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Wireless sensor network for smart composting monitoring and control

Oscar Casas [a], Marga López [a], Marcos Quílez [a], Xavier Martinez-Farre [a], Gemma Hornero [a], Carlos Rovira [b], Mirta R. Pinilla [b], Pedro M. Ramos [c,*], Beatriz Borges [c], Hugo Marques [c], Pedro Silva Girão [c]

[a] Universitat Politècnica de Catalunya, Parc Mediterrani de la Tecnologia, Campus del Baix Llobregat, C/ Esteve Terradas, 7/8, 08860 Castelldefels, Spain
[b] Iris – Innovacio i Recerca Industrial i Sostenible, Parc Mediterrani de la Tecnologia, Avda. Carl Friedrich Gauss n° 11, Castelldefels, Spain
[c] Instituto Superior Técnico-UL, Instituto de Telecomunicações, Av. Rovisco Pais, 1, 1049-001 Lisbon, Portugal

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ABSTRACT

This article describes a wireless sensor network (WSN) designed and implemented to monitor and assist composting processes. After framing the problem, the objectives and characteristics of the WSN are discussed and a detailed description of the hardware and software of network components are presented. The article ends with the presentation and discussion of results obtained with the network.

1. Introduction

The increase of the world population during the last 50 years (from about 3 billion people in 1960 to over 7 billion at present) and of the consumption of goods and products led to the huge production of waste resulting from human activity. The stress of this waste on the environment is particularly important since it includes important quantities of non-bio degradable and even poisonous elements (e.g., gaseous products, plastics, metallic and glass packages and containers, chemicals, etc.). Global warming and pollution events affecting namely water supplies in all continents have been instrumental in the increase of the political consciousness of dealing with all the problems that can endanger the world in which we live. On the other hand, the increase in the demand of raw materials led not only to the increase of their prices, but also to the economic viability of product recycling for reuse. It is in this context that, in developed countries, local, regional, and national authorities promote or even enforce solid waste (both industrial and urban) management policies with resources recovery as one of the objectives.

There are multiple types of organic waste produced by different activities. This includes biowaste (e.g., plant material, food leftovers, food waste), manure, sewage sludge from wastewater treatment, etc., that can be recovered through composting in order to decompose the organic matter and transform the waste into a stable product, useful for agricultural or landscaping purposes. Since Directive 1999/31/EC on the landfill of waste promoted the reduction of biodegradable material in landfill, biological treatments were enhanced.

* Corresponding author. Tel.: +351 218418485.
E-mail addresses: jaime.oscar.casas@upc.edu (O. Casas), marga.lopez@upc.edu (M. López), marcos.quilez@upc.edu (M. Quílez), xavier.martinez-farre@upc.edu (X. Martinez-Farre), gemma.hornero@upc.edu (G. Hornero), crovira@iris.cat (C. Rovira), mpinilla@iris.cat (M.R. Pinilla), pedro.m.ramos@ist.utl.pt (P.M. Ramos), bborges@lx.it.pt (B. Borges), hdsm@lx.it.pt (H. Marques), psgirao@ist.utl.pt (P.S. Girão).

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In [1], compost is defined as an "organic soil conditioner that has been stabilised to a humus-like product, that is free of viable human and plant pathogens and plant seeds, that does not attract insects or vectors, that can be handled and stored without nuisance, and that is beneficial to the growth of plants". To obtain this product, both quality of the raw materials and management of the process are of main interest; on one hand, the presence of inorganic pollutants can limit the use of the product regarding regulations. On the other hand, even when the material is free of pollutants, if initial conditions (mixtures, water) are not properly defined to ensure microbial activity and there is no control of the process through different parameters, the final quality will probably not achieve the standards of stability and hygienisation to be safely used.

There are different systems that allow obtaining adequate compost. Generally, they are based on the monitoring of some basic parameters, such as temperature and moisture, to ensure the quality of the final product and process efficiency. This paper presents a wireless system to control temperature and moisture in composting processes. The system is composed of multiple nodes, placed within the composting pile. Each node measures the temperature and moisture and relays these values to a pile-hub device located outside the pile.

2. Composting

2.1. The composting process

Composting is an aerobic, biologic and thermophilic process that allows transforming a biodegradable material into a stable product, the compost, useful to improve the quality of soil as long as the process has been controlled and raw materials have enough quality. There are several definitions of composting, more or less complex, but the aforementioned concepts include the main keys to be considered in a composting process to produce quality compost. This transformation involves the reduction in weight and volume through the aerobic conversion of the organic compounds into CO_2 and water, and the stabilisation of the material.

Composting can be divided into two phases, decomposition and maturation, basically according to the evolution of the material temperature. During the first phase, intense degradation is produced due to high microbial activity and the increase in temperature is rapid (see Fig. 1). After this period, the reduction in biodegradable material available to microorganisms reduces the activity and the temperature slowly reduces.

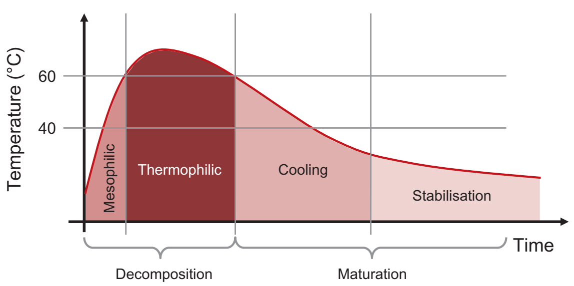

Fig. 1. Temperature evolution during the two phases of the composting process.

The decomposition phase typically lasts over 30 days in windrow composting, while in vessel composting it can be shorter (about 15–20 days) due to more intensive production conditions. During this stage, most of the composting windrows have a height of 1.5 up to 3 m, depending on the turning machinery, but can even be higher, between 3 and 4 m high, when they are not turned, as in extended piles. Other static systems different from in-vessel can also supply the air without turning through perforated slabs, so the size of the heaps can vary significantly.

The moisture content should ideally be around 60% at the beginning of the process, when the different organic wastes are mixed. If moisture content exceeds 60%, there is a loss in porosity and thereby the procedure becomes anaerobic. Fermentation will set in and odours will be emitted from the material as well as methane as a result of the anaerobic decomposition of the biodegradable wastes. If the moisture content decreases below 50%, the rate of decomposition decreases because nutrients must be in solution to be used by microorganisms. Maintaining the correct moisture level during the thermophilic phase of composting can be difficult, especially in an open-air windrow system, due to dry or wet climatic conditions. When the composting activity is greater and temperatures in the core of the composting pile are very high, water must be added at regular intervals to support and maintain maximum activity. It is critical to maintain the moisture level near 60% in the initial period of composting. If the moisture level falls below 50%, composting activity will slow down and eventually cease as the material continues to dry.

The second stage of the composting process is the maturation phase that, in most of the cases, lasts between 30 and 60 days. There are however cases where this stage lasts longer. Along this phase, temperature will diminish and stable structures appear. The dimensions of the composting piles during this phase are not very different from the ones of the decomposition stage. When maturation phase starts, a decrease in biodegradable matter from the decomposition can be observed. Even though the microbial population needs oxygen to maintain its activity to achieve stabilisation, turning or forced aeration is needed less frequently than during decomposition.

Complete monitoring and control of the composting process involve the measurement of several quantities namely, temperature, moisture, oxygen, pH, carbon-to-nitrogen ratio [2], and even volatile organic compounds [3]. Oxygen must be guaranteed since composting is an aerobic process, but minimum moisture content must be also assured to allow microorganisms to develop their degrading activity, where temperature is its direct consequence. So, oxygen, temperature and moisture are the most important indicators of how the composting process is evolving. They must be correctly monitored if one aims to improve the quality of the resulting compost.