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Decomposable Garbage as an Anthropogenic Factor and Need for Positive Perspective: A Review

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Abstract:

Garbage mainly as decomposable waste and recyclable plastics are the loitered waste commonly observed by every urbanite in India. The problems of garbage are likely to be intensified due to shrinking of municipal budgets (Muller and Schienberg, web search). From the perspectives of nature, garbage especially of decomposable type are resolvable commodity provided how we support nature for its processing. Biologists and anthropologists apart from the ruling Government, must work hand-in-hand to scrutinize multiples of existing technologies required to be re-researched and to be re-exhibited on pilot scales that needs to be done in one's hometown. Observations made by Ogawa (web search), shows that successful projects in line of solid waste management in the developing countries are meager and a very few success shown were until with the external support agencies. Later dwindle as socio-economic crisis begin. After analyzing the details of decomposable garbage as disposable/recycling/energy production/composting/landfills -the study has shown the effective transformation of decomposable garbage into economically feasible, bioremedial, sustainable, rethinkable technology as aerobic composting followed by vermicomposting to make use of the product for soil reclamation, organic agriculture as sustainable technology at least for Indian suburbs.

Keywords: Composting, Garbage, Vermicomposting, Recycle, Waste generation

1.0 Introduction:

"Garbage" means – "refuse matter"; "anything useless thrown after use". In human philosophy it is "anthropogenic waste". Rationally it is every man's everyday's unusable commodity but difficult to accept. Garbage has been made a mandatory responsibility of municipal corporations to dispose off on to far off places to create another entanglement of "garbage galore". Garbage is simply not a blamable commodity (Venkataraman, 1995) but an unwanted asset of our day-to-day livelihood. Every citizen in millions of multiples must think, get gathered, assembled, scrutinized, and summoned to take roles of activists to support the technologists for their innovative remedial implementations that are of lowcost and sustainable (IUEIP, 2001) to overcome problematic wastes (Statler, 1990) at the receiving ends and to summon the governments for stipulations. Urbanites' participation in public meetings and committees are a must and to be co-operative through the processes of garbage disposal methodologies at least under semi-scientific methods to enlighten themselves which in the due process bring indirect approachability and responsibility of the municipalities to be regularized in their workmanship. This has been also strongly felt by Muller and Schienberg (Web Article) who stress that equal gender priorities are mandatory. Urban decomposable garbage is the 100% compostable raw material (Flaig *et al*, 1977) more suitable for rural farmers to enrich their soils. Data collected by Furedy, (2002) reveals the fact that Hubli – Dharwad (Karnataka, India) farmers accessed to low paid rate of Rs. 450 to 2,000 for 15 – 50 tons of decomposed dump sites and were using for their arable lands but this practice discontinued due to labor intensification activity. The activity of composting is a sustainability factor (Asnani, 2001) and most suitable as well as economically viable measure from the Indian contest rather than costlier technologies (Gershman *et al*, 1986) like incineration, compaction, landfills, pyrolysis, thermal gasification, neutralysing etc. This review article calls for awareness to prove simple remedial steps (Mega, 1996a) for waste maladies into resourceful product development and its ultimatum destiny to soil to balance the dearth of organic matter and for ecological sustenance (Jung and Jung, 1993) as a fundamental plant science for nutrients (Klein and Klein, 1988) in a sequence of semi-scientific aerobic composting followed by vermicomposting.

Significant differences are observed in the kind of garbage thrown away by the rich and poor. In rich countries recyclable garbage like glass, paper, plastics, metals and other durable waste constitute to a larger share. In poor countries, much of the waste is organic in nature an advantageous option for organic manure and to enter into organic farming by means of composting and/or vermicomposting. In the current scenario, much of the biodegradable organic wet garbage is going in for landfills (Fig: 1, one of the landfill site in Bangalore). Landfill sites (Tanpure, 1992) are the causes for leachate with putrifiable bacteria and cause not only nuisance in terms of odor but also percolate into the ground water and agricultural soils (Robinson and Maris, 1985; Salim, 1992; Tahir *et al*, 1994; Zin *et al*, 1995). Dickes *et al*, (1996) points out that such area no sooner or later generate methane gas – to add much more for ozone depletion. In a country like India several methods and methodologies have been found out by the several workers but a reliable technology from the angles of cost, sustainability, durability, workability has been still a dream and Government support is still vacant. Table: 1 shows the summary of the key predictions by World Bank on Municipal Solid Waste generation (MSW) wherein majority of MSW finds way through landfills by discrete means.

Presently countries and cities all over are running out of space for landfills or closing the existing ones because of environmental concerns like seepage, percolation and runoff (Olaniya and Saxena, 1977) that consist of significant concentrations of either inorganic component such as metal salts and organic substances that cause high BOD (biochemical oxygen demand), COD (chemical oxygen demand), gasification etc (Cointreau, 1982; Pakirappa, 1998) . On several occasions, apart from the leachate of landfills a combination of rain water and surface run off after the rains bring forth strong, concentrated, dark liquor which produce putriscible odor-a sign of improper decomposition making a better option as breeding ground for insects especially flies and mosquitoes to set an array of epidemic diseases (Dickes *et al*., 1996). Apart from landfills the second most common waste disposal process for garbage is incineration with its main objective to reduce the voluminous garbage into less quantity. Although incineration appears to be one of the alternative but it is a dubious solution and perpetuates a cycle of dependence on high-cost technological remedies (Vitousek *et al*, 1986) and unfit for an agrarian country like India. According to El-Zaemey, (1995), in developing countries 30% of the city's budget goes in for transportation and disposal. Moreover, by the method of incineration toxic residues are left behind that need either safer disposal or to make into no toxicity. As a fact incineration is not the option even for richer countries like U.S. and U.K. (European Commission, 1994) from the point of generation of toxic waste from nontoxic biodegradable garbage that rather can safely go in for aerobic composting and vermicomposting for stabilized manure. A 1994 legal ruling in the U.S.A determined that incineration ash must be classified as hazardous waste that cannot be dumped in ordinary landfills (Joni *et al*., 1995). The incineration of garbage is advisable to incinerate at a temperature of up to 850 ^{0} C in the presence of air (Dickes *et al*., 1996) a high cost oriented for Indian economy and can result in the production of the toxic gases like sulfur di oxide, hydrogen chloride and hydrogen fluoride that are to be trapped back and should not enter the atmosphere. Table: 2 shows proportionate garbage disposal method in the developing world.

1.1 Alternatives to incineration-Indian Scenario **(Greenpeace Org, 2004):**

Municipal and hospital waste incinerators are the largest dioxin sources in industrialized countries. PVC plastic is probably the most significant source of dioxin. The U.S. EPA agrees to the fact of production of dioxin (OTA, 1989). Strategies to prevent generation of incineratable waste streams that currently exist are:

- Toxic use reduction planning within industries;
- Waste reduction and alternative forms of sterilisation in hospitals;
- Efficient reduction, recycling and compost actions for household waste. Fig. 1 shows an awareness of anti-incineration action in India (Source, greenpeace.org).

As per Greenpeace report (2004), incinerators and cement kilns that burn hazardous waste can never solve toxic waste problems rather a clean production approach, which substitute's safe materials and processes to stop the generation of hazardous waste in the first place is needed. Alternatives to municipal waste incineration are a mandatory option. Certainly Cost effective and eco-efficient waste management alternatives do exist to avoid incineration. Studies show that Recycling is also profitable. A ban on incinerators, legislated in 1992 in the province of Ontario, Canada, stimulated job creation and the price of secondary materials. The same trend has been observed in the Indian subcontinent since two decades. Under Indian circumstances Govt. of Rajasthan has already set apart 50 biogas of land for setting up Hazardous Waste Dumping Yard at Gudli, District Udaipur, vide their notification No.S.O.290 dated 1.12.1997.

Fig. 1 (A) Anti incineration action in India (greenpeace.org)

1.2 Garbage Galore:

Due to intensive human activities mainly in the form of several fold increase in population structure, the generation of anthropogenic wastes have also increased to multifold. This credit goes to the advancement of science and technology for making human life guaranteed for an extended period with use of renewable and non-renewable resources for his survival facts as well as luxury living at the expenses of ecological nature. This trend has altered the ecosystem at the level of soil, water, air and the physico-chemical, biological properties of nature in toto (Flaig *et al*, 1977). As Satterthwaite (1999), clearly reports that there are increasing evidences that the environment can no longer sustain current levels of human activity. Under Indian scenario, with the rapid urge to grow into metropolitan cities to make advances in technological and economical growth to compete with the developed countries, there is also a compromise to be made with space and natural resources. Advancements in the name of developments are also bringing in urban life and suitable urban infrastructures that are against to nature's laws of thermodynamics. Nature in a complete sense is a balanced act of live biomass to dead biomass (Ewer and Hall, 1972). Today in the name of intensive agriculture and enough mouths to feed, India has marched towards food production but has not given equal importance to the wastes that are generated as part of food production. One such waste is the decomposable garbage - the commodity generated through food production by use of urbanites, the subject of present study. The authors of the book "The State of the Environment Atlas" by Joni *et al*., (1995) rightly stress that it is extremely difficult to measure accurate levels of garbage and as most experts agree that the international information (Coates, 1994) available is little more than an educated guess. Worldwide generation of garbage appears to amount to about one billion metric tons per year, and is growing rapidly. The biggest waste producers are rich countries, and within poor countries, richer people. U.S.A. alone generates an estimated 19% of the world's total domestic waste, and Japan another 4.4%. So in literal terms, "affluence produces effluence" has been the current scenario. **Table: 3** show the waste sources in the European Union (Joni *et al*, 1995).

Fig 1: One of the landfill sites during dry season, in Bangalore, India

Fig: 2 Activity under initial aerobic decomposition of segregated garbage

Fig: 3 Vermiprocess Inspection

Fig: 4 Final Vermicompost

1.3 Garbage Category:

Depending upon the source of generation, garbage/municipal waste generally in terms of solid waste can be categorized as:

1.3.1 Municipal solid waste/garbage includes solid wastes generated in residential, commercial and cottage and/or light industrial areas. It may also include road traffic waste, behavioral waste, demolition and/or construction waste, botanical waste from parks, gardens, schools, colleges, institutions and roadsides, market yard wastes.

1.3.2 Industrial solid waste is made up of wastes generated from industrial sources of agro – industrial Wastes (agricultural products/byproducts entering industrial sector, eg. Sugar factories, distilleries, breweries, vineries, fruit and vegetable processing units, jute and coir based cottage industries etc.); pharmaceutical wastes; chemical processing industries; organic/biological component synthesizing units; textile industrial wastes; colour & cosmetic unit wastes; metallurgical wastes; mining wastes; hazardous wastes as in nuclear sectors; hospital wastes.

1.3.3 Agricultural and/or farm wastes that are generated abundantly at the farm lands like stubbles, hay, husk, weeds, much of post harvested wastes.

1.3.4 Animal and bird wastes that are generated in pig farms, dairy, sheep farms, goat farms, rabbit rearing, poultry (both broilers and layers) and pet bird rearing units.

1.4 Garbage Classification:

According to Asnani (1998; 2001), waste generation ranges from 200g. to 500g. per capita per day in cities ranging from one lakh population. The larger the city, the higher is the per-capita waste generation rate. The total waste generation in urban areas in the country is estimated to exceed 39 million tons a year by the year. Indian mixed waste has a large proportion of compostable material and recyclable wastes. As per NEERI studies compostable matters range from 30% to 57% and inert materials from 40% to 54%. The component of recyclable material is between 5% to 10%. Garbage in general consists of two possible varieties categorized as:

1.4.1 Dry garbage (Recyclable and Reusable) include all kinds of paper, cardboard, cartons and packing of all sorts; containers of all kinds excluding those containing hazardous materials; all kinds of plastics, glass, metals, rags, rubber, wood; foils, wrappings, pouches, sachets and tetra packs; cassettes, computer diskettes, printer cartridges and other related electronic parts; discarded clothing, furniture and electric gadgets.

1.4.2 Wet garbage (Biodegradable and Organic) include food wastes of cooked, uncooked, eggshells bones and decomposed nature; flower and fruit wastes from shops, garden wastes of all sorts; house sweepings; disposable diapers, sanitary wastes and plant biomass wastes. The leading sources of organic wastes vary from climate to climate and economy to economy. Food wastes are always near the top of the list. Some foods generate more wastes than others, e.g. Cabbage and green coconuts in tropical climates. In temperate climates, street trees and grass clippings are a significant source of organic waste (Satterthwaite, 1999). Some manufacturing processes such as paper production generate high levels of organic wastes. With proper concern about the lead content of some colored inks, paper is a good mulch and soil-enhancing agent.

Table: 1 Waste source in the European Union

Types	Percentage
Garbage	6.0
Industrial waste	7.0
Agricultural waste	44.0
Mining	12.0
Demolition	8.0
Sewage sludge	14.0
Other	9.0

Table 2: Proportionate garbage disposal method in the developed world

COUNTRY	LANDFILL [%]	INCINERATION [%]
Japan	34.0	74.0
Ireland	100.0	-
Germany	77.0	17.0
Canada	82.0	9.0
Denmark	30.0	54.0
France	47.0	37.0
U.K.	70.0	13.0
U.S.A.	67.0	16.0
Spain	75.0	5.0

Table 3: Generation of Municipal Solid Waste and practices of landfill by the countries based on income

Country Based On Income	MSW Generation In Tonnes Per Day	Landfill Practices
Low income countries (Afghanistan, Bangladesh, Burundi, Cambodia, Chad etc)	881,666 (203.5%)	Low technology sites, open dumping common
Middle income countries (China, India, Indonesia, Jamaica, Lebenon, S. Africa etc)	211,846 (228.1%)	Some controlled and sanitary landfills with some Environmental controls. Open dumping still common
High incomes countries (Japan, Italy, Kuwait, Poland, U.K., U.S.A. etc)	1,124 (0.5%)	Sanitary landfills with a combination of liners, leak detection, leachate collection systems, and gas collection and treatment systems.

Table: 4 Physical composition of Indian municipal solid waste (MSW) (Sikka, 2001)

Sr.No.	Description	% (wet weight)
1.	Ash and earth	33.58
2.	Garbage	16.53
3.	Leaves	13.05
4.	Ignited coal	8.08
5.	Earthenware	6.65
6.	Hay and straw	6.31
7.	Coconut shell	4.96
8.	Rags	3.60
9.	Paper	3.18
10.	Stone	1.83
11.	Glass	0.88
12.	Leather	0.86
13.	Polythene/plastics	0.65
14.	Iron and metals	0.60
15.	Bones	0.42

Table: 5 Chemical composition of Municipal Solid Waste (Sikka, 2001; Prakash, 2001)

No.	Description	Percentage
1.	pH	7.31
2.	Moisture	41.11
3.	Organic matter	31.24
4.	Carbon	19.58
5.	C : N ratio	37.41
	Mega & micro Nutrients	**Kg/ton of municipal solid waste**
6.	Nitrogen	3 – 5
7.	Phosphorus	1 – 2
8.	Potassium	4 – 6
9.	Calcium	10 – 20
10.	Magnesium	2 – 4
11.	Sulfur	1 – 2
12.	Iron	1 – 2
13.	Copper	0.01 0.02
14.	Zinc	0.1 – 0.2
15.	Manganese	0.4 – 0.6
16.	Boron	0.1 – 0.2

Table: 6 Comparative factors between RDF and coal

Factors	RDF	Coal
Boiler Efficiency (%)	52.62	49.30
Evaporation Ratio (Kg/Kg)	3.68	3.30
Steam Cost (Rs./ton)	326.00	500.00

1.5 Garbage Composition:

The most important aspect when dealt with composting and vermicomposting. Both physical and chemical compositions are considered. Although biological composition is also mandatory this is not given much importance under Indian scenario except while handling the workers are given gloves and gumboots. Works by Bhide and Sundaresan, (1983), reveals the bacteriological analysis done for municipal solid waste of 33 Indian cities indicating a dominance of A. lubriocoides and T. trichiura parasites and the monsoon season giving maximum positive samples.

***1.5.1 Physical Composition*:** Based on the percent recovery as shown in Table:4, maximum materials are ash and earth and the next material is the actual garbage apart from leaves of avenue trees, parks, earth, rags, paper, stone, demolished waste, glass, plastic, rubber, leather, ferrous and non ferrous metals.

1.5.2 Chemical Composition: From the angle of composting chemical composition of the garbage is of wider scope. As physical parameters pH and moisture are considered. The content of nutrients in the form of inorganic nutrients and organic matter apart from C:N ratio are of utmost important to make use as end product for agricultural activity and prior to it is the decomposition factor wherein the activities of microbes are dependent on chemical composition. Table: 5 enlist the chemical components in the garbage.

1.6 Energy Content in Garbage **(Bezbaruha, 1993):**

The energy content in municipal solid waste is community specific and corresponds with the variation in composition of the waste (Gershman *et al*., 1986). The calorific value in municipal solid waste in India as reported by Tanpure, 1992, for Bombay was varying between 600 to 4,000 K cal/kg of dry inert free waste (abundant of wet garbage). Panjwani, 1992 has given a value of 800 to 1,000 K cal/kg.

1.7 Refuse-derived fuel (RDF):

It typically consists of palletised or fluff MSW that remains after the removal of non-combustible materials such as ferrous materials, glass, grit, and other non combustible materials. The remaining material is then sold as RDF and used in dedicated RDF boilers/co-incinerated with coal/oil in a multi-fuel boiler. However, the environmental concerns of incineration also apply to RDF combustion facilities. Another indigenously designed technological implementation for the reduction and conversion of garbage is into refuse-derived fuel pellets (RDF) is by Sikka, (2001). These pellets are to be used as a substitute for coal. A pilot project by the Department of Science & Technology, Government of India, has been set up in Bombay, for producing two tones per day of RDF as a coal substitute. The key operations involved in processing are as follows: Mechanical lifting; Segregation of combustibles from garbage; Drying; Size reduction; Preparation of ingredient mixing and Pellet formation. According to the author, Sikka, 2001, these pellets are in great demand in and around Mumbai, in view of their special eco-friendly characteristics and advantages over the coal in the following applications.

1.8 Pelletization:

It is a process of obtaining refuse-derived fuel (RDF). The garbage collected is separated for combustibles that are dried and shredded. It is then blended with suitable biomass like agricultural waste or sawdust. The blended waste is then pelletized using suitable binding agent. Bombay Municipal Corporation (BMP) is running a pilot plant at Deonar open dumping site where 120 tons per day of raw garbage is processed. Drying is done by hot air generated by a biomass incinerator (Panjwani, 1982). Table: 6 shows the comparative factors between RDF and coal in terms of boiler efficiency (%), evaporation ratio (Kg/Kg) and steam cost (Rs/ton).

1.9 Landfill Gas Recovery:

It is another "MSW-to-electricity" technology that permits electricity production from existing landfills. This is possible via the natural degradation of MSW by anaerobic fermentation (digestion) into landfill gas. Anaerobic digestion can also be used on municipal sewage sludge. Moreover, the energy used to produce the product is lost and only a fraction of the intrinsic energy content of the materials can be recovered. Reuse and recycling, even from an energy perspective, are the preferred options.

1.10 Pyrolysis:

Pyrolysis and thermal gasification are related in terms of technologies. Pyrolysis is the thermal decomposition of organic garbage at elevated temperatures that happen in absence of air. Being an endothermic reaction**,** pyrolysis provide 75% of the energy as gas and gives commercially viable products like acetic acid, acetone, methanol and turpentine oil depending upon the waste used (Panjwani, 1992; Tchobanoglous *et al*., 1977).

1.11 Thermal gasification of MSW:

It is different from pyrolysis in that the thermal decomposition takes place in the presence of a limited amount of oxygen or air. The generated gas can then be used in either boilers or cleaned up and used in combustion turbine generators. Both of these technologies are at the development stage, with a limited number of units in operation. Most of the environmental concerns for incineration also apply to pyrolysis and thermal gasification facilities.

1.12 Cement kilns:

Throughout the world some 60 cement kilns have been modified so that various wastes can be burned along with conventional fuels. However, cement kilns are designed to make cement and not to dispose of waste. A study by the US Centre for the Biology of Natural Systems, found that emissions of dioxins are eight times higher from cement kilns that burn hazardous waste than those that do not burn it.

1.13 Compaction:

In the compaction method the volume of garbage reduces by compressing hydraulically under high pressure. Such compacted blocks can be used as building materials. In this process the waste is made less offensive by reducing odor, fly nuisance and rodent menace.

1.14 Neutralysis:

Neutralysis is the process of converting garbage into light waste aggregates. Valuable end products are obtained through this process. Garbage is mixed with liquid waste and clay and formed into pellets. The pellets when fired produce high energy, and inert lightweight aggregates in the form of ceramic rocks are obtained. The end product serves as a ready building material. The process gives metal present in the garbage as a by-product with high resale value (Panjwani, 1992).

Whatsoever technologies mentioned are of energy oriented and are affairs suitable for First World Countries that are developed to the most part of economic perspectives. However technologies pertaining to composting methodologies are the most suitable option from the angle of end use in the agricultural lands for sustainability and productivity and even for its low-cost effectiveness provided, the skills and understanding of the decomposition factors taken into consideration not neglecting the seasonal variations in an annual cycle.

1.15 Workability shown for 3, 65,000 tons/annum segregated garbage into vermicompost

Assuming that the wet/organic garbage is segregated

Assuming that the wet/organic garbage procured is 1,000 tons/day X round the year = 3,65,000 tons; with an av. 90% moisture [inclusive of rainy, winter and summer seasons] to absorb the leachate lignocellulosic wastes like cocopith [for Southern India] / bagasse [for North-Western India] / jute waste [for Eastern India] used in a ratio of 10Kg wet/organic garbage: 1Kg dry cocopith/bagasse/jute waste is required [in 10:1 ratio]; thus required lignocellulosic waste for 1,000tons of wet/organic garbage would be 100kg/day; therefore for 3,65,000 tons of wet/organic garbage, the required quantity of lignocellulosic waste would be 36,500Kgs [36.5tons]/ annum.

Assuming that the required structures has been established to handle 3, 65,000 tons of segregated wet/organic garbage [i.e., necessities like 5 acres open land, 1 acre dhumsed zero-zero floor with low cost roofing [that lasts for 20 years at least], compartmentalized above ground tanks of 2.0ft height] with required numbers of tippers, hydraulic tractors, power tillers, mini j.c.b., conveyor belt, mechanical sievers, minimum workers to work 8hrs per day basis, packing and stitching].

Table: 7 Salient features of aerobic composting vs vermicomposting

Aerobic Composting	Vermicomposting
Process undergoes in presence of air.	Process undergoes in presence of air provided the garbage undergoes initial decomposition aerobically.
Process undertaken by only aerobic microbes and makes the anaerobic microbes non-functional.	Process undertaken by the compost feeding earthworms in the presence of aerobic microbes only.
Process is limited irrespective of air availability due to succession of microbes, thus may enter into non-completing cycle of aerobic degradation but may give way for anaerobic succession.	Process is complete with earthworms' perfect feeding and defecating activities, so that even after the process of vermicomposting the product will continue to harbor aerobic microbes
Due to technical problems or due to climatic factors the incomplete composting activities continue to be anaerobic conditions causing odor menace and unsuitable for storage or not suitable for productive lands under cultivation.	Under anaerobic situations due to uncertainty factors created by the aerobic succession the earthworms experience methane tragedy, either escape or die forcefully.
The product aerobically degraded compost under all feasible circumstances will have limitations in its usability due to unstabilized nutrient status compared to vermicompost.	The product vermicompost will be stabilized, granular micro pockets of humus which can readily go in for agricultural purposes and even best suited for green-house cultivation of floriculture and olericulture.
Required mandatory semi-natural conditions for the production.	Required mandatory semi-natural conditions for the production. Earthworm cost is the only added cost which is recoverable.
Time taken for the complete aerobic composting operation is 90 – 120days under all climatic seasons.	Time taken for the complete vermicomposting activities is only 90days due to compost earthworm activities.
Leachate problem will be solved by use of ligno-cellulose waste materials, thus fly menace is also controlled.	Leachate problem will be solved by use of ligno-cellulose waste materials, thus fly menace is also controlled.
Minimized man power can adapt mechanization wherever necessity prevails.	Minimized man power can adapt mechanization wherever necessity prevails.
The product fetches comparatively less price than vermicompost	The product fetches comparatively more price than ordinary aerobic compost.

1.16 Necessities to keep in mind for vermicomposting:

- Composting activity is something like baking a cake that require proper raise in temperature from within without any external means of raising temperature.
- Natural allowance of air into the composting material, such that the material needs to be breathing constantly.
- When the composting material breathes naturally, the establishments of air breathing microbes build up by natural means, no need of external stimulants or external addition of microbial inoculums.
- Such natural air-breathing microbes rely on composting material for their survival, growth and reproduction and by doing so they breakdown the complex organic structures in the compost and release simpler, stabilized nutrients as end products
- Once the proper decomposition sets in say 30days, the smell of the compost material will be good earthy odor, then compost earthworms can make their entry.
- With adequate compost earthworms, the compost material will be transformed into vermicompost in 60days.

Table: 8 Nuisances that arise when handling segregated wet/organic garbage prior or later vermi-composting activities inclusive of working mode and marketing of the product

Nuisances that Arise	To Overcome Nuisances
1) Shifting of segregated wet/organic garbage to the site of composting on-to-day basis.	Proper planning, execution and delivery system to be implemented by the municipality.
2) Unloading of the garbage to the above ground tanks.	The height of the roofing should be such that unloading should be easier without any required man-power into the above ground tank.
3) Addition of dry ligno-cellulose material to the tanks to overcome leachate problem	Garbage to be sandwiched by dry ligno-cellulose material. So prior to the unloading of garbage add 50Kg and after unloading add 50Kg with even distribution. This solves leachate as well as fly menace.
4) Assuming 1,000tons of garbage/day	100 lorry loads of garbage to fit in an area of tank that can hold 1,000tons of garbage/day.
5) Assuming 30,000tons of garbage in 30days.	Required tanks are 30 numbers.
6) Assuming 3,65,000 tons of garbage per annum the required number of tanks	Per annum the required tanks are only 90 numbers. 1,000 tons/day enter one tank. Likewise 30 tanks per month. One cycle of conversion of garbage into vermicompost is 90days. Thus the first tank is available for 2nd cycle of garbage filling in the 4th month. So we need 30 tanks for January, another 30 tanks for February, yet another 30 tanks for March. For the month of April, the January tanks will be empty. Likewise after 90 days the existing tanks will be available for the succeeding months of garbage collection.
7) How to take out the converted material out.	Use of mini j.c.b.s
8) Where to store the converted material	Since it is totally stabilized material with earthworms should go in for naturally ventilated semi-godown for segregation, drying, packing and stacking.
9) Required number of trucks/day	One truck can hold 10tons of garbage. To the site of composting is 25K.M. radius. It takes 1hr for load-transport-unload. One truck can make 6 trips per day. Thus required number of trucks per day would be 17.
10) Required number of mini J.C.B.s per day	3 numbers.
11) Required number of tractors per day	3 numbers.
12) Required number of workers per day	One person’s job to take care of 1 tank, to empty 1 tank, to segregate 1 tank, to sieve and pack 1 tank. Likewise 30 workers sufficient to handle everyday all the activities in 8hrs.
13) The obtainable vermicompost product per annum from 3,65,000 tons of garbage	1,000 tons of garbage on vermicomposting reduces to 60% to get only 400tons of vermicompost. Thus per annum the obtainable quantity of vermicompost would be 24,500tons.
14) Monthly procurable vermicompost of 3,000tons salable rate and distribution system.	Per ton vermicompost can be sold to Rs. 2,000. Therefore for 3,000tons obtainable value will be Rs. 60 Lacs / month.
15) Who are the buyers?	Net work distribution through Govt. Depts. of Horticulture, Agriculture, Sericulture.

2.0 Known Methods of Composting of Decomposable Garbage:

Composting in general means controlled decomposition processes of organic nature. Composting is bacterial decomposition of organic solid waste to get relatively stable end product. The composting process involves bio-chemical conversion of organic matter into humus. Mesophillic and thermophillic organisms carry out the processes of composting. Advantages of garbage composting promise two prime factors; a feasible form of a method for disposal of wet/organic garbage and to obtain a resourceful humus product at a economically feasible cost in a short duration of time to improve the productivity of arable soils. At any given time compost technology is a very simple, accurate and adaptable methodology pertainable to the local conditions. Almost everything of the wet/organic garbage will be converted into humus except a small amount of resistant residue, which needs to be further degraded as compost. Under normal situations compost has low toxins and the used material is segregated wet/organic garbage only, devoid of hospital waste, and would have undergone complete, systematic practice of composting methodologies (Weber and Heinrich, 1982).

Biochemically wet/organic garbage contain biodegradable organic fraction that mostly of water soluble constituents like sugars, starches, amino acids, organic acids hemicelluloses, celluloses, fats, oils, waxes, lignins, lignocelluloses and proteins (Tchobanoglous *et al*., 1977). These organic constituents are subjected to bacterial conversion for their energy and multiplication. In the due course microbes break down the complex organic constituents into simpler organic and inorganic constituents that are easily absorbable by the plant root system for their energy, growth, biomass and multiplication. The conversion in terms of decomposition process by composting systems of wet/organic garbage is a relatively slow process (Fig: 2) and an offensive odor producing is normally not recommended, for which such a practice becomes faulty process of composting activity. As a general rule of practice, composting operation consists of seven steps, namely:

1) Segregation of wet/organic garbage from the rest of the material at the source itself;
2) Shredding if necessity prevails, otherwise this step is vomited;
3) Enhancement of decomposition, by natural means without any extra energy;
4) Time-bound composting factors;
5) Stabilization of the compost into ready product with analyzing the product for physicochemical constituents as a proof for properly assimilable components;
6) Packing of the product according to the general rule of compost packages;
7) Built-in Marketing net-work for immediate use of the product at the receiving end.

2.1 Biological Nature of Garbage:

Nature's Law is Ecological Balance. There is always a relationship between Live Production Biomass ⟷ Dead Organic Decomposition Biomass (Sharma, 1993). The amount of wet garbage generated is nothing but the dead organic decomposition biomass that needs facilitation for its degrading processes to release inorganic nutrients required for that much amount of live production biomass. Under ecological sustainability, any dead/lifeless material decomposition or purification (Sullia and Shantharam, 2005) process starts immediately depending on the presence or absence of air. Garbage especially that, which has been freshly deposited, contains a large proportion of putricible material, e.g. food and vegetable refuse under different decomposition stages. Such wastes undergo biodegradation (Prakash, 2001) i.e., the action of microbes to break down the waste into more simpler organic compounds, such as carboxylic acids and ultimately to water, carbon dioxide, hydrogen, methane and ammonia, depending on whether or not the microbial action is aerobic or anaerobic. The decomposing living organism like bacteria, fungi, yeast and actinomycetes carry out these processes. In the later stages, other bigger organisms like ants, insect larvae, maggots, worms, centipedes, millipedes, rotifers and earthworms enter depending on the aerobic or anaerobic status of the garbage material (Ewer and Hall, 1972). Upon the circumstances, the biological treatment processes generally harness these different groups of organisms for the conversion. Under the composting methodologies (Enger *et al*, 1978) the existing ones are anaerobic composting and anaerobic composting. With a modification there exists mechanical composting as well as windrow composting.

2.2 Anaerobic Composting:

This process is carried out by anaerobic bacteria, which decompose organic matter fraction of the garbage in the absence of air/oxygen. Anaerobic microorganisms' breakdown organic compounds by reduction process and by releasing the metabolizable nutrients (Bhide and Sundaresan, 1983). The process is, however, very slow and produces offensive odor of hydrogen sulfide (H_2S) and mercaptine derivatives (Panjwani, 1992) and hence normally not preferred. The anaerobic process had been popular in India where it provided for co-disposal of refuse and night soil in a small scale. It is done either in pits or trenches by placing alternate layers of refuse and night soil. The pits or trenches are left for many months. This method is low cost and require less of material handling, it need large land area and long retention time and hence abandoned in favor of aerobic process (Ambrose and Jack, 1982). In another version, the digested matter later blended with sewage sludge for stabilization as well as for nutrient status (Tchobanoglous *et al*., 1977). All the components of garbage, however, cannot be treated together as it may increase the detention time making the system uneconomical (WMPPP, 1995). Pretreatments are required for the successful digestion operation (Obeng and Wright, 1987). Estimates show that a 150 tons per day containing 60% methane and 40,000 tons per annum of organic fertilizer. However, in anaerobic decomposition only a small portion of easily degradable organic matter is converted into gas (Panjwani, 1992).

2.2.1 Aerobic Composting/Open Composting:

In this method the degradation of organic waste using aerobic bacteria in an oxygen environment i.e., surplus aeration. During aerobic decomposition, aerobic microorganisms oxidize organics into Co_2 and nitrate ions. Carbon in waste is used as a source of energy by the microbes, by doing so they break down the complex substances into simple inorganic constituents. The process is normally completed in both mesophilic and thermophilic ranges of bacterial activities. Aerobic composting takes about 3-4 months under tropical climates and stabilization is a must by ensuring turning of the material at least once in fortnight. By doing so the compost gets well aerated and the factors of anaerobicity do not set in.

2.2.2 Windrow Composting:

In windrow composting solid waste of wet/organic garbage are placed in windrows in an open field. The windrows are turned once or twice to per week for enhancement of aeration. This continual turning takes place up to five weeks. The compost is usually cured for an additional period of 2 – 4 weeks to ensure stabilization. In total, the windrow method of composting process takes about 2 to 2.5 months (Bhide and Sundaresan, 1983). Titus *et al*., 1980, suggest turning of windrows everyday for five days helped in conversion time of 30days. Material without shredding took about 50days for conversion and every alternate turning with 30-40% compostable fraction took 25 – 30 days. However, Jambhekar, 1991, assures that the windrow method of composting to degrade completely requires at least six months.

2.2.3 Mechanical Composting:

It is an aerobic process, which overcomes the limitations of conventional aerobic composting processes as regards to space and labor. Several mechanical composting methods have been developed for controlled process operation. Such a method takes only five to seven days to produce stable product. It is very much preferred in the developed and industrialized countries and not suitable for developing countries due to high cost of fossil fuels. As a living example, the Bombay Municipal Corporation (BMC) set up a mechanical composting unit of 300 tons per day at a cost of Rs. 12.1 million. It had to be closed down due to non-appreciation of the product by the farmers. While the cost of production was Rs. 350/- per ton, the compost could be sold for only Rs.80/- per ton (Panjwani, 1992) and failed as economically non-viable option.

3.0 Rethinkable Technology for Conversion of Decomposable Garbage:

From the studies of "garbage science" it is a well known fact that the nutrients and living organisms present in the wet/organic garbage is the clue for decomposition process, which when given a perfect balanced decomposing activities under systematic semi – scientific aerobic composting followed by vermicomposting methodology result in a valuable humus product for the enhancement of soil fertility status. The conversion of wet/organic garbage into humus is the most significant, easiest, and cost-effective technology, particularly to the prevailing ecological conditions of urban bioregions of the world. The technology, aerobic composting followed by vermicomposting is suitable for the countries based on their economy. Gupta, (2004) stresses the importance of composting/vermicomposting of Indian decomposable garbage. As we know nations of the First World (Western bloc and Eastern bloc) are very well sound with technology and economy (Seager *et al*, 1995) that can offer and go in for costlier affairs of garbage disposal methods like incineration, energy generation. Coming to the countries with an economy consistently and fairly strongly developing over a longer period like India, can certainly depend on aerobic composting followed by vermicomposting for the prevailing tropical climate and to overcome the dearth for organic matter in the soils apart from their existing favorable working community.

Analyzing the detailed aspects of systematic semi-scientific methodology of aerobic composting followed by vermicomposting (Fig: 3) is the need of the hour, (out ruling anaerobic composting completely for its nuisance of obnoxious odor and fly menace and for the liberation of methane gas), for its faster, safer and friendlier conversion of wet/organic garbage into vermicompost. Although vermicompost biotechnology is the most available existing methodology for the conversion of wet/organic garbage into vermicompost since 3 – 4 decades, over and over again several workers have worked and proven the best results under micro level (laboratory conditions) but under macro level (under pilot scale and/or ward level) the work of aerobic composting followed by vermicomposting technology for the wet/organic garbage has not been unanimously accepted by neither the Government nor the civic bodies due to one of or several of the reasons mentioned here under :

- Due to intermittence in continual supply of partially aerobically decomposed garbage availability to the compost feeding earthworms or
- Due to the compaction of the aerobically decomposed garbage or
- Due to either low population or high population build up of compost earthworms or
- Due to mishandling of the process under unscientific scenario thinking that aerobic composting and vermicomposting is an easy affair, or
- Due to unavoidance of leachate or
- Due to unavoidance of fly menace or
- Due to political lobby - leading to unacceptance and not agreeing to the economically viable aerobic composting followed by vermicomposting for non-corrupted act.

The present study reveals the above said lacunae in a step wise manner with a thorough knowledge of the systematic aerobic composting followed by vermicomposting based on several years of observations and work experiences (Kale and Sunitha, 1993; Kale *et al*, 1993; Sunitha *et al*, 1994; Sunitha and Kale,1995a; 1995b; 1997; Sunitha, 2001; 2011). In the vermiculture process, compost feeding earthworms are used under semi-natural conditions for converting the wet/organic wastes into vermicastings (earthworm excreta). This process has been successfully used in a limited scale in Bangalore, Pune, Mumbai etc. But there are no successively under operation on continual basis of large-scale centralized plant experiences in India. Hence this approach is recommended as an additional method of composting of waste through private sector participation or through contractual arrangement. However, this technology need not be adopted by the Corporation departmentally as it will be difficult for the Corporation to handle the production of earthworms, their timely induction, and following the vermiculture processes. The effort to privatize the disposal of waste through vermicomposting is recommended along with microbial composting of waste provided a general knowledge on aerobic composting and vermicomposting as shown in table: 7.

A modified suitable protocol for the conversion of wet/organic garbage into vermicompost with systematic semi-scientific adaptations for continual workability is the prerequisite. Here the required conditions are explained in semi-scientific method for use of general public. Since the protocol was felt more mandatory than the work implementations which are provided by the other scientific workers, presently the following statements are laid and the workability are shown for 3,65,000tons/annum of segregated wet/organic garbage into vermicompost in table: 8. Keeping in mind for the users of entrepreneurs and eco-conscious persons some of the necessities to keep in mind during vermicomposting of decomposable garbage are mandatory as shown in table: 9. Due to the change in the climatic conditions of rainy, winter, summer, variation in the garbage proportion of vegetable wastes and food wastes apart from handling, unloading and the process it is common to come across some or the other nuisances and how to overcome such situations are shown in table: 10.

4.0 Conclusion:

Again and again several authors have shown estimates for conversion of wet/organic garbage into vermicompost, at house-hold level, ward level and at the level of municipalities but implementations have sparsely been taken up for aerobic composting followed by vermicomposting. The reason could be either aerobic composting or vermicomposting results have shown only for a temporary period or the sustainability act has not been done or a continual pattern of activity under all season based activity has not been recorded anywhere in India. The reasons have been clearly pointed out in the present review article. In the present study a better option for the utilization of the decomposable part of garbage into resourceful vermicompost, an organic biofertilizer to encourage soil reclamation, to march towards organic agriculture has been stressed out. Under the Act of Government Policies, vermicompost technology for the conversion of decomposable garbage is surely crosses the barriers of constraints faced at the level of technology, finances and sustainability not only for disposal but at the angle of supply of humified organic manure (Fig: 4) for agrarian soils.

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