

Biogas -An Environmentally Exciting Concept - Boggled Down by Trace Components

Biogas is produced by anaerobic degradation of organic compounds and could be the substitute for natural gas and fossil fuels. It contains mostly three components, which are methane (CH_4), carbon dioxide (CO_2) and nitrogen (N_2). However, other trace species exist as well, which are hydrogen sulfide (H_2S), hydrogen (H_2), nitrogen (N_3), ammonia (NH_3), oxygen (O_2) and carbon monoxide (CO). Furthermore, typical biogas is saturated with water, dust particles, siloxanes, aromatic and halogenated compounds^{1,2}.

The composition of biogas varies depending upon the substrate composition, as well as the conditions within the anaerobic reactor (temperature, pH, and substrate concentration).³ Landfill gas typically has methane concentrations around 50%. Advanced waste treatment technologies can produce biogas with 55%–75% methane,³ which for reactors with free liquids can be increased to 80%–90% methane using in-situ gas purification techniques.⁴ As produced, biogas contains water vapor. The fractional volume of water vapor is a function of biogas temperature; correction of measured gas volume for water vapor content and thermal expansion is easily done via simple mathematics⁵ which yields the standardized volume of dry biogas⁶.

In many cases, biogas contains siloxanes. They are formed from the anaerobic decomposition of materials commonly found in cosmetics, soaps and detergents. During combustion of biogas containing siloxanes, silicon is released and can combine with free oxygen or other elements in the combustion gas. Deposits are formed containing mostly silica (SiO_2) or silicates (Si_xO_y) and can contain calcium, sulfur, zinc, phosphorus. Such white mineral deposits accumulate to a surface thickness of several millimeters and must be removed by chemical or mechanical means.

Recently, a lot of attention has been focused on volatile organic silicon compounds (VOSiC) present in biogases. They induce costly problems due to silicate formation during biogas combustion. The cost of converting landfill gas and digester gas into electricity is adversely affected by this undesirable presence. VOSiC in biogases spark off-formation of silicate deposits in combustion chambers. They engender abrasion of the inner surfaces leading to serious damage, which causes frequent service interruptions, thus reducing the economic benefit of biogases. It is already known that these VOSiC originate from polydimethylsiloxanes

(PDMS) hydrolysis. PDMS (silicones) are used in a wide range of cosmetic, consumer and industrial applications. PDMS are released into the environment through landfills and wastewater treatment plants. There is a lack of knowledge concerning PDMS biodegradation during waste storage. Consequently, understanding PDMS behavior in landfill cells and in sludge digester is particularly important.

Cyclic volatile methyl siloxanes (cVMSs) are important components in personal care products that transport and react in the atmosphere. Octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), dodecamethylcyclohexasiloxane (D6), and their gas-phase oxidation products have been incorporated into the Community Multiscale Air Quality (CMAQ) model. Gas-phase oxidation products, as the precursor to secondary organic aerosol from this compound class, were included to quantify the maximum potential for aerosol formation from gas-phase reactions with OH. Four 1-month periods were modeled to quantify typical concentrations, seasonal variability, spatial patterns, and vertical profiles. Typical model concentrations showed parent compounds were highly dependent on population density as cities had monthly averaged peak D5 concentrations up to 432 ngm⁻³. Peak oxidized D5 concentrations were significantly less, up to 9 ngm⁻³, and were located downwind of major urban areas. Model results were compared to available measurements and previous simulation results. Seasonal variation was analyzed and differences in seasonal influences were observed between urban and rural locations. Parent compound concentrations in urban and peri-urban locations were sensitive to transport factors, while parent compounds in rural areas and oxidized product concentrations were influenced by large-scale seasonal variability in OH⁷.

References

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