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BIODEGRADABLE WASTE MANAGEMENT BY ANAEROBIC DIGESTION: A COMPARISON BETWEEN POLICY APPROACHES AND REGULATION IN ITALY AND ISRAEL

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ABSTRACT
Biodegradable waste is a significant component of municipal solid waste (MSW); anaerobic digestion allows the recycling of this waste. This paper presents a comparison between definitions, management, and usage of digestate/sludge and sewage from the anaerobic digestion (AD) of biodegradable waste in Italy and Israel in light of the legislation in both countries. Italian legislation is focused on three main components of the whole management/ recycling chain of bio-waste: the source of the waste, the characteristics of the digestate, the environmental matrix (i.e., soil and water) affected by the use of the digestate. Some relevant differences are currently present in the legislation concerning bio-waste and the sewage sludge management. In particular, both EU and Italian legislation lack specific "end-of-waste criteria" regarding the digestate from the AD of bio-waste. The legislation in Israel, on the other hand, is more focused on the application of the digestate and sewage from AD plants on soil rather than the source of the bio-waste. The focus on the end product (waste, water or sludge) is due to scarcity of water as well as soil sensitivity for agriculture use. The comparison indicates profound differences between the two countries, revealing inter alia advantages and disadvantages.

1. INTRODUCTION

In a dynamic, complex, and globalised world, an integrated and multidisciplinary approach is needed in order to analyse and solve complex problems. Such an approach is highly reflected in a joint international research (Brissaud, 2008). Scientific cooperation between Italy and Israel goes back to the early days of the Israeli state, inter alia as both are Mediterranean countries with similar agricultural crops and raw food materials (Tous & Ferguson, 1996). The scientific cooperation between the two countries is not limited to the natural sciences and Mediterranean studies, but extends to history, art, the classics, archaeology, and numerous other scholarly domains (Pagliaro, 2017). The current study compares policy approaches and regulation for biodegradable waste management by anaerobic digestion in Italy and Israel in light of the great challenges both countries are facing in the management of biodegradable waste and its by-products.

Thanks to a strong and reliable political, legal, and economic supporting scheme (EC, 2001), the EU has become a leader in production of renewable energy, with a total production of about 70 M ton oil equivalents. Anaerobic digestion (AD), with more than 17,500 facilities in the member states of the EU, and with total installed power of about 9,000 MW (EBA, 2016) contributes approximately 7.5% of the total renewable energy in Europe (EEA, 2016). Most diffused feedstocks for AD are represented by energy crops (ECR) (mainly maize), contributing to the production of more than 50% of the whole of the biogas generated (EC, 2017a), yet representing a cost increase from about 0.08 €/kWh to about 0.15 €/kWh (Schievano et al., 2015). This last aspect represents a serious threat to the viability of these facilities considering that many of them are now approaching the end of the period of economic subsidies.

A possible and widely studied solution (Pognani et al., 2009; Schievano et al., 2009) is the partial or total replacement of ECR with other substrates among which bio-waste is of particular interest. AD as treatment for bio-waste recycling is also considered a suitable technology for the implementation of a circular economy in this sector (EC, 2017b). Furthermore, since the bio-waste represents more than 30% of the whole of EU municipal waste, in order to achieve the overall recycling goals imposed by EU legislation (WFD, 2008) (i.e., 50% within 2020) recycling of bio-waste is crucial. Economic aspects limit the exploitation of AD in this

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sector to only about 10% of the EU28 bio-waste potential (ISPRA, 2017). For this reason, the replacement of ECR with bio-waste could provide an important opportunity for using the under capacity of existing ECR facilities the viability of existing ECR facilities and the further implementation of EU policy in the bio-waste sector at reduced investment costs. One should bear in mind that the management of the digestate is of particular concern in light of the absence of uniform EU end-of-waste (EoW) criteria. In fact, according to EU legislation (WFD, 2008), digestate from biomasses and ECRs are still considered biomasses, whereas digestate from waste is still considered waste. This legal distinction has affected successive management schemes. The most frequently adopted solution is preliminary solid/liquid separation with successive post-composting of the solid fraction to achieve the standard quality imposed by the organic fertilizer regulation. Since about 90% of AD used for ECR is of the wet type, more than 70% of the solid/liquid separation is still represented by the liquid fraction of the digestate. In some cases, its use on land can be authorized by legal entities in accordance with the R10 recovery operation "land treatment resulting in benefit to agriculture or ecological improvement" (Annex II, WFD, 2008) but in other cases its further processing in wastewater treatment plants (WWTP) could be requested in order to achieve standard water quality before discharge and/or reuse. In this case, even if the outlet water from WWTP is reused, the bio-waste cannot be considered recycled. WWTP is another important EU and Italian sector in which AD is widely exploited even if mainly for environmental considerations (i.e., the biological stabilized sludge before disposal/use) (Di Maria et al., 2016; Di Maria and Micale, 2017). Currently in the EU area there are some 36,000 WWTPs equipped with an AD section for sludge, representing another relevant source of digestate/sludge to be managed. Sludge can also be recovered by the R10 operation.

This approach arises from the Italian and EU legislation that imposes two main goals on the waste sector (CD, 1986; CD, 1991a,b: EC, 2015; WFD, 2008). The first goal is to manage waste without affecting the environment, including human health. The second goal is to make the best possible use of waste materials that can replace raw materials. In the specific case of digestate and sludge, the goal is to replace mineral fertilizers with the ones obtained from those processes. Due to great differences in climatic conditions and soil characteristics across Italy and EU, more specific details related to the quality of soils and specific features for use of these materials on land are usually outlined in local legislation.

Israel is characterised by an arid and semi-arid climate and its water resources are very limited. Water is one of the most significant environmental issues and a major concern in Israel, where the arable land area is approximately 4,200 km2 and the irrigated land area is about 1,866 km2 (Inbar, 2007). The water sector in Israel is subject to the Water Authority (WA), which has overall responsibility for it (Water Law, 1959) and legislation is created at the national level. The Water Authority also supervises the establishment of wastewater treatment facilities by the local authorities, mainly city associations or water corporations that are also required to maintain these systems (Sewage Law, 1962). The Water Law declares that all water resources are public property subject to the control of the state, thus there are no private water rights or resources in Israel and water may only be used by permit holders. As water consumption exceeds the natural rate of replenishment, while the intensity of freshwater use is extremely high by OECD standards (OECD, 2011).

Financial instruments for reducing consumption, such as a 40% increase in domestic water prices (introduced in January 2010) and financial penalties for pollution were also implemented in order to enhance overall water cycle management. Established in 1937, Mekorot, the National Water Company, supplies 70% of total water consumption. Water supplied to agriculture is mainly provided by Mekorot directly or by Agricultural Water Associations. Mekorot treats some 40% of the country's wastewater. The Ministry of Environmental Protection (MoEP) is responsible for protecting water quality and preventing water pollution. In the eastern Mediterranean region, irrigation with water of marginal quality has a long history, with Israel being the most prominent pioneer in advanced treated wastewater use policy and technology (Schacht et al., 2016).

This paper aims to compare and discuss the differences in legislation and practices related to biodegradable waste treatment and its liquid and solid digestate recycling between EU (and hence the Italian) and Israeli legislation.

1.1 List of Acronyms

AD	Anaerobic Digestion
CFU	Colony Forming Units
COLL	Collection
ECR	Energy Crops
EoW	End of Waste
EU	European Union
KWh	Kilo Watt hour
MBT	Mechanical and Biological Treatment
MCM	Million Cubic Meters
MoEP	Ministry of Environmental Protection
MoI	Ministry of Interior
MPN	Most Probable Number
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
OECD	Organization for Economic Co-operation and Development
PFU	Plaque Forming Units
STD	Standards
TS	Total Solids
WA	Water Authority
WR	Water Regulations
WWTP	Wastewater Treatment Plants

2. METHODOLOGY

The scientific approach in this study is based on a joint international study for conducting a comparative analysis of the policy approaches and regulation in Italy and in Israel. Such a comparison is expected to point to advantages and disadvantages of the management systems in both countries and thus contribute to the enhancement of these systems.

The comparison implemented in this study required the collection, classification, and processing of various data, including documentation such as laws, regulations, government decisions, and qualitative data. The data was retrieved from literature and from official documents of legal entities charged with waste planning and monitoring. Furthermore, data from previous works of the authors were considered. The legislation in both countries was reviewed and processed into a visual scheme of the technical and legal recycling pathway of bio-waste via AD in both countries, providing an accessible way to understanding the various "decision junctions" along the pathway as a tool to support conclusions drawn from the comparative analysis.

The following definitions will be adopted in the study: liquid digestate, the fraction of digestate characterized by a Total Solids TS ≤ 10% w/w and sludge, the digestate characterized by a TS ≥ 15%. It is important to note that in the EU, as in Italy, the term "sludge" is usually used to refer to the sludge generated by the sludge treatment lines (primary and activated) of wastewater treatment plants; the above term "sludge" applies to Israel as well.

3. RESULTS

3.1 Italian legislation and scenario

3.1.1 Waste management legislation

The reference legislation for waste management in Italy arises from the adoption of the latest EU directive, the Waste Framework Directive 2008/98/EC (WFD, 2008). This directive imposes some relevant goals to be achieved by the member states at given times. In particular, by 2020 not less than 50% of waste, such as paper, plastics, cardboard, metals, and glass, is required to be prepared for reuse and/or recycled. The recycling of bio-waste, as defined by the EC Environment, by recovery operation R3 "Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes" (Annex II, WFD, 2008) is intended to contribute to the achievement of this goal.

Alternatively, bio-waste can be considered recycled after AD if the digestate is effectively used on land. In this case, due to the absence of EU EoW criteria, the authorization of this operation is subject to the standard qualities imposed by the Council Directive 86/728/EEC (CD, 1986) on the agronomic use of sludge from WWTP classified as the R10 recovery operation. This imposes limits regarding the concentration of heavy metals and other pollutants, including pathogens, for the sludge but also limits on the content of heavy metals for the soils on which the sludge is spread (Table 1). Another relevant legal aspect to be considered in use on land is Council Directive 91/767/EEC (CD, 1991a) concerning the protection of water against pollution caused by nitrates from agricultural sources. This Directive limits the amount of nitrogen in soils to 170 kgN/ha/year for vulnerable areas, and 340 kgN/ha/year for non-vulnerable areas. In any case, separated collection of bio-waste is a compulsory requirement for its recycling (main water and wastewater legislations are listed in Table 2).

TABLE 1: Chemical and physical features for use of sludge from WWTP on land (D.Lgs., 1999).

Parameter	Value
For sludge from WWTP	
Cd (mg/kg TS)	20
Hg (mg/kg TS)	10
Ni (mg/kg TS)	300
Pb (mg/kg TS)	750
Cu (mg/kg TS)	1,000
Zn (mg/kg TS)	2,500
TOC (%TS) (min)	20
Total P (%TS) (min)	0.4
Total N (%TS) (min)	1.5
Salmonella MPN/g TS (max.)	10^3
For soil	
N for vulnerable areas (kg/ha/year)	170
N for non-vulnerable areas (kg/ha/year)	340
Cd (mg/kg TS)	1.5
Hg (mg/kg TS)	1
Ni (mg/kg TS)	75
Pb (mg/kg TS)	100
Cu (mg/kg TS)	100
Zn (mg/kg TS)	300

3.1.2 Wastewater management legislation

In cases where the digestate from bio-waste cannot be used on land, it usually undergoes a liquid/solid separation. According to current legislation and standard quality, the solid fraction can be composted for the production of organic fertilizer, whereas the liquid fraction is moved to WWTPs with appropriate permits. In these facilities, the liquid digestate is usually co-treated with domestic wastewater, and the goal of the treatment is to reintroduce the water into the system in compliance with the water standard quality imposed by the current legislation. Specifically, there are two main water standard references (Table 3): one for discharge in surface water (e.g., lakes, rivers), the other for reuse.

In the latter case, the legislation refers to three possible reuses: agricultural, industrial, and domestic, with the exclusion of drinking and hygienic use. Currently, at the EU level, water reuse is strongly promoted (CD, 1991b), but no target has been defined yet. Italy currently reuses about 9% of its wastewater based on quality of water discharged by WWTPs, while the potential is estimated to be 60% (EC, 2015). Even if the purified water is reused, this cannot be considered recycling of bio-waste since the goal of WWTP is to remove N and P, which represent the real focus of recycling for the EU legislation (i.e., R3 and R10 operations).

3.1.3 Anaerobic digestion of bio-waste

In the EU28, the bio-waste production potential is of about 90Mtonnes. Currently, approximately 40 Mtonnes

TABLE 2: Main water and wastewater legislations in Italy.

Year	Legislation	Purpose
1896	Local regulations on hygiene of soil and house	To establish the main regulation for surface water cleaning, drinking water supply and delivery, wastewater disposal
1904	Legal regulation for hydraulic works	To establish the state as responsible for the protection of public water and related works
1933	Legal regulation for water and hydraulic power plants	To identify the users in terms of small and large public water withdrawal, define the regulations for the search for and extraction and use of ground water, roles for the transmission and distribution of electrical energy
1934	Sanitary legislation	To outline the hygienic conditions for water outflow and impose treatment for wastewater before discharge in water bodies
1963	Master plan for aqueduct	To plan the water supply and delivery system
1976	Legal regulation for protection of water from pollution	To represent the first legal framework regarding wastewater management, collection, and treatment
1898	Legal regulations for the reorganization and protection of the soil	To establish soil protection, water reclamation, management of water bodies
1994	Regulation on water resources	To rationalise the national water supply system
1999	Regulation on water protection from pollution	To define the general principles for prevention and reduction of the pollution, sustainable use and preservation of natural self-capacity of purification of water bodies
2003	Regulation on water and wastewater reuse	To impose possible reuse of the wastewater after purification process and the standard quality

TABLE 3: Main water quality standards for discharge in surface water and reuse in Italy (D.Lgs., 2006; D.M. 2003).

Parameter	Units	Surface Water (max)	Reuse (max)
pH	mg/l	5.5-9.5	6-9.5
SAR[a]	mmol/l	-	10
Solids	mg/l	None	None
BOD5	mg/l	25-40	20
COD	mg/l	125-160	100
Total P	mg/l	2-1	2
Total N	mg/l	15-10	15
N-Ammonia (as NH_4)	mg/l	15	2
Conductivity (mS)	mS/cm	-	3,000
Al	mg/l	1	1
As	mg/l	0.5	0.02
Ba	mg/l	20	10
Be	mg/l	-	0.1
Bo	mg/l	2.0	1.0
Cd	mg/l	0.02	0.005
Co	mg/l	-	0.05
Total Cr	mg/l	2.0	0.1
Cr+6	mg/l	0.20	0.005
Fe	mg/l	2	2
Mn	mg/l	2	0.2
Hg	mg/l	0.005	0.001
Ni	mg/l	2	0.2
Pb	mg/l	0.2	0.1
Cu	mg/l	0.1	1
Se	mg/l	0.03	0.01
Sn	mg/l	10	3
Tl	mg/l	-	0.001
V	mg/l	-	0.1
Zn	mg/l	0.5	0.5
Total CN	mg/l	-	0.05

Legend: a=Sodium Adsorption Ratio for soils

are recycled mainly by composting (3,500 facilities) and only 8 Mtones are processed or co-processed by AD (about 245 facilities). Italy has a bio-waste production potential of approximately 9 Mtonnes. Of this amount, as of 2016, 3.4 Mtonnes are recycled by composting in 274 plants, about 2 Mtonnes are recycled by integrated AD and post-composting facilities in 31 plants, and about 0.25 Mtonnes are processed by AD in 21 plants. A large part of the liquid digestate generated after solid/liquid separation is currently processed by WWTP. A minor amount is currently used on land in accordance with the R10 operation.

3.2 Israeli legislation and scenario

3.2.1 Waste management legislation

Until the early 1990s, 97% of the MSW produced in Israel was landfilled in hundreds of unregulated sites that were used and operated by local authorities. Following the closure of hundreds of unregulated dumps during the 1990s, the MoEP declared a “recycling revolution” that included a comprehensive program for transitioning from landfilling to turning MSW into a resource via recycling. The initial goal set by the MoPE in 1998 was to increase MSW recycling and recovery rates to 25% by 2007. Beginning in 2006, further steps were taken, including the imposition of a landfill levy and the establishment of a financial support program for local authorities to promote separation at source (Daskal et al., 2018). To date, separation at source of bio-waste is not mandatory and most bio-waste is landfilled without any treatment. In particular, AD is not mandatory, implementation of this treatment method is relatively low, and the definitions of this process are vague as there are no clear classifications regarding recycling vs. recovery. In light of the above, sludge management in Israel is mainly associated with WWTP.

3.2.2 Water and wastewater management legislation

Leapfrogging in the treatment and reuse of wastewater in Israel occurred when the state took the lead on this issue, set standards, and financed projects, making Israeli industry a world leader in wastewater treatment and disposal. There are numerous laws and regulations that relate to water and wastewater in Israel. Table 4 presents the most central of these.

3.2.3 Sludge management legislation

The Water Regulations (WR, 2004) are aimed to prevent the pollution of water resources and the creation of environmental nuisances as a result of uncontrolled disposal of sludge originating in municipal sewage. The regulations classify sludge according to various definitions based on the level of treatment and the characteristics of the material obtained. Table 5 presents classification of sludge and various materials according to the Water Regulations (2004).

TABLE 4: Main water and wastewater legislation in Israel.

Year	Legislation	Purpose
1957	The Drainage and Flood Prevention Law, 1957	The 11 drainage authorities are primarily responsible for drainage of agricultural runoff, including through channelisation of rivers.
1959	The Water Law, 1959	Establishes the framework for the control and protection of Israel's water sources.
1962	The Local Authorities Sewage Law, 1962	Prescribes the rights and duties of local authorities in the design, construction, and maintenance of sewage systems.
1971	The Water Law Amendment, 1971	Outlines prohibitions against direct or indirect water pollution, regardless of the state of the water beforehand.
1981	Discharge of Industrial Sewage into the Sewage System, Model Local Authorities Bylaw, 1981	Sets recommendations to local authorities on the treatment of industrial sewage and its disposal into the sewage system.
1988	Streams and Springs Authorities Order (Yarkon River Authority), 1988	Establishes the Yarkon River Authority, which includes: prevention and abatement of stream pollution, planning and implementation of rehabilitation schemes, and transformation of the area into a recreational site.
1991	Prevention of Water Pollution – Rinsing of Containers for Spraying, Regulations, 1991	Prohibits aerial spraying of biological and/or chemical substances for agricultural purposes near a water source, including Lake Kinneret, the open sections of the National Water Carrier, the Upper Jordan River and its tributaries, and other sources of drinking water.
1992	Prevention of Water Pollution – Cesspits and Septic Tanks, Regulations, 1992	Establishes prohibitions and restrictions regarding the construction of new cesspools and septic tanks and on existing ones, including timetables for the gradual elimination of cesspools under certain conditions.
1994	Prevention of Water Pollution – Reduction of Salt Use in the Regeneration Process, Regulations, 1994	Requires industries to undertake a number of technical steps to bring about salt reduction in the regeneration of ion exchange in order to reduce the quantity of salt used in the water-softening process and the consequent emission of brines into the municipal water system.
1994	Streams and Springs Authorities Order (Kishon River Authority), 1994	Establishes the Kishon River Authority, whose functions include: prevention and abatement of stream pollution, planning and implementation of rehabilitation schemes, and transformation of the area into a recreational site.
1997	Prevention of Water Pollution – Gasoline Stations, Regulations, 1997	Requires specific conditions for the establishment and operation of gas stations, including installation of fuel-water separators, use of impermeable construction materials, special measures and equipment to prevent leakage and oil pollution, measures for protection against corrosion, and monitoring equipment and procedures.
1997	Prevention of Water Pollution – Evaporation and Storage Ponds, Regulations, 1997	Aims to prevent water pollution from evaporation and collection (storage) ponds, on the one hand, and restricting their use, on the other.
1998	Prevention of Water Pollution – Prohibition on Discharge of Brines to Water Sources, Regulations, 1998	Prohibits the discharge of brines from ion-exchange renewal, from food, tanning and textile industries, and from hospitals to water sources and the municipal sewage system.
1998	Prevention of Water Pollution – Sewage Disposal from Vessels, Regulations, 1998	Prohibits the discharge of sewage from a vessel to a water source, requires commercial vessels to install adequate sewage collection facilities, and calls for the establishment of adequate reception facilities on shore.
2000	Prevention of Water Pollution – Metals and Other Pollutants, Regulations, 2000	Aims to protect water sources from heavy metals and other pollutants by limiting the volume of wastewater discharged from pollution sources and reducing the concentration of pollutants in it.
2001	The Water and Sewage Association Law, 2001	Increases efficiency of municipal water supply and sanitation services via public service entities called 'Water and Sewerage Corporations'.
2003	Prevention of Water Pollution - pH Values of Industrial Sewage, Regulations, 2003	Sets pH values of industrial sewage in order to protect the environment and prevent the pollution of water sources from the corrosive impacts of industrial sewage.
2003	Salt Concentrations in Industrial Sewage, Regulations, 2003	Sets threshold values for salt concentrations in industrial sewage.
2004	Prevention of Water Pollution – Usage of Sludge, Regulations, 2004	Aims to prevent water source pollution and environmental degradation as a result of improper disposal of sludge originating in municipal sewage treatment plants.
2006	Prevention of Water Pollution – Fuel Pipelines, Regulations, 2006	Reduces potential risks from fuel transport pipelines, thereby preventing environmental degradation and pollution of water sources.
2010	Effluent Quality Standards and Rules for Sewage Treatment, Regulations, 2010	Aims to protect public health, prevent pollution of water sources from sewage and effluents, facilitate the recovery of effluents as a water source, protect the environment, including ecological systems and biological diversity, soil, and agricultural crops.
2011	Prevention of Water Pollution – Wastewater Conveyance System, Regulations, 2011	Aims to prevent leaks from wastewater conveyance systems in order to protect water sources, ecosystems, biodiversity, and other natural resources and prevent environmental hazards, inter alia, by imposing charges and issuing directives in accordance with the provisions of these regulations.

TABLE 5: Classification of sludge and various materials according to the Water Regulations (2004).

Definition	Description
"Sludge"	A by-product of a sewage treatment process in a sewage treatment plant (except in a process in which crude filtering and separation of sand and oils is carried out)
"Stabilized Sludge"	Sludge that has undergone treatment according to a plan approved by the Ministry of Environmental Protection
"Class A Sludge"	Stabilized sludge that satisfies the following requirements: (1) The geometric mean of the density of faecal coliform type bacteria, determined from at least seven samples of the sludge, is less than 1000 MPN per one gram of dry material or the arithmetical mean of salmonella bacteria, determined from at least seven samples of the sludge, is less than 3 MPN per four grams of dry material (2) The arithmetical average of enteric viruses determined from at least seven samples of the sludge is less than one PFU per four grams of dry material (3) The arithmetical average of density of viable helminth ova determined from at least seven samples of the sludge is less than 1 to four grams of dry material, provided that the sampling was conducted in accordance with the method prescribed in Book 3 and explained in Book 4
"Class B Sludge"	Stabilized sludge in which the geometric average of the density of faecal coliform type bacteria determined according to at least seven samples is less than two million MPN or CFU per one gram of dry material
"Dry Material"	Material obtained after drying of sludge at a temperature of 105 degrees centigrade by the method prescribed in Book and explained in Book 4
"Volatile material"	Material found in sludge that evaporates after heating of the dry material at a temperature of 550 degrees centigrade, in the presence of oxygen, according to the method prescribed in Book 1 and explained in Book 4
"Total nitrogen"	The arithmetical amount of concentrations of Kjeldahl nitrogen, N- nitrite and N- nitrate according to the methods described in Book 1

In 2016, 118,019 tons of sludge were disposed of from 63 WWTPs. Thirty-three percent of this amount was discharged into the Mediterranean Sea and 67% was removed to land destinations as presented in Figure 1 (MoEP, 2017). In 2016, most of the sludge that was removed to land-based destinations (which did not flow into the sea) was used for agricultural purposes, after it passed additional sanitary processing and turned into fertilizer/soil enhancement for unlimited use ("Class A Sludge" in accordance with the regulations – see Table 5). The trend of sludge disposal from WWTPs between 2002 and 2016 is presented in Figure 2.

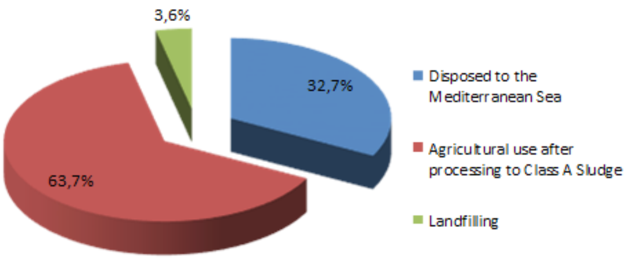

FIGURE 1: A diagram of sludge disposal from WWTPs for 2016 (MoEP, 2017).

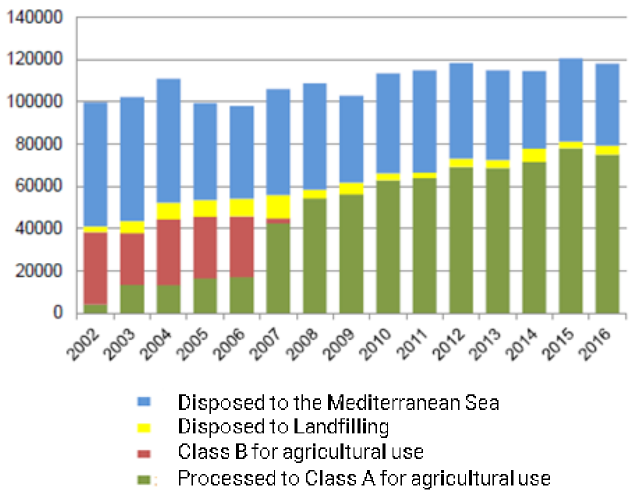

FIGURE 2: A diagram of sludge disposal from WWTPs between 2002 and 2016 (MoEP, 2017).

3.2.4 Effluent management legislation

As water scarcity is a major concern, Israel has introduced ambitious water policies and pioneered cutting-edge water-efficient technologies, including drip irrigation, brackish and seawater desalination, and soil aquifer treatment for reuse of treated wastewater.

In Israel, the local authorities are responsible for the construction and operation of wastewater treatment plants. Israel's wastewater treatment plants use intensive (mechanical/biological) and extensive treatment processes. From a total of 500 million cubic meters (MCM) of sewage produced in Israel in 2008, about 70% of the effluents were reclaimed. Local authorities are responsible for the treatment of municipal sewage. In recent years new or upgraded intensive treatment plants have been set up in municipalities throughout the country. The ultimate objective is to treat 100% of Israel's wastewater in order to bring it to a level that enables unrestricted irrigation in accordance with soil sensitivity and without risk to soil and water sources (MoEP, 2014). The effluent quality and wastewater treatment regulations issued by the Ministry of Environmental Protection (MoEP) and the Ministry of Health in 2010 include 36 parameters that may not be exceeded in effluent whose use in irrigation will be unrestricted or that will be discharged to rivers. Sewage treatment effluent is the most readily available water source and provides a partial solution to the water scarcity problem. Table 6 presents the restrictions on the use of effluents.

4. DISCUSSION

This comparative survey highlights some profound differences between Italy and Israel in the approaches and in legislation concerning the recycling of bio-waste and the management of sludge and liquid fractions generated from

TABLE 6: Israeli standards for effluent (average levels) (MoH, 2010).

Parameter	Units	Unrestricted Irrigation	Rivers
Electric conductivity	dS/m	1.4	n/a
BOD	mg/l	10	10
TSS	mg/l	10	10
COD	mg/l	100	70
N-NH4	mg/l	20	1.5
Total nitrogen	mg/l	25	10
Total phosphorus	mg/l	5	1.0
Chloride	mg/l	250	400
Fluoride	mg/l	2	n/a
Sodium	mg/l	150	200
Faecal coliforms	Unit per 100 ml	10	200
Dissolved oxygen	mg/l	>0.5	>3
pH	mg/l	6.5-8.5	7.0-8.5
Residual chlorine	mg/l	1	0.05
Anionic detergent	mg/l	2	0.5
Mineral oil	mg/l	n/a	1
SAR	(mmol/l)0.5	5	n/a
Boron	mg/l	0.4	n/a
Arsenic	mg/l	0.1	0.1
Mercury	mg/l	0.002	0.0005
Chromium	mg/l	0.1	0.05
Nickel	mg/l	0.2	0.05
Selenium	mg/l	0.02	n/a
Lead	mg/l	0.1	0.008
Cadmium	mg/l	0.01	0.005
Zinc	mg/l	2	0.2
Iron	mg/l	2	n/a
Copper	mg/l	0.2	0.02
Manganese	mg/l	0.2	n/a
Aluminium	mg/l	5	n/a
Molybdenum	mg/l	0.01	n/a
Vanadium	mg/l	0.1	n/a
Beryllium	mg/l	0.1	n/a
Cobalt	mg/l	0.05	n/a
Lithium	mg/l	2.5	n/a
Cyanide	mg/l	0.1	0.005

AD. Figures 3a and 3b schematically present the Italian and Israeli procedure for bio-waste recycling via AD, respectively.

This comparison suggests three main differences between the EU legislation (Italy) and the Israeli legislation:

1) Source of the bio-waste, which has to be collected separately (for Italy and EU);
2) Quality of the digestate in terms of physical, chemical, and biological features;
3) Quality of the soils receiving the digestate, mainly in terms of heavy metals content.

In Italy, if one of the last two steps are not verified, the liquid has to be processed in a WWTP, resulting in a failure of bio-waste recycling (Figure 3a). This approach arises from two main factors: the implementation of the waste management hierarchy and the absence of EoW criteria for the digestate. According to EU legislation, the goal of the hierarchy is to make the best possible use of the waste materials for replacing and/or avoiding the consumption of raw materials. Pursuing this goal in the bio-waste sector means effective use on land of its organic nutrients content, e.g. N, K, P, for replacing mineral ones avoiding the consumption of mineral resources. On the other hand, there are currently no defined criteria specifying when the status of the bio-waste changes from waste to product (i.e., EoW criteria). This means that the use on land of digestate is not really forbidden, but it is necessary to activate an alternative legal procedure for assessing whether or not this activity can be performed. The legal pathway for doing this is stated in article 6 of the WFD 2008/98/EC, which enumerates the general mandatory criteria for the end-of-waste status: (a) the substance or object is commonly used for specific purposes; (b) a market or demand exists for such a substance or object; (c) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and (d) the use of the substance or object will not lead to overall adverse environmental or human health impacts. The absence of a uniform EU legal support leads local and member state legal authorities to adopt procedure from similar legislation that in the specific case are usually represented by the current one concerning the agronomic use of sludge from WWTPs (Figure 3a). Of course, the chemical, physical, and biological features of the WWTP sludge are significantly different from those of the digestate from bio-waste. One main reason for concern is the risk of pollutant compounds, such as heavy metals, that can be quite high in sludge (Table 1). The reason for these concerns arises from the impossibility of having stringent control over the quality of the wastewater collected by the WWTP. In fact, sewage grids are usually mixed systems that collect domestic, commercial, and industrial sewage that, depending on different context, can significantly affect the quality of the sludge. Furthermore, sewage grids also collect rainwater from public roads and parking areas, and thus bring to the WWTP large amounts of pollutant compounds.

If, on the one hand, the EU and Italian legislation is strongly oriented toward the implementation of the waste management hierarchy, on the other hand it shows some weaknesses regarding the implementation of an efficient management of water resources. In the current EU legislation, which imposes an efficient use of water resources, unlike the waste management sector, no reuse/recycling targets were defined. In addition, in this case the lack of legal and political framework limits the achievement of high performances in this sector.

Yet, as Figure 3b shows, in Israel the approach is different. The national goal is the reduction of landfilling via recycling and thus, a landfill levy has been imposed since 2007. AD in this case is considered a suitable technology for the recovery of bio-waste via the production of a soil amend-

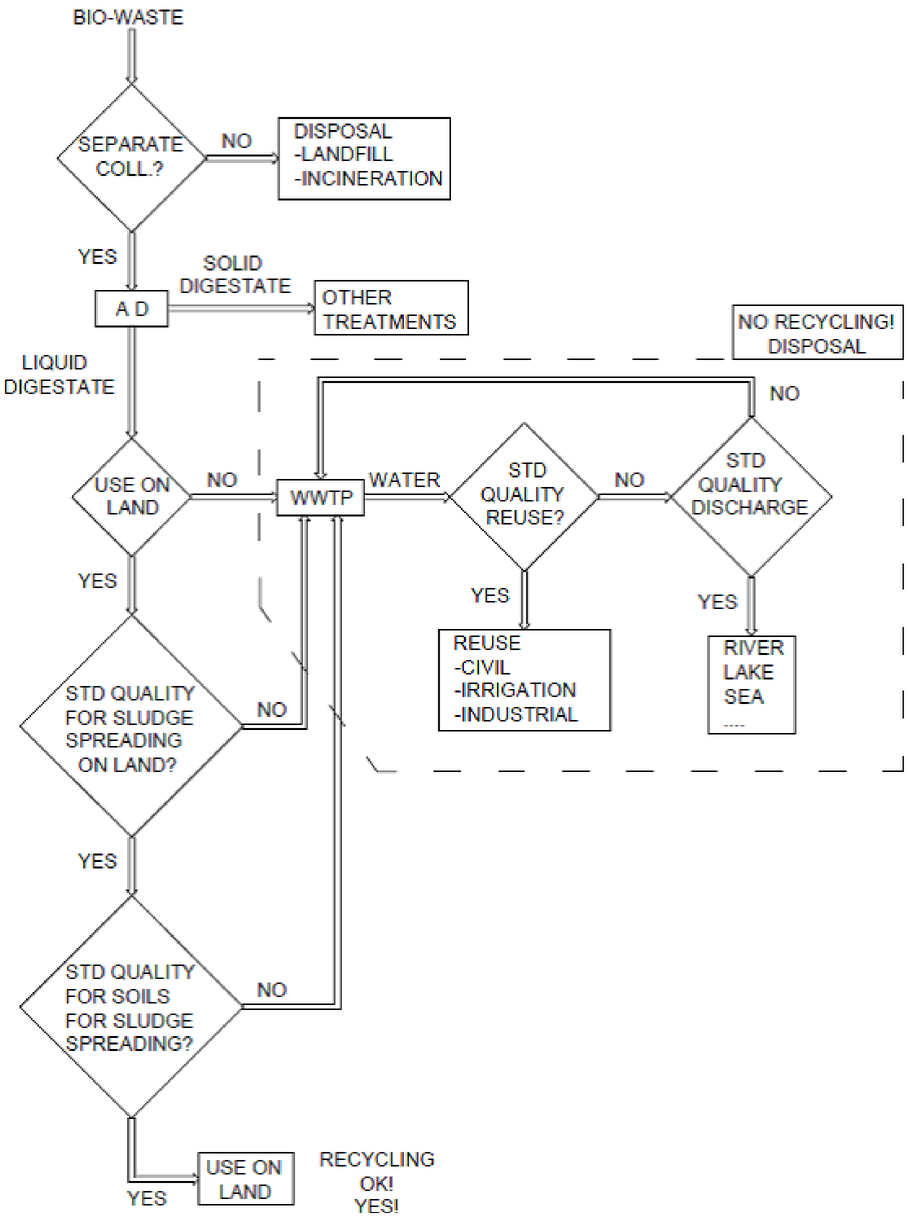

FIGURE 3a: Scheme of the technical and legal recycling pathway of bio-waste via AD in Italy.

ment and/or fertilizer. However, Israeli legislation is not focused on the source of the material, as demonstrated by the absence of mandatory rules on the source separation of bio-waste. Moreover, AD is not specifically indicated by national policy as a suggested technology and its application is left to the choice of local authorities and municipalities. AD of bio-waste is thus an optional recycling method, performed mainly to reduce landfilling and increase recycling, based on the availability of adequate treatment facilities. Additionally, in Israel, unlike in Italy, bio-waste can be landfilled without any pre-treatment and there are no EoW criteria. Concerning the other two aspects related to quality of digestate/sludge and the soils that receive them, some other differences and similarities exist. In fact, both in Italy and Israel there are policies for assessing the quality of the digestate/sludge, with some differences.

The use of solid digestate (sludge) and liquid digestate (effluent) in Israel are well regulated, since there is concern regarding the possible effects of the use of these products on soil and water quality. On the other hand, Israeli legislation concerning sludge (i.e., the solid part) is more oriented toward pathogen content (see Table 5) and less focused on other potential pollutant risks, such as those caused by nitrogen. Italian and EU legislation also interact with water protection legislation where limits on the concentration of different nitrogen and other compounds (e.g., P) are also carefully addressed. Finally different approaches to the quality of receiving soils can be also detected (Tables 1,5).

Concerning the standard quality of water generated by WWTP of liquid digestate effluents (Tables 3,6), it is possible to note that, in general, Israeli standard quality is more stringent for discharge in rivers than for reuse. In contrast, the Italian and EU approach imposes more stringent limits for reused water in particular with regard to the main

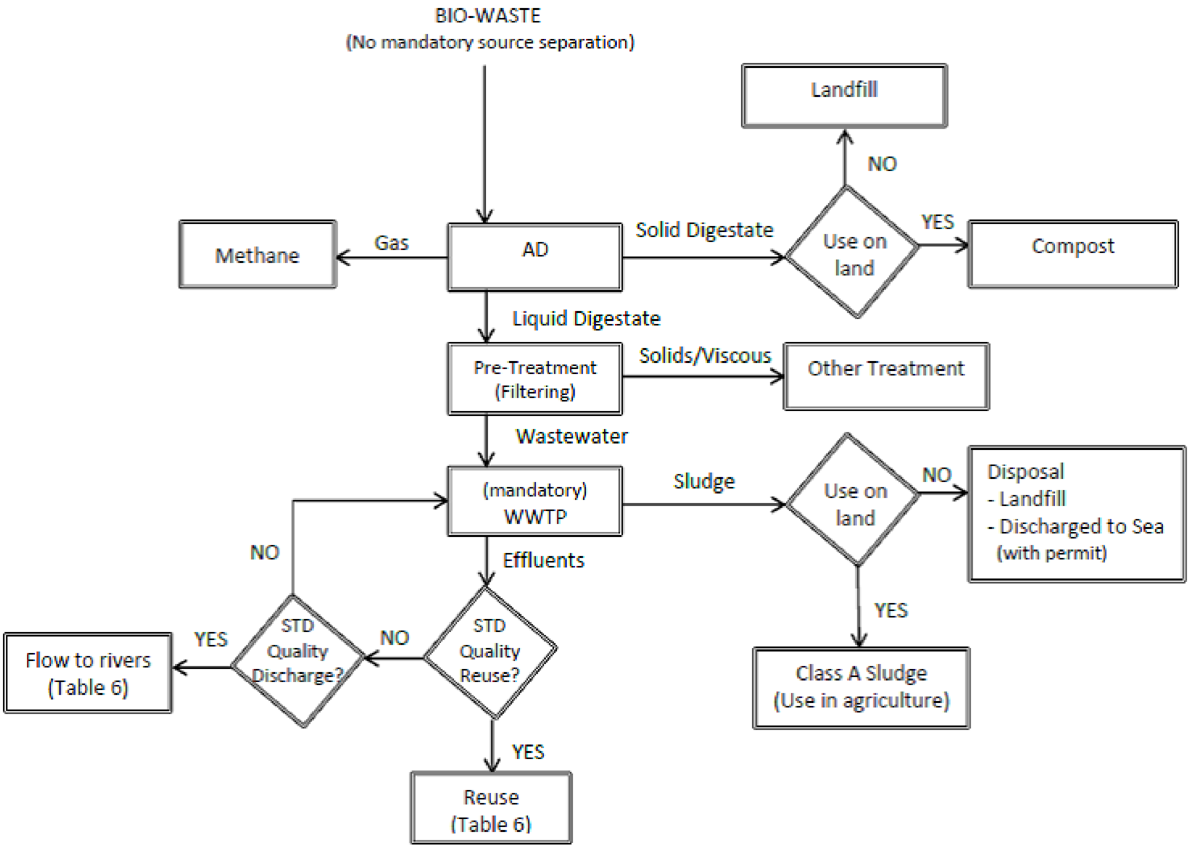

FIGURE 3b: Scheme of the technical and legal recycling pathway of bio-waste via AD in Israel.

parameters and COD, N and P. This difference highlights the priority Israeli legislation gives to the reuse of water, as opposed to Italy and EU where currently this priority is stated, but not fully addressed.

5. CONCLUSIONS

The comparison presented in this paper points out some profound differences between regulation in Italy and Israel and raises some substantive issues:

1. The main differences that emerge from this study are the following:
   I. Bio-waste definitions are different – the EU regulation addresses the source of the bio-waste, which dictates the product's destination, and thus in Italy the source of the bio-waste is the decisive factor that dictates its usage and destination. In Israel, on the other hand, the regulation relates to the receiving media of the products (soil/ agriculture use/rivers).
   II. In order to recycle bio-waste, separation at source is mandatory in Italy, as the EU is concerned about contamination and possible health hazards of the recycled materials (e.g., compost and reclaimed water) whilst in Israel separation may be implemented at the end point based on technologies such as MBT.
   III. The Italian legislation includes EoW criteria that apply inter alia to bio-waste only regarding its solid part, whereas in Israel such criteria are not yet anchored in legislation.
   IV. Even if largely promoted by EU legislation, full implementation of AD of bio-waste in Italy, as in the UE, suffers from the absence of uniform EoW for the digestate.
2. In order to "close the loop" of bio-waste via bio-waste recycling according to the EU legislation, separate collection must be of a very high quality. This requirement might be an obstacle in achieving the EU recycling goals, so further research should be implemented in order to determine whether the EU's strict legislation, which requires source separation, is indeed a must, or whether separation in an advanced sorting facility (MBT) is sufficient for further treatment in an AD facility.
3. The differences that arise from the comparison in this paper emphasize the crucial role of regulation and legislation. We conclude that adequate legal support is crucial for achieving sustainable systems.
4. Elaborating this comparison and further analysing the regulation and management systems of both countries may make it possible to enhance the wastewater cycle in a way that will contribute to the advancement of sustainable wastewater treatment systems in both countries, taking a step forward towards a circular economy.

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