about Plasmas
from the Coalition for Plasma Science

Cleaning the Environment

"Water and air, the two essential fluids on which all life depends, have become global garbage cans." – Jacques Cousteau

To Cousteau's list of global garbage cans we can add the earth beneath our feet. Soil, air and water have all suffered from the effects of industrial waste and pollution, making the quality of our environment a vital issue for our time. To help with problems of greenhouse gases, like carbon from factories and automobiles, and with concerns about "global warming," researchers are developing new ways of aiding the environment by using plasmas.

Plasmas are fundamentally different from other states of matter. While solids, liquids and gases have no electrical charge, plasmas contain lots of freely moving ions (positively charged particles) and electrons (negatively charged particles). This difference makes plasmas able to transform pollution into environmentally safer materials. The transformation can occur through heating or through interactions involving particles that are not available in regular gases.

Plasma can be used to clean and monitor smoke stack emissions.

To process pollutants efficiently, plasmas generally operate at about atmospheric pressure. This is a relatively high pressure for plasmas, much higher than is used in plasma applications like fusion energy and computer chip manufacturing, which operate at low pressure – near vacuum conditions. Imagine trying to bottle a bolt of lightning – a naturally occurring plasma at atmospheric pressure – and you can get some idea of how difficult it is to control and use man-made atmospheric-pressure plasmas.

Mastering this difficulty can help lead to a cleaner environment. When operated in what is called 'thermal mode,' all the particles in the plasma (electrons, ions and neutral particles) get uniformly hot. In plasmas the temperature of the charged and neutral particles can become much higher than is possible with incineration, so they can destroy waste more thoroughly. Furthermore, creating a high temperature thermal plasma requires little gas flow because no air or oxygen is required, while an incinerator requires large amounts of air to burn wastes. Consequently plasma furnaces could be used instead of incinerators to process municipal waste more thoroughly and with less combustion exhaust.

Plasmas also reduce the need for expensive gas filters (commonly called "scrubbers") designed to decrease the amount of pollutants released into the atmosphere. In addition, the plasma process eliminates ash, which in present municipal incinerators is considered hazardous enough to bar from interstate transport. Instead of ash, high-temperature plasmas in arc furnaces can convert materials into a glassy substance, separating out the molten metal, which can then be recycled. The stable glassy material can be used in landfills with essentially no environmental impact, since it cannot leach into the soil. Plasma furnaces are being used in Honolulu and Japan to treat hospital and municipal wastes. When environmental laws require scrubbers to be used on smoke stacks, plasma processing of waste could become the least expensive alternative.

There are also nonthermal atmospheric pressure plasmas, those in which only the electrons get hot. These plasmas are effective against other kinds of pollution. Since energy is not required to heat all the particles to a high temperature, nonthermal plasmas can selectively and efficiently destroy pollutants targeted by the hot electrons and by unique chemical species that the hot electrons create. Nonthermal plasmas can destroy pollutants such as volatile organic compounds (VOC) from cleaning fluid or manufacturing solvent vapors, as well as nitrogen oxides in automobile exhaust.

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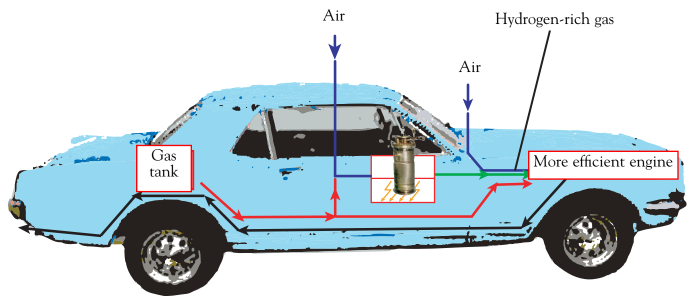
Plasmas (both thermal and nonthermal) can be used to monitor environmental pollution with high sensitivity in air and smoke stacks. A plasma generated in a smoke stack excites trace elements in the smoke to make those elements emit light. Using a spectrometer, an operator can identify the elements and determine quantities of the pollutants. Such pollution monitors have demonstrated sensitivity of better than one part per billion for lead, chromium, beryllium, mercury, and other pollutants, allowing better control of hazardous air pollution. The Environmental Protection Agency (EPA) and Department of Energy have been testing prototype plasma-aided emissions monitors for this application.

Plasmas can also be used in vehicles to reduce pollution from conventional fossil fuel combustion by "reforming" the fuel before it is burned, breaking it down into compounds that burn more cleanly. Research is being done on a "plasmatron," a miniature high-voltage thermal plasma that helps separate the hydrogen atoms from complex organic molecules. This device can be used to reform hydrocarbon fuels, such as gasoline, into cleaner burning hydrogen or syngas (a mixture of hydrogen and carbon monoxide).



A small plasma device under the hood can make a car run more cleanly and efficiently.

Superfund sites, the major soil contamination projects identified by the EPA, also benefit from plasma processing. High temperature plasmas can process solid wastes and chemical spills in soil, destroying toxic compounds or converting them to safer forms. At the Hanford site in Washington, which the Department of Energy describes as "the world's largest environmental cleanup project," a plasma was used to target and destroy carbon tetrachloride pumped from the soil.

A community outreach worker in Mexico installs a UV tube developed by University of California, Berkeley researchers to purify water for individual households.

Some low-pressure plasmas can emit large amounts of ultraviolet (UV) radiation, X-ray radiation or electron beams through windows into the atmosphere. These plasmas can be used for a variety of environmental needs. For example, intense UV radiation can disable the DNA of a microorganism in water, making it impossible for that microorganism to replicate. This plasma-based UV method takes only 12 seconds, has no effect on the taste or smell of the water, and is effective against all known water-born bacteria and viruses. It has been used in Bangladesh, where Waterhealth International and the U.S. Department of Energy have demonstrated that surface water (in ponds and shallow hand-pumped wells) could be used for drinking once it was decontaminated with UV radiation, eliminating microorganisms carrying water-born diseases such as cholera. Intense UV water purification systems are especially important for developing countries since they can be easy to use and have low maintenance, high production and low cost. Plasma-based UV water treatment systems use several thousand times less energy than boiling water!

Developing and implementing plasma technologies could help restore and protect our environment, providing new cleaning methods, preventing or reducing pollution, and helping countries comply with environmental regulations. They may provide the only solutions to many of our environmental challenges. Once fully developed, these technologies could make today's "global garbage cans" a thing of the past.

Suggested reading:
"Plasma Science and the Environment," editors Wallace Manheimer, Linda E. Sugiyama, and Thomas H. Stix, American Institute of Physics, Woodbury, NY, 1997.
"Thermal Plasmas," Pierre Fauchais and Armelle Vardelle, IEEE Transactions on Plasma Science, Vol. 25, No. 6, 1258-1280, 1997.

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