

# Operation of composting process of sewage Sludge through the respirometer with hermetic rotary reactor

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## Abstract

Our study evaluates the operation of the sewage sludge composting process measured in the gas phase, using of an automated respirometer with hermetic rotary reactor, determining the temporal evolution of O<sub>2</sub> consumption and CO<sub>2</sub> production during the process, obtaining data lines 1440/day, with the advantage of greater representativeness accuracy.

**Keywords:** Composting, Sewage Sludge, Respirometer

## Introduction

Sewage sludge, also known as biosolids, is a byproduct of sewage treatment processes, whose characteristics depend on the quality and types of treatment which it has undergone (Adani et al. 2004; Agrawal and Singhand 2007). Its final disposal is a problematic step that represents up to 50% of the operating costs of sewage treatment plants (Bettoli and Camargo 2007). The pressure imposed by society for better environmental conditions points to the need for advances in the efficiency of wastewater treatment, and consequently of the sludge produced, which must be adequately managed and disposed of in the environment (Agrawal and Singhand 2007). Because it is not compactable, cut grass occupies considerable space in landfills, reducing their service life and increasing operating costs, thus requiring the creation of more efficient forms of treatment for its disposal.

Composting thus appears as an alternative method for the decomposition of organic matter. Several studies have employed composting for the treatment of sewage sludge (Amir et al. 2005; Bettoli and Camargo 2007; Fang et al. 1999; Fang and Wong

1999, Jouraiphy et al. 2005; Kovacs et al. 2007; Ponsa 2009; Tremier et al. 2005; Ubay et al., 2007), to produce stabilized and pathogen-free compost for use as fertilizer.

The discussion about indicators for determining the stability of compost is fraught with controversy. Several authors have suggested the use of different indices of stabilization (C/N, humidification and germination indices, respirometric indices) (Gómez et al. 2006; Guadia et al. 2008; Hamoda et al. 1998, Jouraiphy et al. 2005; Komilis 2006; Ponsa et al. 2009). In aerobic composting processes, in which the activity of aerobic bacteria predominates, the rate of oxygen consumption ( $O_2$ ) and of carbon dioxide ( $CO_2$ ) production over time can be controlled in an enclosed environment, e.g., inside a reactor (Fang et al. 1999; Gea et al. 2004; Scaglia et al., 2005). This process is known as the respirometric method. Among the various tested indices, the oxygen consumption rate (also called the dynamic respirometric index) has provided the most reliable values for the evaluation of microbial activity in a composting environment.

The purpose of this investigation is to apply the respirometric method in sewage sludge and grass co-composting, evaluating the feasibility of implementing it as a tool to obtain precise parameters of organic matter degradation, as well as parameters for the design and operation of the process, seeking to achieve greater efficiency in the use of this organic matter. For this research we used an automated respirometer with hermetic rotary reactor developed in an experimental project conducted at the School of Engineering – FEB of the São Paulo State University – UNESP at Bauru, state of São Paulo, Brazil. In this method, the parameters of the biological degradation of organic waste are measured in the gas phase, ensuring the homogeneity of the results obtained by monitoring the  $O_2$  consumption rate,  $CO_2$  production, biochemical oxygen demand (BOD), pH, the carbon: nitrogen (C: N) ratio and moisture in real time.

## Materials and Methods

Experiments were conducted to evaluate the performance of the automated respirometer with hermetic rotary reactor developed for use with the respirometric method in the co-composting of sewage sludge and cut grass. These experiments were performed on the premises of a composting pilot project at the Laboratory of Solid Waste, School of Engineering – UNESP at Bauru.

The use of the respirometric method involved the assembly of an automated respirometer with a hermetic rotary reactor Figure 1 illustrates the general structure of the apparatus developed to analyze the composting experiment. The apparatus consisted of the following elements: a 90-liter rotary drum enclosed inside a box equipped with glass viewers (to minimize the odor of the process and allow it to be viewed), a gas analyzer, and a computer for automatic data acquisition and control of the rotary drum. The devices are interconnected and interdependent.

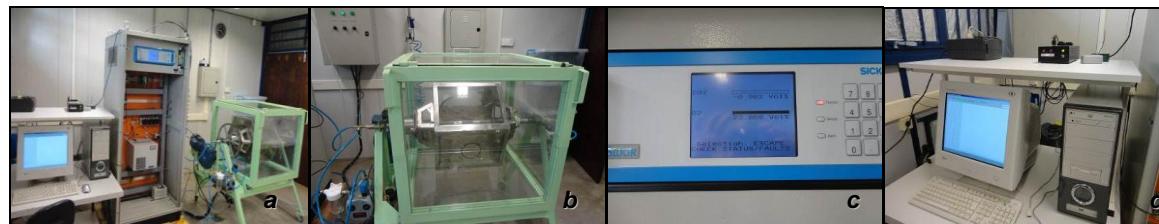


Figure 1 – (a) General structure of the apparatus, (b) rotating drum, (c) gas analyzer, and (d) microcomputer for data acquisition

The apparatus is also equipped with two sets of blowers (air pumps), one for feeding the reactor and the other for recirculation. Connected to the recirculation line, the complete system has a gas analyzer (Sick Maihak S710) equipped with a display, which records the gas concentrations in percentages (%O<sub>2</sub> and %CO<sub>2</sub>), with options to collect and record data at intervals of 1s to 600s. For this experiment, the data collection interval was set to 60s to record a total of 1,440 rows of data per day. This apparatus has a serial communication interface that sends the data to a computer, which receives them online in the form of a sequence of alphanumeric characters (string).

A specific software program was developed at the School of Sciences of UNESP Bauru, which receives data continuously from the analyzer, and separates the information about the levels of O<sub>2</sub> and CO<sub>2</sub>. According to the percentage levels of gas concentrations, the software also controls a hardware mechanism that enables injecting a desired and predetermined concentration of air flow into the reactor to consume the bacteria involved in the degradation of the wastes. In this study, we worked with O<sub>2</sub> levels ranging from 5% to 20%.

The waste was sewage sludge from the “Manoel Ferreira Leão Neto” Sewage Treatment Plant of the Water and Sewerage Department of the city of Araraquara, state of São Paulo, Brazil. This liquid material was subjected to a dehydration process to remove its moisture. The sewage sludge was co-composted with cut grass (chopped) collected during the grass mowing of public areas by the Municipal Administration of Bauru. Figure 2 illustrates the wastes used. Table 1 lists the values of the inorganic substances found in the sludge and the maximum permissible values. Before starting the co-composting process, the solid phase of the sewage sludge was analyzed in the laboratory, and the results of this analysis are given in Table 2.



Figure 2 – (a) Sewage sludge received from the treatment plant (with high moisture content), (b) dehydrated and ground sewage sludge, (c) grass cutting service of the City of Bauru, (d) dried and chopped grass

Table 1 – Maximum permissible concentrations of inorganic substances in sewage sludge destined for agricultural use and the values found (dry weight)

Substances	Maximum Concentration*	Sewage sludge **
Arsênio (mg.kg <sup>-1</sup> )	41	-
Bário (mg.kg <sup>-1</sup> )	1300	-
Cd (mg.kg <sup>-1</sup> )	39	< 0,0006
Pb (mg.kg <sup>-1</sup> )	300	< 0,02
Cu (mg.kg <sup>-1</sup> )	1500	31,00
Cr (mg.kg <sup>-1</sup> )	1000	42,00
Hg (mg.kg <sup>-1</sup> )	17	-
Molibdênio (mg.kg <sup>-1</sup> )	50	-
Ni (mg.kg <sup>-1</sup> )	420	< 0,008

Selênio ( $\text{mg} \cdot \text{kg}^{-1}$ )	100	-
Zn ( $\text{mg} \cdot \text{kg}^{-1}$ )	2800	150,00

Source: \* Resolution nº 375 from Conselho Nacional do Meio Ambiente (CONAMA), 2006.

\*\*Hidrosan Engenharia.

Table 2 – Values obtained in laboratory tests of the compost obtained in the process of co-composting of sewage sludge with cut grass

Parameter	Value
C%	22,67
N%	1,44
w%	14,62
C/N	16/1
Ph	8,02

## Results and Discussion

The composting process was started on 24 Jan 2012, after concluding the data collection on 29 Feb 2012, which resulted in 39,870 rows of data. The ratios of oxygen consumption, production of carbon dioxide and BOD were determined and analyzed based on the unit mass (g) measured in each of the 55 “purging cycles.” This purging involved discharging the gases present in the rotary reactor and introducing of a new volume of ambient air whenever the percentage of O<sub>2</sub> reached levels below the programmed one, in simultaneous cycles, until the compost became stabilized.

Figure 3 shows a high initial consumption of close to 8 g/cycle, which stabilizes at approximately 6.5 g/cycle. This consumption gradually decreased until it reached a value of 1 g/cycle, confirming the end of the waste decomposition process. It was also observed that by the end of the 55 purging cycles, approximately 355.83 grams of oxygen were consumed. These data can be used in large scale projects.

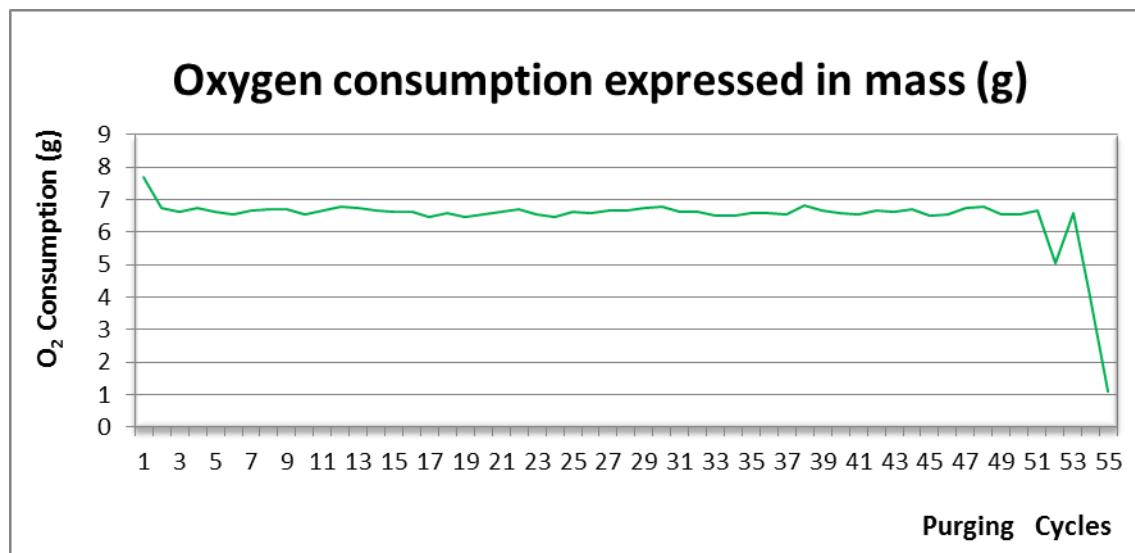


Figure 3 – Oxygen consumption expressed in mass (g) distributed over the period of the composting process

Figure 4 illustrates the production of carbon dioxide during the purging cycles. The unit of measurement used here is mass (in grams). Note the high initial production of close to 14 g/cycle, which then remains close to 12 g/cycle during most of the process, declining to about 2 g/cycle once the process has stabilized. The total production of carbon dioxide, expressed in mass, was approximately 624.08 g.

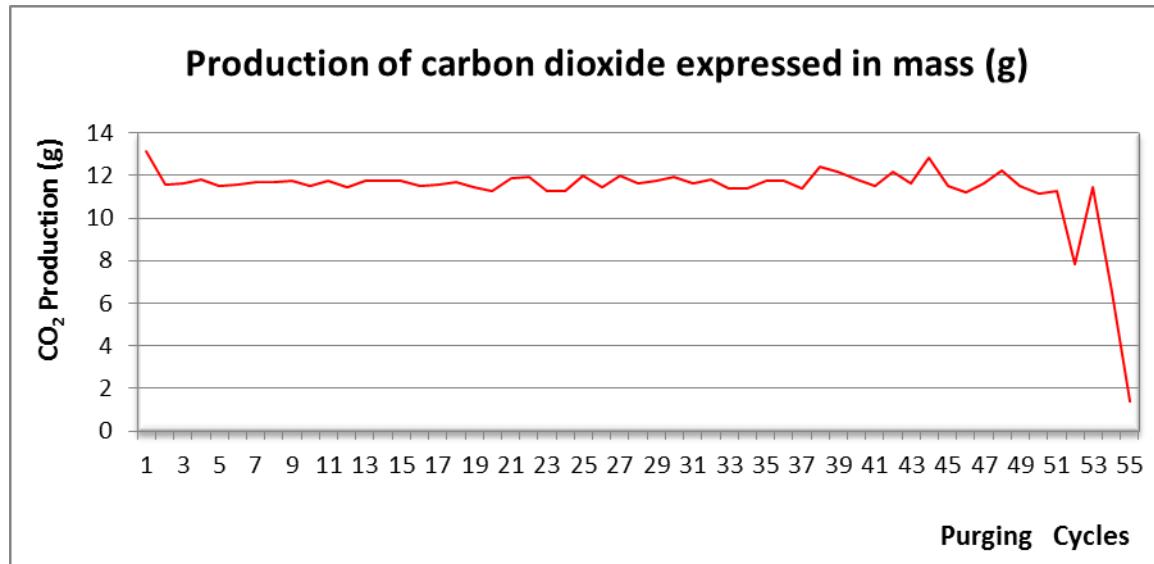


Figure 4 - Production of carbon dioxide expressed in mass (g) distributed during the process

Figure 5 illustrates the ratio of the percentage O<sub>2</sub> to that of CO<sub>2</sub> (CO<sub>2</sub> / O<sub>2</sub>). This index ranges from 0.8% to about 1% in the period in which the process is in its most active phase. As the process nears its conclusion, this index declines to about 0.65%.

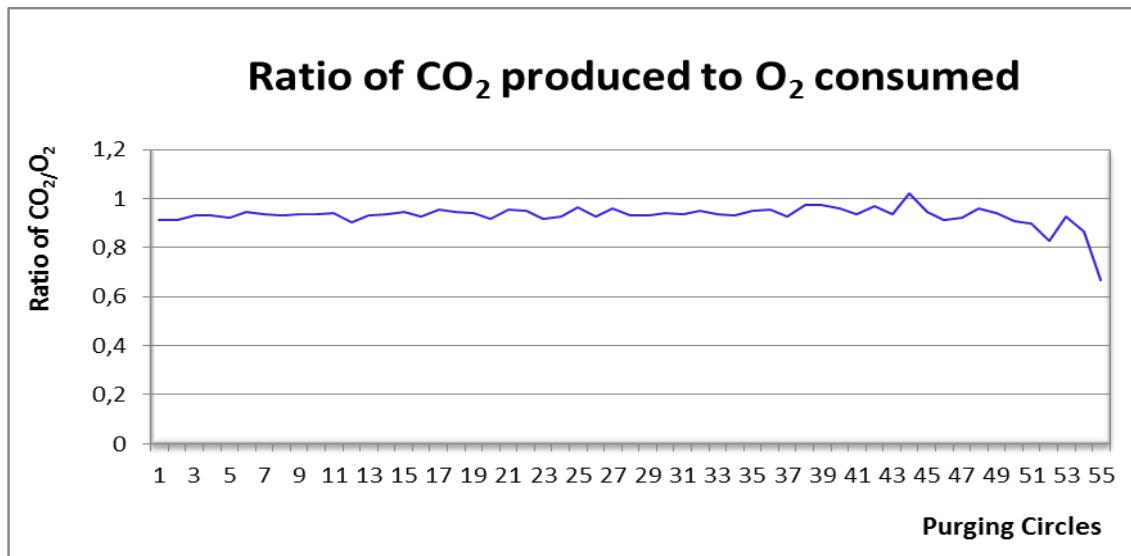


Figure 5 – Ratio of CO<sub>2</sub> produced to O<sub>2</sub> consumed in each purging cycle

Figure 6 depicts the BOD, which is the unit of measurement for calculating the

amount of oxygen consumed by bacterial activity, which is proportional to time, i.e., the longer the time the greater the amount of biodegradable organic matter decomposed by the activity of aerobic bacteria.

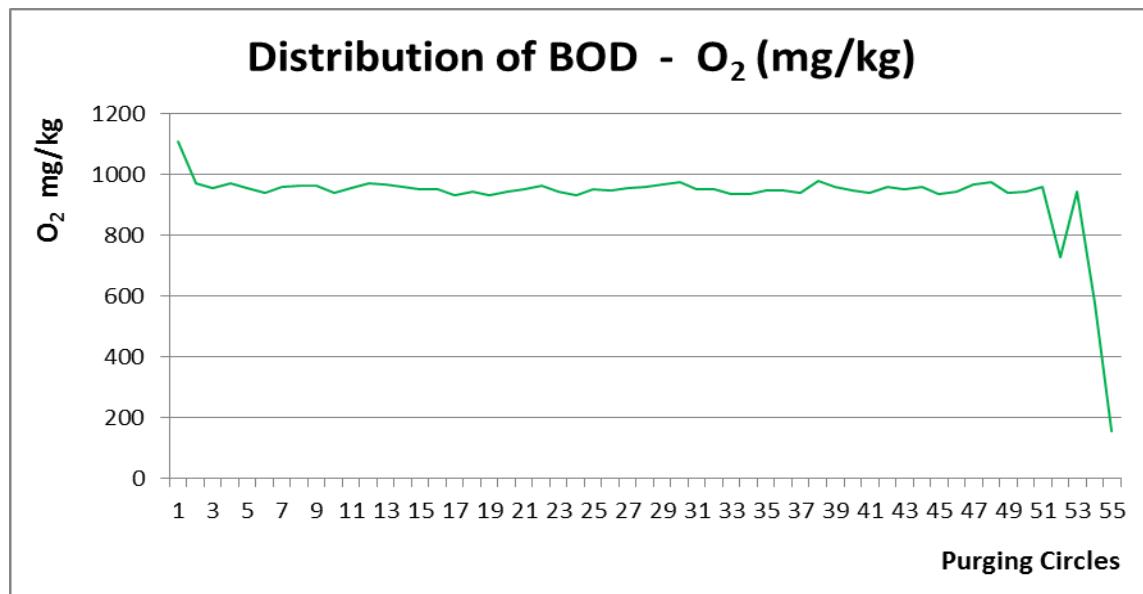


Figure 6 – Distribution of BOD during the composting process

The BOD value indicates the oxygen flow required to decompose an organic material, enabling one to calculate the time and the quantity of gas involved in composting. In other words, one can dimension the entire process and the reactor to be used, and thus apply its parameters to a real scale process.

The values of moisture and pH were evaluated manually in the gas analysis of the process since they are not yet automated. In Figure 7, note that the moisture showed indices of 25% to 40% below the indices considered optimal for the process, which would be from 50 to 65%.

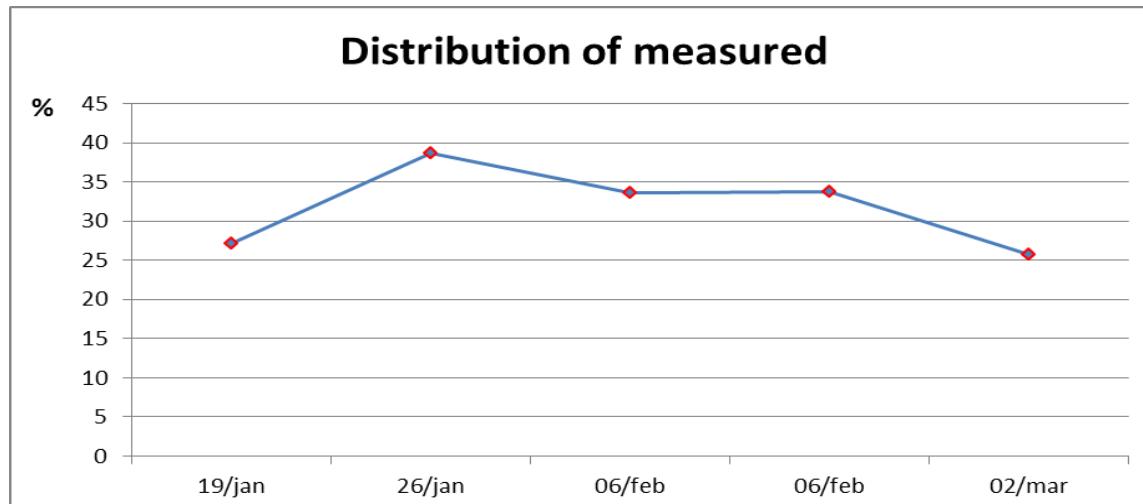


Figure 7 – Distribution of measured moisture presented by the compost during the composting period

In Figure 8, note that the pH measured at the beginning, which was almost neutral, i.e., 7.0, became alkaline during the process, showing a pH of 7.5 to 8.5.

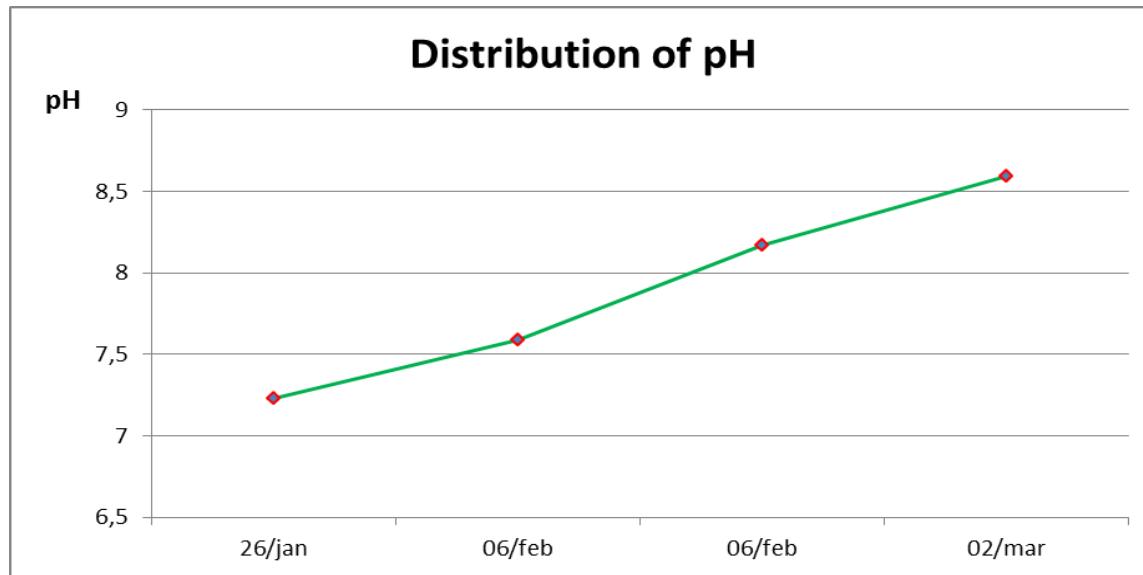


Figure 8 – Distribution of pH measured in the compost during the composting period

Monitoring the C: N ratio during composting indicates the progress of the process, since when the compost reaches a semi-cured state or biostabilization, the C: N ratio is around 18/1 and the pH between 7 and 8 [14]. The compost showed a C: N ratio of 16/1 and a pH of 8.02, demonstrating its stability. The pH was found to decrease by the end of the process, declining from 8.59 to 8.02 after 106 days.

## Conclusions

Evaluations of the traditional composting process by means of solid medium are basically limited to the analysis of the parameter of temperature, which is measured randomly in a heterogeneous medium and at very long intervals of time.

The respirometric method proved to be an extremely useful and reliable tool with respect to the responses it can provide in the operational monitoring and evaluation of the progressive degradation of solid waste. The measurements of parameters in the gas phase, based on the evolution of O<sub>2</sub> consumption and the respective CO<sub>2</sub> production over time, proved to be far superior in terms of representativeness, accuracy and reliability when compared with the traditional method.

Our contribution to the evaluation of the respirometric method by co-composting of sewage sludge and grass enables the parameters of the method to be used for the design, operation and control of the composting process applied to a real scale process.

With regard to the wastes used here, co-composting sewage sludge and grass clippings proved to be viable, and its use as an agricultural compost offers environmental advantages over other practices of final disposal of these two wastes.

Another contribution of this work was to accelerate the composting process, which lasted only 30 days, compared to the sewage sludge composting times of 100 and 135 days reported by other studies.

The concern raised by using sewage sludge as a fertilizer lies in the disinfection

of pathogens and the percentage of heavy metals commonly found in this type of waste, and several studies have used techniques to minimize the presence of heavy metals. The sludge used in this study contained no heavy metals that would represent risks for its use as a fertilizer. However, for future research we suggest that the apparatus developed here be used in monitoring the composting of sewage sludge containing higher percentages of heavy metals.

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