Power Generation, Energy Management & Environmental Sourcebook

Proceedings of the 14th World Energy Engineering Congress

1991 World Environmental Engineering Congress

October 23-25, 1991

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Chapter 14

Plasma Pyrolysis of Medical Waste

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Abstract

The problem of waste disposal continues to plague the health care industry in the United States. Canyons have been transformed into mountains of waste. Across the country, disposal sites are closing without available replacement sites. Disposal costs continue to rise. Incinerators cannot operate because they release toxic air contaminants (TAC's) from the combustion process into the environment.

Plasma pyrolysis, an electrotechnology at work, is an environmentally benign answer to the waste disposal dilemma. A new application of a proven technology (the plasma torch) reaches instantaneous arc temperatures of 21,000^{O} Fahrenheit. It converts all organics into clean fuel gases and vitrifies inorganic material into an inert glassy slag. All by-products are recyclable. There are a variety of uses for the vitreous glassy slag. It can be used as concrete filler in roadbed construction, in composition roofing and for building insulation. The product gas can be used as a boiler gas or for methanol production.

Environmental pollution is eliminated, as well as the long term liability associated with disposal of medical waste at municipal solid waste sites. Landfills will no longer be considered "dumps", but sources of transportation fuel. Plasma pyrolysis of both medical and municipal solid waste is an innovative, environmentally sound solution to a complex and growing problem.

Introduction

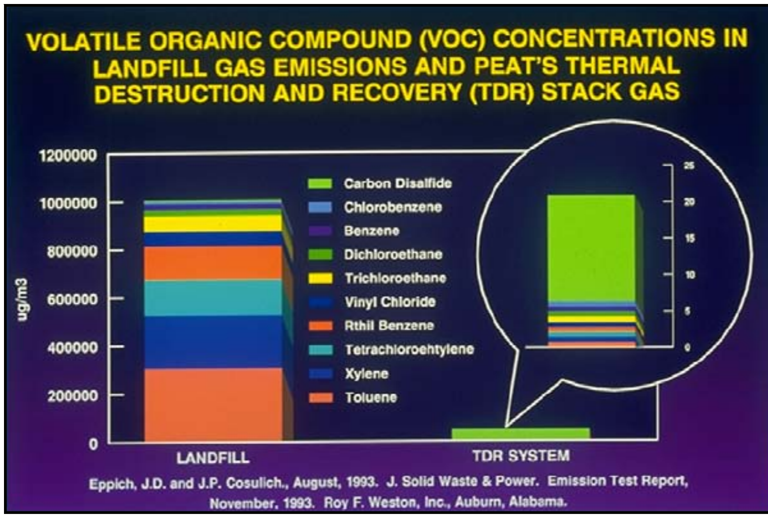
Kaiser Permanente is one of the largest prepaid Health Maintenance Organizations in the country. Kaiser spans twelve regions throughout sixteen states and the District of Columbia. The Southern California Region is one of the largest, with about 200 buildings (including eleven hospitals.) We manage over 16-million square feet of floor space. Forty utilities provide service to our facilities at an annual cost of over $42 million. Transportation services throughout the region are provided by a fleet of 425 vehicles.

Kaiser Permanente's rapid growth in Southern California places an increased demand for additional energy services. There is a direct correlation between energy consumption and environmental pollution. Increased efficient use of energy improves environmental quality. Our heightened environmental awareness coupled with expanding membership growth produces a real dilemma. We must meet the health care needs of our members while making the best possible use of our energy and preserving environmental resources. This includes reducing energy costs while meeting environmental challenges. Ozone formation, brown clouds, acid rain, burgeoning landfills, global warming and the greenhouse effect come to mind when we talk of environmental deterioration.

The Problem

With syringes washing ashore in New York, Florida and California and "red bag" waste showing up at landfills, the problem is further exacerbated by court ordered closures of landfills. According to the Environmental Protection Agency (EPA), half of the estimated 6,600 land-fills in the country are being closed over the next five years. Additionally, even though a hospital or health care facility may not violate any of the Resource Conservation and Recovery Act (RCRA) regulations, it is still held liable under common law for improper handling or disposing of its pathological and biological waste, should any harm be done to any person or property. This cradle-to-grave mentality carries a lifetime liability for all generators of medical waste.

The early 1970's brought into the forefront a new heightened environmental awareness. This has manifested itself in the form of the Clean Air Act, RCRA, Medical Waste Tracking Act (MWTA), California Health and Safety Code, California Administrative Code, Best Available Control Technology (BACT) and a myriad of other environmental laws and legislation.



Comparison of Landfill Emissions vs. Plasma Pyrolysis

Additionally, on-site incineration minimizes the risk associated when contracting for transportation and processing by outside vendors.

Source of heat in an incinerator is the energy of the waste itself, which is not enough energy for proper combustion. Natural gas is added to enhance the combustion process. A proper stoichiometric balance must exist in the incineration process for complete combustion. To meet environmental regulations, incinerators must reduce airborne pollutants and TACs. This generally means the process must run in a "starved air" condition, producing incomplete combustion. Incineration emissions include by-products of benzene, dioxins, furans, nitrogen oxides, sulfur dioxide, mercury and cadmium, all of which must be removed from the gas stream. Most of the by-products are considered TACs. Dioxins are formed as unwanted by-products of incomplete combustion when chlorine and carbon mixtures are present. Manufacturers use cadmium to make red bags red. Cadmium is a heavy metal and TAC. In addition to the emissions from incomplete combustion, considerable amounts of energy are left in the bottom ash.

The RCRA list of medical wastes that need to be tracked include at least seven categories:

1. <u>Cultures and Stocks</u> - cultures from medical and pathological laboratories, live and attenuated vaccines, dishes & devices

2. <u>Pathological Wastes</u> - body parts, tissues, body fluids and containers

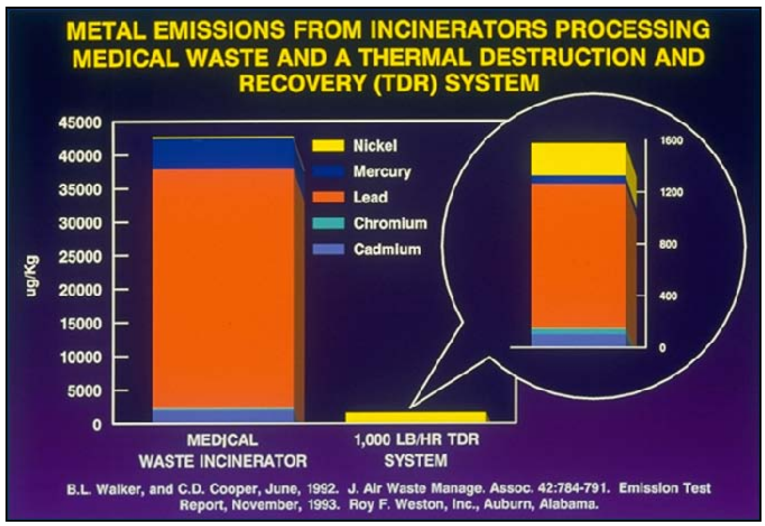
3. <u>Used Sharps</u> - syringes, hypodermic needles, scalpel blades blood vials, test tubes, tubing used in animal or human patient care, research or treatment

4. <u>Animal Waste</u> - carcasses, body parts, bedding, fluids

5. <u>Human Blood and Blood Products</u> - serum, plasma blood components

6. <u>Isolation Waste</u> - material contaminated with blood, excretion

7. <u>Unused Sharps</u> - scalpel blades, syringes, hypodermic needles



Comparison of Emissions—Incineration vs. Plasma Pyrolysis

<u>Perceived Solutions</u>

The preferred medical waste treatment method is <u>on-site</u> where the waste generator can <u>maintain full-control</u> of processing. Onsite incineration is a popular choice when deciding the method of disposal of hospital waste. Incineration reduces weight and volume by 90 percent, assures complete destruction of all pathogens and microorganisms and detoxifies chemical waste. It also reduces the volume that must be landfilled.

During recent years, regulatory agencies such as the EPA, California Air Resources Board (CARB), South Coast Air Quality Management District (SCAQMD) and the San Diego Air Pollution Control District (SDAPCD) have taken an aggressive stand on particulate and emissions discharges. The EPA indicates that 80 percent of the incinerators in the United States will cease to operate due to more stringent regulations.

Typical Example of Medical Waste

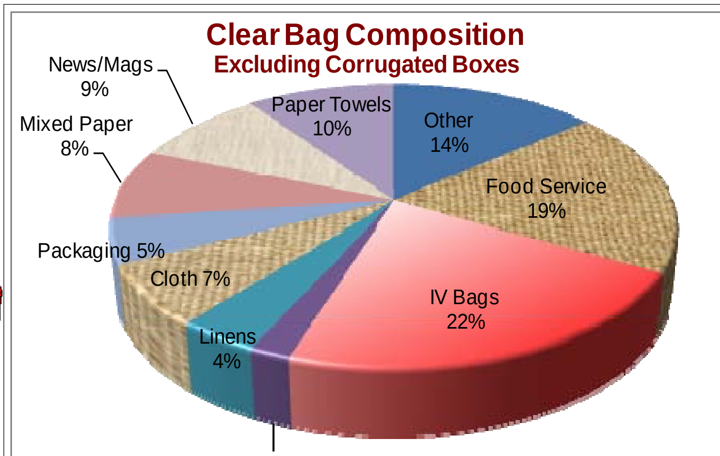


Figure 1

Composition of Medical Waste

The composition of medical waste is similar to the composition of municipal solid waste except that it is classified as infectious and may contain more moisture. In order to quantify the waste stream, Kaiser Permanente commissioned a study to examine the waste stream at our Sunset Medical Center in Hollywood, California. From the study, a Solid Waste Management Plan was prepared by Waste Energy Technologies, Inc. Development of the Plan was based on actual generation of waste rates. Composition was determined through weighing and sorting of all waste. According to the report, the facility generates 8,600 pounds of solid waste per day.

The attached charts developed by Waste Energy Technologies show clear bag composition in Figure 1; red bag composition in Figure 2; and, kitchen waste in Figure 3.

Composition of the waste stream includes a significant concentration of polyvinyl chloride plastic (PVC) and other plastics. In the combustion process PVC breaks down and forms hydrogen chloride (HCL) gas. If this waste stream were incinerated, most plastics would form HCL that would result in hydrochloric acid. This is a highly corrosive by-product.

According to the EPA, ash from the incineration process is considered a hazardous material. Landfilling medical waste, ash residue and other hazardous compounds carries with it a lifetime ability. It is difficult to argue for incineration as an answer to the waste disposal problem due to emission from the combustion process. Emissions produced in the incineration process cannot be economically scrubbed to a level that would eliminate TACs and particulate discharge.

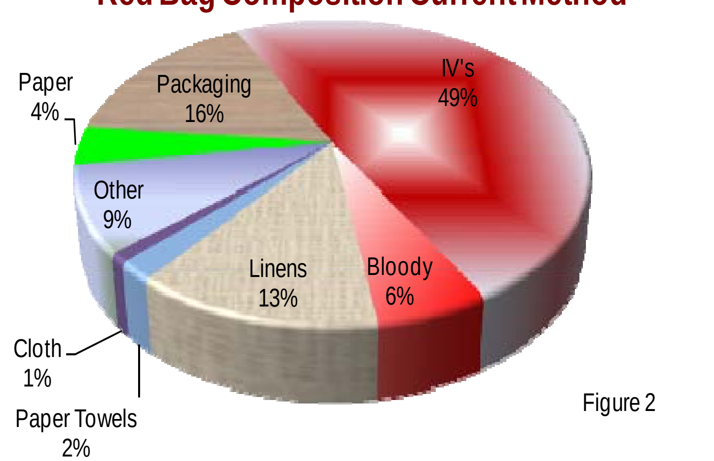


Figure 2

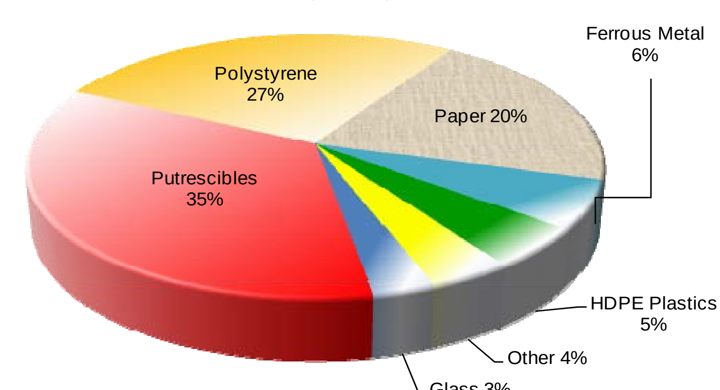


Figure 3

To render the hospital waste stream environmentally benign, any process considered must eliminate all TACs, particulate discharge and provide complete destruction of all pathogens and microorganisms. It also must vitrify all ash residue preventing the possibility of leaching into groundwater supplies.

Plasma Energy

Plasma energy technology was originally used more than 30 years ago in the space program to simulate the torrid temperatures of reentry into the earth's atmosphere. Research laboratories, steel mills, reactive metal industries and metal cutting are among the fields in which plasma energy technology is a proven application. Plasma systems assist in aluminum recovery, heat vacuum furnaces for titanium processing and provide heat in glass and ceramic processing.

Plasma energy is a naturally-occurring source, and it is the most prevalent state of the universe. Lightning - the discharging of static electricity that occurs in thunderstorms - is an example of naturally-occurring plasma energy.

Plasma is often called the fourth state of matter. Plasma energy is actually heat energy produced when electric current flows through a gas. Plasma forms when electrical current ionizes a gas as electricity flows through it, which is, heating by electricity. Resistance of the ionized gas to the flow of electrical current (like any other conductor) creates extremely high temperatures. This is the essence of plasma energy. Gases such as helium argon, nitrogen or air can be ionized to become the conductor. The plasma torch converts electricity into heat energy by resistance heating using a plasma column as the heating element.

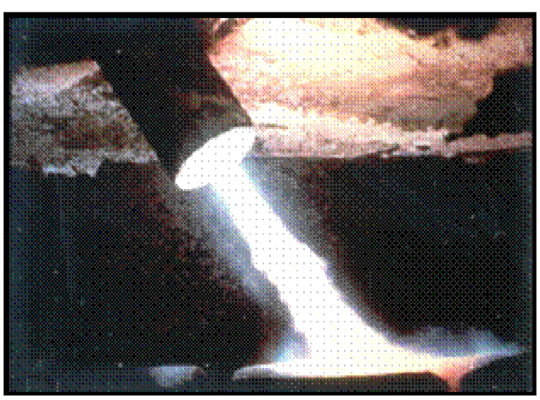
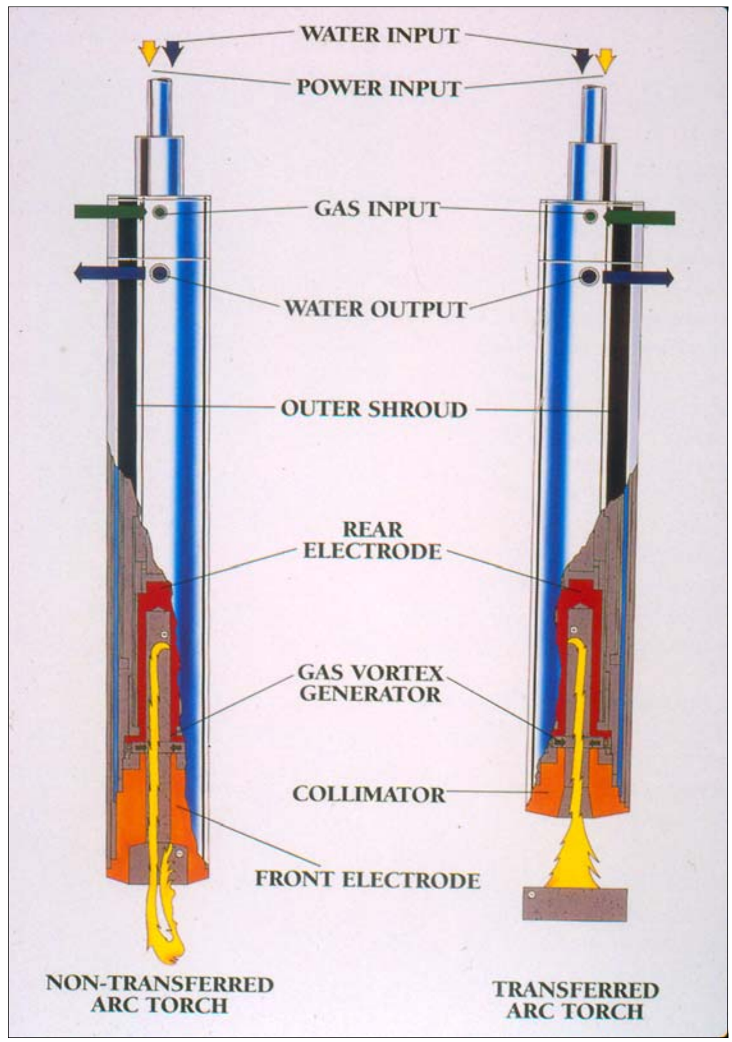


Photo 1 Transferred Plasma-Arc Torch
Courtesy Plasma Energy Corporation

Types of Plasma-Arc Torches

Plasma arc torches are hardware used in a heating process and can be adapted for many applications in industry. There are two types of torches typically produced, transferred arc and non-transferred arc. For purposes of discussion, this project will incorporate the use of a transferred arc torch. The transferred arc torch uses the working material to conduct electricity. The photo shown below is a transferred arc torch. Polarity is in the rear electrode and its negative polarity is the working surface. This results in an intense, direct heat that is ideal for pyrolysis of hospital waste.

The non-transferred arc torch uses two internal electrodes. Injecting a small amount of ionized gas extends the plasma flame beyond the tip of the torch. The non-transferred arc produces a more dispersed heat for annealing and drying processes.



Courtesy of Plasma Energy Corporation

Plasma Pyrolysis - A Technological Solution

The intense heat of plasma energy has the effect of changing solid materials chemically. This process is called pyrolysis. Pyrolysis is the chemical change of material brought about by the action of intense heat in the absence of oxygen. Instantaneous arc temperatures of 21,000^{O} Fahrenheit converts all organic material into basic atoms that recombine into simple gases. The waste is not burned or combusted, but is pyrolyzed at high temperatures. Combustion does not occur and ash does not form in the pyrolysis process. The intense heat developed in plasma causes molecules to separate randomly during pyrolysis. The resulting fragments coalesce to form compounds and gases (Figure 4). The combination of high temperature in the absence of air and a controlled input of steam converts organic and solid materials into a vitreous substance and a hydrogen-rich, clean gas. Plasma pyrolysis electrically converts organic and inorganic material into a glassy residue and clean fuel.

Pyrolysis is a clean and effective method for rendering hospital and municipal solid waste environmentally benign. In essence, the plasma pyrolysis process recycles waste in an environmentally sound and safe manner. It protects and enhances our environment.

Demonstration Project

The health care industry is beginning to apply plasma energy technology to dispose of medical waste in an efficient and safe manner. A plasma demonstration project is permitted at the Kaiser Permanente Medical Center, 4647 Zion Avenue, San Diego, California. This 328 bed medical facility is the first in the United States to obtain a permit to build a plasma system to pyrolyze medical waste.

In this history making project, hospital waste will be pyrolyzed with a plasma arc torch. The 500KW plasma arc torch, engineered by Mason & Hanger National, Inc., is designed to process waste at 1,000 pounds per hour. Because it is not a combustion process, the volume of gases produced is one-sixth to one-tenth the volume of gases produced by an incinerator. Plasma energy captures the energy contained in the waste that would otherwise be lost in landfills. The composition of the gas produced in the pyrolysis process is listed below in Figure 5.

The plasma pyrolysis process has many advantages over conventional incineration of hospital waste. Plasma-arc torches produce the lowest-mass sustainable heating source available. The temperatures achieved in the plasma process are the highest controlled sustainable temperatures known. Fuel gas produced in the process may be used as feedstock in boilers to make steam or in other processes.

Some of the advantages of plasma energy include:

1. Up to 200:1 solid volume reduction

2. Solid weight reduction -- 2000 pounds to 100 pounds slag

3. 100% recyclable by-products

4. Eliminates landfill requirements

5. Eliminates long term liability for infectious waste

6. Environmentally benign

7. Precise temperature and process control

8. Maintain control from "cradle to grave"

Use of Hydrogen-Rich Fuel Gas

The product gas may be used in many various energy intensive applications including production of methanol. A cost benefit analysis was performed to determine the highest and best use of the product gas for our application.

Independent Lab TCLP Toxicity Test Results

Solid Glass Residue

150 Lbs Glass

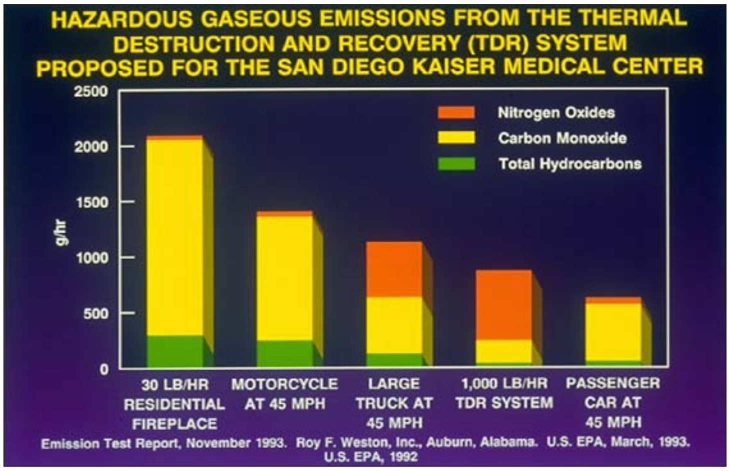
Arsenic	@<0.1	5.0*
Cadmium	@<0.02	1.0
Lead	@<0.2	5.0
Silver	@<0.5	5.0
Barium	@<0.5	100.0
Chromium	@<0.2	5.0
Mercury	@<0.01	0.2
Selenium	@<0.1	1.0

* Permissible Concentration (mg/L), EP Toxicity

INNOVATION

Mason & Hangar National, Inc.

Figure 4



A 500KW plasma torch is not large enough to economically produce product gas in sufficient quantities as feedstock for methanol production. A central plant that serves many hospitals would require a torch large enough to make it cost effective for methanol production. Municipal landfills would be prime candidates for plasma pyrolysis systems requiring large torches.

The hydrogen-rich fuel gas produced by the plasma torch can be used as feedstock for boilers, chillers or fuel cells. (See Figure 5)

The fuel cell shares many characteristics of a battery --no moving parts, silent operation, and an electrochemical reaction to generate energy. Chemical reaction in the cell is the combination of hydrogen ions and oxygen ions interacting to form water, producing electrical and thermal energy. The hydrogen-rich fuel produced in the plasma torch is an ideal match for the fuel cell. The combination of two emerging technologies used to recycle hospital waste is recycling in its highest form. The medical center's converted waste stream will produce two forms of energy from the fuel cell. This electrical and thermal energy can be used at the medical center.

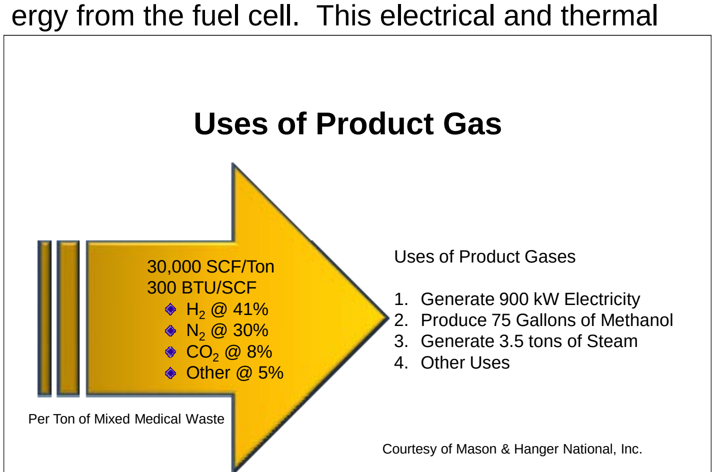
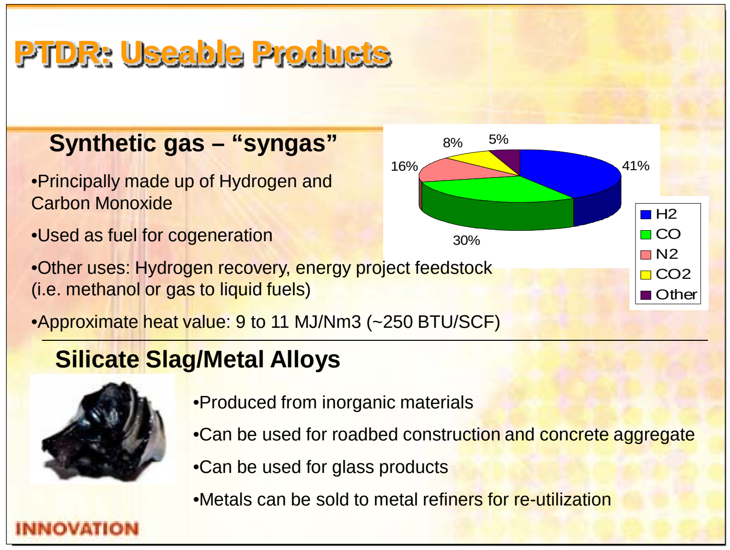


Figure 5

Use of Glassy Slag

The plasma pyrolysis process is an environmentally clean process. It generates heavy metals that are encapsulated within the glassy slag. EP Toxicity tests of the glassy slag indicate that the vitrification process encapsulates cadmium, lead, mercury, chromium and TACs. The vitrified solid from the plasma torch contains the balance of the waste products that did not change into gas. These will not release heavy metals or pollution to the environment. Permissible concentrations of the EP Toxicity test are listed below. Each ton of medical waste processed will produce 100 pounds of slag.



As mentioned earlier, the glassy slag can be used for concrete aggregate, road bed construction, composition roofing and may even be spun into insulation. In Japan the slag is used to build decorative water fountains. Paper weights, pendants, trinkets and glass tiles are other possible uses for the slag.

Conclusion

This exciting, historic project will revolutionize the way society processes waste. Plasma pyrolysis of municipal solid waste can yield 75 gallons of methanol for each ton of waste processed.

Essentially, a landfill could be mined (reformed) with plasma pyrolysis for its rich source of carbon monoxide and hydrogen. These are the basic building blocks in producing methanol. Landfills can be an excellent source for a clean transportation fuel.

High temperature thermal reduction, or pyrolysis, is the most effective and environmentally benign process of waste reduction to date. Controlled plasma temperatures of 21,000^{O} Fahrenheit render all organics, pathological and biological waste inert. The plasma pyrolysis process converts medical and municipal solid waste into a clean hydrogen-rich gas and glassy slag. Plasma produces no TACs, dioxins, cadmium or other harmful emissions. Plasma heating can achieve temperatures not possible by fossil fuel heaters.

Pyrolysis results in a reduction of over 90 percent in the volume of material. On-site plasma pyrolysis process disposes of hospital waste, thus eliminating the need to transport it on public streets and bury it in landfills. Lifetime liabilities are virtually eliminated for the waste stream generator and landfill operator.

Kaiser Permanente's senior management in Southern California has made the commitment to promote energy conservation, reduce environmental pollution and provide a healthier place to work and live for our neighbors and employees. Using Plasma pyrolysis for the destruction of medical waste is a demonstration of our progressive leadership in the health care industry.

Note: Emission test charts added to this document in 1993.