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A COMPARATIVE STUDY OF ISSUES, CHALLENGES AND STRATEGIES OF BIO-WASTE MANAGEMENT IN INDIA AND ITALY

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ABSTRACT

The aim of the present study is to compare the current level of implementation of bio-waste management in Italy and India. Italy generates about 1.33 kg/per capita/day of municipal solid waste (MSW). Bio-waste makes up about 30% of the whole MSW generated and about 60% is recycled. The main process is by aerobic composting, whereas anaerobic digestion is used to a limited extent. In India waste production ranges from about 0.20 kg/per capita/day to about 0.60 kg/per capita/day. The amount of recycling of this waste is very poor and there is a lack of treatment facilities. Anaerobic digestion for the Indian scenario could be a suitable solution for co-treatment of bio-waste with other biodegradable materials in order to supply energy and fuel in rural areas. The main differences between the two countries concerning waste and in particular bio-waste management are mainly the recycling strategies, end of waste criteria and energy recovery perspective.

1. INTRODUCTION

Even with different perspectives, waste management is one of the key issues to be addressed both by developed and developing countries in order to achieve a sustainable implementation of the different human activities worldwide.

According to Marshall and Farahbakhsh (2013), progress in this activity was historically driven by five key factors: public health, the environment, resource scarcity and the value of the waste, climate change, and public awareness. In particular health care and the environmental aspect are affected directly, as for example, by the emissions generated from incorrect collection and disposal of waste (Couth and Trois, 2011, 2012; Tian et al., 2013, Aich and Ghosh, 2016), and indirectly as a consequence of raw materials consumption and transformations (Di Maria and Micale, 2014-2015).

Nowadays the most effective approach for waste management recognized worldwide is based on the 3-R concept: Reuse, Recycle and Recovery. This was extrapolated from the broader concept of the waste management hierarchy introduced in the EU in 1977 by the European Commission (CEC, 1977), stating the main activities and goals to be pursued with strict hierarchical order in waste management: Prevention, Reuse, Recycle, Recovery, Disposal.

The concept of hierarchy was definitively introduced in the EU legislation in 1991 by the first Directive 91/156/EEC on waste (Council Directive, 1991), becoming a fundamental component of the integrated waste management approach. This was in force up to 2008 when the latest Waste Framework Directive (WFD, 2008) introduced another important goal to be achieved within 2020 by member states, stating that at least 50% of waste generated has to be reused or recycled. Recycling also includes the organic fraction via biological treatments, able to generate organic fertilizer exploitable in agriculture according to legislation of the member states.

Furthermore, putting the waste management hierarchy into practice was also indicated by the EC as a key activity in communication n.614 (COM 2015) concerning the EU Action Plan on circular economy. A key factor for maximizing recycling and reuse is proper waste collection based on efficient source segregation able to return high quality recyclables directly exploitable in the recycling industry. Municipalities are the authorities charged with providing municipal solid waste (MSW) collection directly or by private/public companies. Presently in the EU15 and in Italy, collection coverage is practically 100%.

Continuous effort for the full implementation of these concepts and goals led to the following main figures concerning MSW management at the EU15 level (ISPRA, 2016):

- Global MSW generated: 207,862,000 Mg (i.e. about 1.4

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kg/day per capita);
- Fraction of MSW recycled: 29.5%;
- Fraction of MSW composted and/or processed by anaerobic digestion (AD) for recycling: 17.4%;
- Fraction of MSW incinerated: 29.9%
- Fraction disposed in sanitary landfill: 23.1%.

Considering that the percentage of bio-waste in MSW at the EU15 level is about 30%, the above figures indicate that more than 50% is currently recycled by composting or processed with AD and post-composting (Di Maria et al. 2016; Smidt et al., 2011). The remaining amount could be considered quite equally shared between incineration and landfilling. All landfills currently operating are sanitary landfills that have all of the necessary equipment required by current legislation for emissions control and also very often with landfill gas energetic recovery.

Currently the EC is still focusing particular attention on bio-waste management. In fact, even if collected with high source segregation efficiency, bio-waste, unlike other waste materials (e.g. plastics, paper, metals), as returned cannot be directly exploited as raw material by the recycling industry. Furthermore its disposal in landfill is a serious environmental threat due to the generation of gaseous and liquid (i.e. leachate) emissions having high polluting potential. According to the European Environmental Agency (EEA, 2011), landfill gas emissions contribute up to 3% of the whole anthropogenic greenhouse gas (GHG) emissions in the EU due to the high amount of methane (i.e. about 50% v/v) and N_2O with a GHG potential 23 and 300 times higher than CO_2, respectively (Beyolt et al., 2013; De Gioannis et al., 2009; Desideri et al., 2003; Di Maria et al., 2013a). On the other hand, mainly as a consequence of rainwater infiltration, landfills generate leachate that can be considered a triphasic system with the characteristics of a highly polluted wastewater with high concentrations of: organic and inorganic contaminants; pathogens; humic acids; ammonia nitrogen; heavy metals; xenobiotic and inorganic salts (Di Maria et al., 2018). The content of these substances is influenced by many factors (e.g. waste composition, climatic conditions, extent of waste degradation/decomposition) and must be removed in accordance with EU water standard legislation (Di Maria and Sisani, 2017, Landfill Directive 1999/31/EC; Schiopu and Graviliescu, 2010; Slack et al., 2005; Spagni et al., 2008; Wisizniowski et al., 2006).

On the other hand, waste management in the majority of developing countries is still primarily based on uncontrolled dumping and/or littering (Henry et al., 2006; Sharholy, et al., 2008) together with domestic burning (Guerrero et al., 2013), causing serious health and environmental problems (Al-Khatib et al., 2010). As reported by Kumar et al. (2009), more than 90% of MSW in India is directly disposed of on the land in an unsatisfactory manner and collection coverage is often less than 60% (Henry et al., 2006; Zhang et al., 2010). Couth et al. (2001) reported that in Africa GHG emissions from waste management are 3 times higher than those in developed countries and similar results were also reported by Tian et al. (2013) concerning the Chinese scenario. Zhang et al. (2010) reported per capita production in China ranging from 0.4 kg/day to 1.0 kg/day (with the peak achieved in given areas also up to 1.7 kg/day (Manaf et al., 2009). The organic fraction ranged from 45% up to more than 80% of the whole waste generated (Al-Khatib et al., 2010; Henry et al., 2006; Zhang et al., 2010), leading to serious health and environmental concerns. In general the main goal in waste management consists in its transport outside of cities (Marshall et al., 2013). Furthermore the rapid and unplanned growth of cities has resulted in a number of extreme land use planning and infrastructural challenges that have crippled the capacity of government and local authorities to increase MSW service to the degree they are demanded (Marshall et al., 2013). Collection services are also inadequate due to lack of funding and technical expertise (Al-Khatib et al., 2008; Henry et al., 2006). Similarly, Guerrerio et al. (2013) reported that failure of waste management in cities of developing countries is due to inadequate technical, environmental, financial, socio-cultural, institutional and legal aspects. A primary role for recycling is played by informal waste scavenging and picking, often done in unsafe conditions directly on dumpsites or on collection trucks, scattering waste all around along the route (Manaf et al., 2009). In general recycling figures are very poor, less than 10%, (Kumar et al., 2009). Also there is a major lack of facilities for the treatment of the largest and most threatening waste component, the organic fraction.

As indicated by Henry et al. (2006), composting is a sustainable way to manage organic waste in these countries, leading to environmental protection as well as to generating revenue from selling fertilizer. Similar recommendations were also reported by Sharholy et al. (2008) for improving the rural economy in India. Couth and Trois (2011, 2012) indicated composting as one of the main activities to pursue for sustainable waste management in Africa, able to reduce GHG from about 900 $kgCO_2eq/Mg$ to about 300 $kgCO_2eq/Mg$ compared to disposal in landfill. Kumar et al. (2009) reported that centralized composting facilities produced poor quality fertilizer due to the absence of source segregation of the organic fraction, also causing decrease in interest by potential investors. Promoting decentralized facilities for community composting has been indicated as an alternative solution, able to overcome the low quality of fertilizer of centralized plants (Henry et al., 2006; Sharholy et al, 2008). As an alternative to decentralized composting, some authors have indicated decentralized AD as another suitable way for processing organic waste in developing countries. AD is a widespread method for disposal of various types of waste and returns a biogas with a methane content from 50% v/v to 70% v/v (Bond and Templeton, 2011). Various appliances such as stoves, electrical generators, and lighting and cooking devices can be fuelled with biogas, offering an appropriate application for its use in developing countries. Furthermore, due to the absence of transmission and distribution of energy generated from fossil fuels in rural areas, particularly in remote locations, decentralized renewable energy generation could be an important contribution to improve the quality of life in such areas (Demirbas and Demirbas, 2007).

AD is able to ensure sanitation of biodegradable compounds by reducing the pathogen content in substrates (Bond and Templeton, 2011) and by reducing in-door emissions. In fact the biogas can substitute the use of woody/solid fuels for fuelling stoves, reducing in-door particulate emissions (Demirbas and Demirbas, 2007; Houng et al., 2014) and hence reducing health risks. There has been rapid improvement in public health in China due to use of biogas, with a reduction of schistosomiasis and tapeworm by 90% and 13%, respectively (ISAT/GTZ, 1999; Remais et al., 2009). Furthermore the digestate returned from AD also showed rather good fertilizer properties, with the potential of improving soil fertility (Smidt et al., 2014; Di Maria et al., 2013b). Decentralized and micro-AD facilities have already been developed and adopted in many areas of developing countries such as the Chinese fixed dome, the Indian floating dome and the PVC digester tube (Bond and Templeton, 2011; Ferrer et al., 2011; Mungwe et al., 2016).

The aim of this paper is to compare current figures and challenges in the Italian and Indian scenarios concerning bio-waste management. Possible exchanges of experiences and good practices are also analysed and discussed.

2. MATERIALS AND METHODS

Assessment of the current management schemes for bio-waste in Italy and India was performed using official documents obtained from local and central authorities, literature surveys and from direct observations in given areas and facilities.

The analysis included methodologies, technologies, legislation, and social and economic aspects associated with the different areas analysed. In particular the two areas were compared using the following three main indicators:

- Recycling strategies;
- Presence of end of waste criteria;
- Energetic considerations.

2.1 Italian scenario

Like other sectors, waste management legislation for all the EU member states including Italy is based on Directives of the European Commission, the European Parliament and the Council.

According to the EC Environment, bio-waste is defined as "biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants. It does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood. It also excludes those by-products of food production that never become waste". Relevant Directives concerning the management of bio-waste are mainly the Waste Framework Directive (WFD, 2008), the Landfill Directive (LFD, 1999), and the Integrated Prevention Pollution Control Directive (IPPC, 2008).

The WFD indicates the recycling goals and the need to activate dedicated collection services for bio-waste. LFD mandates Member States to reduce the amount of biodegradable municipal waste that they landfill to 35% of 1995 level by 2016 (for some countries by 2020). Finally the IPPC Directive, soon to be substituted by the Industrial Emission Directive, also indicates measures to prevent and/or reduce the emissions generated by waste management and treatment.

Other important legislation concerning bio-waste is by the Italian D.M. (1998) and by the D.Lgs. (2010). They provide current End of Waste (EoW) criteria for bio-waste, while waiting for the adoption of European criteria. The former indicates aerobic composting, and associated performance (Table 1), as a suitable process for bio-waste recycling together with the waste type. The European directive defines the chemical and physical quality of the final compost for consideration as organic fertilizer and then exploitable/recyclable in agriculture in compliance with the legislation of different member states. The Italian standards for quality for organic fertilizer are reported in the D.Lgs. (2010). Another process suitable for bio-waste recycling is by AD, but presently the absence of specific EoW criteria at both the EU and Italian level pose some criticism for the full implementation of this process.

Aerobic composting of bio-waste separated at source, alone or combined with AD, is the main and most commonly used recycling option. Other possibilities for processing biodegradable waste not separated at source before final disposal are by mechanical and biological treatment (MBT) and/or incineration. MBT can be carried out by bio-stabilization or bio-drying. The aim of biostabilization (Adani et al., 2004; Di Maria, 2012; Zach et al., 2000) is to reduce the biological reactivity of the biodegradable components, prior to mechanical sorting, before disposal in landfill in compliance with LFD. The aim of bio-drying (Adani et al., 2002; Wiemerand Kern, 1995) is to produce a Solid Recovered Fuel (SRF) (UNI CEN/TS, 2006) for fossil fuel replacement, also including the carbon-rich bio-waste content by removing excess humidity via aerobic treatment.

2.1.1 Recycling

The MSW generated in Italy in 2015 (ISPRA, 2016) was 29,524,263 Mg, representing 14.2% of the whole MSW generated in the EU15. On average, the fraction of waste collected separately was 47.5% with a maximum value of 58.6% in the northern regions. For central and southern regions these figures were 43.8% and 33.6%, respectively. More than 20% of the waste collected separately was bio-waste (i.e. about 6,000,000 Mg), indicating a specific source separation level > 60%.

Practically all the bio-waste collected separately was processed for being recycled as organic fertilizer in the

TABLE 1: Waste type and main performances for aerobic composting according to Italian End of Waste legislation.

Parameter	Value	u.m.
Waste type	Bio-waste from separated collection	-
Days of treatment	90 (min.)	Day
Process temperature	55 (at least for 3 days)	°C

263 biological treatment facilities (Di Maria 2012; Di Maria et al., 2014) operating at the national level, 26 of which are equipped with integrated anaerobic digestion and post composting (Di Maria et al., 2016: Smidt et al. 2011). There are 162, 43 and 58 facilities for Northern, Central and Southern regions, respectively. Bio-waste processed in the integrated AD and post-composting facilities was about 1,600,000 Mg, equal to the whole amount of organic fertilizer (recycled) generated in 2015. About 220,000 Mg of bio-waste were co-digested exclusively with other substrates in 20 AD facilities, 18 of which were located in Northern and 2 in Southern Italy. According to the current legislation AD alone was not able to comply with the End of Waste criteria necessary for agronomic utilization (D.M., 1998; D.Lgs, 2010). From the technical point of view, the first limitation was due to the temperature levels needed for achieving the sanitization requirements (Table 1), making only thermophilic processes able to warrant > 3 days of treatment at not less than 55°C. The second limitation was the lack of complying with the characteristics required by the organic fertilizer legislation (Table 2). One of the main criticisms was the low level of the Germination Index, indicating significant residual phytotoxicity of the digestate. Di Maria et al. (2013b, 2014) and Massaccesi et al. (2014) reported a Germination index of digestate ranging from 35.7% to 53%, resulting lower than the threshold value of 60% imposed by Italian legislation (Table 5). These problems can be solved by a successive post composting treatment. In any case even if EoW criteria were not fully met, use on land can be performed by specific authorizations released by the competent authorities. On the other hand AD leads to the production of renewable energy even if investment, operating and maintenance costs are higher. For this reason there has been a large diffusion of AD facilities since 2013 when economic incentives became available for the production of electricity from biogas. In general, these incentives, up to 0.28 €/kWh, enabled the viability of the whole investment for plant sizes not less than about 1,000 kW (i.e. about 7,000-8,000 MWh/year). At the end of 2013 these incentives were substantially eliminated and the new frontier for incentives for AD was by bio-methane production. Bio-methane can be obtained from biogas by upgrading the process to remove CO_2 and other pollutants, returning a gas in compliance with technical requirements (UNI/TR, 2014) for its injection in natural gas grids or exploitable as fuel for transport. In any case a preliminary economic analysis shows that bio-methane plants are viable for thermal power associated with the gas generated > 3,000 MW. The organic fertilizer generated was, in general, quite low, usually < 12 €/Mg, but very often < 5 €/Mg, whereas the inlet fee for such recycling facilities ranges from about 60 €/Mg to about 100 €/Mg.

2.1.2 MBT, incineration and landfill

In 2015 the amount of waste processed in the 118 MBT facilities, 36 in Northern, 32 in central and 50 in Southern regions, was 10,532,209 Mg, 89.7% of which was from residual MSW coming from separated collection and 7.5% from waste generated from other waste treatments. The remaining fraction was from other wastes generated from civil and industrial sectors. Of the 8,804,068 Mg output generated by MBT, about 64% was landfilled or used for landfill management (e.g. covering layers), 1.3% was recyclables (i.e. metals), 1% was SRF and about 28% was incinerated or co-incinerated. In practice MBT is an alternative solution to incineration quite used due to the lower capital, operating and maintenance costs. Investment costs range from 200 €/Mg/year to 300 €/Mg/Year, depending on plant size and on the technological solutions adopted. The gate fee was from 60 €/Mg to 100 €/Mg. MBT energy consumption ranged from about 30 kWh/Mg to about 50 kWh/Mg of electricity necessary for both process and emission controls. On the contrary MBT is not able to handle the same mass, volume and biological reactivity reduction as incineration, entailing more landfill.

The 41 incineration plants operating in 2015, 26 in Northern, 8 in Central and 7 in Southern regions, processed 5,582,052 Mg of waste, about 18.9% of the whole MSW generated, producing 4,430 GWh of electricity and 2,754 GWh of thermal energy. Even if some studies highlight the environmental performances of alternative processes (Di Maria and Fantozzi, 2004), mass burning is the only technology adopted at the industrial scale. The technologies adopted were: 87% grid, 10% fludised bed, and 3% rotary kiln. Similar results were also reported at the EU level. Of the 15 plants operating in combined heat and power mode, the average electrical and thermal energy recovery per Mg of waste processed was 0.65 kWh and 1.04 kWh, respectively. For the plants recovering electrical energy exclusively, the figure was of 0.77 kWh/Mg. Investment costs for incineration facilities ranged from about 300k€/Mg/day to 500k€/Mg/day, whereas the inlet fees are usually more than 100€/Mg. Finally the amount of waste landfilled was 7,818,796 Mg (26% of the whole generated). More than 80% of this waste was disposed of in landfill after previous treatment as MBT. The landfill inlet fee ranged from about 70€/Mg up to 120 €/Mg, depending on local conditions and on the features of the waste disposed. The high landfill fee is often a consequence of environmental taxes and penalties (landfill levy) aimed at discouraging the use of such facility in waste management, making other solutions and pre-treatment, such as incineration, economically more attractive.

2.2 The Indian scenario

In India almost all waste management legislations were revised or introduced in 2016. According to the 2016 solid waste management (SWM) Rules, solid waste is defined as solid or semi-solid domestic waste, sanitary waste, commercial waste, institutional waste, catering and market waste and other non-residential wastes, street sweepings, silt removed or collected from surface drains, horticulture waste, agriculture and dairy waste, treated bio-medical waste excluding industrial waste, bio-medical waste and e-waste, battery waste, radio-active waste generated in the area under the local authorities. Hence the bio-waste in India includes biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants. Similar to the EC directives, in India it does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles and processed wood. India is very rich in three distinct sources of biomass energy, namely energy plantations, agricultural crop residue and municipal and industrial wastes. Being an agricultural country, there are high numbers of cattle and livestock in India. Thus, Indian villages have always had a wealth of bio-resources which can easily be converted to energy.

The practice of source separation of municipal waste is limited or absent in most of cities and villages in India. This results in a mixed composition of waste, leading to several constraints in introducing and implementing technologies for treatment in a sustainable way. The 2016 SWM Rules specifically state that waste generators will store source segregated bio-degradable, non-biodegradable and domestic hazardous wastes and they must be collected throughout the country by designated authorities. The bio-degradable waste shall be processed, treated and disposed of by composting or by bio-methanation in the premises as far as possible for gated communities or by the local urban bodies in the waste treatment facility in identified areas including other energy recovery options. The local urban body (LUB), being the lowest body within the three-tier Indian governmental system, has to prepare a solid waste management plan according to state policy and strategy on solid waste management with a target time and submit a copy to the respective departments of the State Government or Union territory Administration or agency authorised by the State Government or Union territory Administration.

The rules specify composting as one of the technologies for processing biodegradable waste in the waste treatment facility and recommend standards for the compost for compliance in order to prevent pollution from the composting plant. The incoming organic waste at the site must be stored properly prior to further processing. To the extent possible, the waste storage area should be covered. If, such storage is done in an open area, it must have an impermeable base with the means for collecting leachate and surface water run-off into lined drains leading to a leachate treatment and disposal facility. Pre-process and post-process rejected material shall be removed from the processing facility on a regular basis and shall not be allowed to pile up at the site. The windrow area must have an impermeable base. Such base shall be made of concrete or compacted clay 50 cm thick and have a permeability coefficient less than 10–7 cm/sec. The base must have a 1 to 2 per cent slope and be surrounded by lined drains for collecting leachate or surface run-off. The leachate must be re-circulated in the compost plant for moisture maintenance. The end product compost is required to meet the standards specified under the Fertilizer Control Order notified from time to time. In order to ensure safe use of the compost, the specifications for compost quality must be met (SWM Rules 2016, India). The Indian rules define the chemical and physical quality of the final compost for being considered as organic fertilizer and then exploitable/recyclable in agriculture. The comparison will be discussed latter in this paper.

The overall flow of 90% of the collected solid waste, nearly 1,270,531 tonnes per day out of 1,410,046 tonnes per day of the solid waste generated (data based on 2013-14, Source: CPCB Bulletin Vol.- I, July 2016, Government of India) is distributed in processing and treatment activities like, Recycling, Composting, biomethanation, waste-to-energy and land filling (Figure 1).

The general supply chain of the solid waste in India has both formal and informal intervention (Figure 2). The collection system in most of the cities is formally carried out by the local urban bodies. Segregation is done by a group of people called rag pickers or Kabadiwala, who are involved informally on their own for separating valuable materials from the waste collected to sell to recyclers for their livelihood, whereas in many cities the LUB are involved in the waste segregation or source segregation collection system.

2.2.1 MRF and recycling

In India the various main treatments of the organic fraction of municipal solid waste involve composting, and biomethanation, while the non-biodegradable part of MSW involves material recovery, recycling, RDF, waste-to-energy and the remainder goes to landfill (Figure 1). Waste collection is done in a source-segregated manner as well as mixed types of waste. The source-segregated waste undergoes further segregation for recycling in the Material Recovery Facility (MRF) manually or with the aid of machines. Valuable recyclable waste is separated informally from the landfill or dumpsites by people on their own. Nearly 27% of the MSW processed amounts to 34,752 tonnes per day. As per the CPCB Bulletin (Vol.- I, July 2016), the Government of India follows some of the data of the MSW treatment and disposal status in India as in 2013-14. Table 2 shows the number of composting/vermi-composting plants in the States of India as of 2013. Of course in the next five years, the number will increase at a faster rate because of the new solid waste management rules introduced in 2016. The Government of India supports the use of compost. Co-marketing of compost at 3 to 4: 6 to 7 bags by fertilizer companies is now being promoted. House–to-house collection ranges from 40-90% in 18 States, whereas waste segregation ranges from 20-80% in 5 States. The rest of the Sates are in the process on introducing the process. The recorded number of operational compost / vermi-composting facilities are in 553 Urban Local Bodies (ULBs) and compost/vermi-composting facilities are under construction in 173 ULBs. Pipe composting is very popular in the State of Kerala where more than 7000 units are in operation. There are more than 0.4 million bio gas plants oper-

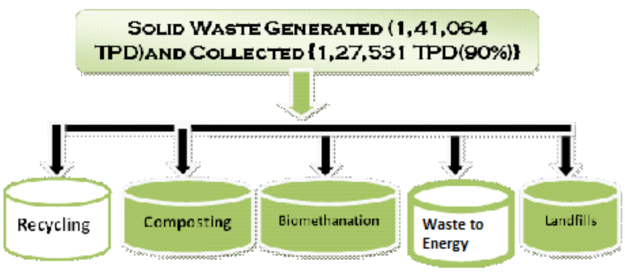

FIGURE 1: Flow of the solid waste collected in India.

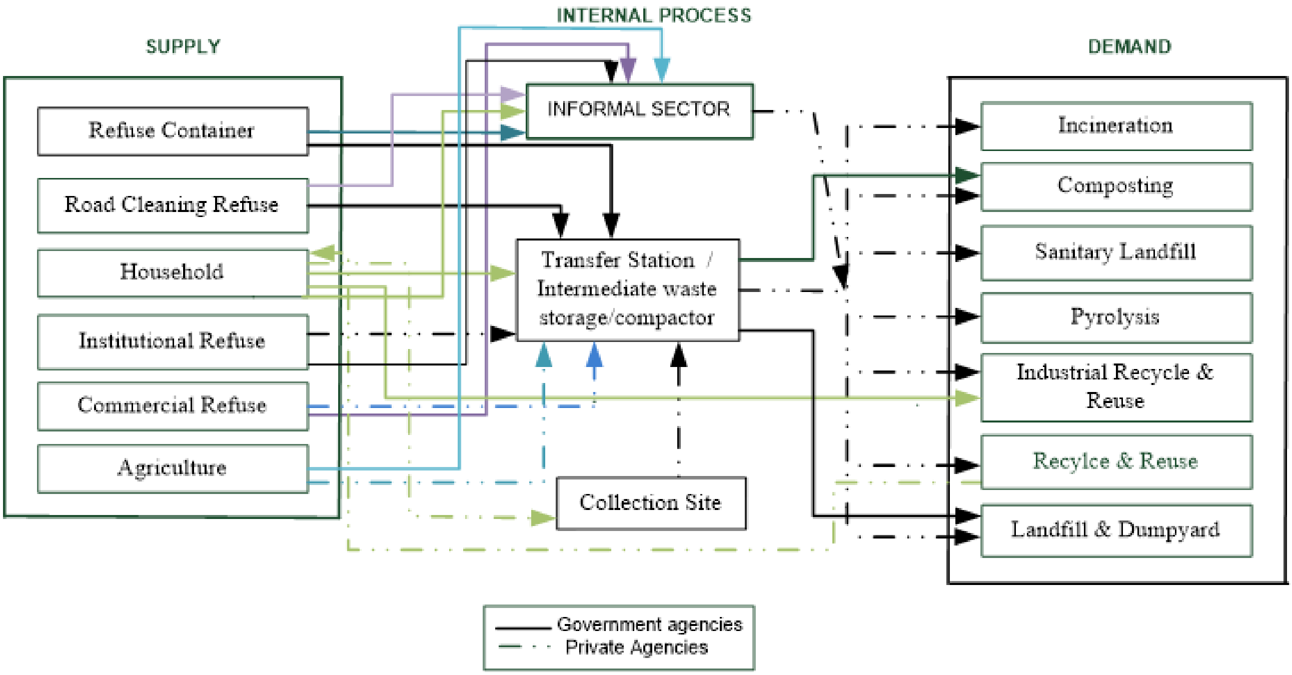

FIGURE 2: MSW Supply Chain Framework in India (Source: Ghosh, et al, 2016).

ating in India at the small-scale household level. There are nearly 645 recorded biogas plants carried out by ULBs and industries (600 in Kerala).

2.2.2 MBT, incineration and landfilling

More than 70% of the solid waste in India is destined to go to more than 1285 landfill sites and 95 landfill sites are under construction in different parts of the country. The number of sanitary landfill sites is very low. At present nearly 10,000 Tonnes Per Day is landfilled with respect to 4,515 TPD in 2013-14. The 2016 SWM Rules mandate the minimum amount of waste to go to landfill. There are very few waste to energy plants, but there is a new initiative to install WtE plants in many of the States (Tables 3 and 4). Nearly 12 RDF/Pellet manufacturing plants are in operation in India, whereas there are six energy generation plants. The calorific value of waste in India is low (Nixon et al, 2013a,b).

The use of biomass and bio-waste resources at the country level (using all residues including rice husk) and cogeneration (using Bagasse) plants are the major sources of power generation. Nearly 4.9 GW are produced in India from the use of bio resources, out of which 56.28% is generated from bagasse-cogeneration, 27.43% is generated from biomass power gasification, 11.27% is generated from non-bagasse based cogeneration, 3.07% is from biomass gasification in rural areas, 2.15% from waste–to-energy and only 0.36 from gasification in rural areas (Figure 3).

3. COMPARATIVE ANALYSIS AND DISCUSSION

In general one of the main drivers detected during this study for improving management of waste and in particular bio-waste is by the combination of efficient and effective political, economic and legal programs. This was implemented the EU and in particular in Italy since the be-

TABLE 2: Number of composting / vermi-composting plants in various States in India.

State	Number of plants (composting/ vermi-composting)	State	Number of plants (composting/ vermi-composting)
Andhra Pradesh	32	Madhya	4
Chhattisgarh	15	Maharashtra	125
Delhi	3	Meghalaya	2
Goa	5	Orissa	3
Haryana	2	Punjab	2
Gujarat	86	Rajasthan	2
Himachal	13	Tripura	13
Karnataka	5	Uttarakhand	3
Kerala	29	West Bengal	9

Source: CPCB (2013)

TABLE 3: Recent initiatives of Waste to Energy Plants in India (as of 2017).

State	WTE Plant Location/capacity	Status
Delhi	Okhla (2000 TPD)	Okhla plant operating, one commissioned, one under construction
Madhya Pradesh	600 TPD at Jabbalpur, Indore, Bhopal	Jabbalpur generating power to grid, others are in contract stage
Gujarat	Surat, Vadodara, Mahar (3000TPD)	Contract stage
West Bengal	Kolkata, and Howrah	Tendering Stage
Andhra PradeshTelengana	Four Locations Karimnagar	Tendering Stage - In Operation
Maharashtra	Pune two	One failed, one in Tendering Stage
Bihar	One Plant	Tendering Stage

TABLE 4: Number of energy recovery plants in some states.

State	No. of RDF plants/Waste to Energy Plant (PP)/Biogas (BG)	State	No. of RDF plants/Waste to Energy Plant/Biogas (BG)
Andhra Pradesh	3-RDF, 4 PP	Delhi (UT)	1-RDF, 1PP
Chandigarh (UT)	1-RDF	Gujarat	2-RDF
Chhattisgarh	1-RDF	Kerala	2-BG
Maharashtra	19-BG	Madhya Pradesh	1--RDF

Source: CPCB (2013)

ginning of the 1990s, and has led to a quite high efficiency and effectiveness of the waste management system both in terms of efficient use of resources and of environmental protection. Citizen awareness concerning waste management has stimulated policy and public administrators to pursue continuous efforts to improve this activity by increasing reuse and recycling, decreasing disposal and pursuing an efficient economic program. Considerable attention in Italy is mainly focused on material reuse, recycling and the environment, including health care protection. Energetic recovery is mainly oriented at improving the efficiency of the whole management system rather than as a priority to be pursued in waste management. Furthermore due to the high level of electrification throughout the country there is a low need for decentralized plants for satisfying the electrical needs of isolated communities. The interest in decentralized energy generation was promoted mainly as a consequence of the introduction of economic support programs for the production of renewable energy as a consequence of the broader European policy on renewable energy production. Furthermore, economic and technical aspects typical of the waste sector limited the wide diffusion of power plants in this sector compared to others such as that of biomass. In particular, for a total of > 1,550 AD facilities operating in Italy, only 46 process bio-waste. This clearly indicates the existence of technical and economic barriers.

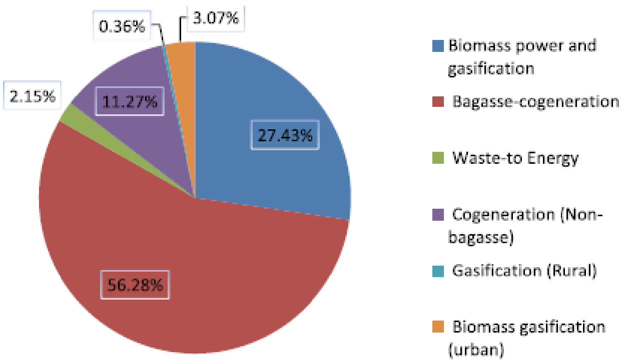

FIGURE 3: Source-wise break-up (%) of bioelectricity production (4.9 GW) as of 2016.

The Indian scenario is characterized by different aspects. The political and legal program for waste management is faced with important social, economic and also health care issues. The informal sector, which is mainly the extraction of recyclables from waste, gains revenues from this activity and is an important income for a large part of the population. On the other hand they operate in critical health and working conditions. Furthermore the large use of dumpsites is also another relevant risk for both the environment and public health. Implementation of a legal program and economic support by public authorities for the activity performed by the informal sector could be a first step for improving both waste management and environmental and social aspects. As largely demonstrated at the EU level for increasing both the amount of recyclables and their economic value, an efficient separation at the source is mandatory. Another important aspect concerning the Indian scenario is the need for decentralized energy production, mainly in rural areas were small-scale AD facilities also fed with bio-waste could lead to an improvement in the quality of life. Due to the full implementation of a national electrical grid, this option is of relevant interest and is also an opportunity for creating new jobs. The large presence of bio-waste in MSW generated together with economic and technical aspects appears to be a key limiting factor for the widespread implementation of waste-to-energy plants, making construction of new sanitary landfills a more attractive solution. The low quality and economic value of the resulting compost is one of the limiting factors for an efficient and larger implementation of bio-waste recycling. This is mainly a consequence of the low quality of the bio-waste that is generally collected, commingled with other waste and successively hand separated. The most recent Indian legislation (Table 5) imposes quality standards for both chemical and physical aspects to be achieved for producing organic fertilizer from bio-waste. Currently two main standards are in operation (FCO, 2009; 2013). Comparing these with the current Italian legislation (Table 5) (D. Lgs., 2010), physical features imposed by the different legislations appear quite similar with respect to the moisture content and pH values. Italian legislation imposes higher values for the total organic carbon content together with an indication of the fraction of organic nitrogen with respect to the total nitrogen. There were other main differences for the heavy metals concentration, which were, on average, significantly higher for the Indian legislation. These differences in limits can be a consequence of the features of agricultural soils between the two areas, but also of the different quality of the bio-waste processed. There were some relevant differences for the nitrogen (N) concentrations between the two Indian standards, whereas there was no indication as to the concentration of other nutrients such as P and K as reported in the Italian legislation. Finally no limits were imposed on the level of maturity achieved by the fertilizer by the Indian legislation, whereas this aspect is of particular concern in Italian legislation.

4. CONCLUSIONS

The present study highlighted the main differences between Italian and Indian bio-waste management. The

TABLE 5: Mean chemical and physical features required by Italian and Indian, legislation for classification of compost from bio-waste as organic fertilizer.

Parameter	Italian		Indian			
	D.Lgs. 75/2010		Organic Compost (FCO 2009)		Phosphate Rich Organic Manure (FCO 2013)	
	Value	**u. m.**	**Value**	**u. m.**	**Value**	**u. m.**
Moisture Content	<50	% w/w	15.0-25.0	%w/w max	25	%w/w max
Bulk density			< 1	mg/cm3	Bulk density 1.6	g/cm3
pH	6.0-8.5	-	6.5-7.5		1:5 solution) maximum6.7	
TOC	>20	% on TS	>12.0	% w/w	>7.9	% w/w
TKN	-	% on TS	% on TS	% on TS		
N organic	>80% of TKN	% on TS	% on TS	% on TS		
C/N	<25	-	<20	-	< 20:1	-
Cu	<150	ppm on TS	<1000.00	mg/kOon TS	<1000.00	mg/kg
Zn	<500	ppm on TS	<300.00	mg/kg	<300.00	mg/kg
Pb	<140	ppm on TS	<100.00	mg/kg	<100.00	mg/kg
Arsenic	-	-	<10.00	mg/kg	<10.00	mg/kg
Cadmium	<1.50	mg/kgTS	<5.00	mg/kg	<5.00	mg/kg
Chromium	<0.5	mg/kgTS	<50.00	mg/kg	<50.00	mg/kg
Mercury	<1.5	mg/kgTS	<0.15	mg/kg	<0.15	mg/kg
Nickel	<100	mg/kgTS	<50.00	mg/kg	<50.00	mg/kg
Total Nitrogen (as N)	-	-	>0.8	% w/w	>0.4	% w/w
Total Phosphate (as P205)	>0.5	%TS	>0.04	% w/w	>10.4	% w/w
Total Potassium (as K20)	-	-	>0.04	% w/w	-	% w/w
Colour	-	-	Dark brown to black		Dark brown to black	
Odour	-	-	Absence of foul Odor		Absence of foul Odor	
Particle size	-	-	Minimum 90% material should pass through 4.0 mm IS sieve		Minimum 90% material should pass through 4.0 mm IS sieve	
Conductivity (as dsm-1), not more than	-	-	4.0		8.2	
Germination Index	>60	%	-	-	-	-

Legend: TKN = Total Kjeldal Nitrogen - TOC = Total Organic Carbon differences can be grouped into three main categories: recycling strategies, end of waste criteria, energetic policy. Legal, social and economic aspects are also involved.

Recycling in Italy is based on the implementation of a reliable economic, legal and political supporting structure with a sustainable funding program. In India recycling is mainly performed by the informal sector with no legal and economic scheme.

Concerning end of waste criteria, Italy focuses attention on the whole process starting from the source of the bio-waste (separated collection), the performance of the processes (temperatures, length of treatment) until receiving the media and fixing quality standards for the final product. Indian legislation cares more about the receiving media by fixing quality standards for the final product.

In Italy the anaerobic digestion of bio-waste is also coherent with the renewable energy production legislation and with the EU 2020 and 2030 goals. Current legislation and economic supporting schemes has led to the construction of centralized plants. For India anaerobic digestion is a suitable solution for supplying energy and fuel, particularly in rural areas, hence promoting the adoption of decentralized facilities in which bio-waste can be co-processed with other biodegradable substrates.

On the basis of the above-reported results the following recommendations can be made.

For India: activation of an economic and legal plan for turning the informal sector into a formal organization able to ensure the same level of income for workers; implementation of a collection scheme able to increase the separation at the source of bio-waste for improving the final quality of the compost.

For Italy: implementation of legislation on the end of waste criteria for anaerobic digestion, focusing on the final quality of the product and on the receiving media; greater promotion of the organic fertilizer market for increasing the economic value of the final product.

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