Waste Research at the IRNAS, CSIC

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The agricultural and livestock sectors are of great significance in the region of Andalusia (South of Spain) (Table 1). Important quantities of agricultural and agroindustrial residues are generated by these activities, frequently causing environmental problems. These residues contain organic matter and nutrients and could therefore be recycled and used as fertilizers or amendments, with or without a previous treatment (composting, concentration). For some of these wastes, recipes for compost mixes, such as olive oil wastewater based compost, have been developed by private companies. Afterwards, laboratory and field experiments have been conducted to study the best conditions for their agricultural use and their degradation process in the soil (González-Vila *et al.*, 1992, Martín-Olmedo *et al.*, 1994). In other cases, such as those of the vinasse based composts, both the compost fabrication and its use have been studied previously to the marketing stage (Díaz *et al.*, 1993, Madejón *et al.*, 1994). Our first research projects at IRNAS dealt with the properties and reuse of municipal solid waste (MSW), and are still in progress.

Table 1 Some figures showing the importance of the agricultural sector in Andalusia and Spain (Ministerio de Agricultura de España, 1993)

Final Agricultural Output (1991)					
Spain/EC	%	Agriculture		15	
		Livestock		10	
		Agriculture + Livestock		13	
		Agrofood Industry		10.5	
Working Population in Agriculture in Spain				10.7%	
Land Distribution in Spain (1991)		Arable land	Grazing land	Woodland	Other
Spain	1000 ha	20089	6438	15858	8084
Andalusia	1000 ha	4175	708	2655	1191
Andalusia/Spain	%	21	11	16	15
Livestock Distribution (1992)		Cattle	Sheep	Goats	Pigs
Spain/EC	%	6.3	25	23	17
Andalusia	1000 heads	516	3144	1169	1972
Andalusia/Spain	%	10.4	12.8	41.2	10.8

Table 2 shows a list of the most intensively studied wastes at the IRNAS. The topics covered for these wastes include the monitoring of the performance of various treatment systems (concentration, aerobic and anaerobic treatment), the study of the composting process and the study of land treatment or land utilization with treated and untreated wastes. In many of these studies, special attention has been paid to the interaction phenomena in the system waste-soil-plant-water. Some usual aspects studied in this context are shown in Figure 1.

Table 2 Some residues studied at the IRNAS

Waste use	Treatment/Recycling	Research	Selected References	Actual
		(1)		(2)
Sugarbeet Vinasse	Concentration			E
	Anaerobic treatment			
	Use of effluents	***	Cabrera <i>et al.</i> , 1987	D
Concentrated Vinasse	Direct land reuse	***	González-Vila <i>et al.</i> , 1992	E
			Martín-Olmedo <i>et al.</i> , 1995	
			Murillo <i>et al.</i> , 1993	
			Díaz <i>et al.</i> , 1993	F
	Co-composting with cotton gin trash, olive press cake, grape marc and use as fertilizer	***	Madejón <i>et al.</i> , 1994, 1995	
Olive mill wastewater	Several treatment systems	***		D
	Land utilization of anaerobic treated effluents	***	Cabrera <i>et al.</i> , 1987	D
	Direct land treatment	***	López <i>et al.</i> , 1992	D
	Composting and use	***	González-Vila <i>et al.</i> , 1992	E
			López, 1992	
			Martín-Olmedo <i>et al.</i> , 1995a,b	
Olive mill wastewater + olive press cake (from new system)	Composting	*		F
Wheat straw	Composting	***	Almendros <i>et al.</i> , 1987	N
Extracted eucalyptus leaves	Use of compost	**	Murillo <i>et al.</i> , 1990	D
MSW	Composting and use	***	Cabrera <i>et al.</i> , 1989, 1991	
			Fernández <i>et al.</i> , 1987	
			González-Vila <i>et al.</i> , 1982, 1985	
			Murillo <i>et al.</i> , 1989a, b, 1991	
			Troncoso <i>et al.</i> , 1983	E
Sewage sludge	Composting	***	Hernández <i>et al.</i> , 1990	E

(1) * Starting; ** In progress; *** Advanced or finished

(2) N, without application; F, probable use in future; D, developed for use but not used or used in few cases; E, extensive use

Municipal Solid Waste (MSW)

Since 1965, several composting plants have been established in Sevilla and nearby cities. The Sevilla urban compost plant, the biggest in Andalusia, was closed some years ago, but now the Government is encouraging new plants for Sevilla (1300 ton day⁻¹ of MSW) and other municipalities. Most of the compost produced in these

plants is applied to the rice paddies in the Guadalquivir delta and to vineyards.

Some research projects on wastes in the IRNAS dealt with the properties and effects caused by MSW on soils and plants. Compost from the Sevilla composting plant was often employed in these studies which were focused on:

1. The characterization of the organic matter of the composts (González-Vila and Martín, 1985; González-Vila *et al.*, 1982; Fründ *et al.*, 1987; Almendros *et al.*, 1987a, 1991) and the fitting of techniques and analytical procedures.
2. The effects of the agricultural use of composts in the soil organic fractions, mainly the humic acids (González-Vila and Martín, 1987) and the soil lipids, which exercise a considerable influence on the physical and biochemical soil properties related to its fertility level (González-Vila *et al.*, 1985).
3. The effects of the compost on the soil nutrient contents, such as phosphorus (Cabrera *et al.*, 1991), potassium (Murillo *et al.*, 1991) and heavy metals (Cabrera *et al.*, 1989).
4. The effects on the soil physical properties (Fernández *et al.*, 1987).
5. The response of various plant species to compost addition (Hernández, 1989; Hernández *et al.*, 1992; Murillo *et al.*, 1986, 1989a, b, c, 1995; Troncoso *et al.*, 1983).

Vinasse

Vinasse (V) is the wastewater obtained from the distillation of alcohol after the alcoholic fermentation of sugarbeet molasses. Normal vinasse has high BOD ($20\text{--}70\text{ g L}^{-1}$) and high salt content ($\text{EC } 25\text{--}30\text{ dS m}^{-1}$) (Table 3). In Spain, ca. 10^6 m^3 per year of normal vinasse are produced.

Until a few years ago, sugarbeet vinasse was kept in evaporation ponds, which can cause pollution of ground water, a strong smell, appearance of insects and other nuisances. The first studies on vinasse at the IRNAS dealt with the pollution of wells surrounding the vinasse ponds. Following this investigation, sugar companies decided to treat vinasses.

Table 3 Characteristics of sugarbeet vinasses

		Normal	Concentrated
pH		4.3–5.0	4.6–5.3
Dry matter	% w/w	10.6–15.3	25–63
Org. matter	% w/w	7.4–11.1	23–40
N–Kjeldahl	% w/w	0.5	1.7–3.3
P (P_2O_5)	% w/w	0.01	0.1
K (K_2O)	% w/w	0.7	2.2–4.6
Ca	% w/w	0.25	0.3–1.0
Mg	% w/w	0.16	0.3–0.7
Na	% w/w	0.4	1.3–2.8

Plants for anaerobic treatment were designed and the effluents of these plants

were used in fertirrigation (Cabrera *et al.*, 1987). These studies showed decreases in crop yields due to low P supply and salt accumulation in the soil treated with vinasse. A few factories installed systems for the anaerobic treatment but some others installed systems to produce concentrated vinasse which shows better properties for its recycling (Table 3). Concentrated vinasse (CV) is being used as fertilizer and for animal feeding, but the high salt content of the vinasse produced in the south of Spain limits use for a second time.

The experiments carried out with CV applied to several crops showed that moderate doses of CV ($<9000 \text{ kg ha}^{-1}$) did not cause any damage to germination and seedling performance (López, 1992; López *et al.*, 1993; Murillo *et al.*, 1993a). Concentrated vinasse (P supplemented) applied in deep fertilization produced yields similar to, or even higher than those obtained with mineral fertilizers (López, 1992, 1993; Murillo *et al.*, 1993b). These yields are related to the high nitrogen mineralization rate of vinasse (López, 1992; Martín-Olmedo *et al.*, 1995a).

Soils treated for 3 years with CV showed a moderate increase in their fertility levels (Lopez, 1992), particularly in organic-N which is slowly released over time (Martín-Olmedo *et al.*, 1995a). No salt accumulation in treated soils was found after three consecutive years of application, despite the high salt content of vinasse.

No significant changes were observed in the humic fractions and lipid content of treated soils (2 years). However, analyses by GC-MS of the lipid compounds occurring in the subsoil layer in bound forms, revealed that some hydrophobic components had accumulated (González-Vila *et al.*, 1992).

The concentrated vinasse is also being co-composted with other abundant by-products produced in Andalusia, mainly to facilitate its incorporation into the soil, which presents some problems due to its high viscosity. The composting process was studied (Díaz *et al.*, 1993) and the compost was employed in greenhouse and field trials with excellent results particularly in the fertilization of sugarbeet and cotton (Madejón *et al.*, 1994, 1995). Some communications on this subject are presented at this Congress (see Madejón and Díaz).

Olive oil mill wastewater

The disposal of olive vegetation water (OWW) from olive processing industries is a problem in many Mediterranean countries for similar reasons to those mentioned above for vinasse: its high organic load (BOD 10–100 g L⁻¹, COD 40–200 g L⁻¹) and salt content (E.C. 8–22 dS m⁻¹).

Several treatment systems for OWW have been proposed or employed with different success. Cabrera (1995) reviewed the situation of OWW treatment in Spain.

The chemical characteristics of the OWW organic matter were studied by Sáiz-Jimenez *et al.* (1987) focusing on their lipidic fractions which contain non-stabilized hydrophobic constituents.

In the case of OWW, recipes for compost mixes of the sludge obtained after dessiccation of the wastewater in ponds and other agricultural residues were developed by private companies. Such composts are welcomed by farmers. The phytotoxicity that OWW presents, due to its polyphenols, disappears with composting. So, composts of OWW do not inhibit the germination of plants such as cress or ryegrass (Cabrera *et al.*, 1990) as OWW does.

Figure 1 Interaction phenomena in the system waste-soil-plant-water

Successive applications of composts have been proved advantageous for the fertility status of soils, increasing their organic matter and N contents (López, 1992; Martín-Olmedo *et al.*, 1995a, b) which are usually very low in semiarid regions.

The effect of composts upon the organic fraction of agricultural soils have also been studied by Gonzalez-Vila *et al.* (1992).

The application of OWW composts did not cause an imbalance in the nutritional status of ryegrass, barley, corn and sugarbeet. Although low Mn and Zn

content were detected, they were above the sufficiency level (Cabrera *et al.*, 1990; López, 1992).

Land treatment of OWW is an alternative disposal procedure, especially for small factories which can not afford more expensive treatment methods. For loading rates lower than $500 \text{ L m}^{-2} \text{ year}^{-1}$, in carbonate rich soils, no effects of the treatment up to 1 m soil layer were detected (López *et al.* 1992, 1995).

In water courses or soils, OWW forms soluble chelates with oligoelements and heavy metals, especially Mn and Zn, facilitating their dissolution and mobility. The interaction between them and the composition and stability of the compounds formed have been intensively studied (Cabrera *et al.* 1984, 1986; Bejarano, 1995; Bejarano and Madrid, 1992; Madrid and Díaz-Barrientos, 1994a, b). The enforcement of EC directives on wastes in addition to the great general pre-occupation with the environment and the development of biological farming systems will enhance the use and research of wastes, and especially composts, in the South of Spain.

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