

DIAGNOSIS OF BIOSOLID MATERIALS USING A LOW-COST DIFFERENTIAL RESPIROMETER

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Abstract

This study justifies the applicability of a simple respirometric technique to diagnose the biosolid materials collected from municipal sewer lines. Samples of active settled sludge were collected from three different sewer lines of Sylhet city area (Bangladesh) enriched with residential, commercial and industrial discharge respectively. Reaction vessel of the respirometer, partially filled with biosolid samples has been integrated with a compensation vessel to neutralize the temperature-pressure effect on the manometer readings. Results deduced from the systematic analysis of respirograms show that the biosolids from residential source could be used effectively as soil conditioner due to its high content of biodegradable materials while industrial sample exhibited toxic inhibitory effects on microbial degradation process.

Keywords: Biosolid materials, Differential respirometer, Respirogram, Inhibition, Soil conditioner.

1. Introduction

Production and use of compost materials as soil quality enhancer is increasing day by day in various agricultural fields. In this context, Biosolids-the residue generated during treatment of domestic and municipal sewage or settled during flowing of wastewater through municipal sewer line by physico-chemical and/or biological process, could be used as organic soil conditioner and partial fertilizer especially in the developing countries of the world [1, 2]. It can be applied to agricultural lands (pastures and cropland), disturbed areas (mined lands, construction sites, etc.), plant nurseries and forest areas. For making beneficial and effective use, it is very important to measure the biomass activity of the biosolid materials before utilizing them in practical field.

Nomenclatures

d	Distance travelled by both meniscus in the manometer tube
k	Flask constant
P_0	Initial pressure in the reactors
P	Pressure at time t
P_{atm}	Atmospheric pressure
T	Experimental temperature
V_g	Initial gas volume in the reactors

Abbreviations

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolve Oxygen
OUR	Oxygen Uptake Rate
STP	Standard Temperature and Pressure
SUST	Shahjalal University of Science and Technology

Biosolid materials that contain nutrients and microorganisms are able to degrade organic matters flowing with the wastewater through the sewer line before discharging into the natural sinks. Figure 1 shows the typical biochemical process in sewer lines which are modelled in relation to DO (Dissolve Oxygen), BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand). However, travel duration of the sewage particles within the sewer line, flow velocity and turbulence, natural aeration process, oxygen transfer rate etc. have pronounced effects on the biodegradation process of flowing wastewater [3].

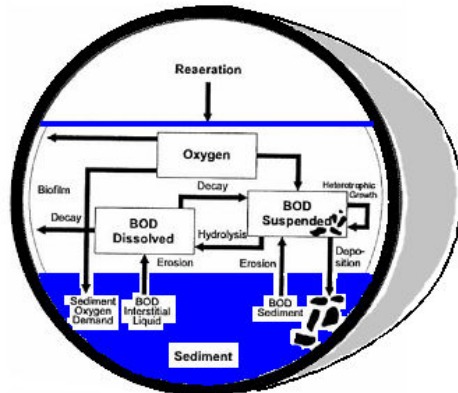


Fig. 1. Typical biochemical process occurred in sewer lines [3].

Many procedures for measuring the biomass activity of biosolid materials are described in the literature [4, 5]; however, the apparatus fabricated in the laboratory and the procedures presented in the paper require very simple accessories and chemicals available in the local market at a cheap price. Microorganisms in sewage sludge use oxygen to consume organic matter. The level of microbial activity in sludge is indicated by the microorganism's oxygen

uptake rate. High oxygen uptake rates indicate high microbial activity and high organic matter contents while low oxygen uptake rates indicate low microbial activity as well [6]. The objective of this study is to assess the biodegradation capacity of biosolid mass in terms of oxygen consumption obtained from a simple respirometric investigation.

Respirometry is a measurement and interpretation of the biological oxygen consumption rate (aerobic) or biogas generation rate (anaerobic) under well-defined experimental conditions. This oxygen consumption comes from the microorganisms contained in the wastewater or biosolid materials as their survival phase (endogenous) and biological oxidation of the biodegradable constituents (exogenous). Under aerobic conditions, the microorganisms consume oxygen in proportion to the organic matter and biomass present in the sample. In case of headspace gas respirometer, microorganisms in the wastewater sample take aerial oxygen to degrade (oxidize) the organic substances in it. As oxygen is consumed to oxidize the organic substances, carbon dioxide (CO_2) is evolved which is trapped by a special type of scrubber placed in the headspace of the reactor. As a result, headspace pressure is decreased which is indicated by the fluid movement in the manometer [7-9].

The OUR (oxygen uptake rate) measurement is very simple to perform in the laboratory, but it demands more effort in interpreting the results to extract useful information. Figure 2 shows a typical respirogram, according to Kristensen et al. [10] for a mixture of organic materials as substrate and municipal activated sludge as biomass. The highest peak represents the directly biodegradable substances while the next level indicates a more slowly degradable material and so on further down to the endogenous respiration rate [10, 11].

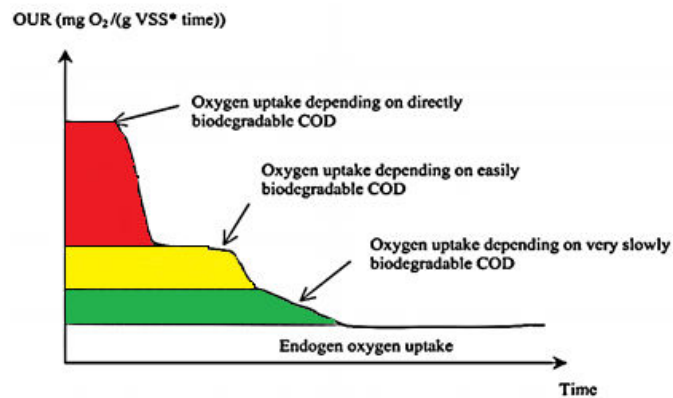


Fig. 2. Typical development of the respiration rate as a function of time for a mixture of carbon sources according to Kristensen et al. [10].

2. Materials and Methods

2.1. Sample preparation

Fabrication of respirometer, collection of samples and subsequent experimental investigations were carried out during February to June in 2012. Biosolid materials

used in this study were sampled from three different sources of Sylhet municipal area. The three sampling points were enriched with residential, commercial and industrial discharge respectively. Before respirometric study, all the samples were air-dried and grounded to prepare well-mixed slurry with distilled water. Different parameters for the experimental setup are presented in Table 1.

Table 1. Details of the experimental setup.

	Experimental Reactor	Compensating Reactor
Weight of biosolid sample, gm	50	0
Sample volume, ml	150 (biosolid slurry)	150 (distilled water)
Headspace volume, ml	750	750
Incubation period, hrs	120	120

2.2. Respirometric device: principle of operation and data treatment

Oxygen uptake value of the biosolid materials were measured by a ‘**BIOSUST**’ differential respirometer (Model BSMR-BS103) fabricated at Centre for Environmental Process Engineering of SUST which is shown in Fig. 3 along with some important technical specifications as listed in Table 2.

Table 2. Technical specifications of ‘BIOSUST’ respirometer.

Measuring criteria	Respirometric (manometric)
Manometer height	25 cm (volume range: about 8 ml)
Manometric liquid	Colored water solution
Temperature range	(18-35±1)°C
Power supply	Input: 230V AC, Output: 12 V DC
Weight	Approx. 4 kg

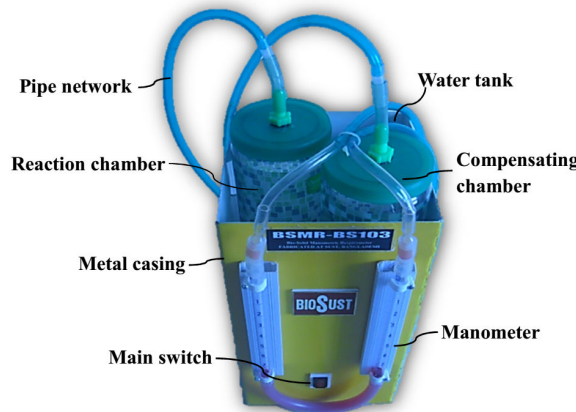


Fig. 3. ‘BIOSUST’ differential respirometer.

The differential respirometer consists of two air-sealed glass vessels, two small pans filled with carbon dioxide scrubber, a U-tube manometer fitted with

flexible rubber pipe and a magnetic stirrer. The whole system, as illustrated in Fig. 4, is integrated with a water bath to maintain constant thermal background through a peristaltic pump.

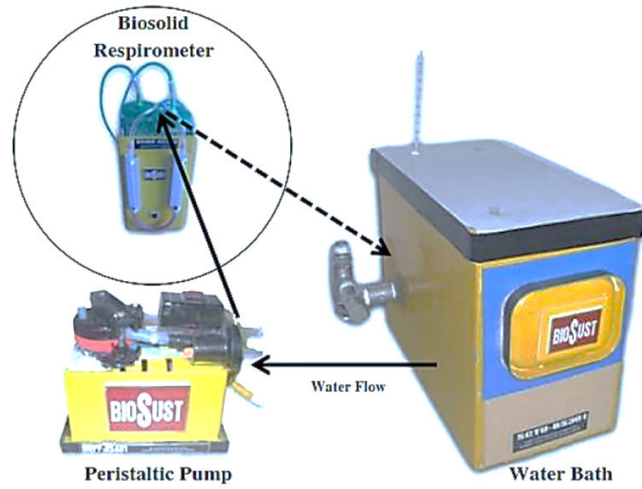


Fig. 4. 'BIOSUST' respirometer integrated with a water bath through a peristaltic pump.

Referring to Fig. 5, Let the initial pressure in both reactors is P_0 (i.e., the barometric pressure at the time the apparatus is closed off), their gas volume up to the meniscus of the index fluid in the symmetrical position is $V_{reaction\ unit} = V_{compensation\ unit} = V_g$. Then approximately the total volume of oxygen consumed in time t is (at STP) given by the relation [12]:

$$V_{O_2\ consumed} = K * \left[\frac{P}{P_{atm}} * \frac{273}{T} \right] * d$$

where, $K = \frac{2V_g}{P_0}$ = flask constant, P =pressure at time t , P_{atm} =atmospheric pressure, T =experimental temperature and d =distance travelled by both meniscus in the manometer tube

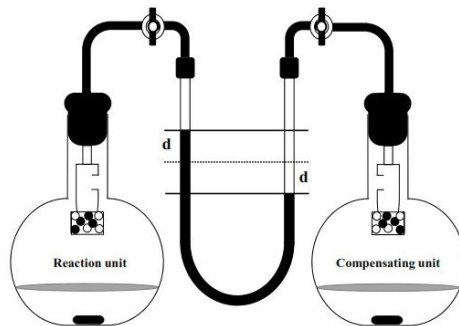


Fig. 5. Schematic diagram of a differential respirometer.

3. Results and Discussion

Respirometric results of the biosolid samples in relation to time as expressed on a cumulative basis over a period of 5 days are illustrated in Fig. 6. It is revealed from the respirogram that the acclimation period for microbial mass is about 20 hours for all the samples. However, for the sample 1 and 2, oxygen utilization keeps going up until reaching the endogenous phase while third sample shows a remarkable inhibitory effect on the oxygen consumption.

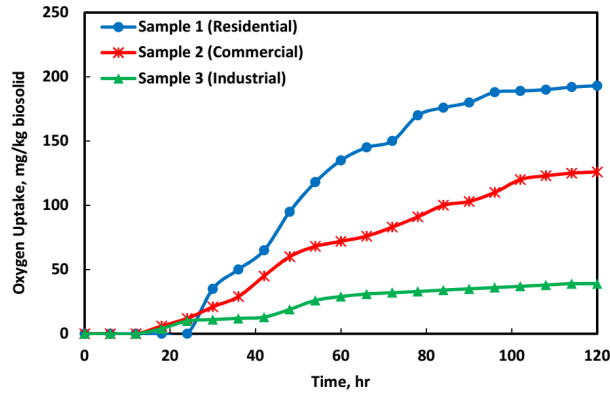


Fig. 6. Respirogram representing cumulative oxygen uptake for 5 days incubation period.

The OUR fingerprint for biosolid sample enriched with residential sludge, as in Fig. 7, indicates the presence of three major groups of organic constituents. The amount of oxygen consumed by the sample within 120 hrs of observation was approximately 200 mg/kg. Here the first peak was observed at about 30 hrs of contact which was 4.25 mg/kg-hr. A second group of readily biodegradable constituents caused a second high OUR peak at 50 hrs. Oxidation of third group of constituent extends beyond 60 hrs. The oxidation of moderately biodegradable organic constituents was followed by a small tail of slowly degrading constituents before returns to endogenous rate.

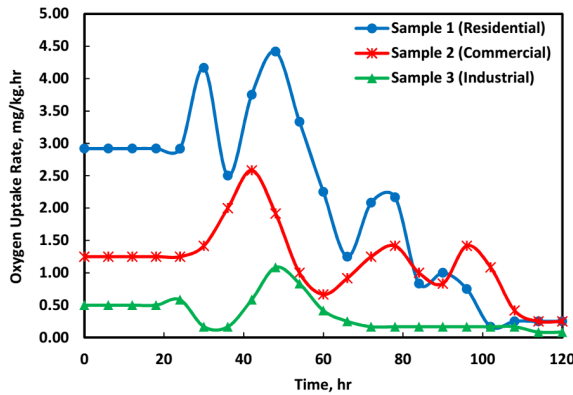


Fig. 7. OUR profile for the biosolid samples.

For the second sample, the first peak was observed at about 43 hours of contact which was 2.50 mg/kg-hr. A second group of biodegradable constituents caused a second high OUR peak at about 78 hours. Endogenous respiration was encountered beyond 110 hours.

A critical phenomenon was observed in the OUR fingerprint obtained for biosolid sample 3 which was enriched with industrial sludge. In this case, after bio-oxidation of a certain organic group, microbial substrate consumption rate was suppressed. A plausible reason behind the suppression may be due to the toxic inhibitory effects exerted on the microbial food consumption by some unknown end products generated during the oxidation of the first group of organic matters. Since the sample was collected from a sewer line enriched with chemical industrial discharges, certain toxic compounds may interrupt the natural biodegradation process.

4. Conclusions

Respirometric method can be a suitable option for assessing biodegradation criteria of biosolid materials without employing complicated and costly microbial bioassay or biochemical laboratory investigation. Some important findings of the study are listed below.

- Biosolids enriched with residential wastewater could be used as soil conditioner and partial fertilizer providing with necessary treatment for field application.
- Due to toxic and inhibitory effects, industrial biosolids should not be used for the soil conditioner directly.
- Industrial wastewater should be treated to minimize the toxic effects before discharge to the natural sinks such as lake or river.

However, these biosolids need to undergo some extra treatment and mixing with other micro-nutrients before practically used as fertilizer in the field. The scope of the present investigation is to quickly sorting out the collected biosolids in favour of soil conditioner and/or fertilizer on the basis of the amount of biodegradable material and microorganism present in the samples. If, through the respirometry, one can prove the sufficiency of organic contents with no toxic or retarding agents, then the biosolids could be recommended as main raw materials for manufacturing of compost fertilizer and/or soil conditioner. Of course the respirometric result is not enough to recommend a biosolid sample to apply in agricultural field directly. The concerned agro-product manufacturing company should perform other important examinations such as moisture content, pH, C/N ratio etc. to prove the suitability of the biosolid materials for field application [13]. Nevertheless respirometry can offer the first screening test employing very simple and cost effective techniques which is very important for the developing countries of the world.

Acknowledgements

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