ROLE OF BIOFUELED GAS TURBINES IN SOIL REMEDIATION

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INTRODUCTION

Clean up of soils polluted with metals pose difficult and expensive problems in many places around the world. Remediation has ranged from vitrification of the polluted soil to disposal in landfills. Dr. Rufus L. Chaney, reference 1, has proposed "Green Remediation" as a means of treatment. "Green Remediation" relies on the ability of plants to accumulate metals from the soil. Upon reaching maturity the plants can be harvested and burned with subsequent recovery of the metals from the ash. Some specifics of growth, species selection, and various aspects of agronomic management are covered in reference 1. It is the purpose of this presentation to introduce the prospect of using a biomass fueled gas turbine power generating system as a remediation vehicle in conjunction with growth of metal accumulating plants some of which have been given the name "Hyperaccumulators". The biofueled gas turbine power generating system is described and various aspects of its use are presented in references 2, 3, & 4.

BACKGROUND INFORMATION

The use of metal accumulating plants as fuel was first brought to the attention of Aerospace Research Corporation by Dr. Barry Noval and Lionel Gillston of Energy Products Enrichment, Inc. of Norristown, Pa. They suggested a multiple use of the biomass fueled gas turbine in which operation with metal accumulating plants would produce an ash-ore product that could be smeltered to recover the metal. In areas where the contaminated land could not support full time operation, nonpolluted land growing crops such as sweet sorghum together with sawmill waste, demolition waste, and clean municiple waste could be used.

Conversations with Dr. Robert P. Bosshart of Horsehead Resource Development Company, Inc. of Palmerton, Pa. revealed that there is considerable interest within that company in use of metal accumulating plants to clean up contaminated soil. Soils in the Palmerton area where zinc smelters are located have become contaminated over the years. One problem is that much of the contaminated land is too steep to cultivate by conventional methods. An estimated 1000 acres of level land may be available for use in a remediation program. Sixty to eighty percent of the fuel needed for an economical biomass fueled gas turbine installation would have to come from other sources.

Throughout the U.S. and the world there are large land areas that have become contaminated with metals such as lead, copper, zinc, cadmium, arsenic, and nickel and may be candidates for phytotreatment. While it may be desirable in some cases to delay installation of phytotreatment systems until more research is performed on candidate metal accumulators, there are many locations where biomass fueled power generation systems may be installed and economically operated with marginal accumulators. Under the Public Utilities Regulatory Policies Act power companies are required to purchase the power at their avoided energy costs. Growth, harvesting, transportation, storage, and processing of the biomass fuel and ash disposal constitute the main differences in the biomass fueled gas turbine power generating systems and those now in operation and use with petroleum and gaseous fuels around the world.

GROWTH OF METAL ACCUMUULATORS

As pointed out in reference 1, the metal accumulators may be specific in their tolerance for the contaminating metals. The selection of species will require agronomic expertise and will involve soil analysis, not only from standpoint of metal contamination but also from standpoint of alkalinity and nutrient content. A mixture of plant species may be required to accommodate multiple contaminants and erosion control. It is pointed out in reference 1 that few hyperaccumulators are available which generate substantial biomass. A low level accumulator which generates substantial biomass may achieve the same metal uptake for a given area as a hyperaccumulator with low biomass production. The higher biomass production would improve the economics of power generation. In climates with short frost free seasons it may be necessary to grow a variety of crops to support a power system. For example, bagasse from sorghum which constitutes substantial biomass for fuel after the sweet juice is extracted is seasonal. However, elemental analysis of sweet sorghum bagasse show the presence of chromium, barium, nickel, zinc, and copper among the lighter metals. Therefore, it is a good accumulator candidate. It can be grown in combination with hyperaccumulators as well as high producing legumes and grasses.

TRANSPORTATION AND STORAGE

Transporting and storage of biomass presents an economic problem because of its low density. For that reason it is important that hauling distances be short and storage operations be well planned. Legumes and grasses can be round baled and stored in the field near roads where they can be picked up and hauled to the point of use. The bales can be capped with plastic or left exposed to the weather. Both practices are followed throughout the United States. The storage of sweet sorghum is more complex. It is estimated that the harvesting and processing of sweet sorghum can be stretched out over a period of approximately six months in single crop climates. Mixing of varieties and staggered plantings will be required. The six month estimate is based upon information contained in references 5 and 6. The bagasse remains of the sorghum have to be dried and put in covered storage to prevent deterioration from fermentation. Providing covered storage for the large amounts of bagasse that would be required for year round use may not be practical. In tropical areas where year round growth of sweet sorghum is possible, the storage problem is minimal.

PROCESSING

Densification of legumes and grasses is necessary for feeding into the pressurized combustion chamber. Densifying involves grinding, pelleting, and crumbling. Efficient machines are commercially available for accomplishment of all three tasks. The pelleting process requires steam which can be supplied by a waste heat boiler heated by the turbine exhaust gases. Use of some of the generated electricity will also be required. Extraction of the juice from sweet sorghum may be accomplished by grinding or squeezing through rolls. The product from either process is referred to as bagasse. Bagasse from grinding can be dried and with little further screening or grinding be fed into the combustor. The bagasse from squeezing retains its identity as a stalk and must be subjected to substantial grinding before drying and feeding into the combustor. The sweet juice can be reduced to syrup with heat from the gas turbine exhaust. Storage of the syrup will allow year round operation of an ethanol plant. The seed head on the sorghum can also be used in ethanol production.

DISPOSAL OF THE ASH

The ash generated in the combustion chamber passes with the hot gases to a cyclone filter. The ash falls to the bottom of the cyclone where it is recovered, and the cleaned hot gases are ducted to the turbine. The cleaned gases normally contain 35 to 50 parts per million of particles that are on the order of 2 micrometers or less in diameter. The heavy metal content of the particles and any hazard potential will have to be evaluated. It is expected that particles containing heavy metal constituents will be more completely filtered due to higher density.

Biomass ash normally contains a commercially recoverable amount of potassium oxide which reacts with water to form highly soluble potassium hydroxide. Leaching of the potassium hydroxide while leaving the generally insoluble heavy metal oxides in the ash is one approach to recovery of the potassium.

The metal content of the ash will depend upon the variety and types of plants being used as a fuel as well as the condition of the soil in which the plant is grown. If the metal can be economically recovered and the residue from the recovery process is free of contaminating metal, the ash may be returned to the soil. If it is uneconomical to recover the metal, the most economical disposition probably will be into a qualified landfill.

ECONOMIC CONSIDERATIONS

The objective in using biofueled gas turbine power generating systems in soil remediation is to reduce clean up costs or to turn a profit if possible. The payment received for the generated power is the key factor. The avoided energy costs for power that public utilities are required to pay in complying with the Public Utilities Regulatory Policies Act will not normally be adequate to allow economical use of fuels other than waste products such as sawdust. Utilities with power plants located near coal mines generally have avoided energy costs less than 2¢/kw hr. with a charge to customers of 5¢ to 8¢/kw hr. Businesses generally pay a demand penalty in addition. Paper mills in coal producing areas are large users of sawdust and bark in their boilers. With 1993 prices for coal it is more economical for paper mills to switch to coal when the price of sawdust approaches $28 per ton on a bone dry basis. To compete with coal would require production of approximately ten tons of dry biomass per acre at $280.00 per acre. To meet a production goal of ten dry tons per acre probably would require harvesting a summer crop of sweet sorghum plus a winter cover crop in the northeastern part of the U.S. where there is an identified need for remediation. Unless there is a very large acreage, for example, five thousand acres of land to be remediated, reliance upon waste products for supplemental fuel probably would be the most economical approach.

In addition to bagasse, the sweet sorghum in the northeastern part of the U.S. would produce approximately 1.5 tons of sugar per acre which is equivalent to approximately 130 gallons of ethanol. The heat from the gas turbine exhaust can be used for processing the ethanol. An industrial user of power that has land to be remediated may well profit from generation of its own power with sale of the excess to a utility.

SUMMARY

Of the methods available to effect soil remediation phytotreatment of contaminated soils promises to be the most economical. The number of years required to accomplish the task will depend upon the skillfulness in soil management, the variety of plants used, and the severity of the contamination. The ability to turn a profit with burning of the biomass in a gas turbine power generating system will depend upon the payment received for the power produced, payment for by-products, operating costs, cost of biomass production, and availability of waste for alternate fuel. By-products will consist primarily of potassium and the metal of contamination. In the case of sweet sorghum, ethanol produced from the sweet juice would be a major by-product. Biomass waste from sawmills and demolition can fill in during seasonal lulls in crop production.

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From a literature search in 1992 by Dr. Shu-I Tu and associates of the Plant and Soil Biophysics Research Unit of the North Atlantic Area Regional Research Center of the U.S. Department of Agriculture the following individuals have been working on the selection of plant varieties with unique abilities to accumulate certain metals: R.B. Clark of University of Nebraska, E.A. Brams of Prairie View A&M University in Texas (university information number is 409-857-3812), D.R. Parker of the University of California at Riverside (department phone number is 907-787-5116), Dr. Grunes and collaborative with ARS at Ithaca, NY (607-255-3003), and V.V. Baligar with ARS at Beckley, WV (center information number is (304-252-6426). G.N. Richard at the University of Montana at Missoula (campus information number is 406-243-0211) has been working on the influence of cations pyrolysis of wood. The assistance of Dr. Shu-I Tu is appreciated.