BASES FOR A SEWAGE SLUDGE TREATMENT PLANT BY IRRADIATION IN MEXICO

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ABSTRACT

A good place for the first sludge irradiator in Mexico would be the sewage water treatment plant Toluca Norte. This plant has a definitive biological treatment, and it treats only domestic wastewater and assures therefore a good and steady sewage sludge quality and it has a capacity (440,000 inhabitants) to deliver sufficient sludge (approximately it 22,000 $ton.y^{-1}$ or 70 $ton.d^{-1}$) to the irradiator. Capital and operating cost calculations of a sewage sludge treatment plant by irradiation in Mexico were obtained using a mathematical model considering a 50 kW electron linear accelerator of 10 MeV beam energy, an irradiation dose of 5 kGy, a treatment capacity of 346 $ton.d^{-1}$, an absorption efficiency of 40%, an electricity consumption of 400 kW, an operating mode of 325 days per year and one shift per day. Total annual operating costs is estimated to be $1,007,900 for treating 346 $ton.d^{-1}$ with an irradiation dose of 5 kGy, this includes both fixed ($664,000) and variable costs ($343,920). The unit cost at maximum utilization was obtained $9.00 per ton.

I. INTRODUCTION

Wastewater treatment plants yield sewage sludge as final by product. Generally the sludge contains physical, chemical and biological pollutants which represent a major handling problem due to its origins/contents and immense volume, or an opportunity because of its humus, nitrogen, phosphorus, potassium and other plant nutrient content which make it suitable as a soil conditioner or fertilizer, if properly treated.

Current sludge management systems [1] in developed countries like Canada and The U.S.A., typically consist of the following processes: thickening, stabilization, dewatering and disposal. Traditional methods of disposal include incineration, landfill and ocean dumping, but these methods are limited by land shortages, cost and environmental concerns. Thus, some communities are changing from a philosophy of sludge disposal to one of sludge reuse.

According with Swinwood [2] sludge is a valuable resource for agriculture, it use is limited by the presence of pathogens, toxic chemicals and heavy metals. Irradiation process can reduce pathogens and destroys some of the organic pollutants. However, radiation does not remove heavy metals. Irradiated sludge can be applied as conditioner of soils only if the content of heavy metals, pathogens and toxic chemical are low. At present, in Mexico only about 10% of sewage is treated. However, as a result of the environmental polices of the Mexican Federal Government, the sewage treatment systems will be increased in the near future and the production of sludge will be bigger. This problem will be of particular importance in the urbanized area called the Mexico City Metropolitan Area (MCMA), composed by the Distrito Federal and part of the State of Mexico, where the population approaches 20 million in 1990 [3] and was predicted by Cabrera [4] to reach 25 million by the year 2000. According with El Departamento del Distrito Federal [5] and Mazari [6,7] the current water use in the MCMA is approximately 60 $m^3.s^{-1}$, existing an increasing demand of near to 45 $m^3.s^{-1}$. The total of wastewater in the MCMA is approximately 81 $m^3.s^{-1}$ [8].These data show that the wastewater production and consequently the sewage sludge production will be increase in the MCMA.

Not only in Mexico City but all over in the country the number of sewage treatment plants will increase tremendously in the next years to come because of this the controlled removal of sludges is considered as a major problem, by the Mexican authorities.

It is clear that the desinfection of wastewater and sewage sludges by irradiation could help in general to control the diseases, produced by these residues. Only the desinfection of the sludges can help to avoid the loss of the hygienic success of sewage treatment plants.

Research has been conducted to investigate in Mexico the remotion of phenols and detergents and to inactivate coliform bacteria in wastewater [9] and also in sewage sludges [10] by gamma irradiation. While the knowledge of the degradation of organic toxic compounds is still limited to some of the toxics under certain conditions, the knowledge about the disinfection effect is wide enough, therefore the dose to reduce microorganisms content in sewage sludges under various conditions.

There is not sufficient research and experience available, for designing a sludge irradiator for the purpose of the degradation of organic toxic compounds. For a plant to achieve therefore effects for the especial case of application by some laboratory experiments have to be conducted to define the main characteristics of such an irradiation plant.

It is strongly recommended to build an irradiation plant in a practical scale on the site of a sewage water treatment plant. Such a plant is necessary not only in a pilot plant scale for demonstration purposes, but also for the proof of the relation to practice of the research investigations.

At first practical sludge irradiation plant in Latin America would also be very useful for many research purpose, similar to the irradiation plant in Geiselbullach, Germany [11,12] where a multidisciplined research program had been undertaken for a period of eight years (1973- 1980). Since July 1973, more than 250,000 m^3 of liquid sludge has been disinfected during that time.

A good place for the first sludge irradiator in Mexico would be the sewage water treatment plant Toluca Norte, which is actually in operation. This plant has a definitive biological treatment and it treats only domestic wastewater and assures therefore a good and steady sewage sludge quality and it has a capacity (440,000 inhabitants) to deliver sufficient sludge (approximately it 22,000 tons per year or 70 tons per day) to the irradiator. It is located near to The National Institute for Nuclear Research (ININ) and the Mexico State Autonomous University (UAEM) in Toluca facilitating the collaboration for a interdisciplinary research programs between both institutions. Moreover there is the possibility to transport the sludge of the waste water treatment plant "Toluca Oriente" (distance about 5 km and 300,000 inhabitants) to "Toluca Norte" for the same irradiation treatment.

II. COST ESTIMATION AND FINANCING.

According with Mckeown [13], using AECL Accelerator's IMPELA Technology of 10 MeV and 50 kW of electron beam power to treat sewage sludge, the capital cost of the sterilization component is around 37% of the total, with the dominant subsystem being the sludge dewatering. Table 1 shows cost for three different capacities and three different alternatives. Mckeown in his work concluded that radiation technology is competitive with other biological processes for the treatment of sewage sludge.

As there is a strong perception in the public in Mexico on nuclear technology, especially when radioactive material is used, an electron beam technique is an alternative, that offer advantageous safety features as the possibility to switch off the radiation at any time.

Normal electron beam plants for sludge irradiation require thin sludge layers, as the penetration of the electrons into the sludge is only about 2.5 - 3.0 mm per MeV. The problems to produce these thin sludge layers, are regarded as important and essential. Therefore it is considered to use an accelerator with a high energy up to a maximum of 10 MeV. If the beam is designed to be used from both sides the sludge layer can be as thick of 3 to 7 cm which is regarded as feasible.

As energies over 5 MeV can produce nuclides, it should be cleared and discussed with the national experts, if an energy over 5 MeV is acceptable for the sewage sludge irradiation in Mexico.

TABLE 1. Accelerator Based Proposal-Plant Capital.

Dry sludge quantity (tons/year)	**Case 1 13,000**	**Case 2 18,000**	**Case 3 23,000**
Capital requirements:	Capital cost (U.S. $)		
Dewatering	3,717,160	4,592,430	5,467,700
Sterilization	4,934,800	4,934,800	4,934,800
Drying	2,176,130	2,554,270	2,931,680
Total	10,828,090	12,081,500	13,334,180

An alternative to avoid the problems with the thin sludge layer can be the batch operation. In this case accelerators with relative low energies (perhaps 1.5 MeV and more) can be used for the irradiation. These machines are of significant lower costs than the high energy accelerators. However, the batch wise operation with electron beam machines is not yet experienced in practical plants, only at laboratory scale tests.

This operation would require additional research work for the homogenous dose distribution and the whole process bears more risks for a successful operation.

Concerning the research experience on sludge irradiation, Hashimoto [14], has shown that the total bacterial counts decreased about 5 log cycles after irradiating with a dose of 5 kGy and irradiation with 2 kGy was enough to kill all coliforms in sewage sludge.

The recent work of Kurucks [15], from the University of Florida at the Miami pilot plant facility has demonstrated the effectiveness of electron-beam waste treatment in toxic chemicals. This work indicates that doses in the range 5 kGy to 10 kGy will be required under these idealized conditions to remove more than 90% of the toxic organic compounds. Higher doses will almost certainly be required under practical conditions.

Work in sewage sludge samples from wastewater treatment plant by Moreno [10] indicated that a dose of 18 kGy removes 80% of phenols and detergents and a dose of 7 kGy decreased six log cycles the total bacteria count.

Work by Trump [16], shows that a dose smaller than 500 Gy is adequate for the desinfection of municipal wastewater whereas a dose of 4 kGy is enough for the desinfection of sludge.

At a dose of 500 Gy and 200 kW, 10 MeV accelerator could treat 2300 m^3/day. As electrons are more efficient than chlorine for desinfection it may be possible to have a satisfactory desinfection at the 500 Gy level. In which case the single accelerator above would be able to treat the most contaminated wastewater in the region. A new accelerator technology has emerged in the past 5 years with the development of industrial accelerators with energies of 10 MeV and penetration of 40 mm and with the necessary power for a practical throughput. Version of this technology have now been operating for 4 years.

The technology for handling sludge to suit these new machines has not yet been designed but this should be a routine engineering task. Conveyor, pull cart and liquid system are in every day use and a system designed to optimize the needs of the Mexican environment is needed. Capital and operating cost calculations of a sewage sludge treatment plant by irradiation in Mexico were obtained using a mathematical model considering a 50 kW electron linear accelerator of 10 MeV beam energy, an irradiation dose of 5 kGy, a treatment capacity of 346 ton d^{-1}, an absorption efficiency of 40%, a electricity consumption of 400 kW, an operating mode of 325 days per year and one shift per day. Total annual operating costs are estimated to be $1,007,808 for treating 346 ton.d^{-1} with an irradiation dose of 5 kGy, this includes both fixed ($663,891) and variable costs ($343,917).

The unit cost at maximum utilization was obtained $8.97 per ton. The costs estimation is sufficiently detailed and has explicit information to allow the Mexican Government to make a clear appraisal of what such a product might cost. Assistance in looking at the overall costs is provided by Table 2 and 3.

TABLE 2. Application, Accelerator Type, Operating Mode and Capital Cost of a Sewage Sludge Treatment Plant by irradiation in Mexico.

APPLICATION		FINANCIAL	
		Accelerator amortization	15 Y
Dose	5 kGy	Shielding Amortization	15 Y
Product Depth	320 mm	Special item amortization	15 Y
Product Width	80 cm	Interest on accelerator	7 %
Specific Gravity	1 g.mL^{-1}	Interest on shielding	7 %
Absorption Efficiency	40 %	Interest on special building items	7 %
ACCELERATOR TYPE		CAPITAL EQUIPMENT & BUILDINGS	(U.S. $)
		Accelerator	
Energy	10.0 MeV	Warranty	
Power	50 kW	Installation	
Scan Width	1.00 m	Proj. Mgmt. & Training	
Electricity Consumption	400 kW	Spare Parts	
		Total accelerator & related	3,796,000
OPERATING MODE		Shipping & Insurance	18,250
Days per year	365 d	Shielding	292,000
Shifts per day	1	Product Handling	400,770
Hours per shift	8 h	Building	365,000
Operating hours per year	2600 h	Special Building Items	483,187
Operator	1		
		TOTAL CAPITAL	5,355,207

TABLE 3. Annual Operating Costs and Capacity of a Sewage Sludge Treatment Plant by Irradiation in Mexico.

ANNUAL OPERATING COSTS (U.S. $)	
FIXED COSTS	
Equipment amortization costs	515,837
Shielding amortization costs	32,060
Building amortization costs	40,074
Equipment maintenance cost (fixed)	75,920
TOTAL FIXED COSTS	663,891
VARIABLE COSTS	
Labor	56,940
Electricity	182,208
Rf tube cost	45,552
Equipment maintenance (variable)	59,217
TOTAL VARIABLE COST	343,917
TOTAL ANNUAL COST	1,007,808

TREATMENT CAPACITY	
Cubic metres per day	346
Cubic metres per year	112,320
Tons per day	346
Tons per year	112,320
Product Velocity	1.25 ($cm.s^{-1}$)
UNIT COST AT MAXIMUM UTILIZATION	(U.S. $)
Cost per ton	8.97
Cost per cubic metre	8.97

The costs cover all of aspects in which Mexico has limited experience. It also covers the major technical uncertainties in the project. This will mean that in future Mexico will be self-sufficient in handling such projects except for the radiation source itself.

III. CONCLUSIONS

Irradiation process is effective both in removing organic chemicals and in desinfecting sewage sludge from a wastewater treatment plant.

Total treatment cost using an electron linear accelerator with 50 kW of maximum power and 10 MeV of beam energy is estimated to be approximately $9.0 per ton assuming an irradiation dose of 5 KGy.

The success of the complete project in solving the problem of sewage sludge contamination in Mexico remains with the Mexican authorities.

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