# SOURCE REDUCTION BY HOUSEHOLD WASTE MANAGEMENT: A PRACTICAL AND EFFECTIVE SOLUTION FOR PROVIDING SUSTAINED ACCESS TO SAFE WASTE DISPOSAL IN CITIES

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***Abstract***
*The lack of safe disposal of waste creates a tremendous burden of communicable disease and other debilitating, life-threatening illnesses for people in the cities. Source reduction - waste treatment technology has emerged as an approach that empowers people and communities without access to safe disposal of waste to improve waste quality by treating it in the home. Several source reduction technologies are available, but, except for landfilling, none have achieved sustained, large-scale use. Sustained use is essential if household waste treatment technology (HWT) is to provide continued protection, but it is difficult to achieve. The most effective, widely promoted and used source reduction HWTs are critically examined according to specified criteria for performance and sustainability. Compost and biogas plants using biological treatments are identified as most effective according to the evaluation criteria applied and as having the greatest potential to become widely used and sustainable for improving household waste disposal to reduce various communicable diseases and keep the environment clean.*

***Key words: Household Waste Management, Source Reduction, Biological Treatment Technologies, Sustainable Development.***

## 1.INTRODUCTION

People worldwide lack access to safe waste disposal and use unsafe waste disposal practices. Even people who access to "improved" waste disposal such as door to door collections, community bins, and open dumping may not have microbiologically safe waste disposal. Improved waste disposal facilities are often contaminated with bacteria and other viruses causing infectious diseases such as chikunkunya, cholera, fever, dysentery, and hepatitis. Lack of access to safe waste disposal contributes significantly to the global burden of climatic change and disease resulting from infectious waste.

Recent systematic studies of sanitation, hygiene and water interventions suggest that the beneficial effects of improving household waste management at the source to reduce communicable disease risks had been previously underestimated. Contemporary reviews estimate 30-40% reductions in waste disposal problems by improving household waste management at source, making such treatment more effective than improvements at various levels. The goal of source reduction by Household Waste Treatment (HWT) and safe waste disposal technologies is to empower people without access to safe waste disposal to improve waste quality by treating it and using the by product (biogas, compost) safely in the home. There are number of different source reduction technologies which policy-makers, implementers, and users can select as appropriate for particular circumstances and populations. Although a variety of source reduction technologies have been suggested, tested, and disseminated, not all have an evidence base of effectiveness and sustained use. This paper focuses on those technologies for which performance efficacy and sustained use have been studied by microbiological efficacy and waste reduction studies.

## SOURCE REDUCTION TECHNOLOGIES

The source reduction technologies to be critically studied are the following:

❖ **Methane production by anaerobic fermentation (Biogas):** This is the mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition. Biogas technology is a complete system in itself with its set objectives (cost effective production of energy and soil nutrients), factors such as microbes, plant design, construction materials, climate, chemical and microbial characteristics of inputs, and the inter-relationships among these factors. Biogas is produced by means of a process known as anaerobic digestion from locally available wide range of materials like animal dung, human excreta, household wastes, water hyacinth, and agricultural wastes as feed material. It's a process whereby organic matter is broken down by microbiological activity. Biogas is mainly composed of 50 to 70 percent methane, 30 to 40 percent carbon dioxide and low amount of other gases. Slurry is the residue of inputs that comes out from the outlet after the substrate is acted upon by the methonogenic bacteria in an anaerobic condition inside the digester. After extraction of biogas (energy), the slurry (also known as effluent) comes out of digester as byproduct of the anaerobic digestion system. It is an almost pathogen free stabilized manure that can be used to maintain soil fertility and enhance crop production. The physical and chemical characteristics of Indian city refuse, nonetheless, show that about 80% of it is compostable and ideal for biogas generation due to adequate nutrients (NPK), moisture content of 50-55% and carbon to nitrogen ratio of 25-40:1. Therefore, the development of appropriate technologies like biogas for utilization of wastes is essential to minimize adverse health and environmental consequences.

❖ **Composting:** Composting is the biochemical degradation of organic wastes. Homecomposting has been practiced for many years in rural areas by placing organic matter and animal manures in soil pits and allowing decomposition to proceed. The end product of composting is humus like material that can be used primarily as a soil conditioner. The key to commercial composting is to provide an environment in which these microorganisms can perform most efficiently, thereby reducing the time required for stabilization. The most important parameters of the composting environment are temperature, the amount of oxygen available, the nutrient content of the waste, the moisture content of the waste, and the PH of the waste. The necessary microbes exist in sufficient quantity in all domestic refuse while the necessary nutrients, when not already present, can be easily supplied through the use of waste water sludge or other appropriate additives (Joseph et al 1975). Homecomposting has the advantage of directly involving people in the disposal of their own waste and the informality of this approach has its own advantages.

❖ **Vermicomposting:** We can compost food scraps such as fruit and vegetable peels, pulverized eggshells, tea bags and coffee grounds. It is advisable not to compost meats, dairy products, oily foods, and grains because of problems with smells, flies, and rodents. It is also advisable not to compost glass, plastic or tin foil. Worm bins can be used indoors all year round and outdoors during the milder months. The advantage of mobile bins is that they can be moved when weather conditions change. Indoors, basements are excellent locations (warm, dark and dry), but any spare space can be utilized, as long as temperatures are between 40-80ºF. Outdoors, bins can be kept in sheds and garages, on patios and balconies, or in the yard. They should be kept out of hot sun and heavy rain.

If we have the correct ratio of surface area to worms to food scraps, there is little to do, other than adding food, until about two and a half months have passed. By then, there should be little or no original bedding visible in the bin and the contents will be brown and earthy looking worm castings. The contents will have substantially decreased in bulk too. It is important to separate the worms from the finished compost; otherwise the worms will begin to die. There are several ways to do this. The quickest is to simply move the finished compost over to one side of the bin; place new bedding in the space created, and put food waste in the new bedding. The worms will gradually move over and the finished compost can be skimmed off as needed. If we have the time or want to use all the compost, we can dump the entire contents of the bin onto a large plastic sheet and separate the worms manually. Watch out for the tiny lemon-shaped worm cocoons, which contain between two and twenty baby worms. By separating the worms from the compost, we save more worms for our next bin. Mix a little of the finished compost in with the new bedding of the next bin, and store the rest in plastic bags for use as required. To avoid fly and smell problems, always bury the food waste by pulling aside some of the bedding, dumping the waste, and then cover it up with the bedding again. Bury successive loads in different locations in the bin.

Although other source reduction technologies are available, they lack scientifically sound evidence documenting their ability to improve waste disposal problem and reduce communicable infectious diseases. Thus, they cannot be assessed here based on these measures of effectiveness and sustainability. These three household source reduction technologies have an evidence base from laboratory and intervention studies, which provides a timely opportunity to compare them on the basis of key criteria for effectiveness and sustainability. This paper examines these source reduction technologies based on available evidence in a rigorous framework for holistic comparisons of their microbial efficacy, health impacts, and sustainability.

**Table I: Estimates of Baseline and Maximum Effectiveness of Source Reduction Technologies against bacteria in Waste**

| Treatment process | Bacterial activity | Optimum Temperature | By-product |
|---|---|---|---|
| Biogas | Anaerobic digestion | 35ºC | Bio gas burns with 60% efficiency in a conventional biogas stove. Slurry is used as fertilizer. |
| Home composting | Aerobic digestion | 30ºC-35ºC | Compost |
| Vermicomposting | Aerobic digestion | <35ºC | Compost |
| Windrow composting | Anaerobic digestion | 55ºC | Compost |

**FACTORS INFLUENCING PERFORMANCE EFFICACY**

The most important parameters of the composting environment are temperature, the amount of oxygen available, and the nutrient content of the waste, the moisture content of waste, and the pH of the waste. The single most important limiting factor is the need for a viable market for compost. Without a market for the finished compost, composting becomes very uneconomical when compared to other refuse disposal systems. Available land for windrow composting plants may be difficult to find in large metropolitan areas. The appearance of windrowed refuse will mostly likely be objectionable to people living in the area. Minimum oxygen content in the compost of 18% is recommended. If the moisture content is below a minimum 40%, biodegradation is significantly reduced; high moisture contents are also to be avoided since they occupy intra-particle spaces and thereby produce anaerobic conditions. Optimal composting is achieved in the pH arrange 5.5-8. Bacteria prefer a near neutral pH, whereas fungi develop better in a slightly acidic environment. Optimal C: N ratio in the starting waste material is about 25, higher values resulting in a slow rate of decomposition, and lower ratios resulting in nitrogen loss. The organic fraction of MSW has a C: N ratio between 26 and 45 and for raw sewage sludge it is 7-12.

Windrow composting: A moisture content of around 60% is the ideal target for optimum composting, though anything within a range of between 40-70% will suffice. The optimum particle size for composting is, of necessity, something of a compromise. The smaller the individual pieces, the larger will be the surface area to volume ratio, which makes more of the material available to microbial attack, thus speeding up the process of decomposition.

The optimum biogas production is achieved when the pH value of input mixture in the digester is between 6 and 7.Ideal conditions for the methanogenic micro-organisms are a pH range from 6.8 to 7.5. Lower moisture contents are preferred since they reduce the liquid effluents from the plant. Operational parameters for the reactor would be controlled to give anaerobic conditions and maximum gas yield. For maximum gas production a temperature in the range 30-35 degree centragrade for mesophilic bacteria and 45-65 for thermophilic bacteria, would be used. A high C:N ratio produces a high acid content and low methane production. The biodegradable fraction of municipal solid waste can have a high C: N ratio of above 50, whereas sewage sludge has a C:N ratio below 10.

In vermicomposting, the earthworms, which survive only under aerobic conditions, takeover both the roles of turning and maintaining the organics in an aerobic condition, thereby reducing the need for expensive engineering. Earthworms secrete mucus, which helps in maintaining a favorable pH, 6.5-7.5. The properly segregated and vermicomposted garbage contains an average carbon/Nitrogen ratio of 17.9.

**Table 2: Household Waste Treatment by Source Reduction Technologies in Controlled Studies**

| Technology | Waste reduction estimate | Estimates of self-reported and/or measured % user perception |
|---|---|---|
| Biogas | Results in an overall refuse weight reduction of about 40 to 50 percent. | Biogas plants are economically viable investments to the owners created optimism for rapid adoption of biogas technology in households. |
| Home composting | Degradation of organic wastes into compost under natural condition normally takes about 6 months. | Using rates decreases to as low as 10% after the attempts to systematize the composting process. |
| Vermi-composting | Earthworm's participation enhances decomposition by 25% with 25% reduction in time for composting. | Using rate is high |
| Windrow composting | 32-34% ends up as compost. | Using rate is low. As windrow is only suitable for small cities having an adequate land area and a suitable climate. |

## WASTE REDUCTION EFFICACY, VARIOUS IMPACTS AND SUSTAINABILITY

### ❖ Waste Reduction Efficacy

The physical and chemical characteristics of Indian city refuse, nonetheless, show that about 80% of it is compostable and ideal for biogas generation due to adequate nutrients (NPK), moisture content of 50-55% and carbon to nitrogen ratio of 25-40:1. Therefore, the development of appropriate technologies for utilization of wastes is essential to minimize adverse health and environmental consequences. Recycling is perhaps the most widely recognized form of source reduction involving the process of separating, collecting, processing, marketing and ultimately using a material that would had otherwise been discarded. This form of source reduction, i.e., recycling, is similar to other forms, in that it:

- Lessens reliance on landfills and incinerators;
- Protects human health and the environment by removing harmful substances from the waste stream;
- Conserves natural resources by reducing the demand for raw materials.

Comparative levels of waste reduction achieved by specific source reduction technologies are shown in table-1.

### ❖ Various impacts of Composting and Bio-Gasification

The compost produced and slurry from biogas plants is often used as a soil amendment in a variety of applications, after ascertaining the quality of the product. Since the product is used for a variety of purposes, contaminants in the compost could be detrimental to the environment (EPA, 1989 and 1995). This is particularly true when one considers that the environmental pollutants are easily minimized through simple treatment procedures (i.e., waste segregation, proper turning and sufficient composting time). In the main, composting facilities of solid waste with manure, sewage sludge and residue from processing create some significant environmental considerations including the following:

- Water impacts: Water runoff from garden waste composting facilities could contain large concentration of nutrients (i.e., nitrates and phosphorous), volatile organics and metals that cause algal blooms in the nearby surface water. Retention basins may be used at facilities to limit water runoff. Water impacts are not generally expected to be serious at yard waste composting facilities. Municipal waste composting, sludge composting and co-composting involve a large amount of potential contaminants, and water impact could be greater at these facilities. Leachate could affect both surface and ground water.

- Land impacts: At garden waste composting facilities, soil may become more acidic, due to the presence of certain leaves and pine needles in the compost pile. Nitrogen depletion may also occur, which can be limited by proper turning. MSW and co-composting facilities carry the potentially harmful impacts of acids, and organic and metal contamination. Again careful pre-processing to divert much of the potentially hazardous materials from the compost facility is an important quality control procedure.
- Odour pollution: odour is one of the most frequent problems at the composting facilities. Frequent turning of compost piles has proven to be effective in limiting odour problems.
- Health impact: The primary public health concerns associated with composting operation result from: drinking contaminated water, toxins in the finished product, pathogens. Nitrate contamination of drinking water can affect the oxygen carrying capacity of the blood in infants, e.g., blue baby syndrome and in elderly, but again under proper composting condition this risk can be minimized. Insects and vermin can spread pathogens. Note that because of the high temperature achieved during the normal composting operations, pathogens found in manure, sewage sludge or municipal wastes are usually destroyed. There are risks to workers as well (e.g., aggravation of respiratory problem). However, proper training and health monitoring as well as proper apparel and equipment can minimize these risks.

❖ **Sustainability.** Although source reduction technologies may demonstrate effectiveness in field studies, this does not necessarily mean that they will do so over long periods of time in actual use. The effectiveness of source reduction technologies will be seriously undermined and communicable disease risks and waste disposal burdens will remain high if people treat waste intermittently, go for long periods without treating, or some people treat the organic waste while others not treating and contaminated the waste. People must be sufficiently motivated and committed to integrate source reduction into their daily lives long after intensive study interventions have ended. The overarching need for any source reduction technology is that it is sustainable; it becomes a part of the daily routine of every household , who uses it for disposing waste and other high level purposes (e.g., biogas for cooking and compost for manuring) all of the time. Key features of a sustainable waste management technology are as follows:

- Reduces the overall environmental impacts of waste management, including energy consumption, pollution of land, air and water and loss of amenity (White et al 1995).
- Overall costs of the waste management system should operate at a cost level acceptable to all areas of the community, including householders, businesses, institutions and government (White et al 1995).
- Able to consistently produce sufficient quantities of byproducts to meet daily household needs.
- Effective for treating many different waste sources.
- Requires relatively small user time to treat waste, thereby not significantly contributing to already substantial household labor time burdens.
- Have a reliable, accessible and affordable supply chain for needed replacement units or parts for which consumers are willing and able to pay.
- Maintain high post-implementation use levels after cessation of intensive surveillance and education efforts, as in field trials and marketing campaigns.

Here we present and apply a scoring system to rate and compare source reduction technologies based on five of these six sustainability criteria: quantity of waste treated, ability to treat different composition of waste, ease of operation and time to treat, cost per kg of waste, and supply chain requirement. For each criterion, a technology is assigned a performance score of 1 to 3, with 1 for low, 2 for fair, and 3 for good performance.

❖ **Quantity of waste treated**. For all the households to dispose organic waste only through treatment (because of decaying nature), the ability of a household waste treatment technology to treat different composition of waste is critical. The segregation of waste and volume of units needed increases user treatment time and the risk that the user will rely on additional untreated sources of waste for disposal. We score waste reduction based on disposing maximum 2 kg of waste within a day or two days of using the treatment units, a sufficient volume of unit to meet all critical waste disposal of a 5 member household. Technologies treating all organic matters including both vegetable and meat waste and producing sufficient quantities of byproducts to meet the daily needs (biogas for cooking and compost for manuring) and safe disposal of waste receive a score of 3. A technology receives a score of 2 if the unit of technology has to be used to treat only vegetable wastes with safe disposal. The technology will receive a score of 1 if the wastes have to be stored and partially treated to meet the criterion of disposal at source.'

## 3. APPLICATION OF THE TECHNOLOGY TO A WIDE RANGE OF QUANTITY OF WASTE DISPOSAL.

❖ **Treatment Robustness:** The applicability of the treatment technology to a wide range of waste reduction is key because of differences in waste sources and spacio-temporal and seasonal fluctuations in waste composition. Technologies that improve waste disposal and reduce contaminations provide households with safe disposal with high material recovery rate regardless of landfilling all the waste without recovery. Technologies that can provide consistent waste reduction with high energy and material recovery are scored higher in treatment robustness. Technologies that reduce waste disposal problem fully and provide energy or useful byproducts with respect to the quantity of waste treated score a 3. Technologies not suitable for meat waste, oil waste etc. but still maintaining effective waste reductions for vegetable waste score a 2. Technologies unable to treat the household waste and providing less waste reduction efficiency under poorer waste spreading conditions score a 1.

❖ **Biogas Technology**: The production of methane from organic waste is based on bacterial action. The anaerobic fermentation of cowdung produces methane, carbondioxide, hydrogen and slurry containing rich manure in the form of nitrogen and phosphrous. The economics of investment in biogas plant depends on capital and operational cost of the plant on the one hand, and valuation of gas and manure produced on the other. Apart from tangible benefits, biogas plant also has intangible benefits like smokeless cooking and improvement in the environment, more leisure time to housewives, and income and employment generated on site and by segregation of waste in their own home.

❖ **Compost:** Proper shredding of waste is needed to increase the surface area of microbial action. The waste needs to be turned to aerate the system. There is microbial secretion, but not sufficient to influence the pH strongly. Proper conditions have to be maintained for prevention of malodour. The time taken is relatively more. A key element of the production of compost from biodegradable waste is the issue of the quality of the final end product in relation to compost derived from traditional non waste sources which are well established in the market place. The compost standards relating to quality and the stabilized biowaste relating to a lower quality product are only suitable for those applications not involving food and fodder production, such as landscaping road construction, golf courses and football pitches. There are also restrictions on the amount and frequency of application of such stabilized biowaste.

❖ **Vermicomposting**: Prior size reduction is not needed. By their burrowing action, earthworms aerate the systems; therefore, stirring is not needed. Earthworms secrete mucus, which helps in maintaining a favourable pH 6.5-7.5. There is no malodour. The time taken for the conversion of the waste is relatively lesser. The vermicomposting pits, in some cases, must have protection against heavy rainfall, direct sunlight and predators. The economics would depend on the scale of operation and the degree of mechanization.

❖ **Ease of process use and time treating waste.** Adoption and consistent use of source reduction technology by households is influenced by both ease of treatment process performance and the time required of the household member tasked with treatment. The more straight forward the operation and maintenance of the technology, the greater the likelihood that it will be adopted and used successfully. This criterion is based on the sum of scores for three elements: process ease, process duration, and process maintenance requirements. Treatment processes having a single step score a 1 and those having multiple steps score a 0. Technologies providing waste reduction within a shorter period score a 1 and those taking longer period score a 0. Technologies requiring periodic maintenance beyond cleaning the treatment unit score a 0 whereas those not requiring maintenance score a 1.

**Table III. Scoring of source reduction treatment technologies (Sustainability Criteria)**

| Technology | Quantity of waste disposed | Quality | Ease of use | Cost | Supply chain | Overall score |
|---|---|---|---|---|---|---|
| Biogas | 3 | 3 | 2 | 3 | 3 | 14 |
| Home composting | 3 | 1 | 2 | 1 | 2 | 9 |
| Vermicomposting | 2 | 3 | 2 | 2 | 2 | 11 |
| Windrow composting | 3 | 1 | 2 | 3 | 1 | 10 |

(Score 1-low, Score 2-fair and Score 3-high)

## 4. COST TO TREAT

Cost-benefit analyses of various household waste treatment technologies have been done, but are beyond the scope of this study. However, source reduction technology cost is an important criterion for adoption and sustained use. For our purposes, we assume households treat 2 kg of waste per day for 365 days. The cost of each technology was calculated as rupees per year. For technologies that are one time purchases this approach may overestimate the cost, but it does provide a consistent basis for comparison. This approach to calculating source reduction technology cost does not take into account many other cost-related factors but it does provide a simple, uniform basis for comparison.

- ***Biogas.*** The typical cost of biogas is a one-time cost of one cubic meter unit is Rs.10000/-, depending on the country and implementer. We can treat a maximum of 5kg of waste per day per unit. Score.3.
- ***Vermi-compost.*** A portable vermipot can treat 30 days of waste with initial investment for pot of Rs.500/, for earthworms of Rs.50/- and cowdung and coirpith of Rs.50/-. Score.2.
- ***Windrowcomposting***. Requires mechanical operation with large space and may need to be purchased at low cost. Score.3.
- ***Home compsting***. It involves one-time cost and depends on the land value of the particular area. Score.1.

## 5. SUPPLY CHAIN REQUIREMENTS

Consistent use of a source reduction technology will also be affected by access. The need for a periodic or continuous supply can be a hindrance to sustained use of a technology, and currently available technologies have supply chain requirements. For this category, supply chain refers to logistical components the user requires to continue using the technology once received or introduced, not the logistical components necessary to make the technology available to the user by implementers. Technologies not requiring any type of supply chain for continued use would have a score of 3. Technologies requiring periodic replacement or replacement parts have got a score of 2. Technologies requiring a continuous supply of consumables to support continued use has got a score of 1. Scores for the four source reduction technologies are summarized in Table III. The overall sustainability ratings from highest to lowest are biogas, vermicomposting, windrow composting and Home composting. Maintain High Post implementation use levels after cessation of intensive surveillance and education efforts, such as those of field trails and marketing campaigns.

Although controlled interventions of source reduction technologies provide valuable information on waste reduction improvement and health impact, what happens subsequently with source reduction use and performance is important to understand and document. Evaluation of post implementation use levels and performance is complex and not easily reduced to a single metric. However, continued source reduction technology use, consistent waste reduction improvement, and reduced risk of communicable diseases are obvious parameters to document as measures of sustainability. Some evidence for these sustainability measures is available from follow-up studies of source reduction a technology is summarized in Table 4.

- ***Vermin-composting.*** Acceptance and continued vermicomposting usage is noted to be high.
- ***Biogas.*** Rapid adoption of biogas has been observed in households. Usage has been observed to be from moderate to high. Recent post-implementation surveys document >70% continued use of household waste treatment of biogas as long as 5 years after installation. The biogas has very low rates of breakage. However, blockage of gas burners and breaking of gas stove parts results in declining use if replacement parts are not available, highlighting the importance of a supply chain to replace broken parts. Overall, biogas provides long periods of effective use for a modest one-time purchase cost and no ongoing costs except those for occasionally replacing broken parts. Therefore, biogas appears to have high potential for sustained use to improve household waste treatment and reduce the burden of waste disposal.

**Table IV. Post-Implementation Household waste Treatment Use and Sustainability**

| Source reduction technology | Sustainability evidence |
|---|---|
| Biogas | Longest study lasted 12months; continued biogas use rates of >70% by households for upto 5 years since installation. |
| Homecomposting | In follow up studies, decline in use as it causes odour nuisance to the neighbours. |
| Vermicomposting | Longest study lasted 12 months, with high use during the study. |
| Windrowcomposting | Disused as it requires mechanical device for its operation and also requires more space. |

- ***Windrow composting:*** Although sustainability of windrowcomposting has only been evaluated over study durations ranging from weeks to months, continued use has been variable and often low. However, windrowcomposting has many disadvantages which limit its application including; 1. The operation is affected by the local climate since the composting refuse is exposed to the atmosphere, 2. Odors from the exposed compost may be difficult to contain and control 3. The retention time is excessive (30-90 days), and 4. The amount of land required is excessive.

- ***Home composting:*** The few studies on long-term sustained use of home composting show poor continued acceptance. Barriers to home composting access include not knowing where to dispose the decomposed waste, land unavailability, odour from waste pit etc.

## 8. DISCUSSION

Laboratory and field evidence documents that Biogas, vermicomposting, homecomposting and windrow composting are effective for improving waste reduction and reducing waste disposal burdens in households and communities of developing countries. Field studies suggest biogas and vermicompost are able to overcome sustainability obstacles by requiring only one-time purchase, producing sufficient biogas and compost for daily household use with little time and effort, and achieving large scale adoption and continued, long-term use. Both source reduction technologies have been shown to improve waste reduction and reduce the disposal burden in rigorous waste treatment studies, and follow-up studies document sustained, effective performance long after implementation. Home composting and windrow composting technologies have also shown the potential for large scale adoption as they are used by many local bodies and individuals, respectively. Other household waste treatment technologies also deserve consideration, but they need to be evaluated for performance and sustainability according to the criteria identified and applied here to biogas and vermicomposting.

Adoption of source reduction technologies can also be accelerated by further improving their production and distribution systems. Understanding the human behavioral factors that drive people to adopt and continue using household waste treatment technologies is also crucial for widespread adoption and continued effective use. Much work is needed to better understand and incorporate into improved practice the role of education, behavior change, individual and group perceptions and attitudes of the aesthetic qualities of waste, and the social-cultural drivers that influence household waste treatment choices and practices of individuals, households and communities.

Expanding biogas plant, vermin-compost pot production, and marketing, distribution for effective and sustained use also requires knowledge of economic factors. Better information is needed on factors that influence the investment in source reduction technologies and continued use by communities and households. The roles of expanded investment in and different strategies for production, marketing, and distribution on large-scale sustainable uptake and use need to be investigated and understood. Business models and other economic factors such as costs of production, distribution and implementation, pricing, subsidy, microfinance, microcredit, willingness-to-pay, and contingent valuation need further investigation and testing to inform and facilitate scaled-up production, marketing and distribution, consumer and community acceptance and uptake, high level coverage, and sustained, effective use.

Practicing source reduction by waste treatment and safe disposal should be like practicing brushing your teeth: they need to be done at all times in order to minimize or prevent health risks. Source reduction technologies such as biogas and vermicomposting have promise as effective, affordable ways to achieve sustained access to safe disposal of household waste for those people worldwide who most need it.

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