable and stable chemicals, which have been used in non-stick cookware, fire retardant materials and stain resistant carpets and have found their ways to Nation's drinking water stream through landfill leachate. Clark Technology's LeachBuster® system was used to remove these contaminants from leachate streams over the past six years. This article is a summary of the results of this study. Concentration of these substances ranged from around 0.5 nanograms/Liter (ng/L) to around 500 ng/L. The system removes all of these compounds from the leachate to under 2 ng/L, which is well below the required discharge limits for most regulatory bodies.

Introduction:

Per- and Polyfluoroalkyl substances (PFAS) are a large group of durable and stable chemicals, which have been used for several decades by the manufacturing industry, in products such as: non-stick cookware, stain- and water-resistant fabrics and carpeting, cleaning products, paints, fire-fighting foams and other fire retardant materials and products, and food packaging/processing materials. When released into the environment, PFAS bio-accumulate and are bio-persistent, which heightens the risk of human exposure through ingestion of food and drinking water. Scientific medical studies have confirmed links to kidney and testicular cancer, ulcerative colitis, thyroid disease, decreased fertility, and high cholesterol triggering associated health impacts. These studies have been confirmed and studied further by the WHO, EPA, FDA, and many others, publishing their own disturbing findings regarding PFAS exposure to humans. According to a 2012 study conducted by the CDC's National Health and Nutrition Examination Survey (NHANES), PFAS was found in the bloodstream of 97% of Americans. Furthermore, the elimination half-life (the length of time it takes for a substance to decrease to half of its original value) for PFAS in humans varies from 2 to 8 years after exposure to a contaminated drinking water source has stopped.

Given PFAS wide-ranging usage in consumer products and their long-term environmental persistence, landfill leachate represents a logical end-of-life source for the accumulation of PFAS. However, when leachate is transported to a municipal wastewater treatment plant, typically those facilities are not capable of removing or treating the PFAS contaminants. Rather, they simply are diluted and returned to the environment.

These same PFAS, over time, have found their way into the Nation's drinking water supplies via industrial discharge and more particularly landfill leachate. Landfill leachate is one of the difficult-to-treat sources of PFAS, which contribute annually to elevated levels of these contaminants in surface water and groundwater sources. Landfill leachate is one of the most contributing nodes in the aqueous conduit of PFAS from manufacturer to human and animal blood streams, as well as other fauna and flora. Interrupting this conduit and removing these substances from the aqueous environment is a national and global health and safety challenge across industries and by regulatory bodies.

According to research published by and through the North Carolina Per and Polyfluoroalkyl Substances Testing (PFAST) Network, comprising of Principals from NC State, Duke, UNC-Chapel Hill, UNC-Wilmington, UNC-Charlotte, ECU, and NC A&T, some organics in leachate (approximately 5%) are partially treated in wastewater treatment plants. The remaining organic and inorganic compounds in the leachate are parsed into three streams namely, discharged with the treated effluent (approx. 60%), dispersed into the air often by aeration (approx. 15%), and removed into the sludge which is typically land applied (approx. 20%).

All of these contaminants and other CECs finally find their way into the Nation's surface and groundwater bodies -- defeating the purpose of collecting and treating them in the first place, which are then consumed by humans and animals through drinking water sources. There are some technologies (i.e. activated carbon, ion exchange), which can successfully remove PFAS from waste streams where there are no or little co-contaminants, such as suspended or dissolved solids, volatile and semi-volatile organic compounds, metals, and semi-metals.

That being said, the LeachBuster® system is the only technology that has been removing PFAS and other CECs, such as pharmaceuticals and personal care products, from waste streams with extremely high levels of co-contaminants, such as leachate, over the past five to seven years.

The System:

Figures 1. Typical *LEACHBUSTER*® Wastewater Treatment Plant.

In search of a means to reduce PFAS related impacts and to safeguard the Nation's ground and surface waters from being polluted by these contaminants, Clark Technology, LLC (Clark) innovated the ***LEACHBUSTER*®** Wastewater Treatment System which removes PFAS contaminants from waste streams, such as landfill leachate, thus preventing them from polluting drinking water supply sources.

Clark designed and installed numerous ***LEACHBUSTER*®** systems in the U.S. and around the world. The various systems have been in operation from 5-10 years removing these same compounds and other contaminants of emerging concern (CECs). The wastewater treatment plants vary in size from processing 10,000 to 100,00 GPD.

LeachBuster® is an innovative single pass graduated membrane filtration system which can treat almost any type of wastewater (organic or inorganic) and produce effluent with up to fourteen different purity levels, ranging from Ultrafiltration (UF) to Ultra-Pure (UP) (which is used in hospitals and the semi-conductor industry) and every level in between including, but not limited to, nano-filtration and reverse osmosis (RO). All of this is achieved without staging or backwashing. The *LeachBuster®* is a totally enclosed, compact and fully automatic system reducing the odor and noise nuisance, space requirement, and constant and multi-operator assistance. This system is equally applicable to municipal, industrial, and commercial wastewater streams, as well as producing potable water for human consumption.

Figures 2. The *LEACHBUSTER®* System landfill leachate treatment plant samples: black leachate to clean water in 3 ½ minutes.

Results:

Clark has numerous years' worth of independent third-party laboratory test data, which can be provided upon request. The following are sample sets of test data for a PFAS group. At this particular landfill, out of 24 species tested for in the leachate, approximately 15 species were present in one sample and 10 species were detected in the second sample. All PFAS species were removed by the treatment system. A landfill's temporal and geographical location directly contributes to the different PFAS species detected in raw landfill leachate streams. Two separate sets of leachate samples are presented in Table 1 below from two separate landfill sites to indicate the *LeachBuster®* wastewater treatment system's ability to remove PFAS from different leachate streams.

Table 1. Concentration levels of various PFAS compounds in the influent and effluent leachate streams and the removal percentages achieved by the system for two sets of test samples from two different landfills.

Fluorinated Alkyl Substances (ng/L) in Each Set of Samples

Parameter	Influent #1	Influent #2	LeachBuster® Effluent #1	LeachBuster® Effluent #2	% Removal in #1	% Removal in #2
PFHpA*	250	350	0.32	0.54	99.9%	99.8%
PFOA	350	540	ND	0.69	99.9%	99.9%
PFHxS	110	220	0.41	0.38	99.6%	99.8%
PFBA	440	770	0.95	2.5	99.8%	99.7%
PFPeA	500	680	0.86	0.92	99.8%	99.9%
PFHxA	740	1200	1.3	1.5	99.8%	99.9%
PFNA	23	18	ND	ND	99.9%	99.9%
PFDA	4.4	ND	ND	ND	99.9%	---
PFDoA	0.67	ND	ND	ND	99.9%	---
PFBS	48	51	0.17	ND	99.6%	99.9%
PFHpS	1.5	ND	ND	ND	99.9%	---
PFOS	47	16	ND	ND	99.9%	99.9%
6:2 FTS	680	160	ND	ND	99.9%	99.9%
FOSA	0.57	ND	ND	ND	99.9%	---

****Acronyms are defined below:***

PFBS*: Perfluorobutanesulfonic acid, **PFBA: Perfluorobutanoic acid, **PFDA**: Perfluorodecanoic acid, **PFDoA**: Perfluorododecanoic acid, **PFHpS:** Perfluoroheptanesulfonic acid, **PFHpA:** Perfluoroheptanoic acid, **PFHxS:** Perfluorohexanesulfonic acid, **PFHxA:** Perfluorohexanoic acid, **PFNA**: Perfluorononanoic acid, **FOSA:** Perfluorooctanesulfonamide, **PFOS:** Perfluorooctanesulfonic acid, **PFOA:** Perfluorooctanoic acid, **PFPeA:** Perfluoropentanoic acid.*

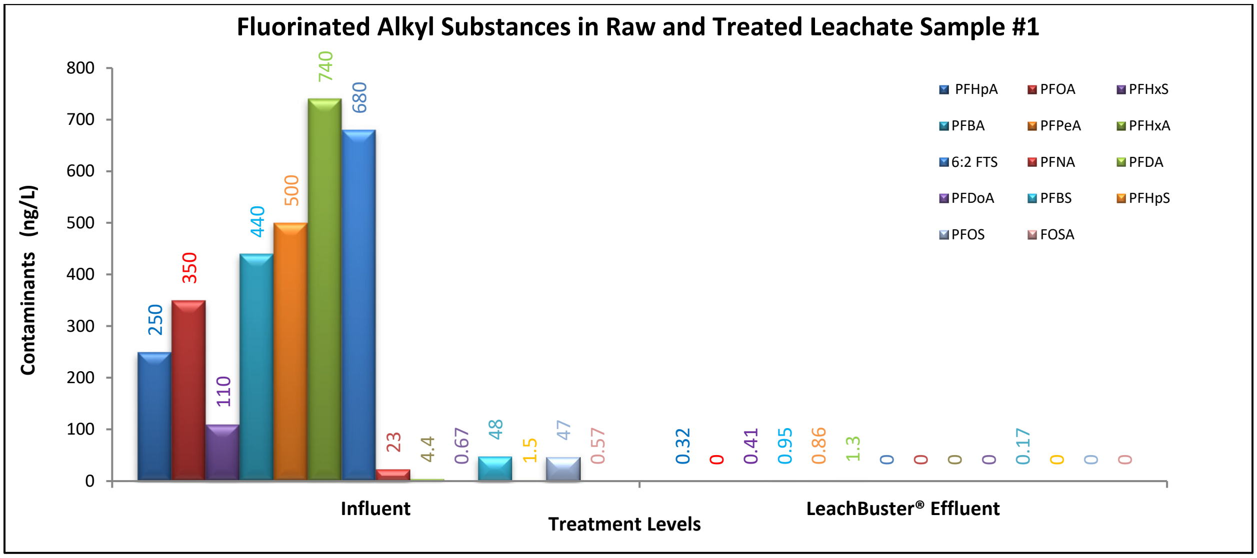

Figure 3. Concentration levels of various PFAS compound in the influent and effluent leachate stream together the removal percentage achieved by the system for the first set of samples.

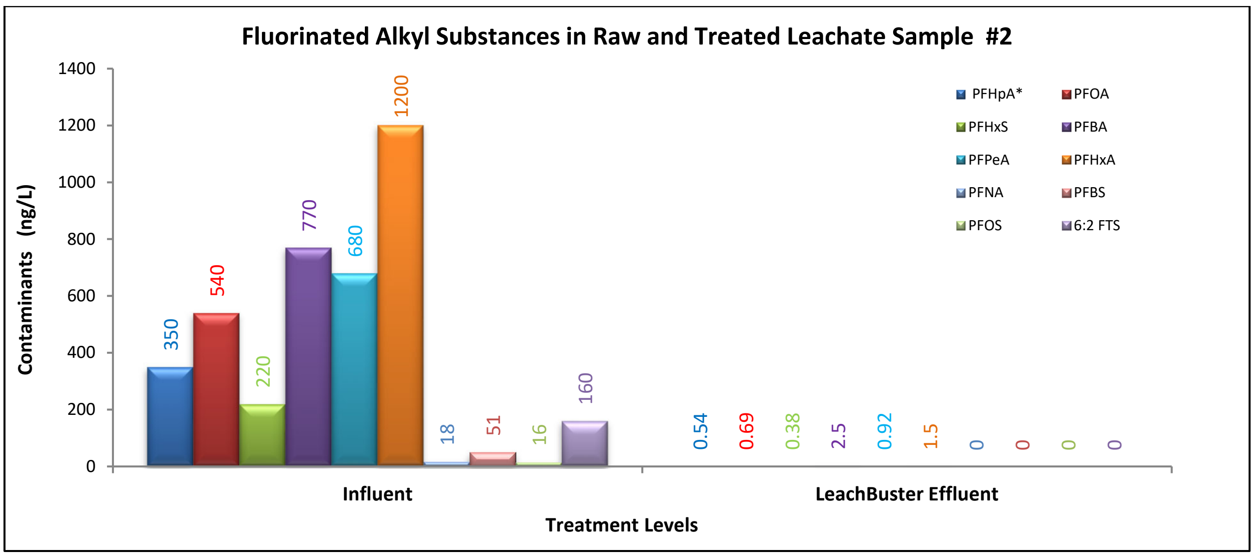

Figure 4. Concentration levels of various PFAS compound in the influent and effluent leachate stream together the removal percentage achieved by the system for the Second set of samples.

As it can be seen in both leachate sample sets and at many other locations, regardless of the initial values of PFAS in the raw leachate, the treated leachate levels were all below two (2) *parts per trillion* (PPT) or *nanograms per liter* (ng/L), which is much less than the most stringent maximum contaminant level (MCL) and/or health risk limits (HRLs) set by any regulators in the United States.

About Clark Technology

Clark Technology, LLC has created a Sustainable Economic Engine which consists of, but not limited to, solid waste (organic) conversion to renewable energy, fertilizer, and clean water; plastics and oil-based waste conversion to fuel oil or diesel of similar fuels and finally, liquid waste into high quality reusable clean water. At the heart of this engine exists the LeachBuster® liquid waste treatment system, a Fourth Generation Anaerobic Digester, and a High Efficiency Pyrolizer.

About the Inventor

Dr. Kazem Eradat Oskoui is a world renowned scientist with over 40 years of experience in innovating and implementing different technologies in various fields of environmental engineering, consulting and science to address some of the most challenging environmental remediation issues. Dr. Oskoui continues to work and collaborate with teams of scientists, engineers, and experts from around the country and the world. His recent innovation and development of the LeachBuster® system, which has addressed among other issues, the problem of PFAS and boron removal in highly contaminated wastewater streams, such as landfill leachate and other wastewaters, is only one of his notable achievements.