Drying solid fractions of animal manure to produce commercial fertilisers

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Abstract
Six types of solid fractions with a Total Solid (TS) content ranging from 12 to 22% were tested in a drying pilot plant consisting of turbine rotating inside a static horizontal chamber operating at 270°C, with a rotary blade system and direct contact between drying materials and hot drying air in closed air flow cycle. A TS content of 86% (SD 3.1%) with a nutrient content of 1.48% N (SD 0.11%) and 0.56% P (SD 0.14%) of the raw material was obtained from the drying process. An average content of 732 mg/kg TKN (SD 82 mg/kg), 995 mg/kg of COD (SD 534 mg/kg), 4.8 mg/kg P (SD 3.8 mg/kg) and 40 mg/kg TSS (SD 40 mg/kg) was found in the condensate from the water vapour, which was post-treated by ultra filtration (UF) followed by Reverse Osmosis (RO). This process resulted in a permeate flow consisting of water with a low concentration of soluble compounds (TKN: 5.7 mg/kg; COD: 23 mg/kg; P: 0.08 mg/kg; TSS: 1.2 mg/kg), dischargeable into surface water, and a relatively small volume of concentrate. The concentrate, can be added to the solid fraction before dewatering in drying pilot, improving the N content of the solid fertiliser obtained.

Introduction
Process and refine animal manure to recover N and P and to produce commercial fertilisers, can be of interest in areas with high livestock density and nutrient surplus [1]. In this study, known as EQUIZOO project (2011-2013) and supported by Lombardy Region, the feasibility of a treatment line, based on drying solid fraction separated from liquid manure to obtain a product with a lower weight and volume (pellet), that is biologically stable and can be stored, transported and more easily handled and sold in bags as commercial fertiliser, was explored. The aim of the trial was to verify the most suitable TS concentration of the raw material for transferring the highest amount of N in the dried fertiliser. A condensate, with high concentration of ammonia and other contaminants also needs to be trated for discharging into water bodies [2].

Material and Methods
Six types of solid fractions were tested in a drying pilot plant: i) three solid fraction from an anaerobically digested cattle manure mixed with biomass, separated with a screw press, with three different dry matter contents (TS: 14%, 18% and 22%); ii) two solid fractions of fresh cattle slurry, separated with a screw press, with two different TS contents (16% and 19%); iii) one solid fraction of a fresh cattle slurry, separated with a drum press, with 18% of TS contents. A solid fraction obtained by a different separator (drum press) was treated to investigate the effects on the characteristics of the dried materials. The materials were tested in order to verify the results achievable in drying different solid fractions with low TS content; the higher is the water content, the higher is the ammonia content due to the high solubility of this compound. A centrifugal hot drum operating at 270°C with a rotary blade system and with direct contact between drying materials and hot drying air was used. An amount of about 100 kg of each type of solid fraction was loaded into the dryer and a volume of 645 m^3/h of hot air at 200 °C was supplied to heat and to transport evaporated water in a close cycle. A mix of solid particles, vapour, ammonia, other organic pollutants leaves the dryer and enters a cyclone where solid material is separated and recovered as dried material to be further processed in a pelletising equipment. The air leaving the cyclone contains dust particles that were removed in a scrubber filled with water. After this treatment the air stream enters a glycol-cooled heat exchanger to condensate vapour water containing also ammonia, odour components and other Organics Pollutants (OPs). The dewatered air leaving the refrigerator flows into a conditioning equipment and is heated up to 200°C and recirculated into the dryer (Fig. 1 and 2). As the content of pollutants is too high for discharging the condensate into surface waters and the content of TKN too low for using as commercial fertiliser, an innovative approach has been adopted in this study to remove ammonia and OPs, based on Ultra Filtration (UF at 20 micrometer) and Reverse Osmosis (RO). The aim of the UF was to remove

residual colloidal and suspended particles, while that of RO was the separation of a large permeate flow consisting of water with a low concentration of soluble compounds such NH_3, K, P and a relatively small concentrate flow in which most of the soluble compounds are concentrated. The concentrate from RO can be recirculated to the solid fraction before entering into dryer. A RO pilot plant operating in batch conditions was used. The concentrate was continuously recirculated to the RO to reduce as much as possible the volume and increase the concentration of the soluble compounds.

Figure 1. Drying pilot plant (VOMM Impianti e Processi S.p.A. - Milano)

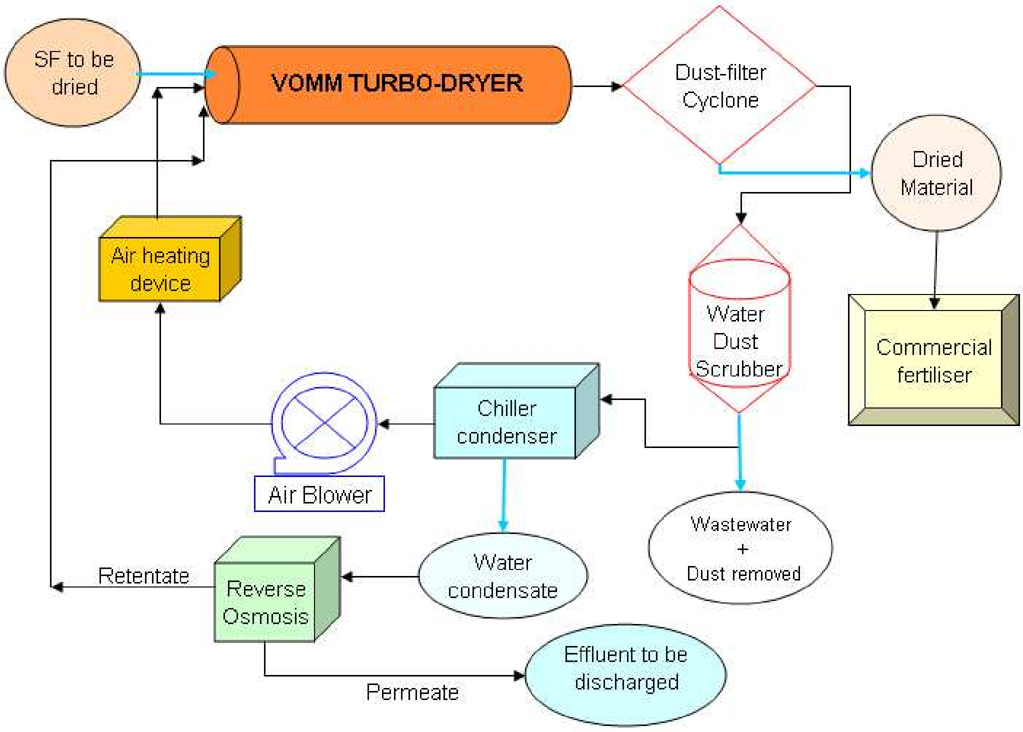

Figure 2. Layout of the drying pilot plant for experimental test

Results

The characteristics of the solid fractions entering the dryer are shown in Table 1. A high TS content, 86% on average, was obtained with the drying process in the pilot plant with all the six tested solid fractions. The nutrient content in the dried material was significant: 1.48% and 0.56% of the raw material for N and P respectively (Table 1).

The volume of condensate produced in the drying process of each of the six materials was 80 litres with a concentration of 732 mg/kg TKN and 995 mg/kg of COD (Table 2). The UF followed by RO, applied to concentrate salified with sulfuric acid because so the ammonia is retained by RO, resulted in 70 litres of permeate with a low concentration soluble compounds (TKN: 5.6 mg/kg; COD: 23 mg/kg; Ptot: 0.08 mg/kg) and a relatively small volume of concentrate (10 litres) in which most of the soluble compounds such as ammonium sulphate, K, P and other soluble mineral are contained (TKN: 8183 mg/kg; COD: 4454 mg/kg; Ptot: 178 mg/kg). Two important results were obtained: i) the large volume of permeate can be discharged into surface water as the limit set by water protection law are respected; ii) the small volume of the concentrate, with its relatively high nutrient content, can be added to the solid fraction before dewatering in the dryer. The aim is to increase the N level of the dried materials to achieve the minimum level of the 3% requested by the national law on fertilisers.

Table 1. Main chemical characteristics of the dried materials of the six type of solid fractions before and after drying.

Types of solid fractions	TS [%]		VS [%TS]		TKN [%FM]		NH_4^+ - N [%TKN]		Ptot [%FM]	
	IN	*OUT*	*IN*	*OUT*	*IN*	*OUT*	*IN*	*OUT*	*IN*	*OUT*
Digestate 1	22	88.2	90.8	91.1	0.43	1.62	20.1	5.9	0.19	0.71
Digestate 2	18	83.0	90.2	90.7	0.40	1.41	18.9	7.0	0.17	0.70
Digestate 3	14	81.8	89.9	91.1	0.34	1.44	26.3	9.9	0.13	0.61
Digestate Average		*84.3*	*90.3*	*91.0*	*0.39*	*1.49*	*21.7*	*7.6*	*0.16*	*0.67*
Fresh cattle slurry 1	19	87.6	88.7	88.2	0.37	1.40	31.7	7.8	0.10	0.49
Fresh cattle slurry 2	16	85.8	84.3	87.5	0.39	1.40	37.3	13.5	0.10	0.47
Fresh cattle slurry 3	18	89.8	87.1	88.4	0.41	1.62	16.2	1.2	0.08	0.35
Fresh cattle slurry Average		*87.7*	*86.7*	*88.0*	*0.39*	*1.47*	*28.4*	*7.5*	*0.09*	*0.44*
Average		*86.0*	*88.5*	*89.5*	*0.39*	*1.48*	*25.1*	*7.6*	*0.13*	*0.56*
Standard deviation		*3.1*	*2.5*	*1.7*	*0.03*	*0.11*	*8.2*	*4.1*	*0.04*	*0.14*

Table 2. Main chemical characteristics of the condensate carried out from drying the six type of solid fractions loaded to the dryer.

Types of solid fractions	pH	TS	TSS	TKN	NH_4^+ - N	Ptot	COD
	[-]	[%]	[g/kg FM]	[mg/kg FM]	[%TKN]	[mg/kg FM]	[mg/kg FM]
Digestate 1	9.42	0.02	0.11	638	94.4	11.2	1876
Digestate 2	9.54	0.02	0.06	807	97.3	6.5	1154
Digestate 3	9.5	0.02	0.03	742	99.3	6.1	1044
Digestate Average	*9.49*	*0.02*	*0.06*	*729*	*97.0*	*7.9*	*1358*
Fresh cattle slurry 1	9.56	0.02	0.01	691	99.9	1.8	800
Fresh cattle slurry 2	9.51	0.01	0.01	845	99.1	1.7	850
Fresh cattle slurry 3	9.41	0.02	0.01	667	98.7	1.8	244
Fresh slurryAverage	*9.49*	*0.02*	*0.01*	*734*	*99.2*	*1.8*	*631*
Average	*9.49*	*0.02*	*0.04*	*732*	*98.1*	*4.8*	*995*
Standard deviation	*0.06*	*0.00*	*0.04*	*82*	*2.0*	*3.8*	*534*

Calculations show that by supplying the concentrate from the RO, a 3% N content in the dried fraction can be achieved, allowing to classify the product as commercial fertilizer with a significant nutrient content.
Simulation shows that the 463 thermal kWh/h from emission hot gas of the CHP unit (1 MWe) biogas plant, fed with a 50% of cattle slurry and a 50% of silage forage, can be used to produce different amounts of commercial fertizers with 85% TS and 3.0-3.5 TKN contents, depending on the TS content of the solid fraction from screw press. An important side effect is the volume reduction of the digestate to be disposed (Fig.3), as lowest is the TS content of the solid fraction to be dried, highest is this volume reduction [3].

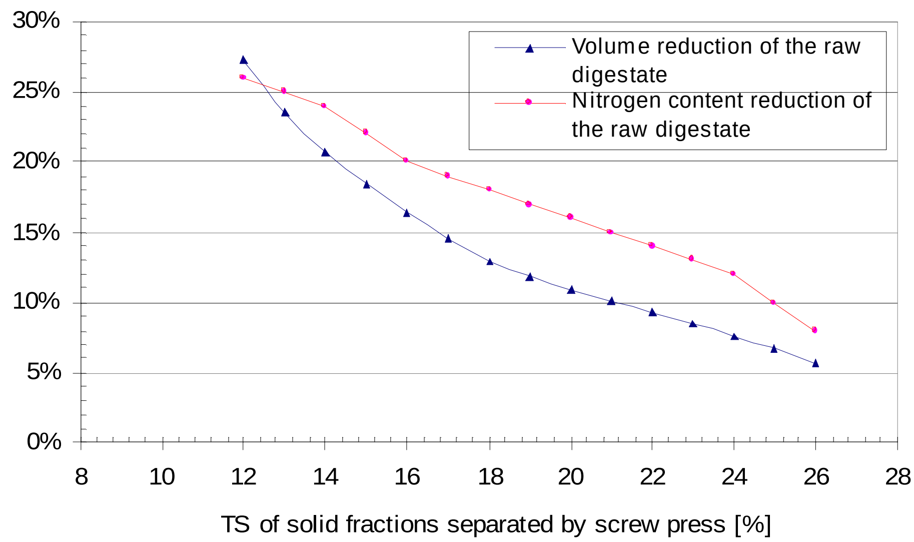

Figure 3. Effect of drying solid fractions with different TS content on the volume reduction and nitrogen removal (as pellet fertiliser) of the digestate produced by the considered 1 MWe biogas plant.

Conclusion and perspectives

The study demonstrated that drying manure solid fractions in a closed cycle plant, avoiding ammonia and dust emissions by recirculation of the exhaust air flow, is technically feasible and a valuable commercial fertiliser can be produced, recovering all the compounds otherwise emitted as pollutants. An important aspect to investigate is the energy supply and the net energy use of the drying process. Energy supply by hot gas of an incinerator or by hot gases from CHP unit in a biogas plant can be an interesting perspective. An evaluation of the investment and running costs to verify the economical sustainability of the proposed treatment line is also needed. Investigations are also needed regarding reliability and operational management of UF and RO process. Remarkable is that in these trials UF and RO are applied to condensate water with appropriate chemical characteristics for this kind of process (Table 2).

A market based approach to transform the separated solid fraction from fresh slurries or separated solid fraction digested in a commercial fertilisers is an attractive strategy, especially if waste heat from renewable energy plants is available for use in the drying process.

Utilising manure surplus as a source of phosphate and other nutrients to produce exportable products of good quality helps reducing the environmental pressure in areas with high livestock production. This approach could also contribute to create a market of recycled materials in the frame of a sustainable green economy.

References

[1] Timmerman and Rulkens, 2009. Phoshorus removal from animal manure. In Alterra report 2158.

[2] Thorneby L, Persson K, Tragard G, 1999. Treatment of liquid effluents from dairy cattle and pigs using reverse osmosis , Journal of Agricultural Engineering Research, Vol. 73, Issue 2, Pages 159-170.

[3] Fabbri C, Mantovi P, Piccinini S, Verzellesi F, 2012. Separazione solido-liquido per gestire l’azoto e produrre energia. L’Informatore Agrario 41, 44-48.