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Draft Indian Standard

PYROLYSIS OF HORTICULTURE AND WET WASTE — GUIDELINES

ICS 13.030.10

Solid Waste Management Sectional Committee, CHD 33	Last date of comments: 08 January 2024

FOREWORD

(*Formal Clauses to be added later***)**

Waste Management is a concerning issue in a country like India with dense population. The exhausted landfills along-with dense population has snowballed the Climate Change impact and it is only fair to say that there is no room for error which negatively impacts the environment and hence bio-diversity.

It is vital to establish and promote circular economy to promote sustainable and green waste management. Pyrolysis technology promises to be one such technology which efficiently processes the waste and reforms it into valuable output. The Catalysis model offers the complete reformation of waste on the same day as generated without any need of segregation or drying.

Horticulture waste and domestic wet waste constitutes a major percentage of waste generated. The waste being voluminous and wet, requires additional energy and fuel requirements while being transported to the disposal sites. Typically, fresh horticulture waste and wet waste contain approximately 35 percent water during normal seasons and during the rainy season, the water content in this waste can go as high as 65 percent. A bulk of this water evaporates while air drying but still a significant amount of moisture is retained by the bulk of the material. This bulky waste requires space for drying and natural drying may take a few weeks to a few months.

There are biological methods which are used to convert waste biomass to bio-compost, bio-gas, bio-methane etc. However, on-site biological processes are not practical as such processes require vast area, sustainable microbial culture, maintenance of bio-culture which requires replacement from time to time, high operating expenses, long time period required for biological reactions to be complete and above all, proper gas cleaning equipment, wet residue disposal means. All these are cumbersome and does not add value to the resource generated from them.

On the other hand, Pyrolysis or thermal processing of the waste is a good solution for addressing this problem immediately as the waste is generated. Further, the climate change concerns coupled with the reduction of renewable energy sources, limiting the use of fossil fuels create a new paradigm in the handling of wet biomass and horticulture waste, as these can be a source of abundant renewable energy sources and an excellent source of Hydrogen gas, which will be driver of economies worldwide in the near future.

These draft standards are aimed at arriving at futuristic solutions, coupled with guidance on the equipment selection. This draft also provides a pathway towards de-centralized waste management, energy recovery at the location where the waste is generated and discourages transportation of the waste to landfills. Further, it also examines the utilization of the energy abundant resources recovered from the thermal processing of such wastes.

1 SCOPE

This Standard covers the guidelines for pyrolysis of horticulture and wet waste.

2 REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

IS No.	*Title*
IS 9569:2022	Solid Waste Management – Glossary (*first revision*)

3 TERMINOLOGY

For the purpose of this standard, the following definition shall apply:

3.1 Horticulture waste – This is the waste biomass generated by cutting of trees, parts of plants, trimming and pruning of tress, dried leaves, grass cuttings, gardening waste, landscaping waste biomass etc.

3.2 Wet Waste – Wet waste is the kind of waste which contains a high water content and derived from household, commercial, restaurants and other sources consisting of organic materials such as leftover food items, rotten vegetables, vegetable peels, vegetable market yard waste, soiled food wrappers made from cardboard, paper, paper napkins, rotten fruits and peels, rotten eggs, egg shells, used tea bags, used tea powder and coffee powder from filters, filter papers, coconut shells, mango seeds , flowers, leaves and garlands from pooja rooms and temples, meat and non vegetarian food items including bones etc. Even though it looks small, wet waste is humungous in bulk as well as for transportation and conversion to other products and resources.

3.3 Pyrolysis – Pyrolysis is a thermal process in which biomass is indirectly heated at elevated temperatures in the absence of oxygen. Thermal decomposition due to intense heat where the chemical composition of biomass changes. Pyrolysis can be further sub divided into (a) Slow Pyrolysis (b) fast pyrolysis (c) Gasification (d) Catalytic transformation (e) thermal depolymerisation (f) Flash Pyrolysis. There are many other categories of pyrolysis based upon the utilization of the process in the chemical and petroleum industry. For the purpose of horticulture and wet waste the above mentioned categories are relevant

3.4 Slow pyrolysis – Pyrolysis process in which the temperature of the biomass is increased in a slow and gradual fashion and within the temperature range of 300 ºC to 500 ºC, is termed as slow pyrolysis. Slow pyrolysis is used to increase gas yield. Rate of heating is limited to approximately 45 ºC/min.

3.5 Fast Pyrolysis – pyrolysis process in which the temperature of biomass is increased at a rapid rate and within the temperature range of 450 ºC to 600 ºC. Rate of heating can be as high as 400 ºC /min

3.6 Flash Pyrolysis – Pyrolysis process in which the temperature of biomass is increased at an extremely high rate within the temperature range of 900 ºC to 1200 ºC and the heating rate can be as high as 900 ºC/ min. Also Flash pyrolysis is used when the biomass particle size is very low and the retention time is kept below 1 second.

3.7 Gasification – Even though gasification is normally associated with the production of syngas and whereas the syngas is produced by thermal processes wherein biomass is heated in the presence of air, oxygen or steam, new developments in catalysis and membrane technologies has paved the way for production of syngas in the absence of air/oxygen and hence gasification through new methods is included here.

3.8 Thermal depolymerisation – Thermal depolymerisation is a process in which biomass co-mingled with waste plastics, waste polymers and rubber etc., is co-processed with horticulture waste or wet waste. Thermal depolymerisation temperatures range from 350 ºC to 450 ºC in a slow heat rate.

3.9 Catalytic transformation – Catalytic transformation is the process in which biomass and/or waste polymers are indirectly heated in the absence limited presence of air/oxygen and the produced vapours are pass through a catalyst bed, wherein the transformation of the gases into high calorific value combustible hydrocarbon gases and methane, is achieved.

3.10 Batch process – The process in which biomass is processed in a fixed quantity batch. Depending upon the waste generated, batch size can be determined and the defined batch quantity is processed inside a reactor. Temperature range is between 350 ºC to 450 ºC and typical batch time is 6 to 8 hours.

3.11 Continuous process – In this process, biomass is processed for 24 h a day, 7 days a week and approximately 330 days a year, continuously. Feed stock is continuously fed into the reactor at determined rates and output products are continuously drawn from the reactor through various outlets. Temperature range is 350 ºC to 700 ºC.

3.12 Residue – It is solid carbon residue left inside the reactor after the completion of the batch process or the solid carbon residue collected from the residue outlet in a continuous reactor

3.13 Vapor products – The outlet gas composition consisting of Hydrogen, CO, CO_2, N_2, CH_4 and light hydrocarbon gases.

3.14 Catalyst – Catalyst is a non-reactive substances which enhances and speeds up the process of thermal decomposition and which also reduces the process energy requirement.

3.15 Reactor – A vessel which is indirectly heated to process the waste material in a low oxygen or oxygen free atmosphere.

4 DESIGN

4.1 General Requirements of Reactor

4.1.1 Reactor design is based on the bulk density of the waste material to be processed. Horticulture waste and/or wet waste is voluminous with an estimated bulk density of approximately 500 kg/m^3.

4.1.2 Depending upon the quantity to be processed, the reactor selection is as follows:

(a) Batch Process Reactor

i) Batch type reactor shall be selected for processing waste from 50 kg to 500 kg per batch. If the material to be processed is more than 500 kg in a day, then a continuous mode reactor is preferred.

ii) Batch reactors are sized depending upon the quantity of waste to be processed. For example, if there is only 100 kgs to be processed, then a 100 kg per batch reactor has to be selected.

iii) Batch time is approximately 8 h to 9 h and it is recommended to operate the batch reactors only once in a day.

(b) Continuous mode reactor

i) Continuous mode reactors may be selected based on the quantity to be processed in a day and shall be selected if it is more than 500 kgs. The continuous mode reactors can be selected based on fixed configurations of 1 TPD, 5 TPD, 10 TPD, 25 TPD, 50 TPD, 100 TPD and multiples thereof.

4.1.3 The reactor shall be made of SS316 steel, preferably internally coated with Titanium or ASTM A516 Gr60 or above. The reactor operating condition are as follows:

a) Temperature range, 350 ºC - 600 ºC

b) Operating Pressure, Atmospheric pressure

c) Energy input per ton processing, 100,000 Kcal

4.1.4 The feed is directly transferred to the reactor through a screw conveyor or hydraulic arrangement. For the waste density of 500-600 kg/m^3, the reactor volume shall be designed approximately 3 times more than the water volume of the reactor. However, the processing capacity depends upon the sizing of the material.

The reactor should to be loaded up to 2/3rd or maximum 75 percent of the total volume for processing and ensuring enough space for the gas vapours to travel in forward direction.

4.1.5 In continuous mode operation the feed is fed by a conveyor through feed hopper. The reactor capacity is decided based on the bulk density of the waste. The feed should be filled to 50 percent of the volume of the reactor maximum. In case the reactor is heated with the gas fuel, then there should be an exhaust gas chimney which should be a minimum of 3 m above roof top of the operating shed.

4.2 Heating system

a) It is recommended to use Electrical heating systems for batch mode reactors. In case of electrical heating, reliable heating coils must be used and the coils must be safely ensconced inside ceramic protection supports.

b) Continuous mode reactors may be heated using electricity or gas from the process itself. Heat load calculations must be based on the sensible heat and latent heat requirements. If gas is used, then the burners used must be self aspirated type with automatic temperature and fuel control integrated with PLC systems.

4.3 Shredder

However, large size branches cannot be accommodated inside the reactor on as is condition, as the low quantity of waste occupies the entire volume of the reactor. Hence it is recommended to use a shredder to shred the material to approximately 2 inches in size. Shredder capacity and configuration may be selected based upon the quantity of waste to be shredded in a day.

4.4 Catalytic bed/converter

4.4.1 The catalytic converter shall be made from SS316/Ti or SS316/L. The converter operating condition are as follows:

a) Temperature range, 350 ºC - 400 ºC

b) Operating Pressure, Atmospheric pressure

4.4.2 The converter consists of catalyst bed which depolymerizes the high molecular weight vapours, cracks them into hydrocarbon molecules and reforms them. There will be pressure drop in the inlet and outlet of the converter which has to be monitored and controlled by differential pressure transmitter through Programmable Logic Controller (PLC).

4.4.3 In the process of molecular reformation conversion, a small portion of the vapours generated are condensed into liquid fuels. However, a major portion of the gas remains un-condensed and the same has to be pumped into a storage vessel through a roots blower. The non-condensed gas is stored in a gas storage vessel as explained earlier. Gas storage vessel shall be made of SS316 steel.

4.4.5 In continuous mode, there shall be a standby converter to ensure uninterrupted operation. This switchover philosophy has to be integrated in PLC.

4.5 Gas Processing

4.5.1 The gas composition during reformation of waste is as prescribed in Table 1.

Table 1 Gas Composition During Reformation Of Waste

(*Clause* 4.5.1)

S.No	Gas	Min, percent	Max, Percent
1	Hydrogen	18	32
2	CO	8	12
3	CO_2	30	42
4	Oxygen	1	5
5	N_2	4	16
6	Methane	6	13
7	C2-C5	4	12
8	C6-C10	1	1.5

4.5.2 *Gas Processing System*

4.5.2.1 *High Value Combustible Gas*

In the process of molecular reformation conversion, much of the gas remains un-condensed and the same is pumped into an intermediate storage vessel through a blower for further processing.

Material of Construction (MOC) for the gas processing system shall be SS316/Ti or SS316/L. The operating conditions are as follows:

a) Temperature range, 40 ºC - 50 ºC

b) Operating Pressure, Atmospheric pressure

4.6 Condenser

4.6.1 The condensable gases from the molecular reformation converter are passed through a water-cooled condenser. The condenser is a specially designed condenser manufactured from Stainless steel for longevity and corrosion resistance. The vapor is passed through the spiral coil side and the cooling water is passed through in a cross-flow direction. The condensed liquid is then collected into an intermediate tank.

The condenser shall be made of SS316/L steel. The operating conditions are as follows:

a) Temperature range, 100 ºC - 150 ºC

b) Operating Pressure, Atmospheric Pressure

4.7 Carbon Storage & Handling

4.7.1 MOC for the carbon storage shall be or SS316/L. The operating conditions are as follows:

a) Temperature range, Ambient temperature

b) Operating Pressure, Atmospheric

4.7.2 Carbon from the reactor shall be recovered after the batch process is over, after the reactor inside temperature drops down to approximately 50 ºC or ambient temperature. This carbon residue can be withdrawn by a screw conveyor and then shall be transferred to a storage. Carbon as received can be directly bagged depending upon commercial requirements. Carbon from the horticulture waste and wet waste can be an excellent source for organic carbon which is a nutrient for soils.

4.7.3 In continuous mode Carbon from the reactor is continuously released during the vaporization process. This carbon residue travels along the length of reactor during the rotation of the reactor due to the contouring provided in the reactor. The carbon cooling system shall be a rotary cooler which should have a water cooling system. The hot carbon from the reactor when passed into the rotary cooler, the same is cooled by the water circulated outside the cooler. The carbon is cooled to the ambient temperature continuously.

4.8 Water Storage & Handling

4.8.1 The pump & storage system shall be made of SS316/L. The operating conditions are as follows:

a) Temperature range, Ambient temperature

b) Operating Pressure, 1 bar - 2 bar

4.8.2 A good quality filtered condensate water can be transferred to an intermediate storage tank with pumping station. It can be used for horticulture/cooling tower make-up water/ can be treated further to make it usable /potable or extract Hydrogen.

4.9 General specification for setting up the plant

4.9.1 Please refer to table 2 for general specification for setting up the plant.

Table 2 General Specification

(*Clause* 4.9.1)

Parameters	**Specification**
Total Power Requirement	130kwh/Ton
Total Estimated Area Requirement	1000 Sq.ft/Ton
Electricity supply	415v/50Hz/3 Ph
Chimney Height	3 m from the roof of the shed

4.10 Safety Precautions

4.10.1 The plant must be situated inside a weather proof shed covered partially on all sides leaving an open space for good ventilation. Exhaust fans must be provided on the top and sides of the shed for air circulation and to evacuate any vapours inside the shed.

4.10.2 There shall be a fire water facility for fire fighting which should include fire water holding tank, fire hose reels, nozzles etc. Also, the shed must be equipped with Fire Fighting Foam and CO_2 fire fighting system.

4.10.3 All the motors, electrical panels used in the plant must be of Flame proof type with proper earthing and lightening arrestors.

4.10.4 All the valves used shall be of Petroleum industry standard (API) and must have SS trim.

4.10.5 As there is gaseous fuel having high energy content is produced, it is recommended to have a proper evacuation system in the form of cylinder filling, gas operated gensets or distribution network for cooking and heating applications.

4.10.6 All the electrical cables used must be fire resistance.

4.10.7 The plant location must be properly marked with fluorescent lines. All the stairs must be covered with non-slip coatings.

4.10.8 Safety instructions, safety slogans and danger markings must be properly displayed.

4.10.9 An emergency eye wash system must be provided inside the plant.

4.10.10 A designated assembly area must be provided close to the plant in case of emergency.

4.10.11 Wind direction indicators must be placed near the plant.

4.10.12 Plant must be equipped with volatile vapour sensors and ambient air quality testing equipment as recommended by the Pollution control authorities.

4.10.13 Safety equipment like coveralls, goggles, safety shoes, helmets must be provided to all the employees and visitors.