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Solar Assisted Dryer for Municipal Solid Waste

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Abstract

Urban India generates 188,500 tons per day (68.8 million tons per year) of municipal solid waste (MSW) at a per capita waste generation rate of 500 grams/person/day. Improper solid waste management deteriorates public health, degrades quality of life, and pollutes local air, water and land resources. It also causes global warming and climate change and impacts the entire planet. Improper waste management is also identified as a cause of 22 human diseases and results in numerous premature deaths every year. The composition of urban MSW in India is 51% organics, 17.5% recyclables (paper, plastic, metal, and glass) and 31 % of inerts. The moisture content of urban MSW is 47% and the average calorific value is 7.3 MJ/kg (1745 kcal/kg). The composition of MSW in the North, East, South and Western regions of the country varied between 50-57% of organics, 16-19% of recyclables, 28-31% of inerts and 45-51% of moisture. The calorific value of the waste varied between 6.8-9.8 MJ/kg (1,620-2,340 kcal/kg). Currently, there is no system or mechanism exists to dry the municipal solid waste. In this research work such system can be designed and developed which will dry the municipal solid waste and remove the odor from it. Dried municipal solid waste can be further used as fuel for boiler.

Introduction

Majority of the MSW collected in India is disposed off on open land or in unsanitary landfills. This is in addition to the irregular and incomplete waste collection and transportation in many cities, which leaves MSW on the streets. Many municipalities in India have not yet identified landfill sites in accordance with MSW Rules 2000. In several municipalities, existing landfill sites have been exhausted and the respective local bodies do not have resources to acquire new land. Such a lack of landfill sites decreases MSW collection efficiency. Unsanitary land filling pollutes ground and surface waters, emits greenhouse gases and other organic aerosols and pollutes the air. Pests and other vectors feeding on improperly disposed solid wastes is a nuisance and above that a breeding ground for disease causing organisms. Since economic reforms in 1992 – 1993, India has undergone rapid urbanization, which changed material consumption patterns, and increased the per capita waste generation rate. Since 2011, India underwent unprecedented economic growth and the urban per capita waste generation increased from 440 grams/day to 500 grams/day at a decadal per capita waste generation growth rate of 13.6%. The change in lifestyles has caused considerable change in the composition of MSW generated in India too. Following a trend expected during the economic growth of a country, the percentage of plastics, paper and metal discarded into the waste stream increased significantly and the amount of inerts in the collected waste stream decreased likewise due to changes in collection systems. From 1973 to 1995, the composition of inerts in MSW decreased by 9%, whereas organic matter increased by 1% and recyclables increased by 8% (Figure 1). However, from 1995 to 2005, inerts decreased by 11%, compostable increased by 10% and recyclables by only 1%. The increase in compostable and recyclables observed (Figure 1) is due to a) increase in recyclable wastes generated due to lifestyle changes, and b) decrease in the overall percentage of inerts due to improvement in collection.

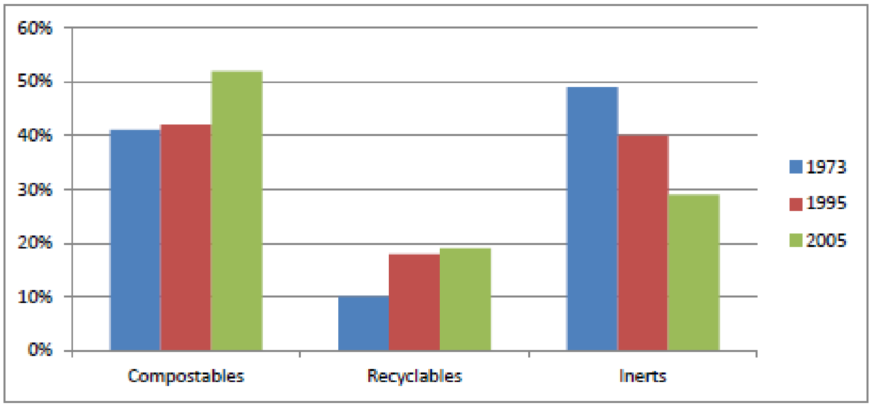

Figure 1: Change in Composition of Indian MSW since 1973, through 1995 and 2005

Drying is basically phenomena of removal of liquid by evaporation from a solid. Mechanical methods for separating a liquid from a solid are not generally considered drying. These principles are applied, in general, to mechanical conventional drying and here concerned mainly with solar drying. However in general, must be noted that conventional drying principles and phenomena are independent of the type of energy used. Ekechukwu and Norton (1999) and Mujumdar, 2007 gives a comprehensive review of fundamental principles and theories governing the drying process. A major part of energy consumption during drying is for the evaporation of liquid water in to its vapour (2258 kJ/kg at 101.3 kPa). The water may be contained in the solid in various forms like free moisture or bound form which directly affects the drying rate. Moisture content is expressed either on dry or wet basis, e.g. moisture content in wet (Xw) basis is the weight of moisture per unit of wet material.

$$Xw = mw/(mw+md)\text{, kg per kg of mixture}$$

and on dry basis (Xd), is expressed as the ratio of water content to the weight of dry material:

$$Xd = mw/md$$

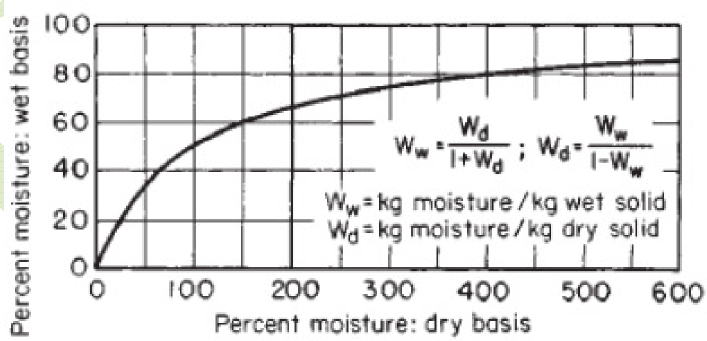

Figure 2: Relationship between wet-weight and dry-weight basis (Perry 2007)

Drying basically comprises of two fundamental and simultaneous processes: (i) heat is transferred to evaporate liquid, and (ii) mass is transferred as a liquid or vapour within the solid and as a vapour from the surface. The factors governing the rates of these processes determine the drying rate. The different dryers may utilize heat transfer by convection, conduction, radiation, or a combination of these. However in almost all solar dryers and other conventional dryers heat must flow to the outer surface first and then into the interior of the solid, with exception for dielectric and microwave drying. During the last decades, several developing countries have started to change their energy policies toward further reduction of petroleum import and to alter their energy use toward the utilization of renewable energies. With very few exceptions, the developing countries are situated in climatic zones of the world where the insolation is considerably higher than the world average of 3.82 kWh/m2 day. In Figure 3daily average horizontal insolation data and sunshine hours of some developing countries are given. An alternative to traditional drying techniques and a contribution toward the solution of the open air drying problems is the use of solar dryers. Accordingly, the availability of solar energy and the operational marketing and economy reasons offer a good opportunity for using solar drying all over the world.

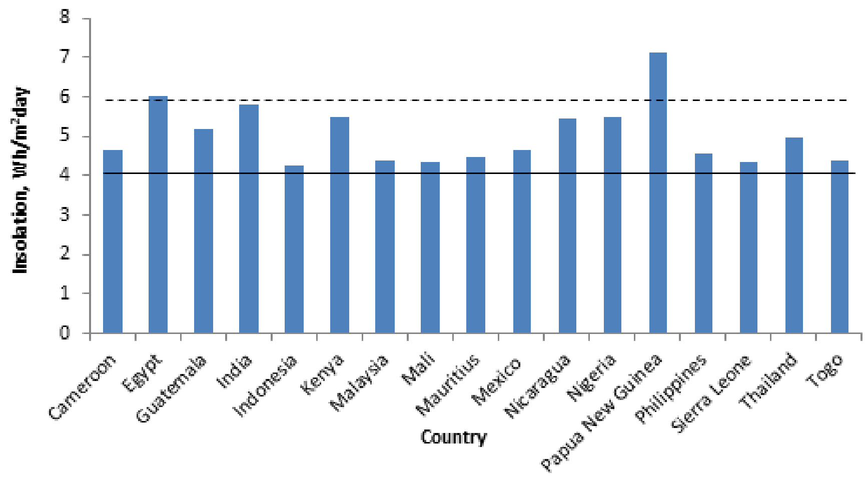

Figure 3: Total horizontal solar insolation for some developing countries

Drying (or dewatering) is a simple process of excess water (moisture) removal from a natural or industrial product in order to reach the standard specification moisture content. It is an energy intensive operation. The widest among drying methods is convective drying (whereby heating takes place by convection between the hot air and the products surface), i.e. drying by flowing heated air circulating either over the upper side, bottom side or both, or across its mass. Hot air heats up the product and conveys released moisture to atmosphere. Thus drying psychrometry is of importance because it refers to the properties of air–vapour mixture that controls the function of drying. In direct solar drying called "sun drying" the product is heated directly by the sun's rays and moisture is removed by natural circulation of air due to density differences.
Two basic moisture transfer mechanisms are involved in drying:
1. Migration of moisture from the mass inside to the surface.
2. Transfer of the moisture from the surface to the surrounding air, in the form of water vapour.

Drying by solar radiation can be divided into two main categories:
(a) Direct, or open-air sun drying, the direct exposure to the sun.
(b) Indirect solar drying or convective solar drying.
Hybrid solar dryers combine solar radiation energy with an auxiliary conventional source of energy. They can be operated either only by solar energy, only by conventional energy sources or by both. In most of the cases hybrid solar drying systems are medium to large capacity installations and operate by a solar ratio in the range of 50–60%.
The hybrid solar dryers combine the features of a solar energy with a conventional or some auxiliary source of energy and can be operated either in combination or in single mode with either source of energy. These dryers generally are medium to large installations operating in the range of 50-60%, and compensate the temperature fluctuations induced by the climatic uncertainties. Bena and Fuller (2002) described a direct-type natural convection solar dryer combined with a simple biomass burner in regions without electricity. A hybrid solar dryer is a modification of the solar dryer with auxiliary source of heating. Amer et al. (2011) has recently designed and evaluated a hybrid solar dryer for drying of banana, consisting of a heat exchanger and heat storage facility.

Proposed Solution

As we know, in developing countries like India, we are continuously facing the energy crisis. Power generation units in India are unable to cope up with demand of nation. So mere use of electricity to dry out the solid waste will not be a fair solution for above stated problem. Therefore seeking for the alternate energy source is the need of current era and fortunately India is gifted with Solar, tidal and wind energy in ample amount. We are coming into a zone of 5.8 to 6.4 kwh/m^2/day which is very huge as compared to other nations in Europe & America. So use of solar energy for the drying of solid waste is one of the best solution as the solar energy is available at free of cost its clean source of energy, solar equipments are nearly maintenance free. Though solar energy are having these much advantages but it has few limitations like the availability of solar energy is completely depends on climatic conditions. It is completely useless during night so better solution is to make combination of solar and electric energy. So we can get the combination of advantages of both solar and electrical equipments. So the solution must have combination of Solar and Auxiliary source as electricity. We can say HYBRID MSW (Municipal Solid Waste) DRYER.

Proposed Construction of Hybrid MSW Dryer

A box type construction lets say Garbage Box to which the solar absorber plate assembly is attached as shown as in figure 4. And conventional energy source i.e. electrical supplied heating coil is placed at the bottom of garbage box. There is an arrangement of hooper at the top of the garbage box for feeding of solid waste. There is also a provision of handle whose extended shaft is inserted into the garbage box and baffle vanes are welded to it which help to agitate the garbage present in the box.

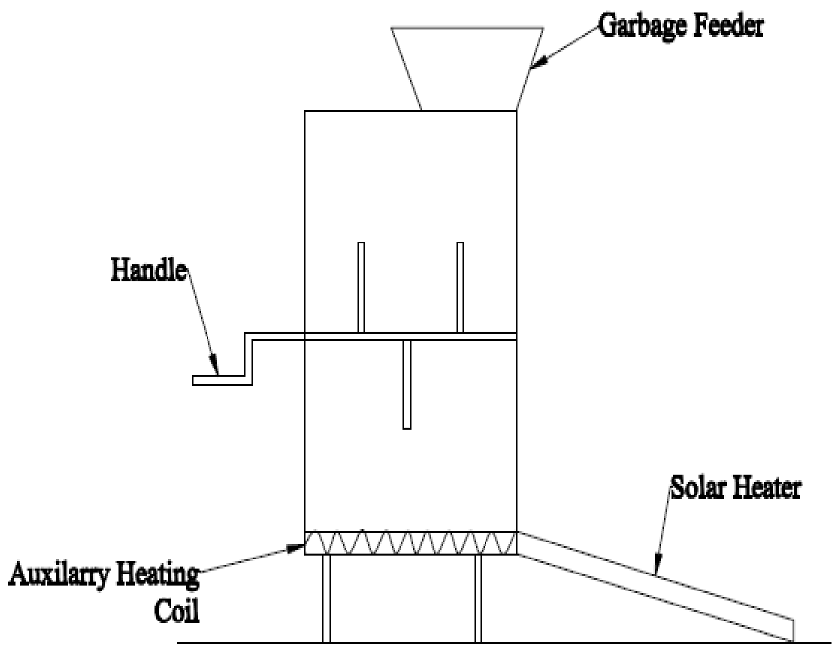

Figure 4: Hybrid MSW Dryer

Working of Proposed Hybrid Dryer

Absorber plate present In the solar heater assembly is get heated due to solar radiation falling on it. An air from environment will enter into the solar heater assembly where the absorber plate is placed. As the air present over there is get heated due to convection. This heated air will move forward as its density will drop and it enters into garbage box where the moist garbage is placed. This type of circulation of heated air is called thermo siphon action. While heated air flowing through the garbage will remove the moisture from it. Provision of electrical heating coil will come into picture when drying is required to carry during nights & cloudy days.

Conclusions

Till date no efforts have been taken to dry the municipal solid waste and no one is focussed on the various health issues arose due to is which can be solved by sole drying of municipal waste. Drying will remove the unpleasant odour and also help to improve burn ability of the solid waste which can be directly feed as fuel to boilers. In metro cities like Mumbai, Nasik, Pune & mega cities like Solapur, Aurangabad such a boilers are used to generate steams which used to generate electricity.

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