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Use of oleaginous plants in phytotreatment of grey water and yellow water from source separation of sewage

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ABSTRACT

Efficient and economic reuse of waste is one of the pillars of modern environmental engineering. In the field of domestic sewage management, source separation of yellow (urine), brown (faecal matter) and grey waters aims to recover the organic substances concentrated in brown water, the nutrients (nitrogen and phosphorous) in the urine and to ensure an easier treatment and recycling of grey waters. With the objective of emphasizing the potential of recovery of resources from sewage management, a lab-scale research study was carried out at the University of Padova in order to evaluate the performances of oleaginous plants (suitable for biodiesel production) in the phytotreatment of source separated yellow and grey waters. The plant species used were *Brassica napus* (rapeseed), *Glycine max* (soybean) and *Helianthus annuus* (sunflower). Phytotreatment tests were carried out using 20 L pots. Different testing runs were performed at an increasing nitrogen concentration in the feedstock. The results proved that oleaginous species can conveniently be used for the phytotreatment of grey and yellow waters from source separation of domestic sewage, displaying high removal efficiencies of nutrients and organic substances (nitrogen > 80%; phosphorous >90%; COD nearly 90%). No inhibition was registered in the growth of plants irrigated with different mixtures of yellow and grey waters, where the characteristics of the two streams were reciprocally and beneficially integrated.

Introduction

The traditional concept of using huge quantities of water to transport domestic waste away from households, resulting in the production of diluted wastewater streams and treatment at centralized facilities, has often been reconsidered due to the related costs, high use of resources and significant surface occupancy (Butler and Parkinson, 1997; GTZ, 2003; Gandini, 2004).

More and more attention is being focused on sustainable sanitation systems, aimed at closing nutrient and water cycles, with low material and energy consumption. In these systems, sewage is considered a valuable source of nutrients and water for plant growth. Sustainable sanitation systems are generally based on collection and treatment of different source-separated sewage streams: yellow water (urine); brown water (faeces) and grey waters from kitchen, laundry, dishwasher, shower, *etc.* (Langergraber and Muellegger, 2005; Cossu et al., 2003a, 2003b;

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Borin et al., 2004). Source separation is carried out to optimize the potential for reuse when compared to "end-of-pipe" technologies (Larsen and Maurer, 2011).

Depending on the purpose of reuse, several studies focusing on the treatment of source-separated sewage streams applied technologies largely similar to those adopted in the conventional treatment of combined wastewater (Jefferson et al., 1999; Maurer et al., 2006; Escher et al., 2006; Kujawa-Roeleveld and Zeeman, 2006; Leal et al., 2010; Larsen and Maurer, 2011; Saeed et al., 2014; Zhang et al., 2015), whilst only a few cases have been studied and used for the phytotreatment of grey waters (Frazer-Williams et al., 2008; Fangyue et al., 2009; Vymazal, 2009).

A sustainable source-separated system, named "Aquanova", has been developed since the early nineties at the University of Padova. The system is aimed at optimizing the integrated management of various source separated sewage stream and biodegradable fractions of solid waste (Cossu et al., 2003a, 2003b).

The Aquanova system is graphically described in Fig. 1. Three different sewage streams are segregated using a source separation toilet and separate piping for grey water outflows. Yellow water and grey waters undergo phytotreatment, while brown waters mixed with shredded kitchen waste undergo anaerobic digestion.

Several aquatic plant species – such as *Acorus calamus Variegatus*, *Alisma plantago aquatica*, *Calla palustris*, *Canna indica*, *Eupatorium cannabinum*, *Iris pseudacorus*, *Lythrum salicaria*, *Lobelia cardinalis*, *Lysimachia nummularia*, *Mentha aquatica Rubra*, *Thalia dealbata*, *Typha latifolia*, *Lemna minor*, *Eichornia crassipes*, *Phragmites australis*, *Typha* – and natural mountain flora – such as *Aconitum napellus*, *Senecio cordatum*, *Senecio rupestre*, *Epilobium alpestre*, *Achillea millefolium* – have been tested in lab-scale and full scale phytotreatment units under different operative conditions, in previous research programmes performed by the authors of this paper (Cossu et al., 2003a).

The results of these studies confirmed the good performances of a wide species of plants in the phytotreatment of grey and yellow waters (Borin et al., 2004).

Considering the interest developed in recent years in the production of alternative energy from oleaginous crops, and the related concern for competing land use by energy crops (the "table or tank dilemma"), the present research was conceived in order to investigate the phytotreatment of source segregated sewage fractions using oleaginous crops active under temperate climatic conditions such as soybean (*Glycine max*), rapeseed (*Brassica napus*) and sunflower (*Helianthus annuus*), already taken into consideration for use in the production of industrial biodiesel (Lavagnolo et al., 2016, Meher et al., 2006; Zegada-Lizarazu and Monti, 2011). In particular, biofuel obtained from sunflower and rapeseed was found to be of excellent quality due to the high content of monounsaturated esters (Ramos et al., 2009).

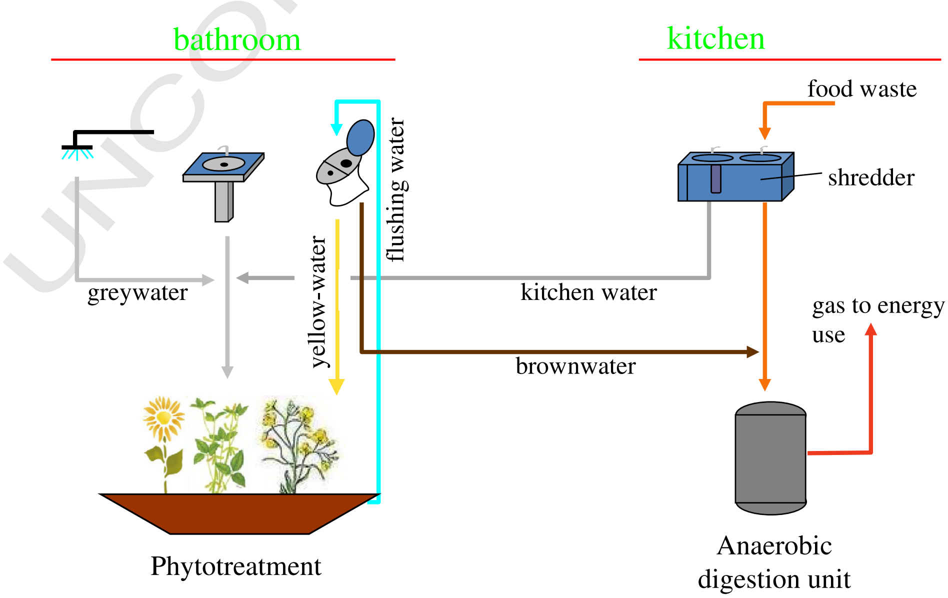
1. Materials and methods

1.1. *Wastewaters*

The experiment was carried out at the Environmental Engineering Centre, Department of Industrial Engineering, University of Padova, where the Aquanova system has been implemented.

The following waters were used as feedstock: grey waters from bathroom sinks (GW); kitchen waters from kitchen sink (KW); yellow waters (YW) from a source segregation toilet (Fig. 2a).

Wastewaters samples were analysed according to the Italian standard analytical methods (CNR-IRSA, 29/2003) and measured in triplicate. pH, alkalinity, total solids (TS), volatile solids (VS), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), N-NH_4^+ and the other parameters listed in Table 1 were taken into account to characterize the feedstock. COD was evaluated by the potassium dichromate oxidation method. BOD_5 was evaluated using a respirometer apparatus (Sapromat E). BOD_5 of kitchen water was



Q1 **Fig. 1 – Scheme of the Aquanova system for the integrated management of sewage and kitchen waste (Cossu et al., 2001).**

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