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amines, such as ethylene diamine and 1,6-hexane diamine, which act as surfactants to assist in matching the coal and solvent solubility characteristics. Powdered coal, amines, and coal-derived oil are mixed, heated to 300° to 400° C, and pumped away from the mine through the pipeline. It is anticipated that a pipe about 18 to 24 inches (45 to 61 cm) in diameter would be sufficient.

As the slurry moves through the pipe, as much as 70 percent of the powdered coal is liquefied under the influence of heat, pressure, the oil medium, and the amine surfactants. (The ground in which the pipeline is buried insulates the slurry, retaining heat.)

At an intermediate point about 100 miles (161 km) from the mine, the slurry is passed through a separation system in which about 30 to 50 percent of its oil content is removed and returned to the mine through a parallel pipeline. The recycled oil is added to new ground coal and fed into the slurry pipeline again. At the intermediate processing station the nonrecycled slurry is processed to reduce its ash, sulfur, and nitrogen content. The slurry, which consists of about 40 percent liquid coal and 60 percent coal solids at that point, is reheated and pumped through another pipeline to the power station, which may be as much as 2,000 miles away.

At the end of the line, the slurry is separated by centrifuging into an oil fraction and a coal-slurry fraction containing both liquid and solid coal in suspension. If necessary, the oil fraction is processed further to reduce ash, sulfur, and fixed nitrogen content to a point at which the oil can be burned in a boiler without special pollution-control equipment.

The coal-slurry fraction is burned in boilers that do have pollution-control equipment. These coal-slurry-fired boilers furnish the baseload energy output, and the "clean" oil-fired boiler is operated for peakloads. With this strategy, the coal burning generates a minimum amount of pollution, yet capital investment in pollution-control equipment is minimized.

This work was done by Warren L. Dowler of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 35 on the TSP Request Card.*
NPO-14425

Fuel Gas From Biodigestion

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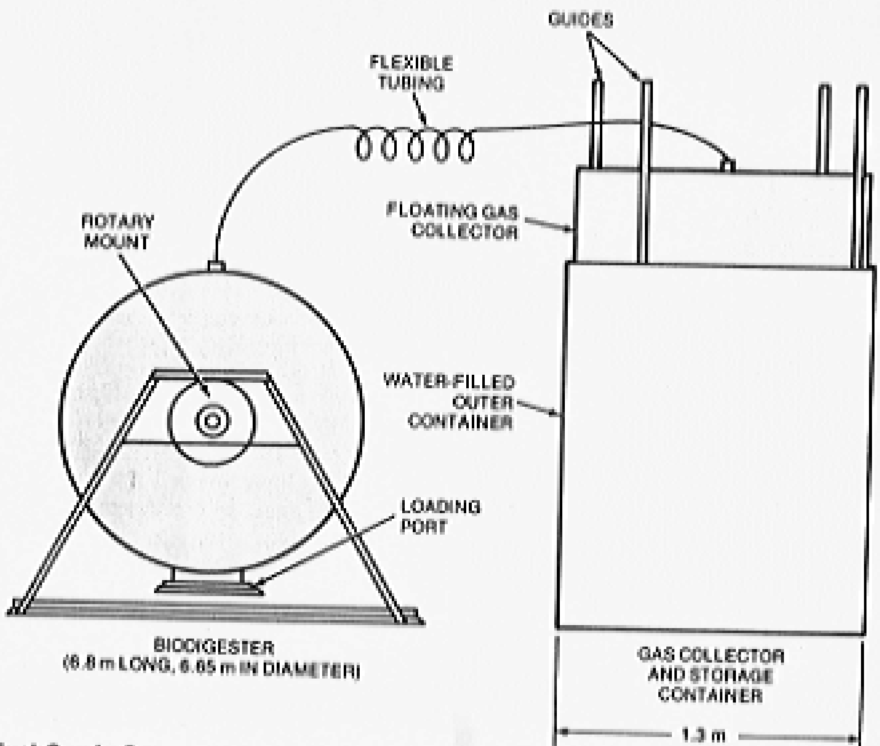
Easy-to-operate apparatus generates methane for household consumption.

Marshall Space Flight Center, Alabama

The apparatus shown in the figure produces fuel gas by anaerobic bacterial digestion of organic matter, such as aquatic vegetation. It includes a simple, safe gas collector for short-term storage, and it generates enough gas (primarily methane) for individual or home consumption. One of its primary advantages over previous designs is a built-in, manually operated agitator that allows the vegetation to be mixed periodically to accelerate gas production.

Already developed and successfully tested is as a prototype, the biodigester consists of a 1,000-gallon (3,786-l) cylindrical container mounted on rotary bearings. For loading, the container is rotated manually so that its large port is upright. Grass clippings, leaves, and other vegetation are dumped into the port. The port is bolted tight, and the container is rotated until the port is at the bottom. In this position, the port is below the surface of the mixture, and air cannot leak through it and interfere with the anaerobic digestion process.

The evolved gas gathers at the top of the container and passes through a



Fuel Gas Is Generated for Individual or Home Consumption by anaerobic bacterial digestion of vegetation in a rotary container. The evolved gas feeds through a coiled tube to a floating collector in a water-filled barrel, at the rate of about 100 to 200 liters per day.

small flexible tube into the storage collector. Three stationary bars mounted inside the tank stir the mixture when the container is rocked back and forth. Thus, one can agitate the mixture without opening the container and releasing gas.

The gas collector is a large inverted canister in a water-filled barrel. As gas flows into the collector, the canister rises (floating on the water) to accommodate the gas. The water prevents the gas from escaping, and vertical guides keep the floating canister from swaying or tipping over. The back pressure from the filled canister is not sufficient to upset the digestion process.

The process produces gas at the greatest rate at a temperature of 36° C, although temperatures 5° C above or below this value do not seriously affect the process. When the outside air temperature falls below 31° C, heated water can be circulated through the interior of the digester. Possible heat sources are gas from the biodigester itself or from a solar collector. The basic design can be adapted easily to larger systems.

This work was done by Rebecca C. McDonald and B. C. Wolverton of the National Space Tech. Laboratory for **Marshall Space Flight Center.** *For further information, Circle 36 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page A8]. Refer to MFS-23957.

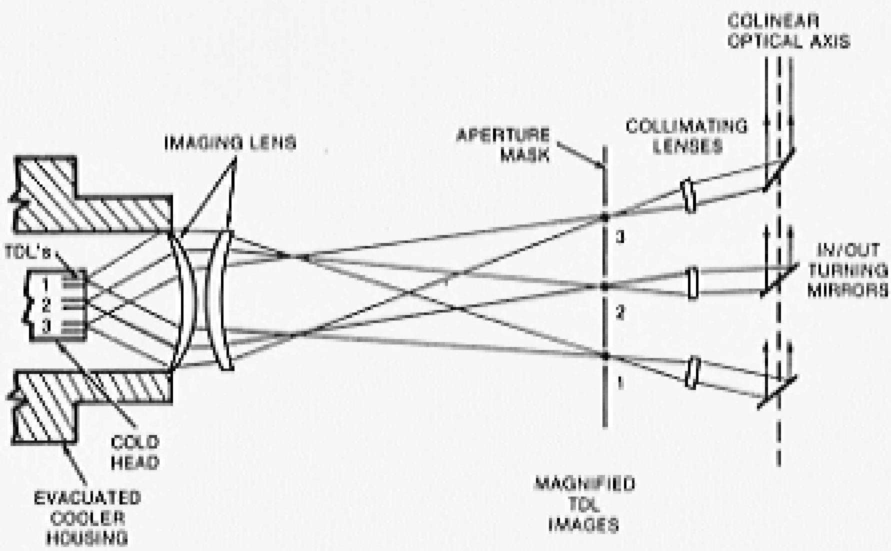
Optically Coupling Tunable Diode Lasers

A set of mirrors and lenses to generate multiple tunable laser outputs

Langley Research Center, Hampton, Virginia

Spectroscopes that use tunable diode lasers (TDL's) as far-infrared light sources often require multiple TDL's to cover a wavelength range unavailable from the single laser. A proposed optical-coupling using lenses and mirrors can combine separate TDL outputs and expand the wavelength range. The proposed method uses a single cooler housing and requires no moving parts within the cooler assembly.

An earlier scheme for obtaining multiple laser outputs from a single cooler housing incorporated a rotating cold head supporting a number of TDL's. In this complex mechanical design, each laser is rotated into position within the cooler head in an evacuated low-temperature environment.



This **Optical Coupling Arrangement** produces multiple TDL outputs from a single cold head. A set of lenses and mirrors will replace a complex mechanical system used for the same purpose.

The proposed approach shown in the figure is a package of three TDL's, separated by approximately 5 mm. These are imaged external to the cooler by a pair of germanium meniscus lenses that will accommodate both the laser separation and the divergent (approximately F/1, F being the F-number) wave front from the individual lasers. The emerging beams are individually collimated and superimposed onto a common optical axis by turning mirrors oriented at the proper angles. The collimated outputs from the three lasers are colinear for interfacing with other optics in the system. A single beam can be selected from the multiple output by inserting or removing the turning mirrors and an aperture mask in the image plane.

The limit to the number of TDL's that can be handled in this manner depends upon the packaging of the laser array and the numerical aperture of the imaging lens. With the system illustrated, an F/0.7 first lens is required to gather the radiation from each TDL.

This work was done by D. M. Robinson and C. W. Rowland of **Langley Research Center.** *No further documentation is available.*
LAR-12438

Treating Domestic Wastewater With Water Hyacinths

Greenhouse system purifies water, extracts fertilizers, and generates fuel.

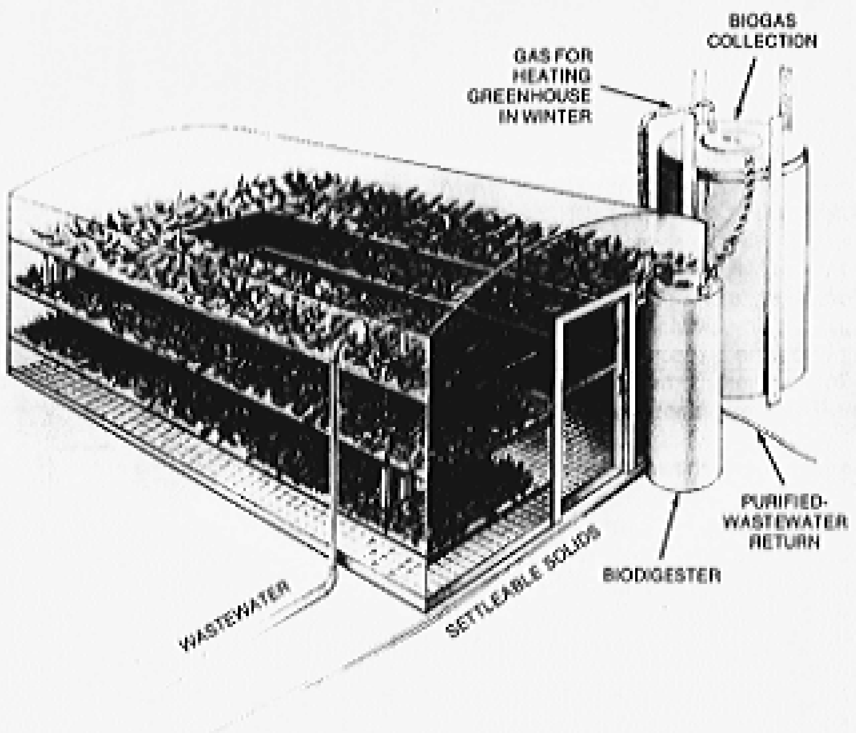
Marshall Space Flight Center, Alabama

Waste and wastewater from individual homes can be treated separately and effectively by a system based on water hyacinths, according to a recently proposed concept. The treatment would purify the wastewater so that it can be reused and would extract usable plant nutrients, rich in nitrogen and phosphorus. In addition, the system could produce methane gas for use as fuel. When fully developed, such a system may supplant septic tanks and central sewage systems for rural and undeveloped areas.

The treatment system consists of a greenhouse in which the domestic waste and wastewater flow by gravity through spiral channels containing water hyacinths (see figure). The soluble waste is removed from the wastewater as it flows through the water hyacinth roots where chemical elements (nitrogen and phosphorus) are removed. Solid waste settles out of the wastewater and decomposes in an anaerobic digestion tank, producing enough methane to heat the greenhouse during the winter months. After the solid waste is removed, the purified water is disinfected with ozone, ultraviolet light, or chlorine and recycled to the house.

The waste and wastewater are pumped to the top channel in the greenhouse, and a check valve in the main sewage line prevents backflow. Reflectors are positioned in the greenhouse to light the hyacinths in the bottom channels.

The number of square feet (meters) of plants needed varies according to their growth rate. Under controlled conditions, the water hyacinths grow rapidly, increasing their weight by 5 to 11 percent every day.



This **Waste-Recycling System** uses water hyacinths to purify wastewater and generate methane gas as a byproduct. A system with 200 ft^2 (18.6 m^2) of water hyacinths would treat the wastewater of a family of four (1,500 liters/day) and would generate 600 to 850 ft^3 (17 to 24 m^3) of biogas.

The flow channels in the greenhouse should furnish 50 square feet (4.65 square meters) of plant surface area for every person or for 100 gallons (378 liters) of wastewater. The channel flow depth should be adjustable from 4 to 12 inches (10 to 31 centimeters) so that the retention time can be varied according to the water quality desired. Once the balance of nutrient loading to plant biomass produced is established, excess water-hyacinth growth can be harvested monthly and converted by anaerobic digestion to additional methane or by composting to organic fertilizer and soil conditioner.

This work was done by Rebecca C. McDonald and B. C. Wolverton of the National Space Technology Laboratory for **Marshall Space Flight Center.** *For further information, Circle 58 on the TSP Request Card.*
MFS-23964

Aquatic Plants Aid Sewage Filter

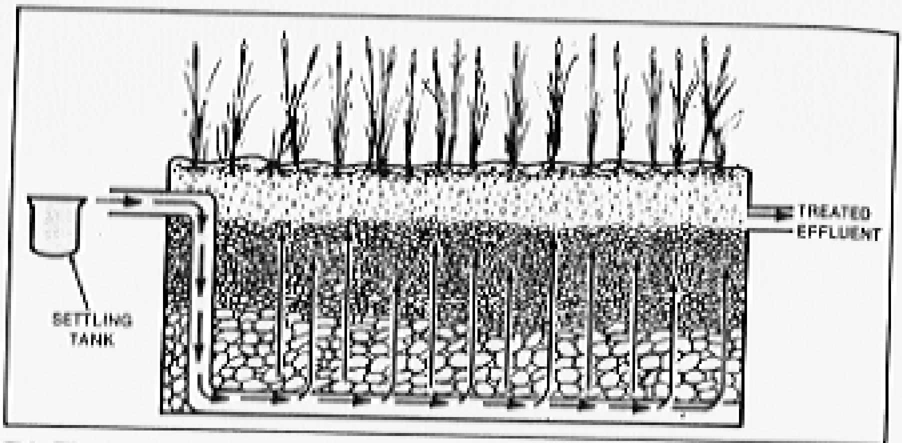
Superior water treatment is obtained at low cost.

Marshall Space Flight Center, Alabama

A method of wastewater treatment combines micro-organisms and aquatic-plant roots in a filter bed. In the first step of the process, anaerobic settling takes place in a septic tank, a covered anaerobic lagoon, an Imhoff tank, or any sludge-collecting and sludge-digesting chamber. After a minimum treatment period of 6 hours, the supernatant liquid from the sludge-collecting tank is pumped into the bottom of the hybrid filter system consisting of micro-organisms and plants (see figure).

Treatment occurs as the liquid flows up through the system. Micro-organisms that have attached themselves to the rocky base material of the filter act in several steps to decompose organic matter in the wastewater under treatment.

The first step involves the hydrolysis of organic compounds into simple organic acids, primarily by facultative (having aerobic and anaerobic viability) and obligate anaerobic bacteria. In the second step, strictly anaerobic bacteria convert these acids into CH_4 and CO_2, with trace amounts of H_2 and H_2S. The last step involves the action of aerobic micro-organisms to convert odorous sulfides to sulfates. The vascular aquatic plants (typically, reeds, rushes, cattails, or water hyacinths) absorb nitrogen, phosphorus, other nutrients, and heavy metals from the water through their finely divided roots.



This Filtering System includes a sludge-collecting tank and a rock filter. Supernatant liquid from the collecting tank is pumped or flows under gravity into the bottom of the filter, then progresses upward through layers of rock on which micro-organisms are attached. The bottom layer consists of rocks 7.5 to 15 cm across. The second layer is made of 2.5- to 7.5-cm railroad rocks. Vinyl core material can also be used for these layers. The top layer consists of pea gravel (0.25 to 1.5 cm) in which the plants are anchored.

Two versions of a small-scale prototype system were set up: one with and one without plants in the filter bed. The system without plants required about 24 hours to bring the biological oxygen demand below the limit set by the Environmental Protection Agency for secondary treatment. The system using plants brought the level below the limit in 6 hours. The system without plants did not reduce levels of Kjeldahl nitrogen, nitrogen in ammonia, and phosphorus, even after 24 hours. Concentrations of all three were markedly reduced with 24 hours of residence time in the rock filter planted with reeds.

This work was done by Billy C. Wolverton of **Marshall Space Flight Center.** *For further information, Circle 83 on the TSP Request Card. MFS-25808*

This invention has been patented by NASA [U.S. Patent No. 4,415,450]. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, [see page A8]. Refer to MFS-25808.

Monitoring Marine Microbial Fouling

An epifluorescence-microscopy method takes only 10 minutes.

Marshall Space Flight Center, Alabama

Two techniques have been developed for studying marine fouling, the biological colonization of surfaces by such micro-organisms as bacteria, diatoms, fungi, or protozoa. The methods were originally developed to study fouling of materials to be used in the Space Shuttle solid-fuel booster rockets, which are recovered after they parachute into the ocean. These methods can be used to determine both the relative fouling rates and the efficacy of cleaning methods to remove fouling on various surfaces including paints, metals, and sealants intended for marine use.

The first technique requires 1 to 2 days for sample preparation, but provides qualitative and quantitative assessment of biofouling. The surfaces of the samples are viewed directly with scanning electron microscopy. These observations are combined with those from standard microbial-isolation methods in