DELTA-D TECHNOLOGY - A GREEN SOLUTION TO UNSORTED URBAN SOLID WASTE (USW) DISPOSAL PROBLEMS IN SRI LANKA

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Abstract

The terms "green" and "green technology" are used to highlight environmental conservation or minimal adverse impact on the environment. In this context, a green building could be defined as one, which has been designed, constructed and operated, ensuring, minimal adverse impact on the environment. Most modern green buildings are able to satisfy the term "green", in respect of construction materials, construction technologies, energy efficient building operations and maintenance procedures. However, solid waste (SW) disposal methods used in many buildings cannot be termed as green, due to the use of several non green operations, such as, non segregation of SW, transport of SW over long distances and the disposal of SW into open dumps, resulting in; soil, water and air pollution; breeding of disease causing insects, pests and microorganisms; emission of greenhouse gases, such as, CO_2 and CH_4 due to aerobic and anaerobic micro-organic activity in solid waste dumps

This paper describes, Delta-D Technology, a process invented and patented by the author, that can rapidly digest and convert all types of organic waste (OW) in unsorted urban solid waste (USW) into mineral rich organic fertilizer (OF), thereby, giving a green solution to USW disposal problems in buildings. The main advantages of Delta-D Technology are, automatic separation of recyclables from non-recyclables, rapid digestion of OW within 1 day, disinfection of OW so that there is no breeding of microorganisms, insects or pests, no bad odour and final conversion into a mineral rich organic fertiliser powder, that can be used for domestic agriculture or sold for cash, thereby making the Delta-D Technology Based USW Disposal Process an income earner. The high cost of transport of USW to open dumps and the emission of large quantities of CO_2 from garbage trucks are also eliminated due to this technology. Furthermore, emissions of malodorous gases, as well as, greenhouse gases CO_2 and CH_4 in garbage dumps can be completely eliminated by this technology.

Key Words: Green Buildings, Unsorted Solid Waste, Open Dumping, Aerobic Anaerobic Activity, Composting, Biogas Generation, Delta-D Technology, Rapid Digestion of of Organic waste, Organic Fertiliser.

1.0 Introduction

The terms “green” and “green technology” are used to highlight environmental conservation or minimal adverse impact on the environment. In this context, a green building could be defined as one, which has been designed, constructed and operated, ensuring, minimal adverse impact on the environment.

Most modern green buildings are able to satisfy the term “green”, in respect of construction materials, construction technologies, energy efficient building operations and maintenance procedures. However, solid waste (SW) disposal methods used in green buildings cannot be termed as green. The main reason is that, in Sri Lanka and many developing countries in the world, unsorted urban solid waste (USW), produced in almost all buildings (green and non-green) are put into plastic bags and simply dumped into garbage bins. Once a day or once in several days, garbage trucks operated by the local authorities collect the USW, transport and dump them in open dumps. There are several non-green operations in this process. The first one, is that, USW containing recyclable waste and perishable organic waste get mixed together, due to which, recyclables cannot be separated for recycling. Hence, recyclables, which are mostly non-biodegradable, get into the environment. The second one, is that, USW has to be transported over long distances for dumping, which consumes large quantities of fuel, mainly diesel, leading to high transport costs and emission of large quantities of carbon dioxide (CO_2), which is the main greenhouse gas that causes global warming. In fact 3.2 kg of CO_2 is emitted per kilogram diesel. The third one, is that, in an open dump, the organic waste (OW) in USW undergoes microorganic decay, causing, soil, water and air pollution, as well as, health hazards due to breeding of microorganisms, insects and pests. If there is anaerobic digestion of OW, methane (CH_4) is produced, which is a greenhouse gas, 22 times more powerful than CO_2.

This paper describes, Delta-D Technology, a process invented and patented by the author, that can rapidly digest and convert all types of organic waste (OW) in USW into mineral rich organic fertilizer (OF), thereby, giving a green solution to USW disposal problems in green buildings. The main advantages of Delta-D Technology are, separation of recyclables from non-recyclables, rapid digestion of OW within 1 day, disinfection of OW so that there is no breeding of microorganisms, insects or pests, no bad odour and final conversion into a mineral rich organic fertiliser powder, that can be used for domestic agriculture or sold for cash, thereby making the Delta-D Technology Based USW Disposal Process an income earner. The high cost of transport of USW to open dumps and the emission of large quantities of CO_2 from garbage trucks are also eliminated due to this technology.

2.0 Introduction to Delta-D Technology

Delta-D Technology [1,2,3,4,5] is a patented process developed by the author, to rapidly digest all types of biomass into mineral rich organic fertilizer, within 1-3 days. The novelty of this process is that a digestive fluid called Delta-D is used to rapidly digest starch, fat, protein, cellulose and other organic matter in biomass. The time required for digestion depends on the type of biomass and the quantity of Delta-D used. After the digestion is complete, mineral powders, such as, Eppawela Rock Phosphate (ERP), Dolomite, Calcite, Mica, etc., are added to enhance the Phosphorous (P), Calcium (Ca), Magnesium (Mg) and Potassium (K) levels in the fertilizer, while neutralizing Delta-D. The final product is an organic fertilizer richer in N, P, K, Ca and Mg than traditional compost. This technology can be used to solve the USW problem since large quantities of USW can be converted into organic fertilizer within 1-3 days, compared to traditional composting which takes more than 6 months. The process has been tested with all types of biomass consisting of plant and animal wastes and the fertilizer produced has been tested by cultivating, rice, vegetables and fruits successfully. With the support of the Janatha Fertilizer Enterprises a corporation under the Ministry of Agricultural Development and the Sabaragamuwa Development Bank, around 3000 farmers and entrepreneurs have been trained to convert agricultural wastes, such as, rice straw, USW and farm wastes, into organic fertilizer, using this technology. The technology has been introduced to 75 local authorities to rapidly convert USW into organic fertilizer.

3.0 The Unsorted Urban Solid waste (USW) Problem in Sri Lanka

In Sri Lanka, all big cities have large populations of people and commercial establishments that generate large amounts of Urban Solid Waste (USW). Disposal of USW is the responsibility of local authorities, such as, Municipal Councils (MCs) and Urban Councils (UCs) by statute, for which a portion of the tax collected is used. Since, MCs and UCs do not have efficient USW disposal systems; they resort to open dumping of USW on land, without scientific evaluation of repercussions. Evils of open dumping of USW are, soil, air and water pollution, breeding of, unhealthy micro-organisms, insects and pests, creating an extremely unhealthy environment for people in the vicinity and destroying the aesthetic beauty of land in and around such dumps. A major mistake made by MCs and UCs is to transport and dump all the USW in one or two central locations, due to which, all the above mentioned problems, which should be equally shared by the entire population of the city, are faced only by those residing close to the dumps. In a strict sense of law, this tantamount to discrimination of human rights and fundamental rights of the people living within close proximity to such USW Dumps. Due to the low density (weight/volume ratio) of USW, the cost of handling and transport of USW is extremely high and accounts for a substantial portion of the revenues of MCs and UCs. Another major problem associated with USW in Sri Lanka is that, it is a mixture of perishable and non perishable material of which separation is extremely difficult, labor consuming and very expensive. Although some MCs and UCs have tried to inculcate the culture of separating domestic and industrial solid waste, at source, into R - recyclable material (paper, polythene, plastics, metals, glass, etc.,) and NR - non recyclable materials (perishable material), it has not been successful, due to the difficulties and higher costs associated with collecting and transporting R and NR separately.

3.1 Presently available techniques for USW disposal in Sri Lanka and the world

Although Open Dumping (OD) is the most commonly practiced disposal system, there are several other systems that have been introduced to MCs and UCs in Sri Lanka, namely, Biogas Generation (BG), Natural Micro-organic Composting (NMC), Artificial Micro-organic Composting (AMC), Enzymatic Composting (EC) and Incineration (I). Techniques which are commonly practiced in other parts of the world are OD, BG, NMC, AMC, EC, I, as well as, Sanitary Land Filling (SLF) and Wormy Composting (WC). The most commonly practiced methods in developed countries are I and SLF.

3.2 Problems associated with USW disposal techniques mentioned in Section 3.1

The techniques OD, BG, NMC, AMC and SLF use micro-organisms to digest the organic component of USW into environmentally acceptable products. Since, micro-organisms are extremely small organisms, so small that they cannot be seen without microscopes of high magnification, their digestion speed is extremely low, due to which USW should be stored in one place for a long time (more than 3 months), under controlled conditions, until digestion is complete. Hence, these techniques require, residence times in excess of 3 months, due to which large extents of land have to be allocated.

EC, has been found to be much faster than the above mentioned techniques, but more expensive, due to the high costs of enzymes. Commonly used enzymes are, amylase, cellulase, lignase, protease, etc. The process is also extremely difficult to control due to the high possibility of enzymes to get denatured and inactive due to the assortment of organic components in USW.

WC, although not practiced in Sri Lanka, is being practiced in many countries, where it has been found to be much faster than most of the above mentioned techniques, since, worms are bigger than micro-organisms. However, the capital cost, the operational cost are much higher than other systems and process control too is difficult. It is being practiced in Australia, where agricultural and farm wastes are mixed and subjected to WC, in rotating cylindrical vessels, with humidity and temperature controlled by air circulation. The residence time required for WC is 3-4 weeks after which the compost is sieved, the worms put back to the vessels and the compost is dried and prepared for sale. .

Incineration (I) is practiced in most of the developed countries, since, USW is segregated at source, into inorganic waste (metals, glass, soil, construction debris, etc.,), dry organic waste (paper, plastic, textile, saw dust, etc.,) and wet organic waste (fish, meat, fruit and vegetable market waste, cooked food waste, etc.,). In developing countries, such as Sri Lanka, due to non segregation of USW at source, incineration requires high capital investment for sorting of waste at point of delivery, and high operational cost to incinerate wet material, due to the requirement of fuels, such as, furnace oil, kerosene, LPG, etc.

3.2.1 The Perishable Organic Components of USW

The perishable, easily biodegraded components in USW are, wastes of fish, meat, fruits, vegetables and ffod wastes. Their major chemical constituents are, sugars, starch, glucose, cellulose, oils/fats (esters formed due to reaction of fatty acids and glycerol) , proteins (polymers of amino acids) and other organic molecules, of which, common names and chemical formulae are given in Table 1.

Table 1 – Commonly found Carbohydrates / Oils / Fats / Proteins in Organic Wastes [6]

Carbohydrates	Ch. Formula	Oils/Fats	Ch. Formula	Amino Acids	Ch. Formula
Glucose	$C_6H_{12}O_6$	Glceryl Trilaurate	$C_{39}H_{71}O_3$	L-Alanine	$C_4H_8O_2N$
Fructose	$C_6H_{12}O_6$	Glyceryl Tripalmitate	$C_{45}H_{93}O_3$	L-Arginine	$C_6H_{14}O_2N_4$
Sucrose	$C_{12}H_{22}O_{11}$	Glyceryl Tristearate	$C_{57}H_{110}O_3$	L-Asparagine	$C_4H_8O_3N_2$
Cellulose	$C_6 H_{12} O_6$	Glyceryl Trioleate	$C_{57}H_{107}O_3$	L-Glutamic acid	$C_5H_8O_4N$

3.2.2 Microbial Activity in Garbage Dumps.

After garbage is dumped, naturally occurring microbes start acting immediately on the perishable garbage. There are three types of microbes in the environment, namely, aerobic, anaerobic and facultative, that are acive in a garbage dump.

What are aerobic microbes? They can only survive in an environment of air which contains molecular oxygen. Their food is the organic waste matter available in the vicinity, which they consume, to produce energy and for cell multiplication. Their wastes are products of oxidation, mainly, CO_2, H_2O and oxides of S, N and other components available in the waste.

What are anaerobic microbes? They can survive only in an environment, devoid of air containing molecular oxygen. If there encounter air they die. Hence, they move into the interior of a garbage dump, where there is no air. Their food is the organic waste matter available in the vicinity, which they consume, to produce energy and for cell multiplication. Their wastes are products of reduction, mainly, CH_4, H_2S, RSH, R_1SR_2, NH_3, Amines (RNH_2), Amides ($RCONH_2$) and other components available in the waste. What are facultative microbes? They can get adjusted to the environment, so that, if there is air or molecular oxygen they will work as aerobes and if there is no air containing molecular oxygen they will work as anaerobes.

Aerobic activity is predominant on the surface and immediately below the surface of the garbage pile, since O_2 is availalable, and the final gaseous products of digestion are CO_2 and H_2O. At a depth below the surface, where O_2 is not available, anaerobic activity is predominant and the final products are CH_4, CO_2 and fouls smelling H_2S, NH_3, mercaptans, amines and amides.

3.2.3 Composting of USW by Natural Microorganism [13,14,15,16,17,18,19,20]

Several systems that have been established in Sri Lanka, at enormous cost to convert USW into Compost using naturally occurring micro-organism, as a solution to the USW problem, have completely failed and have been abandoned. One example is the Heaping and Mixing Technology (HMT) based Composting Plant established to solve the USW problem in Horana, which has been closed down due to water pollution and subsequent public protests. Another example is the presently inoperative; Step Grater Technology (SGT) based Composting Plant, established at a cost of Rs. 7.00 million at Dambulla to convert market waste into compost fertiliser. The third example is the inoperative plant established at Kalutara MC to convert USW into compost fertilizer at a cost of Rs. 7.00 million using SGT.

in the city of Colombo, the former practice was to transport and dump USW collected, in a huge open dump at Bloemendhal, within close proximity to Colombo, the capital city of Sri Lanka. After around 2 months the digested USW was transported to a Compost Plant at Sedawatte, where it was allowed to further digest for another 2-3 weeks, after which it was converted to compost fertilizer by drying in a rotary dryer and grinding in a grinding mill. One of the major problems with this operation was that the open dump at Bloemendhal, emanated very bad odour, produced leachate and surface run offs that polluted, ground water, other water bodies, the surrounding land and the dump was a major breeding ground for insects, pests and disease causing micro-organism. The demand for organic fertilizer produced in this plant was relatively low, due to the foul smell and the impurities that were present. On 9th March 2009, there was a massive explosion and a fire at the Bloemendhal garbage dump, due to CH_4 from anaerobic activity catching fire [7]. As a result, several houses in the vicinity caught fire and subsequently, by court order, the dump was closed down. At present, USW of Colombo city is dumped in several sites in the Western Province, namely, Kolonnawa, Karadiyana (Moratuwa MC).

3.2.4 Manufacture of Biogas from USW

Many state and private sector organizations are promoting BG Systems as a solution to the USW problem in Sri Lanka. Several systems that have been established in Sri Lanka, at enormous cost to convert USW into Biogas, as a solution to the USW problem, have completely failed and have been abandoned. One example is the plant established by National Engineering Research and Development Centre (NERDC) at Kirulapana to convert Colombo Municipal Council Market Waste into Biogas [9], which has been closed down. Another example is the plant established by NERDC at a cost of more than Rs. 40 million at Muthurajawela in 2005 [8,9], to convert USW into Biogas, which has been shut down due to technical problems. A study by Alwis[10] has indicated that biogas production from organic waste, in Sri Lanka, has a very low success rate. A study by Perera[11] has concluded that biogas production by anaerobic digestion of organic solid waste, has very poor technical and economic feasibility.

Biogas (BG) is a mixture of gases comprising, CH_4, CO_2 and foul smelling NH_3, H_2S, mercaptans, amines and amides, resulting from anaerobic digestion organic wastes [12]. The fuel component of BG is CH_4. It has been practically found that CH_4 is formed due the anaerobic digestion of carbohydrates, such as, cellulose, starch and sugars and other polysaccharides, by a species of bacteria known as Methanogenic Bacteria (MB) .

3.2.4 Emission of Greenhouse Gases and Contribution to Global Warming due to Current USW Disposal Practices in Sri Lanka

As explained earlier, garbage dumps and BG plants emit greenhouse gases CO_2 and CH_4. CH_4 is 22 times more powerful thanCO_2. Hence, if there is no mitigation plan, these gases will enter the atmosphere and cause global warming. Moreover, the vehicles that are used to transport USW consume large amounts of diesel. According to information gathered, these vehicles which have a maximum garbage carrying capacity of 2000 kg consume 1L of diesel per 3km.

Calculations on Yield, Gross Calorific Value and Pressure of BG and a comparison between BG and LPG are given below.

Overall reactions pertaining to the production of BG from cellulose are given below.

Hydrolysis: $(C_6H_{10}O_5)_n$+nH_2O --- n$C_6H_{12}O_6$-- (1)
(1)Mass Bal: 162n + 18n --- 180n
Acetogenesis: n$C_6H_{12}O_6$ -- 3n CH_3COOH -- (2)
(2)Mass Bal: 180n -- 180n
Methane: 3n$C_6H_{12}O_6$ -- 3nCH_4+3nCO_2 -- (3)
(3)Mass Bal: 180n -- 48n + 132n

From Mass Balances pertaining to above equations (1), (2) and (3):
The maximum concentration of CH_4 in BG is 50 (Mol) % or 48n/(48n+132n) = 27(Mass) %
The maximum concentration of CO_2 in BG is 50 (Mol) % or 132n/(48n+132n) = 73(Mass) %

<u>3.2.4.1Some important comparisons of BG and LPG (Liquified Petroleum Gas) are as follows.</u>

The Gross Calorific Value (GCV) of BG can be calculated as follows.
Mass of CH_4 in 1kg of BG = 0.27 kg,
Mass of C in 0.27 kg of CH_4 = 0.27x12/16
= 0.2025 kg
Mass of H in 0.27 kg of CH_4 = 0.27x 4/16 = 0.0675 kg
Theoretical GCV of CH_4 = 0.2025x8100 + 0.0675x34500 = 3969 kcal/kg = 14490 kJ/kg
Pressure of BG = 1.1 bar
Partial Pressure of CH_4 in BG = 0.55 bar
Partial Pressure of CO_7 in BG = 0.55 bar

Theoretical GCV of Liquified Petroleum Gas (LPG) = 12900 kcal/kg = 54180 kJ/kg
Pressure of LPG = 7 bar

From the above analysis, it is very clear that BG has less than 25% of GCV of LPG and less than 15% Pressure of LPG. Hence, it is very clear that BG is an extremely inferior gaseous fuel compared to LPG.

4.0 Delta-D Technology A Green Solution to USW Problem in Sri Lanka

By using Delta-D Technology, all types of organic waste matter can be digested within a few hours, by mixing with a digestive fluid called **Delta-D.** After digestion, an acidic organic slurry is obtained, which is mixed with Eppawela Rock Phosphate, Dolomite, Mica, etc., to increase the N/P/K/Mg and other micronutrient levels, while neutralizing **Delta-D,** in the organic fertilizer produced. This product is sieved and the powder is packed and sold as organic fertilizer. Undigested large particles of organic matter remaining on the sieve are recycled back to the process and the polythene, plastics, metal and glass particles that remain on the sieve are cleaned and sold to recycling companies.

The main advantage of Delta-D Technology, is that, digestion can be done within a few hours, whereas, traditional processes, such as, composting and biogas generation require more than 3 months to digest organic waste, due to which, large quantities of Urban Solid Waste have to be stockpiled for several months, requiring large extents of land. Another advantage of this process, is that, it produces pathogen free, odorless, organic fertilizer richer in N,P,K,Mg and other nutrients than traditional compost. The process does not produce leachate which is a highly polluting liquid with high BOD and COD values, commonly produced in open dumps, landfills and composting plants. Another unique feature of the process is the value addition to local, naturally occurring minerals, such as, Eppawela Rock Phosphate, Dolomite, Mica, etc. to produce a nutrient rich organic fertilizer.

The composition of the digestive fluid has to be varied according to the composition of the organic waste that has to be decomposed, as well as, the rate at which the organic matter is to be digested. The composition of the digestive fluid required to digest saw dust, straw or paddy husk will be different to that required to digest fruit and vegetable waste which in turn will be different to that required to digest fish and meat waste. Hence the composition of the digestive fluid will be decided on the basis of the waste to be digested at any given time.

The composition of the digestive fluid has to be varied according to the level of disinfection required in the organic fertilizer, as well. For example, if the organic waste consists of highly infectious material, such as, rotten fish, meat, sewage, or clinical waste produced in hospitals, etc., the composition of the digestive fluid can be adjusted to automatically increase the temperature of the digestive mix to 100^0C or more, so that all harmful pathogenic micro-organism are automatically destroyed. After the digestion is complete, a thick, dark brownish, acidic slurry, is produced which can be neutralized using a mineral powder mix. The composition of the mineral powder will depend on the required composition of the final product, which will be an organic fertilizer containing water soluble N, P, K, Mg, Ca and other nutrients. The following raw materials are used to produce the digestive fluid Delta-D and the Mineral Powder Mix which is used to neutralize the slurry. One of the most important properties of Delta-D is that it only catalyses digestion, which means that after the digestion process is over the Delta-D originally added will remain in the system and it is possible to use the Delta- D to digest more and more organic matter.

Raw Materials used to Produce the Digestive Fluid

Eppawela Rock Phosphate (Apatite), Phosphoric Acid, Sulphuric Acid, Nitric Acid, Acetic Acid, Citric Acid, Sugar, Starch, Fruit and Vegetable Waste, Fish Waste, Saw Dust, Rice Straw or Paddy Husk.

Raw Materials used to Produce the Mineral Powder Mix
Eppawela Rock Phosphate (Apatite), Dolomite, Calcite, Powdered Mica, Powdered Quartz, Mixed Salt from Sea Bitterns, Iron Ore, Foundry Slag, Zinc Ore, etc.

4.1 How Does Delta-D Digest Organic Matter? [1,2,3,4,5]

Delta-D has a chemical combination that can digest all types of natural organic matter by carrying out the following reactions. One of its major features is to initiate catabolism (breaking down) of complex carbohydrates, proteins, etc., with acidic action and subsequently mobilize enzymes available in organic matter, as well as, enzymes secreted by microorganisms to continue the process.

1. Dehydration.

2. Hydration.

3. Oxidation.

3. Breaking down of complex molecules, such as, cellulose, starch, proteins, oils and fats.

4. Converting organic, N, P, K, Ca, M, Na, Fe, Mn, Mo, etc. into inorganic, water soluble forms.

4.2 Demonstrations of Delta-D Technology Carried Out In Sri Lanka

Delta-D Technology has been demonstrated at several government institutions, such as, The Institution of Engineers of Sri Lanka, Ministry of Agriculture (Govijana Mandiraya) University of Moratuwa, Horana Urban Council, Maharagama Urban Council, Lanka Phosphates Ltd., The Central Environmental Authority, and several leading private companies, such as, The Lodge Habarana, The Confifi Group of Hotels, Pussellawa plantations, Horana Plantations, CIC Fertilisers, Keells Food Products, Nelna Farm, Mandarin Farm and several other poultry farms. Presentations and demonstrations have been, made at the Mahaweli Ministry, at a workshop organized by Janatha Fertiliser Enterprises, attended by Hon. Chamal Rajapakse, Minister of Agricultural Development and 60 personnel comprising Mayors and Chairmen of MCs, UCs and PCs in the Southern Province. A demonstration was also carried out at The Central Environmental Authority, Parisara Piyasa, Battaramulla, on behalf of the Horana Urban Council to obtain CEA approval for a plant to be constructed at Horana. The process has been tested with all types of biomass and the fertilizer produced has been tested by cultivating, rice, vegetables and fruits successfully. With the support of the Janatha Fertiliser Enterprises, a corporation under the Ministry of Agricultural Development, around 1330 entrepreneurs have been trained to convert rice straw into organic fertilizer using this technology. The technology has been introduced to several local authorities to rapidly convert USW into organic fertilizer.

4.3 Presentation Of Delta-D Technology At National and International Conferences

The author attended the 22nd International Conference on Solid Waste Technology and Management, conducted by The Widener University, Philadelphia, USA, during the period 18-21 March 2007 and presented two research papers on conversion of solid waste into organic fertilizer. The author also attended the 23rd International Conference on Solid Waste Technology and Management, conducted by The Widener University, Philadelphia, USA, during the period 30th March to 2nd April 2008 and presented one research paper on conversion of solid waste into organic fertilizer using Delta-D Technology. The author in collaboration with two other authors presented one research paper at the First International Conference on Solid and Rock Engineering held in 2007 August in Colombo, Sri Lanka , conducted by The Geotechnical Society of Sri Lanka. The author also presented one research paper on Delta-D Technology at the Annual Sessions of The Institution of Engineers Sri Lanka, held in October 2007. Titles of these research papers are given in the list of references.

4.4 Recommended Methods For Using Delta-D Technology To Produce Organic Fertiliser

Research conducted by the author on waste material, such as, rice straw, farm waste and market waste has lead to the development of the following methods of using Delta-D Technology to produce organic fertilizer..

(A) The Recommended Method For Rapid Digestion Of Rice Straw In Dry Zones Making Maximum Use Of Long Periods Of Sunshine

1) 35 kg of dry rice straw is wetted with a solution of 1litre of Delta-D mixed with 50 litres of water.

2) The wetted straw is laid on plastic sheets and exposed to the sun for 3 days.

3) After 3 days the straw crumbles into powder.

4) The 35 kg of digested straw is wetted with 10 litres of water and is mixed with 5 kg of Eppawela Rock Phosphate (ERP) and stored for 2 days.

5) The mixture produced in step 4 is mixed with 500g of Dolomite (D).

6) Now the product is ready for use as the first fertiliser application for paddy cultivation.

7) For other annual crops and perennial crops, the composition of the fertilizer can be adjusted by

adding plant and animal wastes digested with Delta-D to the digested straw.

(B) The Recommended Method For Rapid Digestion Of Rice Straw In Wet Zones.

Even in the wet zones of Sri Lanka there is ample sun shine right through the year. Hence, Method A can be practiced most of the time. However, if there are rains and it is not possible to expose the straw to sunshine, the following method should be followed.

1) 35 kg of dry rice straw is wetted with a solution of 2 litres of Delta-D mixed with 50 litres of water.

2) The wetted straw is stored in a dry area for 5 days.

3) After 5 days the straw crumbles into powder.

4) The 35 kg of digested straw is wetted with 10 litres of water and is mixed with 10 kg of ERP and stored for 2 days.

5) The mixture produced in step 4 is mixed with 1 kg of D.

6) Now the product is ready for use as the first fertiliser application for paddy cultivation.

7) For other annual crops and perennial crops, the composition of the fertilizer can be adjusted by adding plant and animal wastes digested with Delta-D to the digested straw.

(C) The Recommended Method For Rapid Digestion Of Poultry, Cattle and Pig Farm Waste

1) Excreta of animals, including urine is collected and mechanically mixed into a slurry.

2) Per 100 liters of the slurry, 30 kg of, sawdust, straw or any other type of dry cellulose material is added and well mixed.

3) 2 liters of Delta-D is added to the above mix and allowed to react for 5 days.

4) After 5 days, 10 kg of ERP is mixed to it and allowed to react for 2 days.

5) The mixture produced in step 4 is mixed with 1 kg of Dolomite.

6) Now the product is ready for use.

(D) The Recommended Method For Rapid Digestion Of Fruit And Vegetable Waste (FVW)

1) FVW is chopped to a size below 25mm (L) x 25mm (W) x 5mm (T).

2) Per 50 kg of FVW, 1 liter of Delta-D is added, well mixed and allowed to react for 2 days...

3) After 2 days 20 kg of dry saw dust is mixed with the slurry and allowed to react for 2 days

4) After 2 days 5 kg of ERP is mixed to it and allowed to react for 2 days.

4) The mixture produced in step 4 is mixed with 1 kg of Dolomite.

5) Now the product is ready for use.

Table-1 and Table-2 give the chemical analysis of organic fertilizer produced from straw and combinations of straw, cow dung, poultry dung and fruit and vegetable waste using the above procedure, and recipes used .

Table 2 – Chemical Analysis of Organic Fertiliser Produced from Straw, Cow Dung and Poultry Dung Using Delta-D Technology As First Application For Paddy Cultivation

Component	Straw Only	90%Straw+10%Cowdung	90%Straw+10%Poultrydung
Moisture %	30.0	30.0	30.0
Organic C %	28.5	28.7	28.9
Total N%	0.60	1.27	1.83
Total P_2O_5%	6.80	7.10	7.80
Total K_2O%	1.40	1.60	1.87

Table 3 – Chemical Analysis of Organic Fertiliser Produced from PL and FVW

Species	Formula For Tender Rubber Plants Poultry Litter 1000 kg Delta-D 40 L ERP 160 kg Dolomite 75 kg	Formula For Vegetables FVW 1000 kg Delta-D 20 L ERP 100 kg Dolomite 20 kg
Moisture %	30.24	38.31
Organic C%	33.42	29.70
Total N%	1.86	0.67
Total P_2O_5%	6.80	4.30
Total K_2O%	0.93	0.62

5.0 Operational Costs and Economic Feasibility

The operational costs, profits and the feasibility of manufacturing OF is summarized in Table 4. Operational costs consist of Direct Costs (direct raw material, packing material and labour reuirements) and Overheads. In the following analysis, all costs other than Direct Costs have bee lumped into Overheads.

Table4– Economic Feasibility of Composting Saw Dust by a Combined Process of Delta-D Technology & Aerobic Microorganism Based on a Trial Conducted at University of Moratuwa using Fish and Vegetable Market Waste and Saw Dust

Raw Materials and Labour Required To Manufacture Mixed Slurry (MS)	Quantities	Unit Cost (includes collection, handling and transport)	Costs / Profits
Fish Waste Vegetable Waste Delta-D Labour (it is assumed that 1 labour unit is sufficiwnt to produce 200 (MS)	100 kg 100 kg 4 L 1 Unit	Rs. 5.00 per kg Rs. 5.00 per kg Rs. 200.00 per L Rs. 700.00 per Unit	Rs. 500.00 Rs. 500.00 Rs. 800.00 Rs. 700.00 --------------- Total Cost to Produce 206 kg MS Rs.2500.00 Total Cost to Produce 1 kg MS Rs. 12.50
Raw Materials and Labour Required To Manufacture 50 kg Organic Fertiliser (OF) from Saw Dust	Quantities	Unit Cost (includes collection, handling and transport)	Cost
Water Mixed Slurry Dry Saw Dust ERP Dolomite (D) Labour (it is assumed that 1 labour unit is sufficient to produce 250 kg) Packing Material 25 kg PP	21.6 L 5.0 kg 25.0 Kg 2.0 kg 0.4 kg 1/5 Unit 2 Bags	Rs. 0.20 per L Rs. 12.50 per kg Rs. 5.00 per kg Rs. 10.00 per kg Rs. 5.00 per kg Rs. 700.00 per Unit Rs. 15.00 per bag	Rs. 4.30 Rs. 62.50 Rs. 125.00 Rs. 20.00 Rs. 2.00 Rs. 140.00 Rs. 30.00 --------------- Total Direct Costs to Produce 50 kg Rs. 383.00 Total Direct Costs to Produce 1 kg Rs. 7.66 Cost of Overheads 31% per kg Rs 2.34 Total Cost to Produce 1 kg Rs. 10.00 Proposed Selling Price Rs. 15.00 Profit per kg Rs. 5.00 If production capacity is 1 TPD, profit per day will be Rs. 5000 and the profit per year (300 days) will Rs. 1,500,000.

Table 5 -Recipe, Quality and Cost of Production of Organic Fertiliser Using Delta D Technology Based on a Trial Carried Out in Collaboration with Farms in Kochchikade, Wennappuwa and Marawila Sri Lanka in 2011

Basis – Conversion of 1000 kg/d of Organic Waste and 1000 kg/d of Saw Dust and Straw

Organic Waste Mix - Mixture of Poultry Dung and Litter (PL), Slaughterhouse Waste, Fish Market Waste, Farm Waste, such as, Urine and Dung of Cattle, Pigs, Sheep, Goat,etc.

Output of High N+P+K+Ca+Mg Organic Fertiliser = 4300 kg

Dry Basis - Average Chemical Composition of Product:

N - 4%, P - 6%, K - 2%, Ca - 4%, Mg - 2%, C - 37%, H - 6%, O - 38%, Others - 1%, Moisture - 35%

Table4– Economic Feasibility of Composting Saw Dust by a Combined Process of Delta-D Technology & Aerobic Microorganism Based on a Trial Conducted at University of Moratuwa using Fish and Vegetable Market Waste and Saw Dust

Raw Materials and Labour Required To Manufacture Mixed Slurry (MS)	Quantities	Unit Cost (includes collection, handling and transport)	Costs / Profits
Item	**Qty**	**Unit Price (Rs.)**	**Cost (Rs.)**
Organic Waste	**1000kg**	Rs. 2.00/kg	Rs. 2,000.00
Digested Straw,	**1000kg**	Rs. 4.00/kg	Rs. 4,000.00
Saw Dust, etc	**1000kg**	Rs. 4.00/kg	Rs. 4,000.00
Water	**1500L**	Rs. 0.10/L	Rs. 150.00
Delta-D	**100L**	Rs. 200.00/L	Rs. 15,000.00
Rock Phosphate Powder	**400kg**	Rs. 12.00/kg	Rs. 4,800.00
Dolomite Powder	**200kg**	Rs. 6.00/kg	Rs. 1,200.00
Cost of Labour	12 units	Rs. 600/unit	Rs. 7,200.00
Supervision	2 Units	Rs. 800/unit	Rs. 1,600.00
Electricity, Fuel Other costs			Rs. 1,000.00 Rs. 2,000.00
Total			**Rs. 35,750.00**
Qty of OF Produced	**4,300kg**		
Direct Cost of Prodn		**Rs. 8.32 / kg**	

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