Editorial

Modern and Traditional Ways of Waste Disposal

At a time when the World is embroiled in attempts to conceive or achieve the goal of what has been described as "Sustainable Development", Sri Lanka witnessed one of her worst man-made (unnatural) calamities with the collapse of the Meethotamulla waste dump, on New Year's eve in April 2017.

The United Nations Agenda for 2030 recognizes 17 Sustainable Development Goals (SDG's) to realize the Global dream of sustainable development, whatever the context in which that philosophy may be understood by the different communities of the World. Significantly, SDG-12 of the UN Agenda refers to "Responsible Consumption and Production", referring contextually to the fact that Countries can manage the sustainable extraction of their natural resources more effectively, and also dispose the toxic waste more efficiently. These are as one may say, just empty words with no meaningful and clear directions on how best this process could be scientifically and methodically achieved, without having to face mishaps of the magnitude of the Meethotamulla holocaust. Sri Lanka needs, and also expects more positive and meaningful guidance supported with scientific, technical and financial resources, rather than mere statements that are incongruent with cultural norms of the country, to be able to deal effectively and rapidly with this long neglected issue.

Nevertheless tradition has it that our visionary forefathers engaged in their simple and meaningful lifestyles, developed the means of responsible consumption and production of the natural resources and disposal of waste, in compliance with natures own turn-over cycle, where organic waste components were re-cycled by collecting and allowing these to decompose in small heaps or shallow pits to generate in situ organic manure. Although some components were in fact incinerated, usually under anaerobic conditions in pits to produce ash containing the inorganic fertilizer components such as potassium as well as micronutrients, which were also applied to supplement the organic fertilizer. Traditions in the coconut industry, where animal draught power was used, and in consequence animal waste was systematically recycled for economic production of coconut, is a lesson to be emulated.

A scientifically laid out field experiment at the Coconut Research Institute (CRI) in the early 1950's was designed to compare the performance of the traditional mode of fertilizer application in coconut plantations using buffalo herds, with modern methods using chemical fertilizers. In the traditional method, a pair of buffalo heads was tethered to each coconut palm for 14 nights. It was the belief that the quantity of dung and urine produced by such a pair of buffalo heads, produced adequate quantities of nitrogen and phosphorus for the coconut palm for 2 years. However, it had also been the practice of the traditional farmer to spread a 4 gallon oil can full of kitchen ash round the base of each coconut palm as a supplementary fertilizer. Though the composition of kitchen ash could vary considerably, the common use of the coconut hush as a fuel in the traditional kitchen hearth ensured adequate potassium in the ash. Dried coconut husk can contain as much as 25 % of K_2O in ash (compared to the common chemical fertilizer Muriate of Potash with 50 % K_2O). Significantly this combination of dung and urine of the buffalo heads, together with an oil can full of kitchen ash, was found to contain virtually the correct proportion of NP and K required by a coconut palm for 2 years as recommended by CRI using chemical fertilizers. Thus here one observes how traditional wisdom had prevailed in a case of waste disposal.

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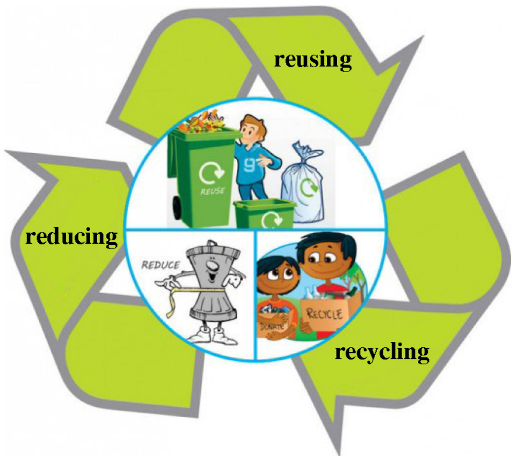
Sorting and recycling of waste (Sustainable waste management)

Mrs Kanchana Dilrukshi Weerakoon

Humans are only one kind of living organisms among other animals and plants. One of the main ways by which the human being differs from other animals is that he has distanced himself from nature and has adopted an artificial life style. This living organism-the human being or *Homo sapiens sapiens* indulges in activities that no other animals indulges in. He uses all sorts of machinery, he learns not only from his parents but gets "educated" through institutions, he believes that he is the most powerful and that the other animals are not so. He has a consumer style which exceeds the requirements for his living. When we study the consumer patterns of all other animals it is seen that they consume only what is necessary for their day to day existence. However man is not easily satisfied and is unlimited in his consumption. His consumption is not only for the daily survival of himself and his family, but is targeted for the future sustenance of future generation. This has created a deficit in resources and competition which affects man more than other animals. The entire living system has been brought to a risky situation by man due to this competition. In order to acquire the deficit in resources man has exceeded nature and has produced consumer goods artificially. This has adverse effects. For example the consumption of processed foods has led to the increased incidence of non-communicable diseases. The wrappings and the packaging of these processed foods has created the threat of waste accumulation, which no other animal has created. In the past the "waste" created due to consumption was not a challenge because it was returned to nature as a resource. However, during an era when the industrial revolution was considered as development, yet man has not been successful in dealing with waste without making it a problem. If "waste" is properly sorted out at the very begining of its generation, then waste management is much easier. Sustainable waste management has to begin even before waste is generated. Prior to the consumption of any resource, we have to think whether using the resource is essential or not. It may be transformed into waste if it is not essential to consume.

For example, imagine that you are purchasing a pair of shoes. You will be given a cardboard box as well as a polythene bag along with the pair of shoes. Now there is something for you to think about. Is it the shoes that is essential for you or the cardboard box and the polythene bag as well. If you do not like to generate waste along with this purchase, then you have got an opportunity to refuse the waste, the box and the polythene bag-that is given to you, free of charge. But do the consumers in our country act with such understanding. Or else you have another opportunity after you bring the box home, you might use it to store some other thing in it and when you finally dispose it, sort it as 'cardboard' and give it to be recycled. However if you brought the polythene bag home there is very little opportunity in our country to recycle it. In this example, we have discussed how your decision and action would result in not generating waste or converting it into a resource. Unfortunately, most of the consumers in our country ignore or disregard both these opportunities. Consequently mountains of waste such as the one at Meethotamulla being created. They will produce the gas methane (CH_4) which will contribute to the increase in global



warming. The unhygienic and toxic chemicals produced during the decomposition of the waste mountain will pollute underground and river waters and sometimes will provide the conditions for the spread of communicable and non-communicable diseases. Is this the sustainable development we are hoping for?

Therefore, sustainable development has to begin in our minds. Waste will remain "waste" if we make it a problem. Even though the final result of our consumption is waste, we can transform it to a resource. A further step is to prevent the generation of waste (zero waste). Then it is also a sustainable waste management.

Is a life style of zero waste generation practical? How can it be done? The 3R concept for waste management is well known. For the past three decades or more, through the use of handbills etc. people are being educated about the concepts of Reduce (minimize) Reuse (using again) and Recycle in waste management. But have we carried out waste management? If we did so would tragedies such as that at Meethotamulla occurred? So now, time is ripe to go beyond the 3R concept and look for new paths for waste management. A 10R concept going beyond the 3R concept will open up a zero waste life style. How can this be done?

There are two main types of waste: the decomposable wet garbage or organic waste and the non-decomposable dry garbage. The non-decomposable waste can be further categorized as recyclables and non recyclables. Sorting of the waste into decomposable and non decomposable waste at the point of waste generation itself is very important. Because the mixing of these two types makes the waste "real" waste. The main reason for the build up of waste into mountains of waste is this mixing. When mixed the decomposable waste cannot decompose and the opportunity of turning the non-decomposable waste into a resource is also lost. The consumer is mainly responsible for generating waste. If every individual of the 20 million people in Sri Lanka takes individual responsibility for waste management then the state or urban councils will have to bear only a limited responsibilitity. If this happens waste will not become a national problem. What can each individual do to prevent waste becoming a national problem. The answer is simple-that is follow the 10R process. The first step in this 10 step chain of processes is to reduce the generation of waste as far as possible. The first step is:

1. Reject (avoid use) - some of the food sold in todays market which are artificially flavoured with no nutritional value what so ever, and propped up by sheer advertising, causing allergies with long term consumption, and finally even causing cancers. For example, the soups containing artificial taste enhancers, sweetened drinks and

instant foods are some of these. Also they are packeted or contained in packagings which cannot be recycled. Consumption of such foods will only have ill effects. By the rejection of these one does not waste money, does not harm ones health, and safe guards the environment by not generating waste.

Doing this with proper understanding is the fisrt step of the 10R concept. Let us consider another simple example. When you use a bank teller machine (ATM) the machine questions whether you need a receit for the money you intend to withdraw. If you have understood the question you can select "No" (reject) as the answer before the receipt is printed. If most of the consumers do this rejection do you think that you will see so many small slips of paper (waste) near the ATM machine?

2. Refuse - This is a more loose step. At most times what is refused may be used on rare occasions. However, if you are vigilant you will be able to follow this step of refusal also.
When you purchase certain goods, without even asking you, you are given free of charge a wrapper or a bag. You are at liberty to refuse the wrapper or the bag. You have to be prepared to refuse. That is you should have with you a cloth bag or a reed bag or at least a reusable plastic bag. Then only you can refuse the bag offered to you and help to reduce the generation of waste.

3. Reduce - If you follow the two steps started above then you will not generate any "waste" by your actions.

4. Reuse - If you take a clothbag or a reed bag or a box with you then you will be able to refuse the wrapper or the bag that the salesman gives you. You can use your bag over and over again. Then no waste will accumulate in your home.

5. Repair - This is a habit we had in the past. If anything went wrong with anything that we used, then we repaired it. This habit does not exist in the modern day society which indulges in over consumption. Learn to move away from this "disposable", or the use and throw away mentality. Instead cultivate the habit of repairing and using. When an article of clothing is torn it is possible to sew it up and wear it again.

6. Replace - The habit of repairing the broken or the non-functioning part of a chair, table or any other object has almost become extinct. This is due to the "disposable" mentality. Disposalble concept makes a huge contribution towards waste generation. Get out of that mentality. It is harmful to the economy also.

7. Recycle - It is possible to hand over paper, some types of plastics, glass, iron, cardboard and electronic waste to places which recycle them. You can get some income and also contribute to the recycling of the limited resources.

8. Rethink - It is compulsory to rethink, inorder to reduce the waste generation and to use the waste. For example a serviate or a door mat can be turned out of an old bed sheet. According to the western system, this is called upcycling. This concept was very well practiced in our culture in the

past. According to the advice given to the Buddhist priests, they were asked to use their old robe in various ways and finally use it as a door mat or plaster it to the clay walls. This is the upcycling concept.

9. Remember - Always remember to take the necessary basket, bag or wrapping material when you go to the market or shop for purchases. Remember to refuse the bag that the salesman gives you free of charge. Then waste will not become a problem.

10. Repeat - The final R of this 10 step process is to repeat it over and over again continuously.

If you have got a good understanding of this concept what ever that remains after your use will not be waste. When purchasing food, purchase only in amounts that you need. By not bringing home unnecessary food stuff you will save money as well as time. Then the waste going out of your kitchen-the wet organic waste-will also be reduced. What ever that goes out of your kitchen can be turned into compost.

Then you are left with the waste that will not decompose. The decomposable and non-decomposable waste should never be mixed. Keep two bins in a suitable location-one for decomposable waste and the other for non decomposable waste. Sort the non decomposable waste into cardboard, paper,glass iron,tins,coconut shells, plastic and store them in separate containers. Hand them over to a recycling

unit at the end of the month, and you will receive money for it. The polythene that you sorted out will be a problem. If you followed the 10R concept the amount of polythene that you accumulated should be reduced to a minimum. However polythene would be a problem even at a reduced level. There is a solution to this also.

Problem of Polythene-ECO Bricks

A very harmful thing that most of us do is the burning of polythene and plastic. Waste management at present is at a very unsatisfactory level and the easiest way for the public to get rid of waste is to collect it and burn it. This is open burning or burning it on open land.

In many countries burning of waste or setting fire to it is prohibited by law, because the smoke released to the environment during burning is harmful to humans and animals, specially the gas that is produced by the burning of polythene and plastics as dioxene ($C_4H_4O_2$). This is a powerful carcinogen. Also this burning releases a large volume of methane and carbondioxide to the atmosphere.

In addition how do we safely dispose the polythene wrappers or bags in which the sugar, salt, spices etc. that we bring to our homes. When we hand over this polythene to the lorry from the municipality which comes every week finally the harm caused is the same as stated above. This is because the municipality collects a large amount of waste on a daily basis and the waste management is extremely difficult. No methodical procedure is followed. Only a relatively small fraction is subjected to recycling. Even though the municipality collects this waste in a specific site, the waste dump causes the spread of flies and mosquitoes. In addition foul smelling gases are also produced. These have adverse effects on the health of the people in the vicinity. The best option is the suitable management of the polythene that collects in your home. You can make an environmentally friendly brick (ECO brick) with the polythene.

How is an Eco brick made?

1. The polythene made for this should be cleaned free of dirt and dried. (If dirty and wet polythene is used the brick may

burst open with time due to the bacterial activity occurring inside the brick)



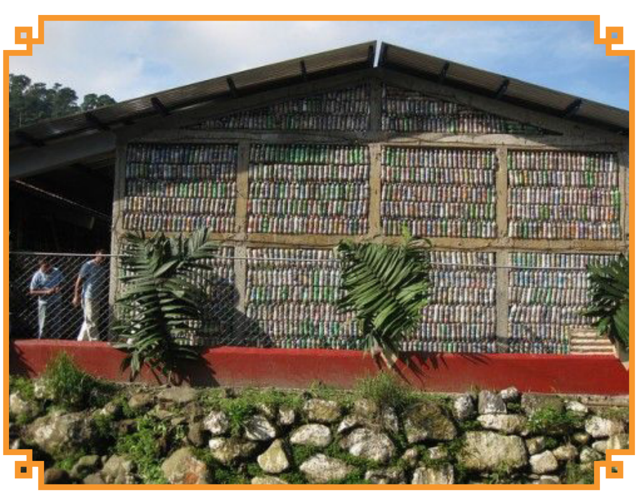
2. Then either fold the polythene into small packets or cut it into small pieces and put into a clean dry plastic bottle that you have discarded after use. (Because plastic water bottles and drinking bottles cause cancer if used more




than once, they can be used for a purpose like this).

3. After placing the polythene wrappers (pieces) in the bottle it should be compressed tightly using a piece of stick. If the bottom of the bottle is not flat but irregular in shape pack the spaces well by pressing onto the polythene in order to fill up all the crevices. Otherwise the brick will not be strong.

4. By pressing in this manner you will be able to make a strong brick when the bottle is completely filled with the polythene that collects daily in your home. To fill the bottle completely you will require the polythene that collects in your home during many months. So this is a solution to the polythene problem in your home because a large amount of polythene can be stored in a minimum of space.



These Eco bricks may be used to make tables, benches or other objects by using cement, clay, ropes, wires etc. (Some countries even build houses using Ecobricks). A Zero waste life style may not remain a dream any more because of the Eco brick described above. It is only if you see a Eco brick that you will realize that it is possible to live safely inspite of the waste, until someday in the future non-recyclable wrappers are prohibited. This is because even if you collect such waste and hand it over to the municipality lorry, according to the waste management procedures currently existing the waste (at most times) ends up in the ocean. There the polythene will turn into microplastic (small plastic particles) and enter into our body through water, soil or fish in the oceans. They may be carcinogenic. So conduct your waste management according to the 10R method and attempt to give a solution to the national waste problem. How pleasent and contended it would be to live in an environment free of any non-decomposable waste.

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Solid Waste Land Fill Technology

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Every living being on earth generates waste during their day to day activities. If you carefully look at the natural environment, you will be able to identify waste generated in various physical appearances, mostly in the solid or liquid form. Waste generated by all living creatures except of humans are naturally recycled in the environment. However, most of the waste generated due to human activities, especially waste generated due to use of artificial man - made items results in an imbalance in the components of the natural environmental processes and adversely affects the environmental balance.

Few decades ago, people in Sri Lanka had simple lifestyles and reasonable area for their households.

The waste generated in the household was disposed within the respective premises. Most people had a pit in the backyard which was used to put waste, which were mostly naturally degradable. When the pit was full, they used to plant a banana tree or a yam (Kiri Ala) bush which will grow using the organic fertilizer generated through natural mechanisms from the waste in the pit. Leaves and other organic waste from the gardens were either burnt or gathered around trees to decay and provide natural fertilizer to the respective trees. There were very little artificial items other than used tins or glass bottles which were re-used for various purposes. All packing and wrapping items were naturally degradable. For example, all grocery items sold were wrapped in used newspaper, while non – food items were wrapped in used cement covers. Fish and meat items were wrapped in *Habarala* Leaves. Food were wrapped either in Banana Leaves or *'Kolapatha'* from Aerecanut Trees. This was a total contrast to what we have been experiencing during the last two to three decades where environmental unfriendly packing items such as polythene and polystyrene foam has come into play.

The changes that occurred within the Sri Lankan economy in the late 1970's paved the way to the use of cheap artificial packing material. With the open economy, global trends invaded Sri Lanka, and items which were not used before, became necessities for Sri Lankans.

The civil unest in the Northern part of Sri Lanka as well as the insurgency in the Southern parts during the late 1980's resulted in many people migrating to main cities from various parts of the country. The infrastructure within the cities was not developed to cater to the rapidly increasing population. The population increase due to migration as well as the natural growth of the existing population demanded the limited land resource to be shared among more people. This resulted in smaller per capita area of land for each family / individual. The waste disposal mechanisms and relevant infrastructure were not upgraded to cater to the increased waste generated by the population. As a result, local government authorities who were responsible for waste disposal of their area had no alternative, but to use any large unutilized land area within the relevant authority's area limits, to dispose waste. These landfills were not scientifically arranged or designed to handle waste in an environmentally sound manner. Even though the need for sound waste management mechanics were highlighted since of early 1990's lack of necessary skills, knowledge and competence as well as capital constraints did not complement the implementation of sound waste disposal facilities. However, the officials responsible tried their level best to ensure sanitary levels in the waste disposal facilities available.

Why is it necessary to establish and implement a scientific waste disposal mechanism?

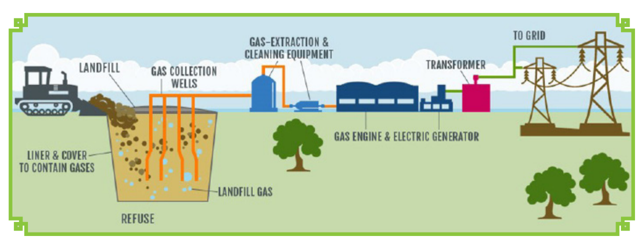
Before answering this question, it is important to analyze the impact of open disposal.

Upon analysis of the waste generated in the country at present, we can identify that majority of the waste, approximately over 60% comprises waste which will naturally decay, as 85% - 90% of such waste comprises water. When rain water falls on the decaying waste, the liquid components produces 'Leachate' which is rich in Nitrate and Phosphates, and which could be used as fertilizer. This is not a quality fertilizer because of numerous contaminants from mixed garbage such as heavy metals and pathogens. However, this Leachate can seep and contaminate ground water and water in fresh water bodies.

In addition, when the waste is disposed through improper or non – scientific mechanisms, the piled up waste, promote anaerobic bacterial action, and the waste will produce 'Landfill Gas' which includes Methane (CH_4) and Carbon Dioxide (CO_2). These gasses are greenhouse gasses and Methane can easily become inflammable under warm weather conditions.

It should also be noted that open dumping of waste including municipal garbage will result in many social and economic problems. There will be hazardous gases with bad odor which are often produced by these dump yards. The dust generated and litters in the dump yard could be a reason for bad environment. These dump yards will also be a breeding ground for vectors such as flies, mosquitoes or stray dogs which spread illnesses. Scavengers such as crows and pests, as well as mice can increase due to availability of food for such animals in these yards.

We have experienced wild animals such as elephants being attracted to the dump yards. The polythene which gets stuck in the digestive system is a common killer of these animals. There is also a reasonable potential to increase population of crocodiles due to dumping of fish and flesh waste near water bodies. The leachate which contaminates water resources will adversely affect fish and other animals depending on such water. The hazards can accumulate through food chains and food webs, and ultimately harm humans in a very aggressive manner. The increase in certain animals such as crows which are scavengers, will adversely affect the natural balance of environment. There are several social problems associated with unorganized and unsystematic waste disposal. Drug addicts use these dumps to collect valuable items such as metal which could be sold. Child labour is used by some of them for segregation of garbage. There have been children buried in garbage while searching for these materials.



Sanitary landfill concept as a final disposal mechanism

Burning of waste is carried out by many people across the world. This is an environmental hazard as well as a health hazard for animals and humans. There are many scientific mechanisms to dispose waste. Recycling and composting are key environmental friendly principles within these mechanisms. There is increasing interest among people to convert waste into electricity in most countries. The main barriers for this process are the requirement of initial capital investment, associated recurrent costs and the technological knowledge pertaining to relevant scientific mechanisms. Sanitary landfill concept provides a more cost effective approach and environmentally friendly mechanism for waste disposal. Within this concept, open garbage dumping is the most common approach adopted, but it will lead to the environmental and social problems discussed above. Hence, sites could be scientifically arranged in a manner that will minimize hazards, and such sites are titled 'Sanitary Landfills' or 'Engineered Landfills'. In these landfills, the gases generated internally within the dumped waste will be controlled, and the leachate should be directed for purification before releasing to the environment or water bodies.

Landfill Technology

Under this topic, we can identify

two main types; the scientific landfills and sanitary landfills. Both mechanisms ensure minimization of problems associated with waste disposal in landfills discussed above.
One of the key challenges in such

landfills is management of seepage of leachate in a manner which would not pollute the environment, especially the water resources. Selection of an appropriate land with suitable soil type and texture is very important. The best is clay soil. The earth should be strong. The soil should be set out systematically and compressed to prevent seepage of leachate to ground water. Sometimes introduction of artificial material to achieve this requirement, such as High Density Poly Ethylene layers (HDPE) can be used for this purpose after calculating the strength required according to the composition of the natural soil layer. Geo Textile covers are used to ensure that sharp and harmful items do not damage the synthetic liner. It is essential to build soil embankments (පාංශුවැටි) around the selected land area to demarcate the area used for dumping of waste. It is essential that these embankments (පාංශුවැටි) are also covered with the aforementioned polythene layers. Thereafter, an appropriate mechanism should be developed to drain out the leachate and contaminated water for proper treatment. Terrain on the bottom of landfill need to be developed to accommodate such a drainage system. Appropriate pipelines made of cement or plastic should be arranged for the purposes of draining out the liquid material for treatment before releasing to the environment. These pipes should have holes on its surface to extract seeping liquid leachate. It is important to ensure that these pipe lines are not blocked, and this could be achieved through positioning an appropriate stone layer (metal) around the pipelines. These covers should be of appropriate thickness sometimes over 1 foot.

These pipelines should be directed to the collection units which are similar to small wells, located at the inner periphery of the landfill. The liquid directed to these units should then be sent for treatment either using surface gravity or by pumping. The liquid generated from the landfill is high in Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) which could adversely affect natural water resources, if released without treatment.

The other main characteristic of a scientific landfill is management of landfill gas generated by anaerobic decomposition activities of bacteria growing on the dumped waste.
As explained earlier the main components of this gas will be CH_4 and CO_2 which are greenhouse gases. The adverse effect of CH_4 as a greenhouse gas is about 20 times more than that of CO_2. The greenhouse gasses induce global warming. The positive aspect of CH_4 is its inflamable charactor. Hence, it can be used as a bio gas. However, we have experienced several fires in landfills due to CH_4 which has not been properly managed. This gas can even be explosive if burned in large quantities.
In order to manage CH_4 in an efficient and effective manner, proper gas vents should be placed at appropriate locations within the landfill. This is achieved through laying of horizontal barrels with holes to emit gas in engineered landfills. With regard to sanitary landfills, further management of the gas is necessary without emitting it to the atmosphere. This is achieved through complete burning of the gas.

It is important to design the structure of the landfill properly to ensure stability of the land. Necessary slopes should be designed.

In a scientific landfill, a 'Reception Lobby' has to be in place in order to receive waste. A proper transportation and road network within the landfill is equally important. The road network and parking facilities should be able to cater to several heavy vehicles moving within the premises regularly.

In order to manage incoming waste, it is important to know the exact quantities received. For this purpose, a weighing bridge should be established within the landfill premises. As the landfill is full of different types of waste which could sometimes have health implications, the employees of the landfill should be given relevant safety equipment. The landfill site should have relevant sign boards in place. Tools for emergency situations and adequate lighting conditions for night operations should be maintained. A washing bay should be in place to wash tyres of vehicles moving out of the landfill and this should be stationed just before the exit gate (s).

The landfill should be separated from other adjoining lands, and the area should be demarcated. Appropriate security mechanisms should be adopted to ensure that unauthorized parties do not dispose litter at these sites.

Managing Internal Operations

Effective management of day to day operations of the landfill has to be one of the main objectives for its success.

Operations within the landfill should be managed in a proper manner to ensure that there is no traffic or other obnoxious event (such as spread of unpleasant odor) to the neighborhoods.

Waste disposal within the landfill should be designed in an appropriately engineered manner. Estimated waste quantities should be directed to respective areas within pre determined time frames. Waste deposition to respective areas should be carried out under a technically competent surveyor's supervision to ensure that the waste is deposited according to the set standards. While compressing the waste, the structural stability of the landfill should be ensured. Appropriate machinery (landfill compactor) should be used for this purpose after scientifically calculating the needs. The compressions should ensure that there is no damage caused to the underneath liner. If the above conditions are not adhered to, the expected lifetime of the landfill will be shortened.
After conclusion of day's activities adequate soil capping should be done. Continuous monitoring should be carried out to check whether there is leachate contamination, in order to confirm stability of the liner system.
Leachate drainage system and gas management system needs to be observed and monitered.
Sound and dust generated due to landfill activities should be controlled adequately and special attention should be paid for control of the unpleasant odor.
Documentation pertaining to all activities should be updated and maintained and mechanisms should be implemented to monitor whether the landfill operates within the set scientific parameters.
Health and safety of workers as well as of neighborhoods should be ensured.

Landfill after the desired lifespan

After the expected lifespan the final capping should be done. This process is more or less same as the underneath liner compiled with a clay liner and a synthetic liner. The synthetic liner will ensure minimization of rainwater seepage in order to ensure minimum generation of leachate. On top of that a soil layer should be placed and grass can be grown on it to complete the process.

Even after completing the landfill process, there should be monitoring mechanisms to ensure that the landfill is within the desired standards. There should be further engineering interventions to meet these standards, if required.

Scientific Landfill as a successful solution

Due to bad experiences with open dumping, people are resistant to sanitary landfills as well. It should be noted that there would be a minimum of adverse effects on the environment, animals and humans if the respective landfill is scientifically designed and monitored throughout to ensure that the landfill complies with set standards.

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Solid Solution to Solid Waste

Prof. Ajith de Alwis

Introduction

April 14th 2017 while the country was celebrating New Year's Day, the collapse of the garbage mountain at Meethotamulla generated from the dumping of solid waste of Colombo and suburbs (Figure 1), claiming many lives with significant damage to property, changed a prevailing solid waste management situation dramatically and perhaps irreversibly. That irreversibility was to good, as it was driving the decision to take action on the prevailing habit of collection and disposal only (Figure 2). Up to that time some parts of Colombo may have claimed clean status though the 'label' was claimed only by diligently following the cleaning process. But the process was never completed with the collected waste only finding its way to Meethotamulla for open dumping. The height of the dump kept climbing and moving above the recommended height of 30 m by the National Building Research Organization, and on the day this collapse occurred the height had been recorded to be around 49 m. From April 15th 2017 Meethotaulla was no longer available for solid waste disposal, but with the society not controlling in ny way the generation of waste, the issue really burst into the open. For many years and in fact for decades Sri Lanka failed in addressing the problem properly, and the Capital city and the suburbs immediately had to find an appropriate way to proceed. That was no easy task, and certainly one cannot come up with a feasible solution in such a constrained situation after failing to develop the necessary abilities in manufacturing and technical services. Having ignored that dumps are relics of outdated mindsets, it could not have been possible to do the right thing at short notice.

Fig 1 : Garbage mountain at Meethotamulla

Few positive developments such as the development of the Sanitary landfill facility at Dompe, some excellent low end composting plants from the Pilisaru program – Kalutara Pohora Watte site etc. were available, but these cannot be scaled up immediately. With the Meethotamulla debacle much more scrutiny was directed to practices island wide, and the fact that there are about 250 more waste mountains of different scale resulting from open dumping came to light. Also it was clear that many an investment made had failed to produce sustainable results as in

Fig 2 : Garbage collection and disposal

the Eastern Province, where all UNOPS (United Nations Office for Project Services) funded sanitary landfill sites have degenerated into open dumps again. Some of the earlier award winning sites too have failed, such as the sites at Nuwara Eliya and Mawanella, demonstrating that it is not always the technical excellence that matter, but the commitment of individuals and the leadership on-site. The significant effect of local political leadership too had been amply demonstrated.

Considering that Colombo in 2017 still carries a lesser population than that of 18th century Paris and Amsterdam combined together, Sri Lanka cannot be stated as facing a significant problem of unmanageable amounts. A cursory glance across universities and institutes clearly indicate that ample human resources have been generated and much training had been imparted. However despite all these achievements, it has been quite clear that a solid solution to solid waste management had failed to appear, and Colombo and the rest of the country still clearly is in search of a solution. It is also apparent that some significant development in solid waste had taken place considering all the discussions, reports and activities that had happened centered on solid waste.

Understand the Problem

It is important to understand the problem if the right solution is to be provided. While all cities anywhere in the world may have the same overall issue, the nature of practices that are unique to each location and country, dictates the most suitable approach. Also the geographical locations and the available space directly influence the options. Hence the quantity and quality of waste are two key aspects that one needs to understand well. This understanding has to be dynamic too requiring that Sri Lanka should consider carrying out periodic surveys across the country.

Sources of Municipal Solid Waste (MSW) are residences, commercial places, institutions, construction and demolition debris, municipal services, treatment plant sites, industries, agricultural and livestock activities. Solid waste management is an obligatory function of all the Local Authorities in Sri Lanka; Municipal Councils, Urban Councils, and Pradesiya Sabhas. The legal aspects are quite clear and are laid out in the various statutes dealing with these bodies. Sri Lanka has the necessary policies, strategies and technical support documents too with regard to managing solid waste. Over the years we can clearly see the development of these aspects. What has been missing is the single-minded execution across all these agencies and institutes with the clear focus on a sustainable solution. There had also been a failure in the technical solution selection and application, which actually has a significant role to play in the final answer.

Status and trends

The current population of Sri Lanka is approximately 21 million, with an annual population growth rate of 1.1%. Present Municipal Solid Waste (MSW) Generation in Sri Lanka is around 6,500 to 7,000 Mt/Day (Mannapperuma, 2017), while present MSW collection is around 3500 Mt/Day (50% of generation). Western Province contributes 60% to the National MSW generation and other eight provinces contribute 40 % to the

Table 1: Waste generation rate at Provincial Level (Source: Ilangasinghe, 2017)

Province	Waste generation rate (%)
Western	58.68
Southern	6.99
Central	8.08
North Western	6.00
Sabaragamuwa	3.23
Uva	3.02
North Central	2.61
Eastern	8.20
Northern	3.29

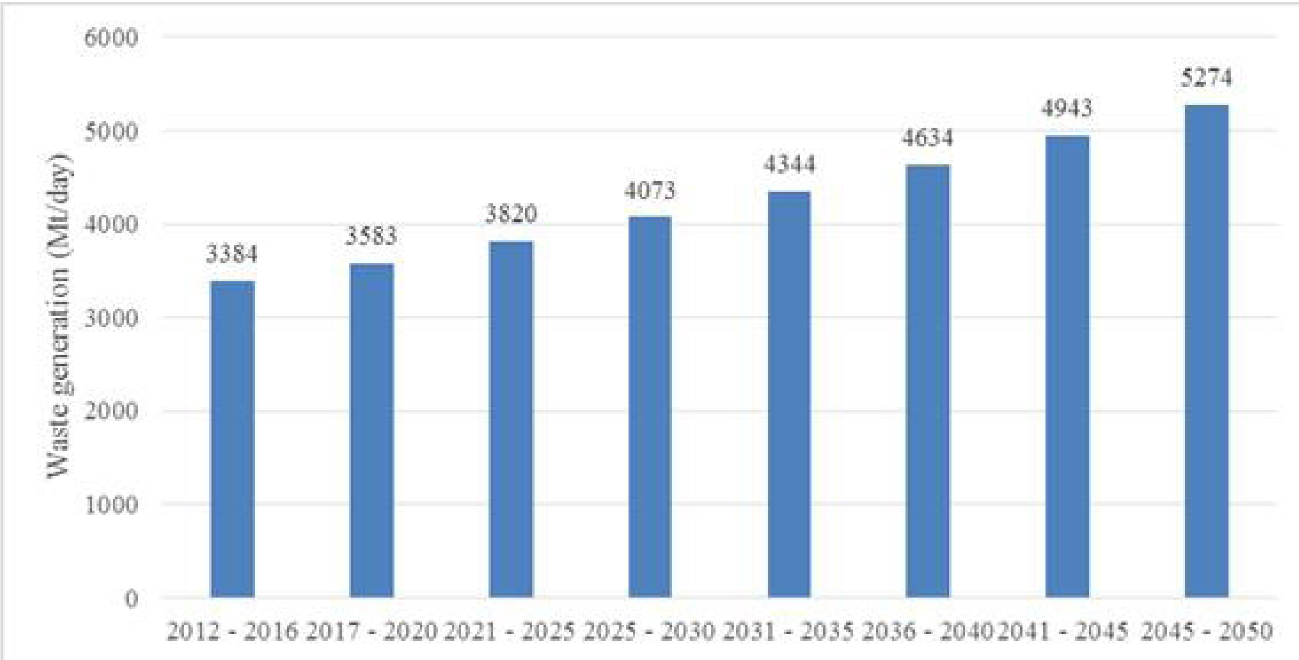

Figure 3: Predicted MSW generation until 2050 in Western province (Source: Mannapperuma, 2017)

total waste generation.

As per Western Province Waste Management Authority, the annual growth rate of garbage generation in Sri Lanka is around 1.2-2.0%.

The above figure shows the expected growth pattern of waste generation in the Western Province of Sri Lanka. Daily waste generation in Western Province is expected to be 3583 MT and 4073 MT respectively by 2020 and 2030. With much development work planned there is likely to be a significant increase in waste over the years and all these scenarios points to the need of a solution that is suitable with future in mind too.

Composition of Solid Waste

There is no annual or regular program to understand the nature of waste in a Sri Lankan context. All available data usually comes from project reports and research studies. This means that the picture available is usually a snap shot of a particular situation and taken over in a small time period. However, when considering all published data, three main aspects stand out, – that is, high organic content, high moisture content and low calorific value. This needs to be clearly understood when planning for the solution. A detailed analysis is presented in Table 2, which presents a solid waste analysis in Colombo.

An aspect that is revealed in the analysis is that there is no major difference between the composition of Colombo and other urban wastes.

Technical Aspects of Service Provision

Planners need to factor in solid waste management as a service that needs to be considered and supported in a city. We are ready to give space to Transport Board, Water Board, Electricity Board Telecom, sports ground etc. The residuals of our stay in town do not get the same consideration. The people who had to handle waste, sadly have to occupy a very low strata of the society. While the society boasts of 3-Phase electricity, clean water etc, the only waste that is incapable of flowing or moving finds itself neglected in planning. It was in ancient Athens that one decreed that the waste should be more than a mile away from the city wall. Athens concept not being valid today, there is the importance of managing waste closer to the place of generation (Proximity Principle). One can keep the city clean and allow the city to benefit too if we make use of the knowledge that we have today.

Collection has to be done methodically and periodically. It should also support the basic principle of 3R (reduce, reuse and recycle) as is the accepted national policy. There had been

Table 2 : Solid waste analysis in Colombo.

WASTE CHARACTERISTICS - CMR

	Estimate		Analysis		Characterisation				
					Area - 1	Area - 2	Area - 3	Area - 4	Area - 5
Category	**CV**	**MC**	**Waste AM**	**SD**	**% by Mass**	**% by Mass**	**% by Mass**	**% by Mass**	**% by Mass**
Easily Biodegradable	18	80%	54%	18%	39.6%	28.2%	71.2%	59.9%	74.1%
Long term biodegradable	18	60%	25%	18%	35.2%	55.6%	7.7%	18.9%	13.1%
News Paper	16	10%	4%	2%	8.0%	2.8%	2.6%	5.1%	2.2%
Cardboards	16	10%	1%	1%	3.2%	1.4%	0.0%	1.1%	0.0%
Plastic	30	0%	2%	1%	1.1%	1.1%	2.9%	0.8%	3.5%
Polythene	45	0%	9%	5%	5.2%	7.1%	9.0%	7.8%	5.1%
PVC	15	0%	0%	0%	0.9%	0.0%	0.0%	0.0%	0.0%
Rubber	20	0%	0%	0%	0.0%	0.4%	0.0%	0.0%	0.0%
Construction Demolitions	0	0%	1%	0%	1.3%	0.1%	0.7%	0.8%	0.2%
Glass	0	0%	1%	1%	1.4%	0.6%	2.3%	0.7%	0.0%
Cotton	19	50%	2%	1%	2.8%	1.3%	1.8%	3.4%	1.7%
Nylon	15	0%	1%	1%	0.9%	0.4%	1.7%	1.4%	0.1%
E-Waste	0	0%	0%	0%	0.0%	0.3%	0.0%	0.0%	0.0%
Clinical Waste	0	0%	0%	0%	0.1%	0.1%	0.0%	0.1%	0.0%
Others	0	0%	0%	0%	0.3%	0.6%	0.1%	0.0%	0.0%
Total					100.0%	100.0%	100.0%	100.0%	100.0%
AM Moisture Content					55.0%	57.0%	63.0%	62.0%	68.0%
CV MJ/kg					7.4	8.0	7.3	7.1	5.7
CV kcal/kg					1765	1917	1743	1706	1373

	AM	min	max		SD
Calculated Moisture Content	61%	55%	68%		8%
Calculated CV Kcal/kg)	1698.6	1363.6	1913.9		12%

a tendency to seek the most expensive solution as per collection vehicles compactors, etc for service delivery. Considering that the rate payments are almost insignificant in many situations from residences, there is no significant generation of finances via taxes to provide an efficient service. However it is clearly seen in cities across, that proper service delivery does not mean the availability and use of expensive vehicles and related equipment. This is an area that Sri Lanka should support via manufacture, as there will be dramatic reduction in costs etc with added flexibility and lower costs. Consider Figure where cycles are used in Beijing and small vehicles are to be seen in Tokyo. These are metros that are maintained clean and with much higher citizen numbers.

Figure 4 : Cycles used in Beijing

Citizen's role

Colombo is throwing out 700 to 800 MT of waste per day and leads the league table of Sri Lankan cities in the amount of waste generation. This quantity when analyzed indicates that the water content is around 60- 70%. The solid waste also indicates 70% of organic waste, which is also largely biodegradable. It is this fraction that contains most of the moisture. The balance portion is non biodegradable, and is usually quite suitable to be recycled. Therein comes out the citizen's opportunity. If one takes care of the organic fraction within ones premises, the tonnage can be

Figure 5 : Garbage collection trends in past & today

reduced drastically. Separating recyclables again will mean no waste to dispose. Then when the disposal amount drop down to may be even less than 100 MT/day, the projects are not as exciting as dealing with 800 MT/day! Hence instead of pointing fingers and shouting against corruption, steps for reducing individuals disposals will solve many an issue. The government will be richer too as all these unnecessary solid wastes have to be transported, and even if the final operation is dumping , costs incurred are saved. At this juncture the best that the Colombo citizen should do is to take a very close look at one's own waste generated. This is applicable to all cities across the country, and should not be considered as a recommendation only to Colombo. A little investment on a compost bin, or better still, if one has some space, a biogas unit can revolutionize the Colombo city. Yet there will be some waste that an individual may not be able to handle comfortably and it is for this minimized quantity together with the other household hazardous wastes (medicines, batteries etc) that the CMC will be called into serve with the State in ensuring the availability of processing space. If no one wants to reduce their waste, then the usual waste matter generated will have to be placed somewhere. We have seen how some desperate efforts to dispose waste in unauthorized places have resulted in strong protests. This is where enlightened decision-making is vital to ensure successful disposal of waste.

Recycling Network

Colombo City needs to improve on its recycling network and related infrastructure, and the same applies across the country. Processes for reverse logistics need to come in. One should have access to recyclable collecting centers. The current system needs definite upgrading and hopefully some of the existing shops and centres would rise up to the challenge of becoming better. Recycling has spun billionaires and in China there are many examples. A Sri Lankan Green Pages is much awaited for the benefit of all citizens.

Figure 6 : Different garbage collection points

Means to support separation should be visible on streets and cities. There should be the proper recycling collection points available too. As one can observe in cities there are places that are available but they do not project a proper business outlook. These can be better organized with even training and financial support to evolve into a national network for recycling service provision.

Technical Solutions for Solid Waste

Generation of solid waste is synonymous with urban living. As cities evolved it is seen from the past that what the city dwellers had done was to shift solid waste to the periphery of cities for dumping. This obviously is a poor way of waste management and in addition, health related issues surfaced with further growth, while different technologies came into manage the growing problem. Over the years many technological pathways have appeared. In USA the Freshkills landfill on the Statten Island, which catered to the solid waste of New York, assumed gigantic proportions, and it had been stated to be visible from space along with the Great Wall of China – apparently a myth though indicating the vastness of the garbage mound! Landfills came after the practice of dumping waste into the oceans was stopped from cities near the coastal belt. Thereafter incineration techniques were introduced. It is easy to understand the fascination with incineration. With burning at high temperatures, which is what incineration is all about the mountains of waste simply disappeared. This reduction of volume proved to be quite appealing as incineration is still practiced and for many what is not visible is not a problem as with air pollution. However the method has been vastly improved and usually energy is recovered either as electricity or heat. Countries with small land areas such as Singapore and Switzerland

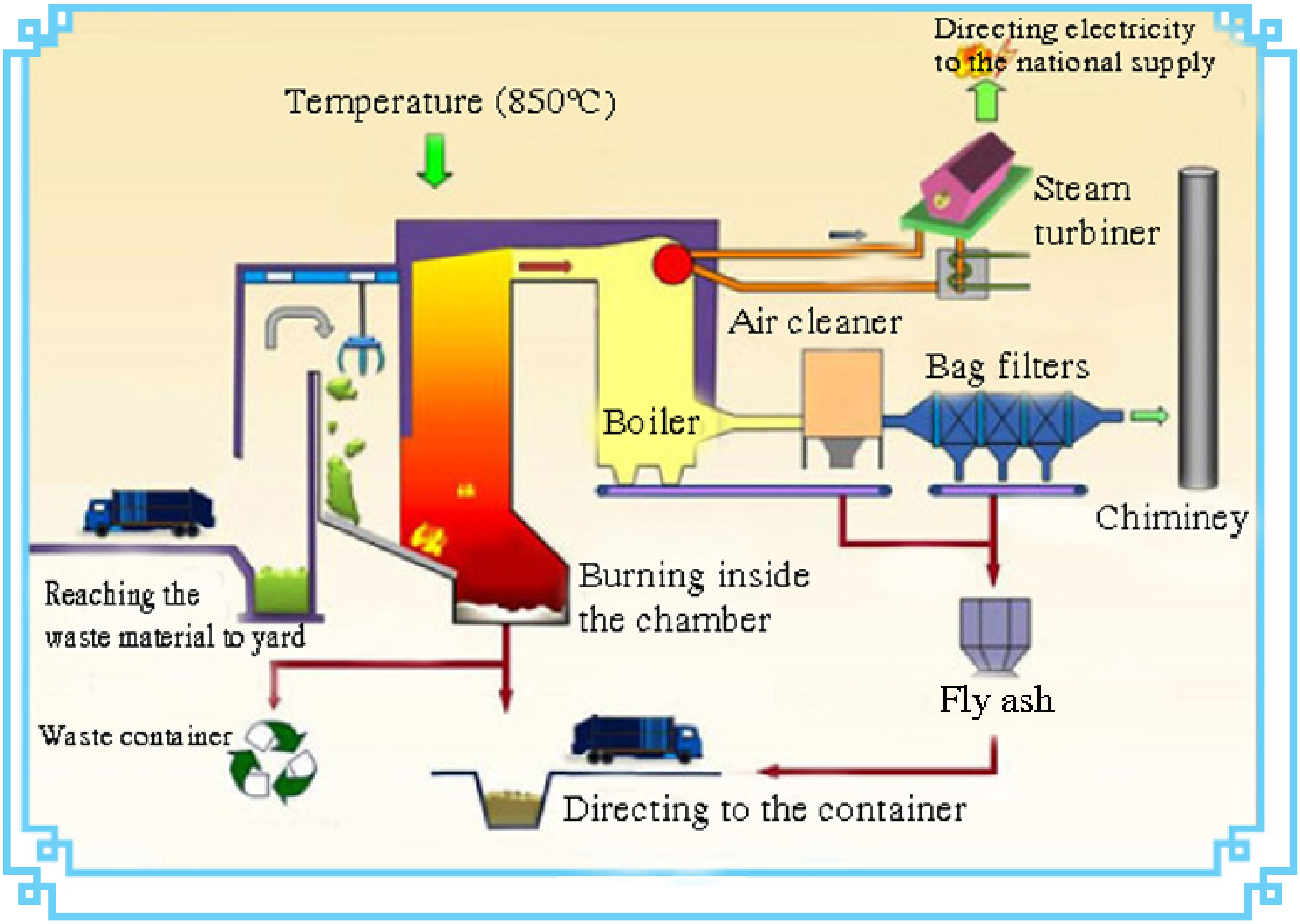

Figure 7 : Waste management system

continue to use this practice of Waste to Energy with incineration as the prime technology. There is today however, a growing body of evidence against incineration as the technology of choice. With sustainable development as the main feature for growth, incineration, which reduces material to ash is frowned upon.

It is important to identify the final solution as well. With a decent level of segregation and with proper recycling infrastructure and a franchise of recycle collection centers established, the organic fraction can then be tackled. A need for landfill space will not be totally out, but the requirement will be quite different and easily manageable. Today interestingly we have home composters who diligently compost the food and other green waste but burn plastic waste in the backyard. There are significant numbers who burn the whole collection by using some additional kerosene, and some expect the plastics to serve as a fuel. We also have a technically designed landfill site at Dompe after many years, and few countries are known to benefit from some of the recycled products exported out from Sri Lanka. There is the significant need for awareness on integrated solid waste management. Awareness should address the attitude towards waste too. It is known that across the country the organic fraction of the waste is more than 60% and can even reach 80%. This considerable fraction with its inherent moisture content is suited for the anaerobic digestion process, which yields biogas and a biofertilizer (soil conditioner). Biogas is without doubt a more versatile renewable energy source due to its determinate energy value and ease of storage. Hence, potential utilization is independent of factors such as geographical location and season – a factor that most renewable fail on. It can be used directly for heating and electricity generation, and as substitute for fossil fuel applications, e.g., transport fuel. The potential utilization of the digestate as fertilizer can also reduce dependence on energy intensive mineral fertilizers. With about 700 and more tonnes of waste per day there is the potential to generate around 4 MW electricity or generate transport fuel. CEB (Ceylon Electricity Board) may frown on just 4 MW, but the salient fact that planners fail to realize is that the waste get managed, energy gets generated and a fertilizer is produced.

There is no question that the identification of the Solid Waste treatment technique has taken far too long. A clear hierarchy for technology choice had been presented in EU (European Union) for its proposed strategy of circular economy drive. In the absence of such an understanding in the country, all proposals have the ability to pick on the process by themselves. Waste to Energy via the thermal route had been the popular choice and some exotic process schemes have been suggested for Colombo. Implementing some of these solutions will mean not separating the paper and plastic fraction from the generated waste, but on the concept of 3R – reduce, reuse and recycle – which is the stated strategy for solid waste management. Even with plastic and paper in our solid waste there is a higher content of organic waste and a significant quantity of moisture. The wetness and the higher organic fraction points to a biochemical route of waste management. All sewage and sludge should come into this process as well, though this stream in the current mechanism belongs to another Ministry. This would add some needed ingredients to make the biochemical process more sustainable. Further, many other organic waste streams can be directed to this process thus enabling co digestion and a better gas generation via biogas,

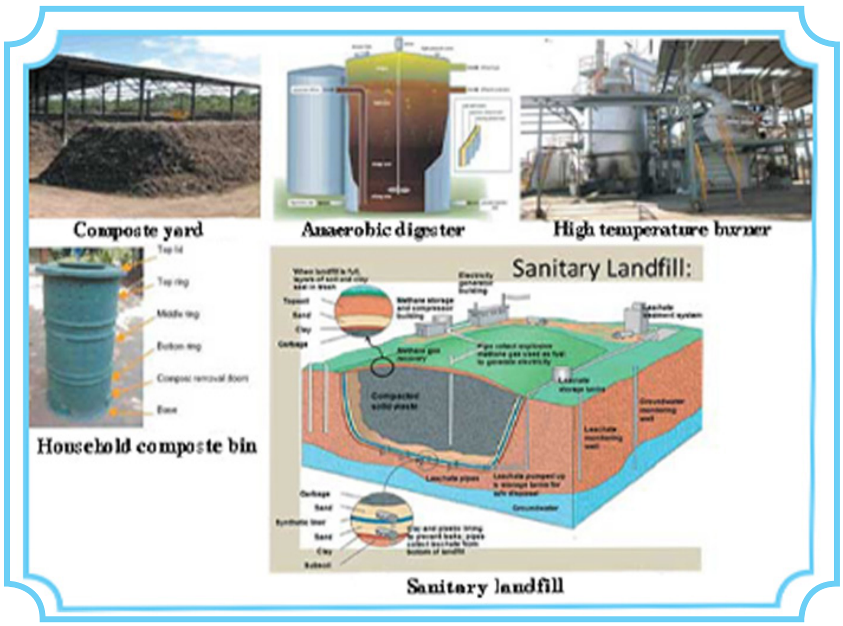

Figure 8 : Sanitary landfill

which results in more power and energy. In some countries such as in European Union biogas is processed to serve as a transport fuel. This process was demonstrated at the University of Moratuwa by driving a three wheeler from biogas generated through biowaste including that of the university canteen (http://www.ft.lk/article/23871/Our-waste-for-our-energy). This points to gas being utilized as a transport fuel and Colombo can aspire to have service stations with biomethane. The technology needs to suit the scale required. Sri Lanka has experienced biogas installations including in Colombo. However, we have failed in scaling up the low end technology scheme, and paid the price of people remembering the failures. At Pattiyapola down south, Sri Lanka had the first renewable energy driven village of the world with UN (United Nations) funding. Electricity was supplied to the village including street lights. The biogas was derived from the digestion of waste cow dung. Biogas based systems are much more suitable as decentralized systems, and perhaps this experience was out of step with the times. However the needs and the technologies are changing , and with smart grids, decentralized systems, fuel cells, sustainable city concepts along with climate change pressures, the ground situation is changing rapidly. Thus solid technical solutions are available which can actually add to the economy rather than be a burden, and that is the recommendation.

Sanitary and Secure landfill availability

Subsequent to recycling and processing there is also a fraction that cannot be utilized readily. Such waste streams need to be located in a landfill. Hence landfills are needed in a decentralized manner to serve the country. Today with the knowledge and experience gained from Dompe, this process can be implemented. Dompe is a purpose built landfill with the non-organic segregated waste as the target waste stream. For hazardous waste streams and similar streams from industry, a secure landfill system is necessary. A useful area to site such a facility as a national facility may be found around Puttalum.

For secure landfills the use of quarry sites with some planning should be considered as feasible. There is the need to stabilize waste before being placed in the secure landfill. There is the need for proper communication measures to educate people on these systems, as the current understanding is inadequate and negative, which are based on past failures.

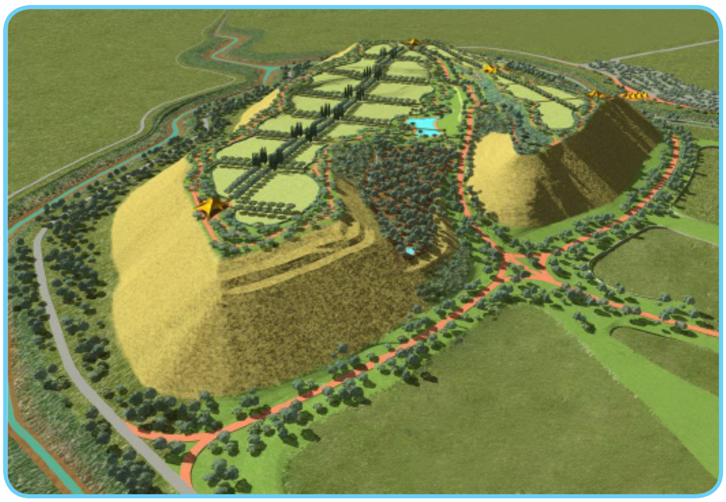

Fig 9 : "Ariel Sharon Park" (Hiriya landfill) Situated in Tel Aviv city

Solution to Dumpsites

We have a long-standing issue with the Blomendhal dump site in Colombo which grew to be a small man made mountain until the supreme court decision in 2009. Today the site is slowly reclaiming itself, but a planned approach is necessary to make use of it. An interesting example is the garbage mountain that was outside Israel's capital "Tel Aviv – the Hiriya" Landfill. Today it has been capped, and land fill gas which is essentially biogas, is extracted, cleaned to produce methane, while electricity is produced and a pumping station for vehicles planned by the side. The waste mountain is known as the "Ariel Sharon Park" and is also a study centre for waste management! They also claim that tourists can have a breathtaking view of "Tel Aviv from a top" the mountain a possibility too with Blomendhal! All these have been achieved through science and technology. There is a lot to learn when a project of this nature is carried out internally and it is clear that technical solutions can be engineered locally. As for dump rehabilitations some detailed work exists in local universities. Total outsourcing may not only mean loss of hard earned money and waste of precious time on endless negotiations, but many lessons that could be learnt will also be lost.

In Conclusion

Marshall McLuhan a Canadian philosopher stated that the new clothing for the planet to be garbage. We certainly see the applicability of this comment when we observe that three quarters have come into fashion! When are we going to put our heads together to realize some of the potential benefits that we have from our waste instead of ignoring it or suffering from its presence.

In the months before the tragedy, some steps were taken by UDA (Urban Development Authority) and the Ministry of Megapolis, and projects too had now been awarded. These projects should have catered to almost all the stated waste quantities of Colombo. All these projects however, will take a minimum of around 2 to 3 years to complete. With the disaster and the site becoming not available for the traditional disposal, a crisis was inevitable. However, the responsibility of the state is now to change the attitudes, explain the situation, be amenable to listening and ensure steps that result in a disciplined urban community. The crisis can only deepen if the emphasis is only in finding places to dump and adopting weak practices. We must rise up to the challenge, and once and for all transform our cities.

In an era where sustainable cities, livable cities, smart cities and green cities are talked about, assessed and awarded the templates for action, we should have the learning mind and the courage to source solutions from within.

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Technological solutions for urban solid waste management

Mr Nalin Mannapperuma

Solid waste is the waste that is physically identifiable as solid or semi solid matter and generated by our activities on a daily basis. Solid waste may be mainly categorized into three groups according to how such waste should be handled or managed. These categories are

1. Municipal Solid Waste
2. Industrial Solid Waste
3. Biomedical Solid Waste

Each of the above groups possess specific qualities and municipal solid waste is considered as the normal solid waste. Industrial waste and Biomedical waste are referred to as hazardous waste and infection waste respectively. This article will discuss mainly the technological methods relevant to the management of normal solid waste or the solid waste that is collected by the provincial institutions.

Waste generation is determined mainly by two factors. They are the extent of the population and their economic status. What is meant by this is that with the increase in population in a country or a region, and the change in the economic status of its people, and the consumer capacity of the people increasing along with their economic capacity, waste generation increases simultaneously. Today the municipal solid waste generated annually in the entire globe is about 1.3 billion tonnes. It is predicted that this could increase upto 2.2 billion tonnes by 2025.

The main reason for the two fold increase in waste generation globally during the next decade is the increase in the economic capacity and the concomitant increase in the pattern of material consumerism among the population of Asia and Asia Pacific regions. Therefore it is likely that the waste problem will be immensely challenging in the future, especially in the zone where we are living.

The global municipal waste generation during the next few decades

It is calculated that at present in Sri Lanka about 7000 metric tonnes of municipal solid waste is generated per day. Of this 60% is generated in the western province. According to the information available at present, the solid waste generation in Sri Lanka increases by 2% annualy. This would increase further along with the special development projects taking place in the country. Therefore, it is important for the institutions dealing with this subject and also for the citizens in general

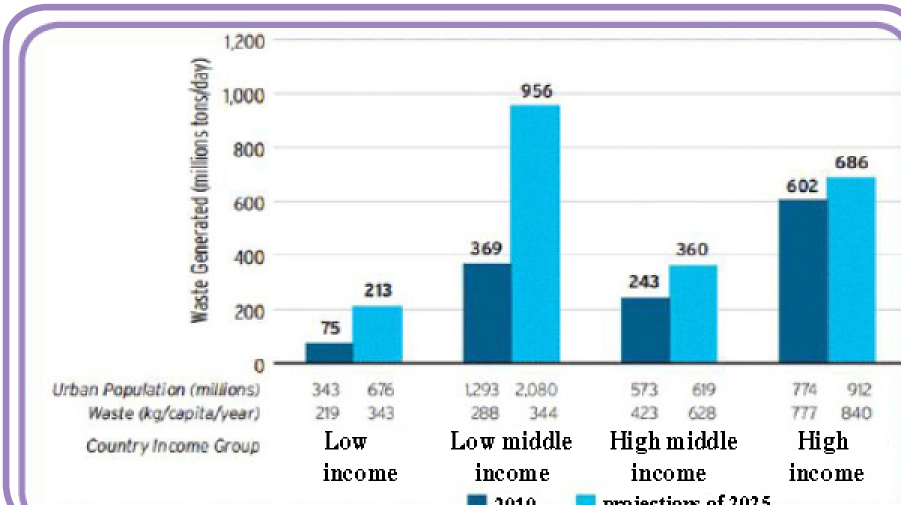


Figure 1 : Generation of solidwaste during the next few decades

to be equipped with relevant knowledge, and a training in waste management and the technological methods that can be used for waste management.

Waste management is not merely the final disposal of waste but it is tied up with a series of background processes. Accordingly in waste management it is necessary to consider the chain of processes such as reduction of waste generation, sorting, collection, reuse, recycling, treatment and the final disposal. Of these the treatment of waste is very crucial. It would be possible to manipulate the waste management technology by gaining knowledge of the scientific background relevant to waste management. Therefore, in the following sections it is proposed to discuss the technological processes of waste treatment.

The various technological processes employed in waste management should be determined by the nature of the waste to be treated. Thus it is important to be aware of the nature of waste. (characterization) Through this it will be possible to employ the most suitable technology and manipulate it for successful management. In order to identify the nature of waste three simple characteristics of the waste are considered. They are:

- Physical Properties
- Chemical Properties
- Biological Properties

The composition, density (specific density) moisture content, particle size and its distribution, the water holding capacity (field capacity) and the permeability to water are identified as the main physical properties of waste material.
For example by knowing the composition of the waste material one can gain an idea of its content and based on this it is possible to decide on the type of treatment. If the waste has a very high percentage of decaying matter and moisture it can be used for making compost or production of biogas.
Chemical properties of waste includes proximate analysis, fusing point of ash, ultimate analysis and energy value. These properties receive much consideration when waste is used for the generation of electricity. For example in order to employ the technology for electricity generation from waste it is essential that the energy content of waste should have a minimum value of 1500-2000 Kcal/Kg. Thus, this information can be obtained by studying the chemical properties of waste.

The biological properties of waste include its biodegradability and the production of bad smelling gases. Even though it is necessary to obtain more information regarding the afore mentioned properties it is not intended to discuss them at length in this article.
However it is possible to identify the real scientific nature of waste based on the above properties and thereby determine the suitable method for treatment of waste. There are various treatment methods for waste management and they can be summarized as shown in the diagram given below.
Waste treatment methods

As shown in the diagram waste treatment can be categorized into three main methods as

1. Physical treatment
2. Thermochemical treatment
3. Biochemical treatment

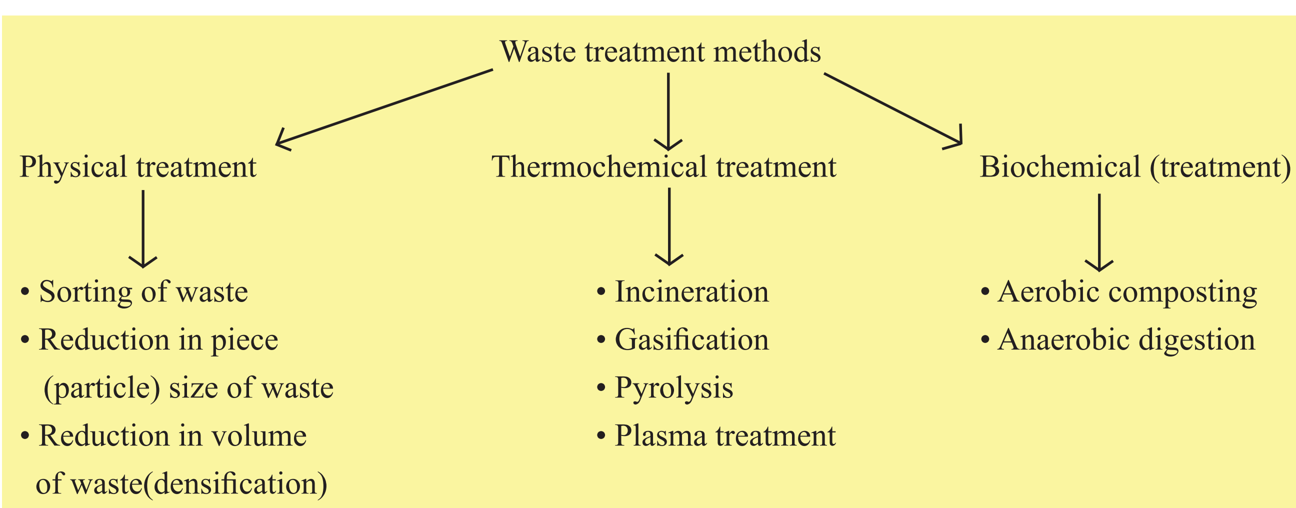


Figure 2 : Classification of waste treatment methods

A. Physical treatment methods

All physical treatment methods are considered as pretreatment methods. Physical treatment methods do not bring about a change in the chemical nature of the waste material. It only causes a change in the physical nature of the waste there by making the waste management process easier. There are several physical treatment methods. The details of these are described below.

Figure 3 : Usage of colour codes to seperate waste

Sorting of the waste

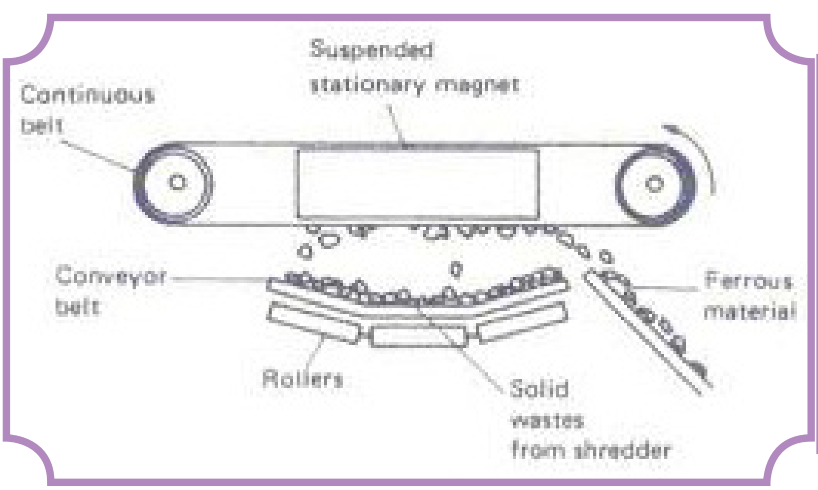
This is a simple process. Sorting may be carried out either manually or using machines. The mixture of solid waste is separated into more uniform fractions by sorting. The separated fractions are then further treated according to their nature. The most difficult task in waste management is the manual sorting. Various methods are employed to make this simpler. Of these the main one is the colour scheme method. The waste cooked food is placed in green bins, waste polythene and plastic is placed in orange bins, paper waste in blue bins and metal waste in brown bins, according to the national policy in Sri Lanka.

Use of the colour schme method for sorting waste

Machinery may be used for sorting waste and is used in the waste management projects at the commercial level. Screening, density separation, Electronic sorting and Magnetic sorting are the separation methods when machines are used. In these mechanized methods of separation technological principles are employed. As an example in the Density separation method the machine is used to separate the fractions based on the density of the particles / pieces of the solid.

Reduction in particle/piece size of waste (shredding/ pulverization)

This is also a physical treatment process during which the solid material is broken down into smaller pieces making it easier for further treatment. As an example, for composting, machines are used to reduce the size of the pieces of waste material. This increases the surface area which brings about better microbial activity. Such machines are used in most



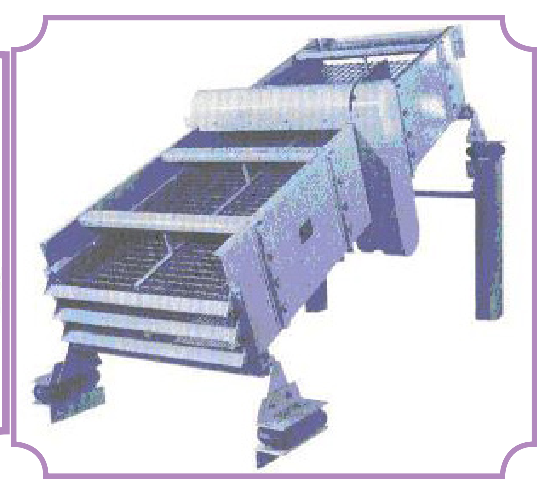


Figure 4 : Equipments for mechanical waste seperation

Table 1 : Thermochemical treatment methods and the resulting products

By products	Pyrolysis	Gasification	Combustion	Plasma treatment
Gaseous by products	H_2,CO,H_2O,N_2 Hydrocarbons	H_2,CO,CO_2, CH_4,H_2O,N_2	CO_2,H_2O, O_2,N_2	H_2,CO,N_2, CO_2,CH_4,H_2O
Solid by products	Ash, coke/charcoal	Ash,Slag	Ash	Slag
Liquid by products	Pyrolysis oil, Water			Pyrolysis oil,Water

waste management projects at a commercial scale.

Increasing the density of waste material - Densification

The main problem in waste management during handling and transport is the volume of the waste material. The physical treatment methods offer a solution to this problem. By subjecting the waste material to high pressure it is possible to increase the density and there by greatly reduce the volume. Then it is easier to store and transport the waste material. Baling and Pelleting are two of the main methods of subjecting the waste to high pressure.

Figure 5 : A machine used to reduce the size of waste particles/pieces (Shredder)

Waste made into Pellets and Bales

B. Thermochemical treatment methods

Thermochemical treatment is one of the methods employed at the commercial level for treatment of waste. During this process the chemical nature of the waste is made to undergo a change. The more suitable waste for this treatment is that which has more moisture and a relatively high calorific value.
This treatment is based on heat. The chemical nature of the waste is changed by heat. This is called thermal decomposition. There are many thermal processes that are employed for this chemical treatment. Incineration, Gasification, Pyrolysis and Plasma treatment are some of these technologies. The treatment methods in each of these processes are different and the products also vary accordingly.

When waste treatment is carried out by thermochemical methods heat is generated. During some thermochemical treatments combustible gases (syn gas : carbon monoxide, hydrogen, methane) and oils with high energy values are generated as byproducts. These by products may be directly used in the production of energy. When considering all these factors it would be possible to produce 14.4 kwh of electricity from 1 metric tonne of normal urban solid waste through this treatment.
The thermochemical treatment method is a fine solution for two of the problems that the world is facing today, namely, the crisis of urban solid waste and the energy crisis.

There are advantages and disadvantages of the Thermochemical treatment method. During this process gases which are harmful are released. Also waste ash (bottom

Figure 6 : Waste made into Pellets and Bales

ash and fly ash) is produced as a residue. Most countries employ various methods of treating these problem causing byproducts generated during thermochemical treatment before releasing them to the environment. Also in many countries limits and regulations have been laid down for the release of the gases from the incinerators to the environment. Accordingly it is very important to control the environmental problems caused by the thermochemical treatment of waste material. Subsequent post investigations are also necessary to be carried out. In Sri Lanka there are no environmentally friendly, thermochemical treatment mehods carried out on a commercial scale. This type of method carried out especially in the Western Province for waste management in the coming years, can be turned into a blessing. In order to popularize this type of a treatment method the government has already taken the policy decision of agreeing to purchase the electricity generated by such a method, taking into consideration the dangerous problems caused by waste.

C. Biochemical treatment methods

- The third main waste treatment method is the biochemical method. It is the waste with a high moisture content and having a relatively high percentage of biodegradable waste material that can be used for this type of treatment. This method can be considered as a naturally occurring process. During this treatment the nature of the waste material is subjected to physical as well as chemical changes. The microorganisms living naturally in nature are used for the process. Biochemical treatment may be discussed as two methods:

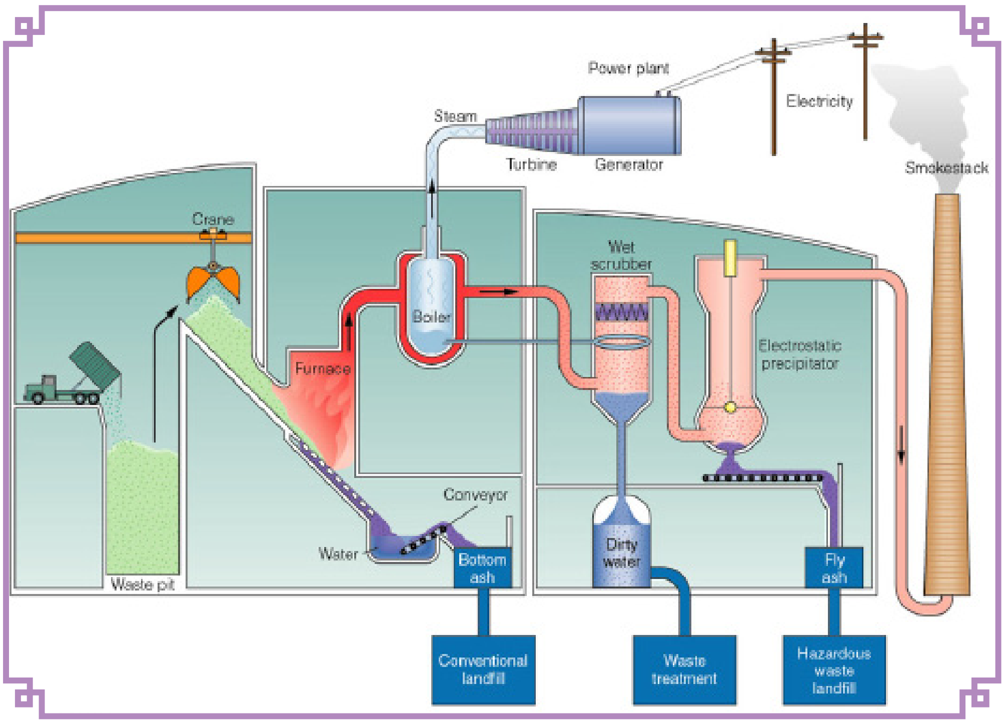


Figure 7 : Diagram of a incinerator used in the combustion of waste

- aerobic composting
- anaerobic digestion

A. Aerobic composting

In a simple way composting can be described as the complete or partial decomposition of biodegradable or decomposable waste material by microorganisms. The direct product obtained is humus or compost. This is a more environmentally friendly method that can be used for waste management. The potential to use the resulting compost in agriculture and land- scaping activities is high. It is possible to use such compost to improve the soils with a lower percentage of carbon (less than 1%) which is present specially in the tropical countries (Tropical ferruginous soil).
Even though composting takes place as a natural process, it is controlled based on scientific principles. There are many factors affecting the decomposition of waste material. By gaining a thorough knowledge of such factors it is possible to make decomposition take place in an environmentally friendly manner and to obtain the maximum beneficial results. The C:N ratio, pH value, air, water content, temperature and the nature of the particle/piece size of the material are among the very important factors affecting the composting process. It is possible to carry out the composting process to obtain better results by maintaining the above factors at optimum levels.
It is possible to carryout compostng in an environmentally

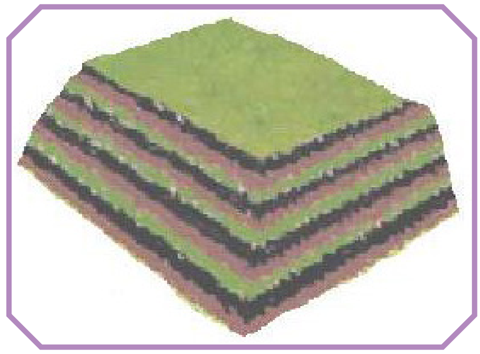




Figure 8 : Pit method, Pile method & Biological enclosure method

friendly manner at various levels such as from the household level to the commercial levels. Various machinery, apparatus and methods can be used for the purpose. Traditional methods such as the pit method, land (or pile) method and biological enclosure method are employed. These traditional methods are less costly and can be carried out by any individual in their home or garden environment. Modern composting methods have already been introduced, considering the acute necessity of composting. Passive piles, windrowing, aerated stock piles, reactor vessels, rotating drums and invasive composting are such techniques.

Each of these methods create the environment to provide the various factors which affect composting at optimum levels. Through such methods it is also possible to obtain compost of high quality.
When producing compost on a commercial scale it is essential to examine the quality of the compost. Accordingly the physical, the chemical and the biological properties of the compost has to be examined. It is also necessary to determine whether heavy metals are presnt. Then it is possible to certify the quality of the compost.

B. Anaerobic Digestion

This is the anaerobic digestion or biogas production method. This is a digestion process carried out using microorganisms. Methane which is a combustible gas is produced as a direct product of this process. With a composition of 65% of CH_4 and 35% of CO_2, biogas technology has a long history, and it is believed that the Chinese introduced this method to the world. It is possible to employ this technological method of waste treatment from the house hold level right up to commercial scale. It is a complex technological process which has to be manipulated with great care and attention. Similar to composting, there are many factors affecting this process and by providing these factors at optimum levels it would be possible to use biogas generators profitably for waste management.
Various technical methods are used world over to generate biogas. They are categorized as follows.
1. Chinese method (continuous fixed dometype)
2. Indian method (continuous floating gas holder type)
3. Sri Lankan method (Sri Lankan batch type reactor)

These biogas generators possess various efficiencies. They have to be manipulated according to specific procedures. In Sri Lanka the present number of biogas generators exceed 2000 and it is possible to use these as a solution to the energy crisis. During the anaerobic digestion process, in addition to the main product of biogas it is possible to obtain liquid fertilizer and compost. The biogas can be purified by removing the CO_2 and then used to generate electricity with a generator. Therefore this method is not only a waste management process but also an important method that can be used to produce energy. The energy contained in one cubic inter of biogas is equivalent to that in 0.6 liters of diesel or 0.67 liters of petrol or 1.25 kwh of electricity.

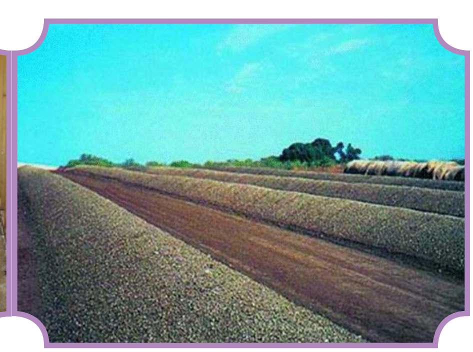



Figure 9 : Static pile & Windrow

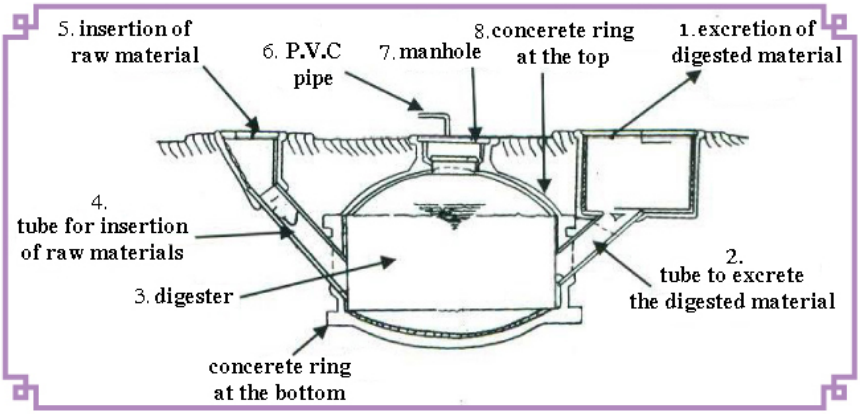


Figure 10 : Chinese method (continous fixed dome type)

The Chinese method is characterized by a continuous fixed dome type and the following features.

- Exit of decomposed matter
- Outlet pipe for decomposed matter
- Digester
- Inlet for raw materials
- Feeding in raw materials
- PVC pipe
- Manhole
- Top concrete ring

Sanitary land filling

In addition to the waste treatment methods given above, it is also important to be informed of the final disposal of the residual matter resulting from waste management. So it is necessary to be aware of the land fill technology. Land filling has received minimum attention by the national policy on waste management. Sanitary land filling was introduced to the world in 1900 as a final waste disposal method. This method by following certain procedures, aims to minimize the harm caused to the environment by irregular deposition of waste material. Scientifically the method is called sanitary land filling. During sanitary land filling, the management of the treatment of the waste water generated, foul smells, and the environmental problems that may be created by the waste material are the main factors to be considered.

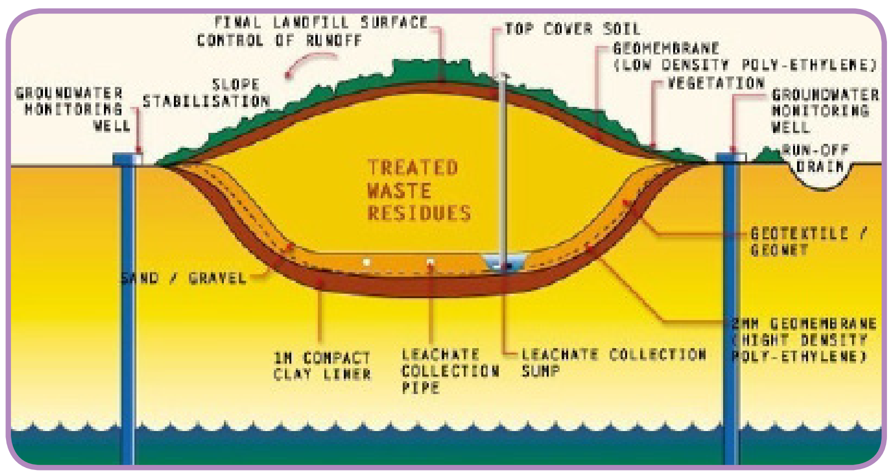


Figure 11 : Plan of a Sanitary land filling

Plan of a sanitary land filling

The objective of waste management in the 21st century is to use waste material as a resource as far as possible. Therefore many countries use sanitary land filling only for the residual waste material - the ash and other matter which cannot be used as a resource any more.
All methods mentioned above (except for the sanitary land filling method) aim to use waste material as a resource. However, it is very difficult to get the general public to use these methods. It is necessary to direct the attention of the public towards this objective. It has to be made clear that it is a social responsibility of the public. Also the public has to be duly informed of the technologies of waste management. It is possible to have a fruitful solution to the waste material problem.

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An assessment on "Waste to Energy" potential in Sri Lanka

Ms J.A.T. Dilhani

Introduction

Garbage is an irritating issue, which causes economic, environmental, social, and health problems to the country. The management of the municipal solid waste is a mandatory responsibility of the relevant Local Authorities (LA). There are 335 LAs in Sri Lanka; 23 Municipal Councils, 41 Urban Councils and 271 Pradeshiya Sabhas. Legislations required for waste management is provided under the Local Government Laws, and the Local Authorities are responsible for the collection and disposal of solid waste in the area of the Authority. The governing legislations related to the three types of Local Authorities i.e. Municipal Councils Ordinance, Urban Councils Ordinance, and Pradheshiya Sabhas Act, have made necessary provisions in relation to the management of waste.

Total waste collection by Local Authorities of Sri Lanka is around 3,700 tons per day out of a total estimated waste generation of more than 6,400 tons per day.

Colombo Municipal Council (CMC) is the key stakeholder which handles the largest waste amounting to 650 ton/day. In view of the economic concerns, the Colombo Municipal Council (CMC) spends around 20% of its annual budget for the management of Municipal Solid Waste (MSW) in Colombo Metropolitan area. The CMC's budget for collection, transportation and dumping of one torru of MSW is estimated to be about LKR 3,500, total amounting to 2.4 million per day, and is 876 million annually.

In addition to environmental hazards, usually one tonne of biodegradable waste releases 300 liters or 0.4 tone of methane, whose comparative impact on climate change is 25 times greater than CO_2. Another serious environmental impact is ground water pollution, which impose limitations on drinking water in and around garbage dump sites of the country. Sri Lanka Sustainable Energy Authority (SEA) has issued 5 energy permits for the production of around 43.4MW. But so far none of the projects have become a reality yet. The above five projects are located in Muthurajawela, Karadiyana, Kaduwela, Gampaha and Aththanagalla in the neighbourhood of the major dump sites. The two major dump sites at Meethotamulla and Blumendal are now abandoned. In addition, there are about 20 minor dumps sites in the country. Table 01 shows the amount of garbage collection in the country.

Considering the social impact, these garbage dump sites have created many problems such as reducing the land value, and creating an

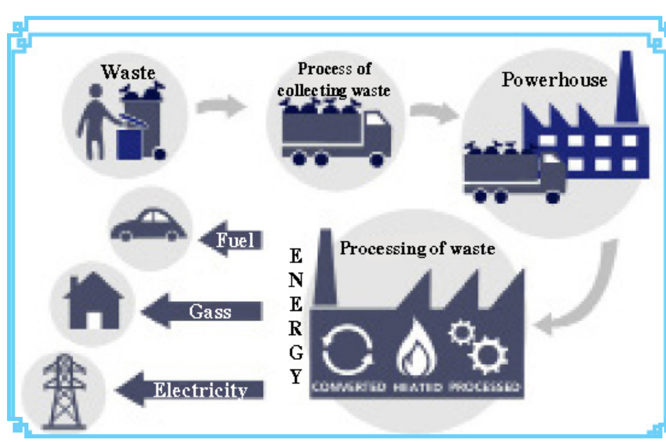

Figure 1 : Process of power generation from waste

unpleasant environment for living with bad odor and attracting many unwanted animals such as dogs, cows, crows and sometimes elephants etc. In addition, liquid and solid waste from households and the community, causes serious health hazard, leading to the spread of infectious diseases. Normally it is the wet waste that decomposes and releases a bad odour and attracting many unwanted animals such as dogs, cows, crows and sometimes elephants etc. In addition, liquid and solid waste from households and the community, causes serious health hazard, leading to the spread of infectious diseases. Normally it is the wet waste that decomposes and releases a bad odour. This leads to unhygienic conditions and thereby to a rise in health problems. Certain chemicals if released untreated, e.g. cyanides, mercury, and polychlorinated biphenyls, are highly toxic, and exposure can lead to disease or death. Some studies have shown alarming number of cancer cases among residents exposed to hazardous waste. The unhygienic use and disposal of plastics and its effects on human health has become a matter of concern. Coloured plastics are harmful as their pigment contains heavy metals that are highly toxic. Some of the harmful metals found in plastics are copper, lead, chromium, cobalt, selenium, and cadmium. In most industrialized countries, coloured plastics have been legally banned. The above mentioned direct and indirect impacts of open dumping of waste has still not been seriously taken into account by anybody. Providing solutions to solid waste management issues will solve the multifaceted dimensions on economic, environmental, social and health hazard, and eliminating this issue can lead to development of the country.

Further, the institutions which are engaged in waste disposal have still not been able to provide sustainable solutions. In accordance with the provisions in Section 4 of the Sri Lanka Sustainable Energy Authority Act No. 35 of 2007, the Authority is vested with the power to "Identify, Assess and develop renewable Energy Resources with a view to enhancing energy security and thereby derive economic and social benefits to the country." The data available with the Authority as well as mapping of waste quantities carried out in the recent past, has shown that nearly 55% of the collected solid waste in Colombo and suburbs are organic matter which can be considered as a renewable source of energy from which electricity/heat energy/bio gas can be generated. Therefore, there is a necessity to coordinate other respective bodies which are managing waste in the country to jointly develop the effective potential benefits out of waste to the Renewable Sector.

Table 1 : Provincial garbage collection

Province	Number of. Local Authorities				Amount of Daily Collection
	MLC	U.C	D.C	Total	
Western	7	14	27	48	1,873
Central	4	6	33	42	319
North Western	1	3	29	32	353
Sabaragamuwa	1	3	25	29	166
Southern	3	4	42	50	227
North Central	1	-	25	26	96
Uwa	2	1	25	27	100
Eastern	3	5	37	44	506
Northern	1	5	28	34	130
Total	23	41	271	335	3740

As an initial step, it is necessary to implement a pilot scale waste to energy power plant by the government, so as to provide technical information to the private developers to identify the suitable technology, and come up with the correct plant type efficiency. It is also necessary to fix a feed in tariff for waste to energy projects as well as provide, funding mechanism through grants, loans, incentives etc. or other indirect incentives such as communication campaigns to develop waste energy projects by the private sector.

2.0 MSW composition and waste characteristics

The key technical parameters required for the designing of a waste to energy plant are the composition analysis and the characteristics of raw material. Presently our country as a developing country is burdened with more biodegradable wastes. It is a known fact that with the changing socio-economic status of a country, it is expected that the organic component of municipal solid waste to gradually decrease, while inorganic and combustible fractions to progressively increase. The Gross Domestic Production (GDP) is a factor for measuring the state of development of a country. A MSW characterization had been conducted in 2004 by the Central Environmental Authority which shows that, the

Table 2 : Generation of Waste (MSW/Percapita)

Country and Area		Generation of Waste (Kg / day / person)
Europe		0.70 - 0.85
United Kingdom		1.25 - 1.80
Developing Countries	Low income category	0.25 - 0.6
	Middle income category	0.5 - 0.85

per capita GDP was USD 1,035. When a similar analysis was done in 2015, the country's per capita GDP was approximately USD 2,135, indicating the requirement for a new MSW characterization within the Colombo municipality. Therefore, a characterization study has been conducted by Sri Lanka Sustainable Energy Authority in 2015 using an internationally recognized methodology, as such reliable information is needed in aligning waste management activities. Table 02 shows the per capita MSW generation in different regions of the world.

Western Province accounts for more than 50% of the country's daily waste generation. MSW generated in Sri Lanka is dominated by bio degradable material and in Western Province it is around 55%. A Composition analysis of solid waste collected by Colombo Municipal Council is given below.

This analysis revealed that the MSW composition had changed from the previous analysis conducted in 2004. Biodegradable percentage has dropped from 65% to 54% between 2004 and 2015. Polythene and plastics percentages have increased to 13.7% from 5.4%, while paper and cardboard percentage had also increased to 10.2% from 7% during the last decade. The average moisture content of these MSW is 63%, with the average calorific Lower Heating Valuve (LHV) values of the sample at 14 MJ/kg according to the test method of ASTM D 5865. Some inconsistency is noticed in the results of calorific value, as it is not certain whether these samples were exactly at zero moisture when the chemical testings were conducted.
The moisture content (63%) of the waste in Sri Lanka is comparatively high due to the higher biodegradable portion in the waste, and it significantly differs from the condition of developed countries. A comparison is given in Table 03: Density and moisture content of MSW

Usually a waste combustion triangle gives the information regarding the suitability of waste for combustion. The combustion triangle drawn according to the Sri Lankan waste characteristics is shown in Figure 02, which gives us the information that Sri Lanka's MSW lies slightly above non auxiliary combustion range. Hence, the thermal treatment of Sri Lankan MSW needs pre drying as pre-treatment. Therefore, Integrated Waste Treatment technologies such as separation of organic bio-degradable for biological treatment, and the remaining portion for thermal treatment or Residual Derived Fuel (RDF), are favorable. Since organic waste is significant in Sri Lankan MSW, segregation at point source and a proper collection mechanism needs to be established within the country, for way forward for supporting Waste-to- Energy projects which have multiple benefits to the country.

3.0 Technology selection

The conversion processes of municipal solid waste processing to energy can be classified in to two main categories; thermal processing and bio-chemical conversion. However, these two conversion categories can be assisted with the waste (pre) processing step. Most commonly used waste-to-energy conversion processes are solid waste incineration and gasification. Waste pyrolysis is also another thermal technology option which is being tested on a large scale, and had shown significant potential for future mass scale applications. Anaerobic Digestion (AD) and

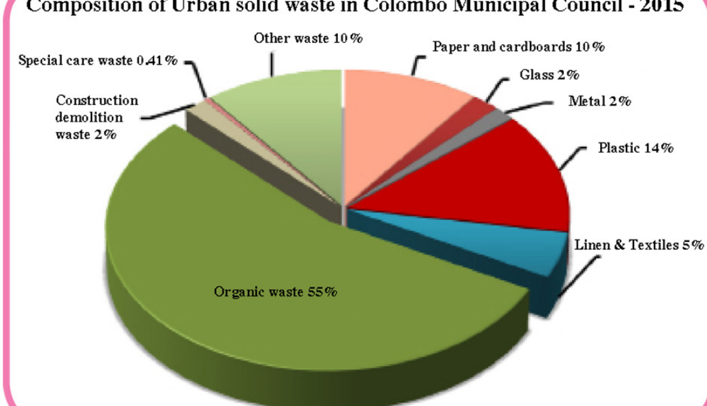

Fig 2 : Composition of urban solid waste in Colombo Municipal Council - 2015

Land Fill Gas (LFG) are the two main bio-chemical conversion processes.

3.1 Waste Incineration

Incineration of biomass waste is the most common form of MSW based power generation technique. This commercially available technology is considered to be very mature, and in the range of few MW to 100 MW or more. Biomass waste is burnt (fully oxidised) and the resultant heat is used to generate high pressure and high temperature steam, which is used to drive the steam turbine (Conventional Rankin Cycle). The steam turbine extracts thermal energy from pressurized, high temperature steam, and converts to a mechanical work driving the electrical generator. There are three major types of turbines, with each one having its own specific characteristics; condensing steam turbine, extraction and back pressure steam turbine. Condensing units are designed to obtain the maximum amount of mechanical work out of a given steam generation in order to maximise electrical efficiency. This is the preference for an electricity generating plant. Extraction steam turbine unit is used to extract steam at intermediate pressure levels so that this extract steam can be used for combined heat and power

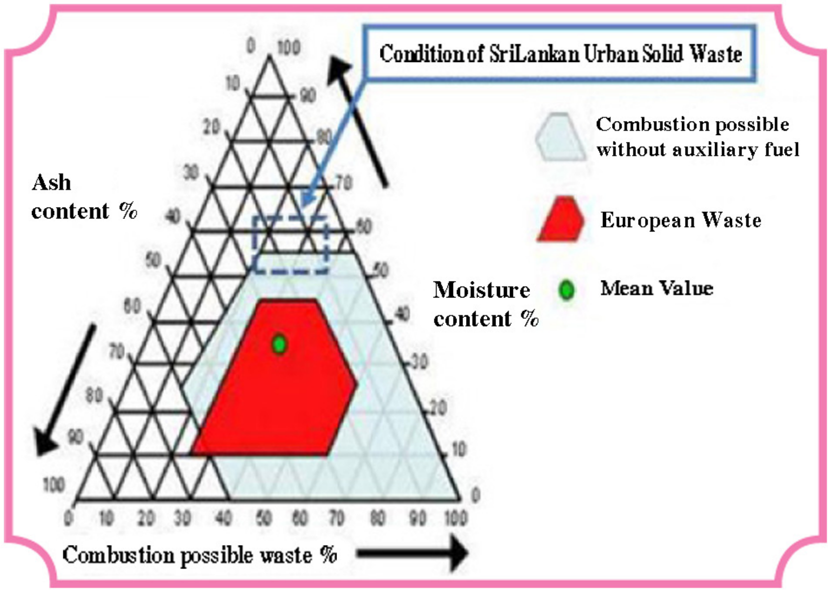

Fig 3 : Combustion triangle

systems. Back pressure design is mostly used when a constant supply of heat is required to provide steam to an industrial or commercial application. Higher exhaust steam pressure and temperature leaving the turbine results in lower shaft power.
Overall process efficiency of electricity generation (from feedstock to electricity and exclusively for electricity generation) is typically about 25%. There is an opportunity to recover some of the processes heat that cannot be fully recovered in the form of electricity, but as heat for process applications such as district heat. If this waste heat is recovered the overall process efficiency can be well above 70%. Apart from incineration, biomass waste can be co-fired with some other fossil fuel feed stock such as coal, which is done in a country like China in order to enhance the calorific value of fuel and to make the raw material homogeneous. Biomass waste can be co-fired up to 5-10% of the main feed stock without any process modification. If biomass process share is to be increased by more than 10%, extensive pre-treatment for biomass and process technology modification are required.
Stoker boilers, rotary kiln and fluidized bed boilers are the most commonly used types of boilers for biomass waste applications.

Table 03: Density and moisture content of MSW

Location	Density (Kg / m^3)	Moisture content	Explanations
United Kingdom	100	25	Contain high percentage of papers and empty buckets.
Europe	150		Contain low percentage of papers and more wet waste.
Developing countries	250 to 350	60	-
Some of the South Asian countries	Up to 500	60	Contain more waste from street refuses.

3.1.1 Stoker Boiler

Direct fire combustion of solid biomass takes place with the excess air. The hot flue gases produces steam in the heat exchange section of the boiler, and this steam is used to drive the steam turbine unit to produce electric power. Steam can also be used for the process heat purpose.
Stokers are designed to feed fuel

onto a grate where it burns with air passing up through it. This stoker located within the furnace section of the boiler also has the facility to remove ash residue after the incineration. Mechanical stokers are the traditional system of feeding fuel to a boiler, and use mechanical means to transfer and add fuel to the fire zone. Usually the fire zone is above the grate but near to the base of the furnace section. Heat is absorbed by the water tubes of the heat exchanger section as well as the water tubes inside the furnace walls. End of the grate is the facility to remove the ash residue. According to the method of adding and distribution of fuel to the furnace, there are two general types of systems; underfeed and overfeed. In both systems air is supplied from under the grate and the combustion zone. Overfeed stokers supply fuel from above or by side the combustion zone, while underfeed stokers supply fuel from under the combustion zone.

3.1.2 Rotary Kiln

In recent years, rotary kilns have played an important role in the thermo-chemical treatment of municipal solid wastes (MSW). Rotary kiln system considered to be one of the most promising incineration technologies, as it can simultaneously treat wastes as liquids or solids of various shapes and sizes, and easily achieve the flexible adjustment by altering kiln inclination, rotational speed, etc. Rotary kiln has a primary gasification chamber, followed by a secondary combustion chamber, which can fulfil the complete destruction and detoxification of wastes, at the same time minimizing emissions of dioxins and heavy metals (Li, S. *et al.*, 2002). Tumbling action inside the rotating kiln mixes waste and air more efficiently resulting in better combustion. All these unique features makes the rotary kiln irreplaceable in MSW incineration.

3.1.3 Fluidised Bed Technology

An upward blowing air jet suspends fuels during the combustion process. The tumbling action, much like a bubbling fluid, allowing solid fuel combustion air to be thoroughly mixed, providing more effective chemical reactions and heat transfer. Thus fluidized bed systems offer higher thermal efficiency and lower toxic emissions (CO, NOx) than fixed bed approaches (Stokers). However, fluidised bed technologies have higher capital and operating costs, and require significant economies of scale, so that only larger plants (>10 MW) are economically viable. Fluidized Bed Combustion system is categorized into two major groups, atmospheric systems (AFBC) and pressurized systems (PFBC), and two subgroups, bubbling-bed (BFB) and circulating fluidized bed (CFB). The major difference between bubbling-bed and circulating-bed boilers is the fluidisation velocity (higher for circulating). In circulating fluidised bed boilers (CFB) fuel is entrained by the high-velocity exhaust flow, and this entrained fuel is captured and returned to the bed for complete combustion. Pressurised CFB are in commercial/industrial applications, although atmospheric-bubbling fluidised bed boilers are more commonly used when the fuel is biomass. Fluidized bed can also be a more effective way to generate electricity from biomass with higher moisture content fuel than typical in a stoker boiler.

3.2 Gasification Technology

Gasification is a thermo-chemical process in which waste (usually biomass waste) is transformed into gaseous fuel, a mixture of several combustible gases (CO, H_2, CH_4). These combustible gases are usually referred to as syngas or producer gas. Gasification utilize less than the stoichiometric amounts of oxygen need for complete combustion. There are four major process steps. The water within the fuel is removed by evaporation during drying. In the absence of an oxidant, volatile gases, mainly CO_2, CO, and hydrocarbons are released from the dry fuel through thermal degradation in the pyrolysis process. The solid matter remaining is called char. Next is the combustion process stage providing the energy required in other process steps. In the reduction zone which is the last process step, remaining char is reduced with CO_2, H_2O and heat to form H_2 and CO. Gasification has several potential benefits over traditional solid waste incineration, mainly related to the possibility of combining the operating conditions (in particular, temperature and equivalence ratio) and the features of the specific reactor (fixed bed, fluidized bed, entrained bed, vertical shaft, moving grate furnace, rotary kiln, plasma reactor) to obtain a syngas suited for use in different applications (Arena, U., 2012). It can be utilized as a fuel gas that can be combusted in a conventional burner, connected to a boiler and a steam turbine, or in a more efficient energy conversion device, such as gas reciprocating engines or gas turbines. Its main components, carbon monoxide and hydrogen, can also be the base for synthetic fuel.

The amount of syngas throughput (thermal or electricity) needed to make these processes economically viable determines which types of gasifier might be most suitable for a particuler application. Fixed bed downdraft gasifiers are suitable for small capacity range (< 1 MW), but fixed bed updraft gasifiers can easily be scaled upto around 20 MW^{th} range. Atmospheric and pressurised fluidised bed and circulating bed, and entrained flow gasifiers can provide large-scale gasification solutions.

In "Plasma Gasification" which is considered to be an emerging technology for biomass waste gasification, biomass is fed to the boiler reactor where an electrically generated plasma arc at a very high temperature is present. When the biomass is exposed to the plasma arc it is heated to a very high temperature at which the organic compounds in the biomass is dissociated into very simple molecules later turning into sysngas consisting of hydrogen, carbon monoxide, carbon dioxide, water vapour and methane. 95-98% waste volume reduction can be achived, nevertheless this process accounts for higher parasitic load as well as very high overheads.

Gasification process needs syngas treatment before using in a combustion turbine to generate electricity. Syngas treatment unit removes fine soot, ash and sulphur compounds. Using syngas in a burner (and steam cycle) may not require complicated gas treatment right after the gasification unit. But the flue gas needs treatment before exhausting to the environment.

Table 04: Heating value of MSW

Country & Area	Boiling point of solid waste (KJ/kg) based on the moisture content
Europe	7,527
United Kingdom	10,454
China	1,850 – 6,413
Big cities in China	4,300 – 6,413
India - Middle cities	3,345 – 4,600
India - Big cities	4,600 – 6,272

3.3 Pyrolysis

Pyrolysis is the thermal decomposition of organic and synthetic waste at elevated temperatures in the absence of oxygen. Output of the pyrolysis products are carbon char, syngas and distillate oil. Process residence time and temperature govern the percentages of liquid, char and gas. Overall, the process has a high efficiency than waste incineration. The process is claimed to produce a more useful product than standard incineration. That is, gases oils and solid char can be used as a fuel, or purified and used as a feedstock for petro-chemicals and other applications. The Pyrolysis process is similar to gasification, but lags behind incineration in economic perspective due to complexity and costs.

3.4 Anaerobic Digestion Process

Anaerobic digestion (AD) is the biological degradation of waste in the absence of oxygen. The main product of anaerobic digestion is biogas, which is a methane-rich gas, typically with about 40-65%. Biogas can be burnt for power generation purposes as well as can be upgraded to natural gas as a biofuel. Even though anaerobic digestion can biodegrade virtually all types of biomass excluding woody materials, wet feedstock such as animal manure, sewage sludge, wet agricultural residues and the organic fraction of MSW are preferred. Anaerobic digestion also occurs naturally underground in landfill cover and produces landfill biogas. Landfill gas can also be collected and used in energy applications as it is AD applications. Whether the waste is treated in a sludge digestion unit, or converted to a landfill gas application, is decided by the water content (waste in sludge form) of the waste resource. The methane content in biogas is influenced by parameters like moisture content, percentage of organic fraction, temperature, and local weather. Thus, control of these parameters is a crucial requirement to have a methane rich gas for power generation. The key co-product of anaerobic digestion process is a nutrient-rich digestate, which can be used as an organic fertilizer. Anaerobic digestion is considered to be mature and well commercialized technology.

3.5 Landfill Gas

Landfill gas (LFG) is a sub category of the anerobic digestion process. LFG contains around 40 – 60% percent methane, and the rest is carbon dioxide, with less than one percent non-methane organic compounds and inorganic compounds. When waste is first deposited in a landfill, it undergoes an aerobic decomposition phase during which small quantities of methane is generated. Within around 1-1 ½ years, anaerobic conditions are established and waste is decomposed to methane and carbon dioxide by methane-producing bacteria. Typical LFG collection systems have three essential components: collection wells or trenches; a condensate collection and gas treatment system; and a blower. According to the EPA (2013) the most common method of LFG collection involves drilling vertical wells in the waste and connecting those wellheads to lateral piping that transports the gas to a collection header using a blower or vacuum induction system. Another type of LFG collection system uses horizontal piping laid in trenches in the waste. These systems are useful in deeper landfillsand in areas of active filling. Some collection systems involve a combination of vertical wells and horizontal collectors. A flare unit ensures that the excess landfill gas or the landfill gas when equipment are offline. A flare unit is a critical compotent of a landfill gas collection system as methane of landfill gas is 21 times more effective at trapping heat in the atmosphere when compared to carbon dioxide.

Collected LFG can be used in an energy recovery system to produce energy. LFG treatment is required in order to remove excess moisture, particulates, and other impurities before being used in an energy recovery system. The choice and extent of treatment system depends on LFG characteristics and the type of energy recovery system employed. Minimal treatments like dehumidification and particulate removal is sufficient for applications such as boilers and most IC engines. Some IC engines and many gas turbine and microturbine applications require further treatment to remove siloxane. Adsorption beds (activated carbon) after the dehumidification process is common in these applications.

All new "waste to energy" plants in developed countries must meet strict emission standards, including those on nitrogen oxides (NOx), sulphur dioxide (SO_2), heavy metals and dioxins. Hence, modern incineration plants are vastly different from old types, some of which neither recovered energy nor materials. Modern incinerators reduce the volume of the original waste by 95-96 percent, depending upon composition and degree of recovery of materials such as metals from the ash for recycling. Waste to energy systems have been developed in the US and Europe to burn solid waste with high caloric content resulting from large fractions of paper and other dry combustibles. The figures are for US 10,500kJ/kg, Europe 7,560kJ/kg. In Indian cities (medium sized) the range is between 3,360 to 4,620 kJ/kg of solid waste. Larger Indian cities have 4,620 to 6,300 kJ/kg of waste. Due to low caloric content of the waste in developing countries, incineration sometimes might not be viable. But it depends on the cost of pretreatment. Table 04 shows the heating value in wet basis for different regions of the world.

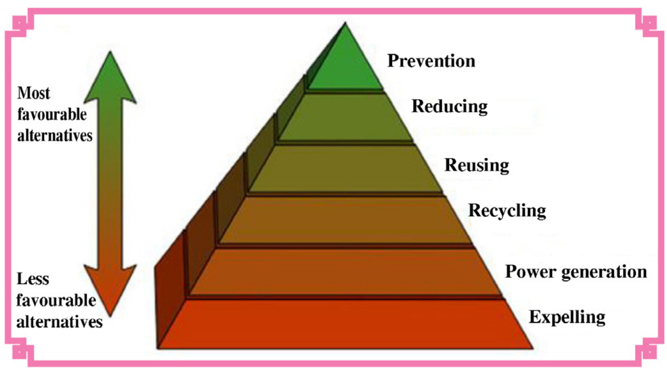

Fig 4 : Waste Management Hierachy

3.4 Electricity generation potential

The electricity generation potential under incineration and heat recovery process for MSW in Sri Lanka is estimated here. Generally incinerators have waste to electricity efficiencies of 14-28%. One of the role model plants "Reno Nord" in Denmark has reported waste to electricity efficiency of 27%. In order to avoid losing the rest of the energy, cogeneration systems are introduced in modern plants. District heating is one such method employed in Europe which is not applicable in tropical countries. From the data available in table 4, the possible electricity generation potential was calculated as in table 5. Assuming that the total waste use for incineration apart from plastic material, the combustible portion is 82% which comprises of all the organic waste, paper and paper board. Further it is assumed that the moisture content may reduce to 20% after mechanical pressing or other mean. Table 5, gives the waste to Energy potential generation data.

Table 5: Electrical Power generation potential –MW

District	Generation (Ton / day)	Sum (Ton / day)	Generation of Power (MW)	Total of power generation
Colombo	1,759	1,318	29.0	21.0
Gampaha	435	232	7.0	3.0
Kaluthara	185	131	3.0	2.0
Anuradhapura	131	70.5	2.0	1.0
Polonnaruwa	46	25.5	0.7	0.4
Kandy	350.2	231.5	5.0	3.0
Nuwara Eliya	69.8	55.3	1.0	0.9
Matale	138.5	62	2.0	1.0
Ampara	295.8	213	4.0	3.5
Trincomalee	105.5	56.75	1.7	0.9
Batticaloa	327	220	5.4	3.6
Rathnapura	235.5	116	3.9	1.9
Kegalle	101.5	68.5	1.6	1.1
Badulla	145	86.75	2.4	1.4
Monaragala	114	48	1.8	0.7
Jaffna	144.11	113.76	2.3	1.8
Killinochchi	8	5.75	0.1	0.1
Mullaitivu	11	7	0.2	0.1
Vavuniya	30	8	0.4	0.1
Mannar	53	46	0.8	0.7
Kurunegala	184	133	3.0	2.0
Puththalam	134.5	82.5	2.2	1.3
Galle	250	144.5	4.0	2.3
Mathara	134.2	106.25	2.2	1.7
Hambantota	92	48.8	1.5	0.8
Total	**5,480**	**3,630**	**87**	**56**

According to present collection of waste, 56MW of electricity could be produced by incineration, while 87MW could be generated if the total waste is collected. However, the Waste to Energy option lies somewhat below in the waste management hierarchy, which indicates order of preference for action to reduce and manage waste (Figure 3). The aim of the waste hierarchy is to extract the maximum practical benefits from products, and to generate the minimum amount of waste. In 1975, The European Union's Waste Framework Directive (1975/442/EEC) introduced for the first time the waste hierarchy concept into European waste policy.

Following the waste hierarchy will generally lead to the most resource-efficient and environmentally sound choice, but in some cases departing from it might be inevitable especially in a crisis or near crisis situation where quick and short term solutions are badly needed. However, once it comes back to normal, the hierarchy should be followed. The situation of waste management in Sri Lanka is becoming a national issue, and need some short term, quickly implementable solutions as well as long term sustainability. In that case energy recovery will be a better option as it has a potential for revenue generation from electricity which compensate the expenditure in collecting, transporting, etc. To make such projects more attractive for the investors, the energy content (electricity generation) needs to be increased in which recoverable material such as polythene and plastics should also be burnt so that it contains higher calorific value compared to paper, textile and de-watered organic material. However, this is again a deviation from the hierarchy, which needs to be reverted to in the long run. Finally it is important to note that long and intermediate term solutions as in the hierarchy, should also be implemented with the short term "quick relief" options for the sustainable development of the nation. Strong policy interventions encouraging attitudinal and behavioural changes of the public are needed to reinforce the activities of relevant institutions.

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