

ENERGY NEUTRAL THERMOPHILIC SLUDGE DIGESTION AND METAL LEACHING PROCESS

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by

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CERTIFICATE

This is to certify that the thesis entitled “**Energy neutral thermophilic sludge digestion and metal leaching process**” being submitted by **Ms. Akanksha Mehrotra** is worthy of consideration for the award of the degree of **Doctor of Philosophy**. The thesis has been prepared under my supervision and guidance in conformity with the rules and regulations of **Indian Institute of Technology Delhi** and is a record of the original bona fide research work. The results presented in this thesis have not been submitted in part or full to any other universities or institutes for the award of any other degree or diploma.

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ABSTRACT

Secondary sludge is generated from the biological treatment of sewage in treatment plants. It is rich in organic matter and hence can easily lead to putrefaction. Moreover, the presence of different heavy metals makes it hazardous for the land application. This study was undertaken to develop a robust process which can stabilize the sludge in addition to its decontamination.

Batch autoheated thermophilic aerobic digestion (ATAD) process was operated during which VSS reduced by 48.23% in 3 days and the average digestion rate constant was 0.315 d^{-1} . Temperature of the reactor was also maintained in thermophilic range ($>55^{\circ}\text{C}$). Thermophilic simultaneous sludge digestion and metal leaching (SSDML) (at 50°C) was carried out successfully during which VSS was reduced by greater than 40% in both sulfur and iron-oxidizing system. Moreover, the area required for disposal decreased by greater than 65% in both sulfur and iron-oxidizing system due to bioleaching of metals and sludge digestion. Total coliforms count was below the detection limit suggesting that the treated sludge was also free from pathogens. The effects of energy source and temperature on the simultaneous sludge digestion and metal leaching (SSDML) were also studied. Sulfur was found to be the better energy source when the temperature of the process was less than 45°C . At higher temperature, iron-oxidizing bacteria were more active than the sulfur-oxidizing ones. *Acidithiobacillus ferrooxidans* was the dominant bioleaching microorganisms at mesophilic temperature while at thermophilic temperature *Alicyclobacillus tolerans* carried out bioleaching in both sulfur and iron-oxidizing system. Members of *Alicyclobacillus* species were found to be the dominant heterotroph during the SSDML process. Iron-oxidizing heterotrophs were also detected during the SSDML emphasizing their role in both sludge digestion and metal leaching. SSDML was also carried out at 50°C in a continuous mode using ferrous sulfate as the energy source. During steady state, VSS was reduced by 50% and area required for disposal decreased by 77.16%.

A novel two-stage SSDML process (using both sulfur and iron-oxidizing species) was performed in the continuous mode in which the first stage was autoheated and the second stage was mesophilic. The temperature of the reactor remained above 55°C during the first stage (autoheated) of continuous operation. Removal of metals from the sewage sludge in the autoheated stage (pH >4) suggests the metal leaching through sludge digestion route. VSS was reduced by 50.85% and 77.07% at the steady state (second stage) in iron and sulfur-oxidizing system respectively. Area required for disposal decreased by 69.60% and 94.91% in iron and sulfur-oxidizing system respectively after the mesophilic stage. Therefore, with respect to sludge digestion and metal leaching, sulfur was found to be the better energy source.

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NOMENCLATURE

ATAD	Autoheated thermophilic aerobic digestion
d	day
DGGE	Denaturing gradient gel electrophoresis
h	hour
HRT	Hydraulic retention time
k	Sludge aerobic digestion rate constant (d^{-1})
mM	Millimolar
PCR	Polymerase chain reaction
SSDML	Simultaneous sludge digestion and metal leaching
TC	Total coliforms
TS	Total solids
TSS	Total suspended solids
VSS	Volatile suspended solids
v/v	Volume by volume
vvm	Volume of air per volume of reactor
w/v	Weight by volume