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Recycling of Urban Organic Waste for Urban Agriculture[1]

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The urban waste challenge

The accelerated growth of the global urban population implies an increasing demand for public services. Yet, urban centres in developing countries are unable to meet such demand – services such as sanitation are poor or inadequate to cope with the increasing rates of urbanisation and the associated higher standards of living. According to the UN 2002 Human Development Report, 2.4 billion people in the developing world lack access to basic sanitation. In Africa, Asia and Latin America, the sustainable management of waste is a major challenge for municipal authorities. Waste is a product or material that does not have a value anymore for the first user and is therefore thrown away; however, it could have value for another person in a different circumstance or even in a different culture (van de Klundert and Anschutz, 2001).

Municipal authorities have insufficient financial, technical, and institutional capacities to collect, transport, and safely treat and dispose of municipal wastes, consequently waste management remains one of the major urban problems (Drechsel and Kunze, 2001). In Ghana for example, 58% of the solid waste (SW) generated is dumped by households in designated dumping sites, 25 % is dumped elsewhere in non-designated sites, and only 5% is actually collected. The quantity uncollected varies from place to place and could be as high as 20% as in the two largest cities of Accra and Kumasi. (GSS, 2000).

The situation in other African cities is hardly different. In many cities household waste collection is restricted to wealthy neighbourhoods, while in the remaining areas waste is dumped along road sides, in illegal dumps and in storm water drains (Mbuyi, 1989). The city authorities in Tanzania collect only 24% of the refuse (Kulaba, 1989) while in Nigeria, 35% of Ibadan's households, 33% of Kaduna's, and 44% of Enugu's do not have access to waste collection. (Asomani-Boateng and Haight). In Ougadougou, Burkina Faso, about 23 % of household wastes are deposited in small drains (Ousseynou, 2000). In India, about 50 % of the refuse generated is collected. As much as 90 % of the Municipal Solid Waste (MSW) collected in Asian cities end up in open dumps. (Medina, 2002). The failure of city authorities to collect waste leads to unpleasant conditions and decomposing wastes constitute a serious health and environmental hazard (Ali, 2004)

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Urban waste could be solid or liquid, organic or inorganic, recyclable or non-recyclable. A considerable quantity of urban waste is biodegradable and hence of immediate interest in recycling (see Box 1).

Box 1 Common forms of organic waste

Solid waste: domestic and market wastes, food waste including vegetable and fruit peelings, charcoal ash. This also includes waste from institutions and commercial centres.

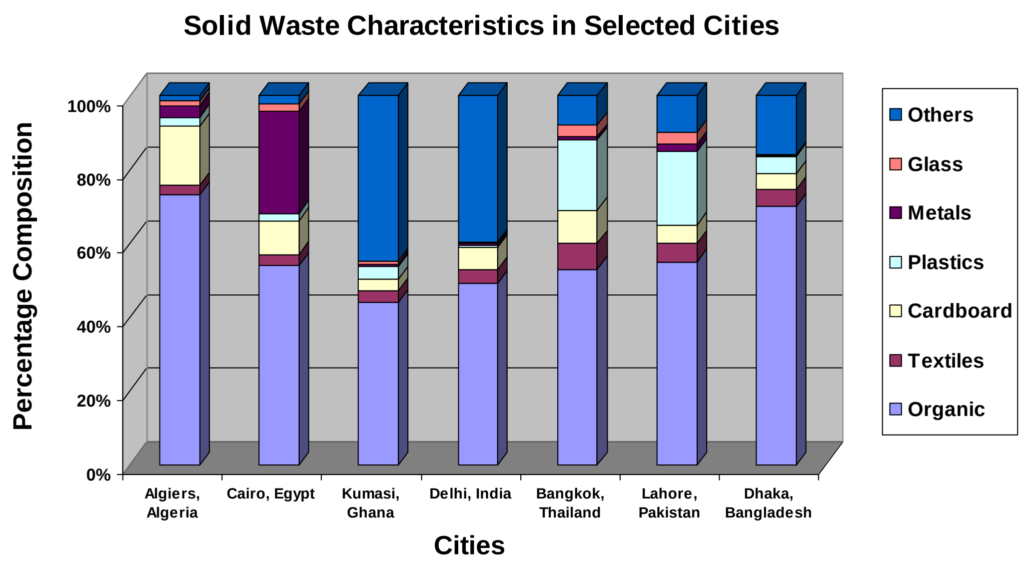
Horticultural and agricultural waste: garden refuse**,** leaf litter, cut grass, tree prunings, weeds, animal dung, crop residues, waste from public parks etc. Manure: poultry, pig, cow.

Agro-industrial waste: waste generated by abattoirs, breweries, processing and agro-based industries

Sludge and bio-solid: human faecal matter from septic tanks and treatment plants

Very large quantities of SW are generated in urban areas; the average SW generation is 0.6 kg per person per day. Based on the composition of solid waste of cities of low- and middle income countries (from Algiers, Alexandria, Cairo, Sao Paolo, Obeng and Wright, 1987), easily bio-degradable fractions range between 44 % and 87 % in weight (see Figure 1). Similar ranges (40-85 %) are also reported by Cointreau et al. (1985) for low-income countries. Levels of urbanisation and modernisation have a profound effect on the production and composition of municipal waste; however, some general trends such as the high content of organic matter (50%-90%) provide an opportunity for exploitation through composting processes (Allison *et al*., 1998; Asomani-Boateng and Haight, 1999). The percentages of organic matter in municipal solid waste in selected African cities were recorded as 56% in Ibadan, 75% in Kampala, 85% in Accra, 94% in Kigali and 51% in Nairobi (Asomani-Boateng and Haight, 1999). The volume and composition may however be subject to large seasonal variations (GFA-Umwelt, 1999). A detailed report on the organic waste flow in integrated sustainable waste management has been written by Dulac (2001). In short, the waste stream is not a homogenous mass but a collection of different materials (organic material, plastics, metal, textiles etc.) that can be handled in different ways to maximise recovery. The organic waste fraction remains the largest proportion to be recovered.

Figure 1 Solid Waste characteristics in selected cities



(Sources: Hughes, 1986; Obeng and Wright, 1987; WASTE 1997; Zurbrügg, 2003 Ali, 2004)

Urban Waste Management Strategy

Many approaches to waste management exist. Generally, solid waste is managed through landfills, incineration and recycling or reuse. However in developing countries, properly engineered landfills are not common while the cost of modern incineration is too exorbitant to bear. Hence, the most common method of waste disposal is some form of landfill, including variants such as uncontrolled dumping in undefined areas, collection and disposal on unmanaged open dumps, collection/disposal on controlled dumpsites (UNEP 2004). It is common to find scavengers moving from door to door or sorting through communal bins to pick dry recyclable materials. However, these pickers are more interested in inorganic recyclable materials such as plastics and glass, but not in organic wastes.

Agenda 21, adopted in Rio in 1992, states that environmentally sound waste management should include safer disposal or recovery of waste and changes to a more sustainable pattern introducing integrated life cycle management concepts (UNEP, 2004). It introduced a step-wise approach to waste management in order of environmental priority. The general principle of the waste management hierarchy consists of the following steps:

- Minimising wastes;
- Maximising environmentally sound waste reuse and recycling;
- Promoting environmentally sound waste disposal and treatment;
- Extending waste service coverage.

After Rio most countries have generally accepted this hierarchy as a strategy towards an environmentally sound waste management system. In the last ten years the concept of Integrated Waste Management (IWM) has evolved and is slowly becoming accepted by decision makers (UNEP 2004). IWM relies on a number of approaches to manage waste, including all aspects of waste management, from generation to disposal, and all stages in between with proper consideration of technical, cultural, social, economic and environmental factors. Resource recovery is critical and is embedded in this strategy.

Recycling of Urban Organic Waste

Current urban organic waste recycling practices include the following:

- The use of fresh waste from vegetable markets, restaurants and hotels, as well as food processing industries as feed for urban livestock (Allison et al. 1998);
- Direct application of solid waste on and into the soil;
- Mining of old waste dumps for application as fertiliser on farmland (Lardinois and van de Klundert, 1993);
- Application of animal manure such as poultry/pig manure and cow dung;
- Direct application or human excreta or bio-solids to the soil (Cofie et al., 2005)
- Organised composting of SW or co-composting of SW with animal manure or human excreta.

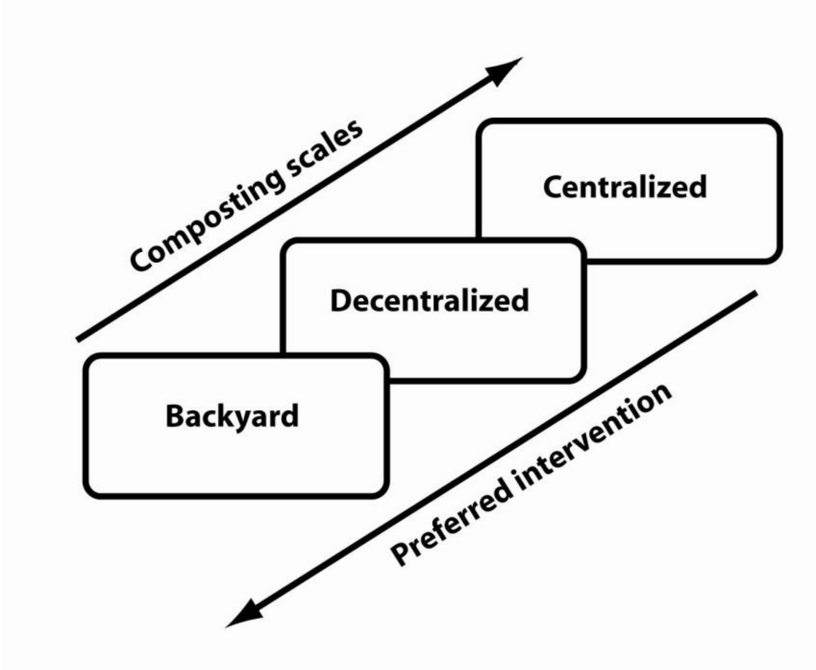
Whichever method is used, a process of microbial degradation releases the useful nutrients in organic waste for soil improvement and plant growth. Composting is the process of decomposing or breaking down organic waste materials (by micro-organisms such as bacteria, protozoans, fungi, invertebrates) into a valuable resource called compost. Composting is done at different scales (large, medium, small) by various people (municipalities, NGOs, communities, individuals) and for various purposes (gardening, landscaping, farming) in the urban areas. In the 1970s, large scale centralised composting was prominent especially in the Western world. However, this has proved to be a failure (Onibokun, 1999). The collection and transportation of organic waste to centrally managed sites is expensive, time consuming and energy intensive; these processes are also dependent on fossil fuel inputs that are often heavily subsidised in order to enable maintenance of fuel inputs, therefore extending economic inefficiency at the macro-level. In situations where funding is secured from donor agencies, the conditions accompanying such funds are often disincentives to good practice. Technological know-how on financial analysis, engineering design of composting facilities and transport schedule modelling has been very limited in developing countries (Cointreau-Levine, 1997). In addition, technological transfers of composting processes and equipment from developed countries were often done in the past without considering local constraints (Hoornweg et al., 1999; Etuah-Jackson et al., 2001) and the technologies transferred were often not applicable in the receiving country.

Also comprehensively planned composting stations, based on a demand-supply analysis, are not common. In fact, waste management authorities in many developing countries hardly have the "luxury" of planning for recycling; instead they focus their limited resources on the priority needs of "waste collection" and "safe disposal" which consume an immense share of the municipal budgets in low-income countries as cost recovery is low (Drechsel et al., 2004). The irony is that if well planned, the costs of waste disposal could be reduced through composting. However, what appears to be a logical win-win- situation for city authorities and farmers, is seldom a reality in the developing world (see the case study by Duran et al on Marilao, Philippines, for an example of an innovative win-win solution). This is due to several factors such as lack of affordable equipment, technical personnel, frequent mechanical breakdowns, and financial restrictions (Drechsel et al., 2004; Asomani-Boateng et al., 1996).

In the 1990s, small to medium scale decentralised composting based initiatives evolved (e.g. see GFA-Umwelt, 1999). However, a transition from centralised composting to decentralised composting approaches is often compounded by the lack of inter-sectoral planning (waste/planning/agriculture) in waste management. Ecological approaches to waste management have only been adopted where predominant conventional waste management approaches are not challenged. Consequently, small-scale decentralised approaches are yet to receive extensive government support at national levels. Cuba is a marked exception to this general pattern in urban planning and management. In the very different geopolitical and social conditions of Havana, Cuba, substantial progress has been made in recycling urban organic waste, as nutrient recycling principles have been implemented in practice and have proven to be very successful (Cruz and Medina, 2003; Díaz and Harris, 2005; Viljoen and Howe, 2005). But generally on a global scale, at the lowest intervention level, backyard composting is practised by few individuals.

By far, the better composting options are those that are decentralised and use organic waste as close to the source as possible. Decentralised on-site (for commercial organic waste) and on-plot (for domestic organic waste) are the preferred levels of intervention with each individual intervention requiring the appropriate technology at the appropriate scale In essence, the primary function is all about getting the nutrients and organic matter in waste back into the soil in the most efficient and effective manner; hence the priority order of backyard composting (household) and decentralised (community) approaches (see Figure 2). Centralised municipal approaches do not have a good track record and the potential scale-of-economy advantages have not materialised due to operational and marketing constraints.

Figure 2 Composting scales of intervention



(Source: Bradford, 2005).

Use of Urban Organic Waste for Urban Agriculture

The provision of sufficient food and the provision of basic sanitation services, two major challenges in (mega-)cities, are inter-linked as the urban food supply contributes significantly to the generation of urban waste (Drechsel and Kunze, 2001). In principle, therefore, recycling organic waste through composting could be a win-win situation for municipalities and farmers (for example see the Marilao, Philippines case study by Duran et al.). The interests of urban waste recycling go well with the promotion of urban agriculture since urban and peri-urban farmers are in need of organic matter as a soil conditioner. Cities and towns, on the other hand, wish to conserve disposal space and reduce the costs of landfills as well as municipal solid waste management. Also important is the need to incorporate informal waste collectors and the private sector that contribute to urban waste management into this process (see Box 2 and the Nairobi, Kenya case study by Njenga and Karanja).

Benefits and Constraints

Zurbrugg and Drescher (2002) report that the potential benefits of organic waste recycling are particularly in reducing the environmental impact of disposal sites, in extending existing landfill capacity, in replenishing the soil humus layer and in minimising waste quantity. Other benefits adapted and summarised from Hoornweg et al. (1999) with particular reference to organic waste composting are that it:

- increases overall waste diversion from final disposal, especially since as much as 80% of the waste stream in low- and middle-income countries can be composted;
- enhances recycling and incineration operations by removing organic matter from the waste stream;
- produces a valuable soil amendment - integral to sustainable agriculture;
- promotes environmentally-sound practices, such as the reduction of methane generation at landfills;

Box 2 Solid waste and urban and peri-urban agriculture in Bamako, Mali

Urban waste produced in Sahelian cities has been providing a source of nutrients and organic material for farmers in the peri-urban interface for quite some time. In Bamako, current developments present interesting opportunities for ensuring a safer and more sustainable recycling of solid urban waste.

In the peri-urban zone of Bamako, farmers involved in mixed cereal and horticultural crop farming prefer to use the solid waste primarily on their staple crops and are prepared to pay for it. The form and manner in which waste is applied is also more appropriate for cereal crops than for the relatively intensive cultivation methods used for vegetables and strawberries, particularly with respect to soil management. In this sense, urban waste is a second-choice product as a soil improver/fertilizer for horticulturalists. But given the relative scarcity of the preferred animal manure, there remains a demand from this group of farmers.

Cultivation on degraded soils has even been revived in some cases due to this readily available resource. However, uncertain land tenure means that farmers have little incentive to ensure the safe disposal of dangerous elements in solid waste. Current plans would eliminate this recycling practice and promote large-scale composting, but the cost for farmers will be too high, leaving them with an incentive to make their own illicit arrangements for acquiring waste material. Furthermore, small enterprises and associations that have come to play a complementary and innovative role in waste management would be forced out.

The key challenge for policy is to regard urban waste not as a dangerous nuisance but as a source of nutrients and organic matter in agriculture, provided that a system for separating dangerous wastes is in place. The master plan is not yet finalised in Bamako, and local actors seem convinced that pilot initiatives as undertaken in the peri-urban areas will be integrated in the plan. The experience in Bamako indicates the value of some form of new stakeholder platform that addresses these linkages in a more concrete manner by working at the more local level of the communes rather than that of the entire municipality (district of Bamako).

Source Eaton and Hillhorst, 2003

- enhances the effectiveness of fertilizer application;
- can reduce waste transportation requirements;
- is flexible for implementation at different levels, from household efforts to large-scale centralised facilities;
- can be started with very little capital and operating costs;
- the climate of many developing countries is optimum for composting;
- addresses significant health impacts resulting from organic waste such as reducing Dengue Fever;
- provides an excellent opportunity to improve a city's overall waste collection programme;
- accommodates seasonal waste fluctuations such as leaf litter and crop residues;
- can integrate existing informal sectors involved in the collection, separation and recycling of wastes.

Although composting seems an attractive option in many respects, it is also constrained (Hoornweg et al 1999) by the following factors:

- Inadequate attention to the biological process requirements;
- Over-emphasis placed on mechanised processes rather than labour-intensive operations;
- Lack of vision and marketing plans for the final product - compost;

- Poor feed stock which yields poor quality finished compost, for example when contaminated by heavy metals;
- Poor accounting practices which neglect that the economics of composting rely on externalities, such as reduced soil erosion, water contamination, climate change, and avoided disposal costs;
- Difficulties in securing finances since the revenue generated from the sale of compost will rarely cover processing, transportation and application costs.

An evaluation of composting projects in West Africa pointed out that apart from being too expensive, a common problem leading to project failure is poor *co-ordination* among institutions and stakeholders due to weak institutional linkages and the lack of an enabling institutional framework, including clear legislation and policies. Experiences from six composting stations of different scales of production in five countries in West-Africa (see the overview in the Annex) showed that compost stations in the sub-region suffer from a number of omissions (Drechsel et al 2005). Lack of thorough market analysis including consideration of alternative soil inputs; transport costs; user's demand as well as willingness and ability to pay for compost prior to station set-up; lack of supportive legal frameworks and institutional arrangement to implement composting initiatives are some of these. In many cases, important stakeholders (land owners, waste collectors etc) were often not involved in planning which then constrained successful implementation. Apart from these, most composting projects are not financially viable, especially when outside funding available for the initial set up is exhausted. These points confirm the need for a comprehensive feasibility study before setting up any composting project.

Framework for Analysis and Planning of Composting

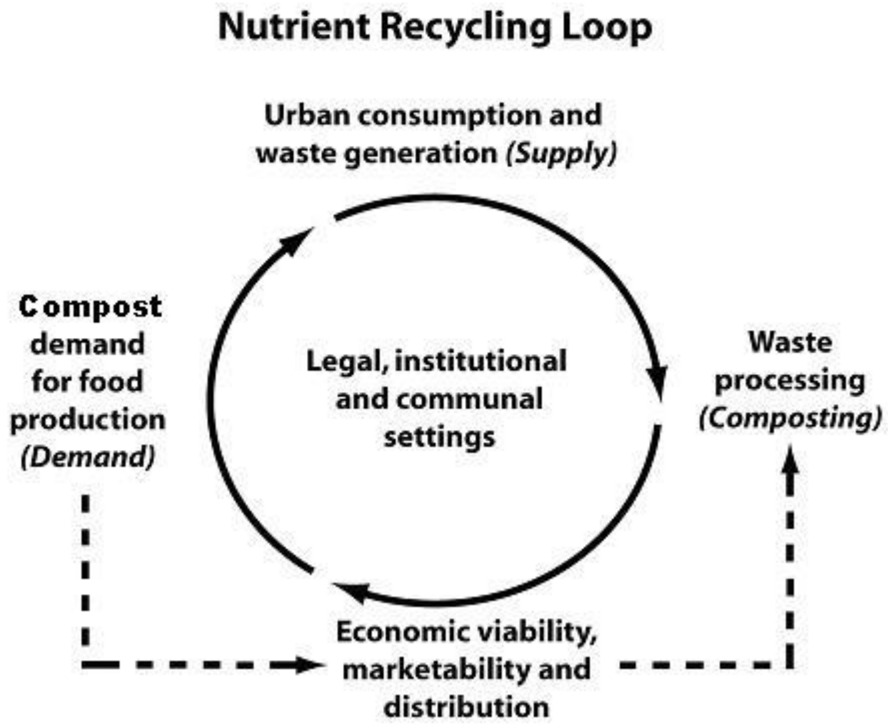
Planning is necessary to ensure a well functioning composting system. Analyses of the various segments - from waste generation, recycling to re-use - is necessary. The nutrient recycling loop concept is very helpful in this process (see Figure 8.3). The recycling loop is represented in this figure by various segments: urban consumption and waste generation, waste processing, compost demand for agriculture, along with an economic feedback mechanism and finally the legal, institutional and communal settings throughout the loop. (Drechsel et al., 2002)

The first segment of the loop, *urban consumption and waste generation,* addresses the supply dimensions of urban waste. It raises questions regarding organic waste production, location, ownership, quality, quantity, time, availability, value, health & safety constraints, etc. This is followed by the second segment *waste processing,* where questions are raised on (possibility of) organic waste transportation, appropriate processing methods (i.e. composting), production capacity, operation costs, sustainability, subsidies etc). The third segment deals with *compost demand* and address questions on users' demand, application, experiences, ability and willingness to pay, cultural constraints, etc. In addition to these three segments, there is an economic analysis linking the demand and composting segments that addresses economic viability, marketability and distribution. The final element looks at the *legal, institutional and communal setting,* in which the issues of planning, regulations, by-laws, policy constraints or support, land availability, local stakeholder participation, monitoring & evaluation, inter/intra-sectoral corporations, etc. are addressed, throughout the cycle of analysis.

This nutrient recycling loop is used to scope and assess all the processes involved in recycling organic waste into a valuable resource at municipal (centralised), community (decentralised) and/or household (backyard) levels for use in urban agriculture. The model provides a diagrammatic illustration of the systematic processes that are involved in selecting an appropriate organic waste recycling technology at the appropriate scale of intervention. For an urban farmer this process may take the form of a rapid appraisal or scribbles on the back of an envelope, whereas for a community-based organisation or a municipal authority it will form a logical guide to a more detailed and rigorous assessment study.

The recycling loop gives the required framework and potential best practice for planning composting for urban agriculture (Cofie et al, 2001, Drechsel et al 2002, 2004, Danso et al 2005). The questions which should be addressed at each moment in this cycle are summarised in Figure 8.4. The effectiveness and usefulness of this framework was tested in Ghana (Drechsel et al, 2004) using specific methods in the analysis of each segment of the recycling loop. It is important to note however that the analysis can have various degree of sophistication depending on the specific location, scale of the intended composting project, available funds, etc.

Figure 3The Nutrient Recycling Loop (modified from Drechsel et al., 2002).



Application of the Nutrient Loop

The supply of organic waste

The key question in the waste supply context is: *Where* is *which* amount of waste of *what* kind of quality and *when* is it available for composting? This will allow identification of recycling needs in terms of design and capacity. Supply studies should focus on the various types, amounts, quality, present and potential uses, current value and availability of organic municipal waste for composting. The analysis of waste supply in West Africa showed that the availability of organic waste is not the limiting factor for compost production, although, not every form of waste is always available as there are often alternative uses (fodder, fuel etc) and seasonal variations. A comparison of waste generation and availability along a south to north gradient from Accra, Ghana to Ouagadougou in Burkina Faso showed that with decreasing biomass production, the amount of organic waste and related nutrient availability per capita decreases progressively as dryer eco-zones are encountered (Danso et al 2005)

A result of waste surveys in Ouagadougou (Eaton, 2003) indicated that 80,000 tons of organic waste is produced each year in the form of solid household waste with a nitrogen content of 26 tons. It was estimated that about 25,000 tons of organic material per year could be composted and sold to farmers for application on a relatively modest estimate of 200 ha of intensive urban horticulture plots. This would correspond to an estimated 8 tons of nitrogen. This leaves approximately 55,000 tons of organic material per year that could be spread over an area of 8,500 hectares of peri-urban staple crop fields, a flow of approximately 18 tons of nitrogen. In other words, the supply of organic material is much more than can be realistically absorbed in agriculture, at least given current economic circumstances (Tessier, A. 2004).

The demand for waste-derived compost

The demand assessment includes the characterisation of all potential clients under consideration of their willingness (and ability) to pay (WTP). It is expected that a major demand for compost in rapidly expanding cities will come from landscape designers (horticulturists, parks and gardens) and real estate developers, so this sector must not be left out in the analysis. The demand analysis should also consider socio-cultural aspects, farm economics, attitudes/perceptions of users of waste compost and actual demand projections. Danso et al (2005) reported for Ghana that many urban farmers have positive perceptions and are willing to use compost although not all have the necessary experience. Farmers' interest in compost was both for its plant-growth enhancing (fertility) effect and soil amelioration. Variations in WTP were recorded between farmers with and without compost experience, different farming systems, urban and peri-urban farms, as well as between different cities with different compost alternatives. The WTP expressed by farmers who already used compost was in several cases lower than among non-users. This was due to past experience with poor quality compost (in Accra) which resulted in poor crop performance and the negligible market demand for "organically" produced crops in Kumasi.

The study further revealed that estate developers were willing to pay higher prices for compost than urban and peri-urban farmers. In comparison to agriculture, the real estate sector has much lower qualitative requirements as compost will mostly be used for lawns and ornamentals. Thus the real estate sector could be the "favourite" customer group with options for private-public partnerships with the municipality. The financial strength of the real estate sector could subsidise parts of the compost production for agriculture.

The process of waste composting

The process of waste composting includes the determination of the type of facility, optimal number, capacity, and location of compost stations per city. Most critical in this assessment is to include possible ways of composting and determine the number of potential compost stations and station capacity with due consideration of waste supply and compost demand. Composting is best achieved by providing optimal conditions for the micro-organisms through the best combination of air, moisture, temperature and organic materials (Agromisa, 1999). Composting processes can be aerobic (with oxygen) or anaerobic (without oxygen) and even alternate between the two during the decomposition process. Anaerobic composting is a low-temperature process that is not recommended for urban agriculture due to the strong odours and the inability to destroy harmful pathogens that may be present in urban organic waste. Conversely, aerobic composting is a high-temperature process due to the development of microbes that generate higher temperatures in the compost pile. The key factors affecting the biological decomposition processes and/or the resulting compost quality are listed in box 3.

Box 3 Factors affecting biological decomposition

- Carbon to nitrogen ratio
- Moisture content
- Oxygen supply, aeration
- Particle size
- pH
- Temperature
- Turning frequency
- Micro-organisms and invertebrates
- Control of pathogens
- Degree of decomposition
- Nitrogen conservation

The choice of a technology for aerobic composting will depend on the location of the facility, the capital available and the amount and type of waste delivered to the site. The two main types of systems generally distinguished are: 1) open systems such as windrows and static piles and 2) closed "in-vessel" systems. These “in-vessel” or "reactor" systems can be static or movable closed structures where aeration and moisture is controlled by mechanical means and often requires an external energy supply. (see the Kumasi, Ghana case study by Adam-Bradford). Such systems are usually investment intensive and also more expensive to operate and maintain. "Open” systems are the ones most frequently used in developing countries. They can be classified as:

Windrow, heap or pile composting: The material is piled up in heaps or elongated heaps (called windrows).

Photo 1.*Compost heaps* at Kumasi co-composting plant

Bin composting: Compared to windrow systems, bin systems are contained by a constructed structure on three or all four sides of the pile. The advantage here is a more efficient use of space. (for illustrations see the Kumasi, Ghana case study).

Trench and pit composting: Trench and pit systems are characterised by heaps which are partly or fully contained under the soil surface. Structuring the heap with bulky material or turning is usually the choice for best aeration. Control of leaching is difficult in trench or pit composting. In some cases, composting materials are completely buried in the trench which then serves as a planting bed, for example Mtshepo’s home gardening in South Africa (Photo 2)

Photo 3.Locally made composting pits in Tamale, Ghana

The aerobic composting process can last from a few weeks to 3-4 months, depending on the type of composting feedstock and the method of composting.

Emerging trends include the practice of vermiculture and the use of effective micro-organisms (EM) to accelerate the composting process. *Vermiculture* is the use of worms to digest organic waste into rich humus, similar to compost, that can then be applied in urban agriculture. Local varieties of both surface and burrowing earthworms can be used, although the latter are particularly suited as they not only digest organic matter but also modify the soil structure. Vermiculture is particularly suited to urban agriculture because it can be applied in a variety of settings and at different scales. The practice is also used very often as part of integrated gardening in community building urban agriculture. Indeed, broad-scale vermiculture is widespread in India, Indonesia and the Philippines (GFA-Umwelt, 1999), while the practice has recently been gaining ground in Cuba and Argentina (Dubbeling and Santandreu, 2003; Viljoen and Howe, 2005). In broad-scale vermiculture, the earthworms are introduced to organic waste piled in elongated rows that are covered with some form of vegetative protection to prevent water logging (Ismail, 1997).

Economics of waste composting

The economic analysis links the supply, demand and process segments. This refers to consideration of the viability of the proposed compost station. GTZ-GFA (1999) has developed a model to assess the economic feasibility of compost stations. Analytical scenarios need to address different levels of technical sophistication and the actual and potential (but realistic) transport capacity of the city-specific waste collection system including profitability and investment analysis for constructing and operating compost facilities in the specific city. Such an analysis was done for Accra (Drechsel et al., 2004) and the results show that the overall cost of building and operating composting facilities in the Accra-Tema Metropolitan area is much lower than for incineration and land filling. Further more, using land fills is about 95% cheaper than incineration under prevailing Ghanaian conditions. The unavailability of land for landfills, incinerators and their transfer stations, and the requirements for meeting environmental quality standards are the major causes of the high capital cost of land-filling and incineration in the area. Composting urban solid waste appears to have the highest total economic benefits especially through labour-absorption.

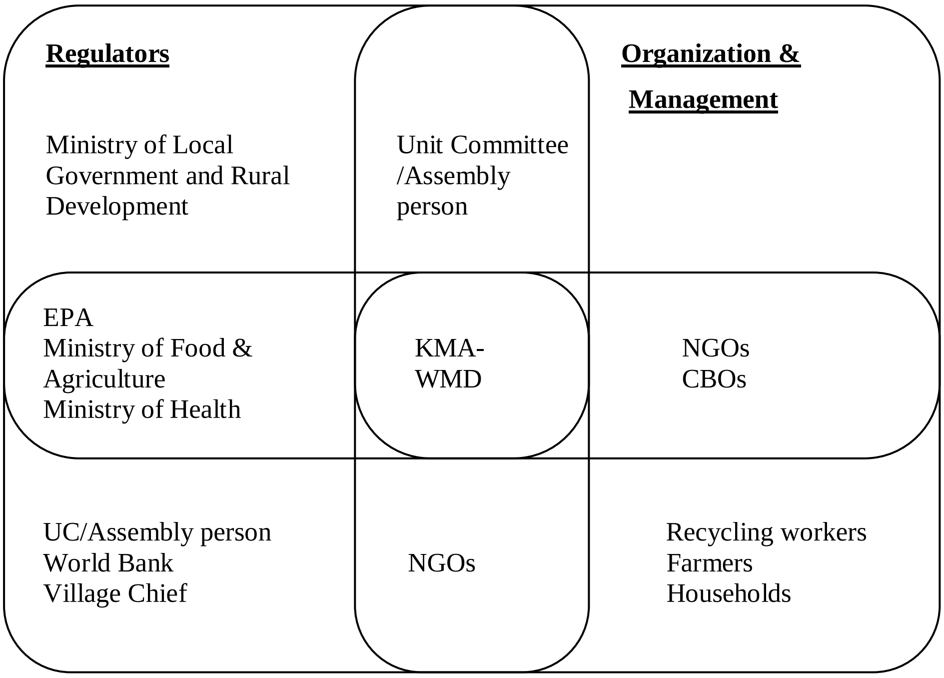
Legal, institutional and communal settings

Legal, institutional and communal factors affect the set-up and sustainable management of compost stations. The legal, institutional and administrative context within which composting and the use of compost could be feasible concerns the environmental and sanitation by-laws and policies as well as public awareness and the roles and perceptions of authorities and other interest groups, especially CBOs and NGOs in composting. Various stakeholder institutions could play the role of regulator, manager, supporter of initiatives or beneficiary. Through stakeholder analysis and role clustering, it is possible to identify which institutions play a central role or a secondary role (See Figure 4).

These institutions in two or more role clusters also play an important role inter-linking other institutions

Vasquez et al 2003 reported related work done in Kumasi, Ghana and observed that the Waste Management Department (WMD) of Kumasi Metropolitan Assembly (KMA) is the central institution to provide assistance on, or to facilitate the regulation, support (financial, technical, human resource), as well as organisation and management of organic waste recycling. Dissemination of information and services from the platform (in the centre) to the beneficiaries (in the nutrient loop) together with feedback from the beneficiaries to the platform provides a mechanism for system improvements and sustainability.

Figure 4 Institutional Platform for recycling of organic waste in Kumasi, Ghana (Source: Vázquez,, 2002)



Health Implications of Organic Waste Recycling

A considerable amount of research has been done on the health implications of organic waste recycling (e.g. Cairncross and Feachem, 1993; Birley and Lock, 1999; Furedy *et al*., 1999; Furedy, 2001). Health implications are a major constraint to recycling organic waste in urban agriculture (Asomani-Boateng and Haight, 1999), in addition to the issues of economic viability and attitude and behaviour (especially of officials). Due to the close connection of organic waste recycling with the food chain, the issue of health is crucial, not just for farmers engaged in urban agriculture, but also for consumers of the products that are derived from recycled organic waste (Asomani-Boateng and Haight, 1999). The often negative perception held by municipal authorities is associated with the use of recycled organic waste in urban agriculture as a "detriment to modern urbanity and a health hazard" (Asomani-Boateng and Haight, 1999). Furedy identifies the principal health hazards as: "survival of pathogenic organisms in residues; Zoonoses associated with animal wastes; increase of disease vectors; respiratory problems from dust and gases; injuries from sharp fragments; and contamination of crops from heavy metal take-up and agrochemical residues via wastes and their leachates" (Furedy, 2001: 23).

Indeed, when urban solid waste contains high levels of human excreta, the application of such wastes in agriculture requires careful management (Asomani-Boateng and Haight, 1999). In addition, when compost piles are badly managed, pathogens such as nematodes and parasite eggs that may be present in the organic waste could survive the decomposition process and be carried to farmers' fields and plots when composts are applied to soils (Birley and Lock, 1999).

Simple health and safety protection measures can be taken to mitigate many of these health hazards by reducing the possible transmission pathways through the use of protective clothing. Compost workers should be equipped with rubber boots, work gloves, and mouth & nose masks to ensure protection. Training and education in the safe handling of wastes and in basic first aid should be given to compost workers and on-site washing facilities and a first aid point should be provided at the workstation. In composting plants, particularly where co-composting techniques are utilised, the regular monitoring of the final compost product is required to ensure that any pathogens present are inactivated during the decomposition process.

Of course, there are many situations when a trade-off has to be made. For many poor and/or subsistence urban farmers, curtailing any hazardous agricultural practice is simply not a viable option. Urban agriculture is a lifeline for many of the world's urban poor, and therefore in most cases attempting to balance the health trade-off will be the preferred solution. Consequently, educating farmers in risk minimisation may well be the most appropriate option. For example, improving waste separation and collection at the organic waste set-out point is one method that can minimise the contamination of organic wastes.

Chemical contamination is another potential risk associated with re-use of organic waste. As organic solid waste is often stored and collected together with other waste fractions, contamination of the organic fraction is easily possible by chemical constituents, especially heavy metals. When applying contaminated compost, these constituents can accumulate in soils. The contamination of soils by chemicals, the potential uptake by crops, and the possible chronic and long-term toxic effects in humans are discussed by Chang *et al*. (1995) and by Birley and Lock (1997). Plant uptake of heavy metals depends significantly on the metal itself as well as compost and soil conditions. Similarly, the presence of a given metal can be harmful in one soil and harmless in another. A number of other parameters have to be known before any risk assessment related to heavy metals is possible. Metals in municipal waste come from a variety of sources. Batteries, consumer electronics, ceramics, light bulbs, house dust and paint chips, used motor oils, plastics, and some inks and glass can all introduce metal contaminants into the solid waste stream. Even after most contaminants have been removed through sorting, the compost may still contain these elements, although in very low concentrations.

In small amounts, many of these trace elements (e.g. boron, zinc, copper, and nickel) are essential for plant growth. However, in higher concentrations they may decrease plant growth. Other trace elements (e.g. arsenic, cadmium, lead, and mercury) are of greater concern primarily because of their potential to harm soil organisms or plants and possible entry into the food chain. The impact of these metals on plants grown in compost-amended or wastewater-irrigated soils depends not only on the concentration of metals and soil/compost properties as mentioned above, but also on the type of crop grown. Different types of plants can absorb and tolerate metals differently. For instance mushrooms should not be cultivated on soil ameliorated with mercury- or cadmium-rich compost. In general, however, there is little evidence of crop contamination through compost. The application of municipal solid waste composts might, however, increase the metal content of uncontaminated soils. This may pose a risk to animals or children in the area who could ingest the composted soil directly.

Further risks arise from impurities of non-biodegradable origin such as glass splinters or other sharp objects contained in the compost product. Such impurities can be a result of insufficiently sorted municipal solid waste before or after the composting process.

There are also indirect health risks caused by the attraction and proliferation of rodents and other disease carrying vectors (Furedy and Chowdhury, 1996).

Challenges Ahead

Composting raises issues not only of the technological approach used, but also of the necessary organisational set-up for operation and management of the composting, delivery of feedstock (raw material) and distribution of the compost product as well as proper extension or education. Hoornweg et al. (1999) list several reasons why the use of organic waste and composting in particular are not widely or successfully practised in cities of developing countries.

- Insufficient knowledge and care in carrying out composting operations leading to inadequate compost quality and resulting in odours and rodent attraction that is deemed a nuisance.
- Lack of markets for the product and lack of appropriate compost marketing strategies and skills.
- Neglect of the economics of composting which relies on externalities, such as reduced soil erosion, reduced water pollution and avoided disposal costs.
- Limited support by municipal authorities who tend to prioritise centralised waste collection services rather than promote and support recycling activities and decentralised composting schemes.

In addition, the following issues related to organic waste recycling require applied research:

- Appropriate methods of segregation at source or sorting procedures to allow delivery or utilisation of pure organic solid waste for the co-composting process and to limit risks of compost contamination by impurities and chemical constituents;
- Marketing strategies and institutional framework
- Regulatory frameworks and realistic standards for compost use.

The recycling of urban organic waste brings several ecological advantages that can enhance energy efficiency through carbon, nutrient and water conservation in urban and peri-urban landscapes (Holmgren, 2002). These advantages can be categorised as the micro-environment benefits as they relate directly to soil amelioration measures, but in addition, energy efficiency should also be considered in the broader sense to encapsulate the wider advantages that can be accrued at national, regional and international scales. For example, recycling organic waste through composting in urban agriculture reduces the need to import chemical fertilizers and food stuffs. Furthermore, when urban organic waste recycling is decentralised there is reduced need for external inputs such as equipment, fuel and transportation.

Many urban and peri-urban areas are vast nutrient sinks as the recyclable nutrient potential from organic waste is seldom exploited and thus lost. This is compounded by the combination of soil nutrient mining in rural and peri-urban production areas and the accumulation of urban organic waste in the disposal sites. In these sites the mined nutrients accumulate in the peri-urban areas, largely through informal waste disposal due to the inefficiency of formal waste disposal structures (Drechsel and Kunze, 2001; Cofie, 2002).

Reversing these trends and patterns requires the adoption of holistic and integrated approaches to organic waste recycling that seek to optimise the use of a combination of methods at appropriate scales of intervention to manage organic waste in urban agriculture is a sustainable way. This means closing the nutrient recycling loop by reversing the negative impact of urban and peri-urban nutrient sinks through maximising nutrient exploitation of urban organic wastes. Furthermore, such interventions can be designed to generate livelihoods and thus contribute to urban food security. The combination of methods at appropriate scales allows for the design of interventions that are geographically applicable to the prevailing urban conditions, while exploiting urban organic waste for urban agriculture also enhances environmental protection by reducing organic waste quantities, as well as reducing the need for inorganic fertilizers in urban agriculture.

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Annex. Questions to be addressed for an appropriate establishment of municipal compost applications for (peri)urban agriculture and other uses (modified from Harris et al., 2001)

Supply

What organic wastes are produced?

Where are they produced /disposed?

Is the waste treated? How?

What are the current disposal costs and/or environmental/social externalities?

What is the quality (potential soil fertility value) of the material and is the material contaminated or phytotoxic?

Are there seasonal variations in its availability or quality?

Who owns the waste?

What is the current use of the waste? (Are there competing uses in comparison with composting, for example untreated fertilizer, livestock feed, fuel, or recycled for other manufacture or use?)

What is the related market demand and economic waste value?

How much/which waste is unused and the de facto available for composting?

Are there waste use/collection constraints related to health, handling, safety and environment which could be addressed?

Demand

Who is interested in compost (urban and peri-urban farming systems, real estate, landscape design, horticulture, etc.)?

What is their experience and/or perception of the product?

What are their requirements on the product?

What is their ability and willingness to pay for the product?

Are there special constraints to compost use related to cultural aspects (taboos), gender, compost marketing, handling?

How high is the likely demand and how does it

Processing

Is composting the most appropriate method to treat the waste for soil improvement?

What should be the capacity of the compost production (comparing supply and demand)?

Which technologies appear appropriate (which technologies have been applied successfully in the sub-region)?

Are these technologies locally available?

Is appropriate maintenance of these technologies likely/possible?

Are there technical waste-use constraints related to separation/collection/transport and how could we address them?

What is the transport capacity of the waste collectors?

What is the public perception towards source separation or composting?

What is the location of the waste sources and of the potential compost users?

How many compost stations are needed to keep transport costs low?

Economics

What would be the total establishment and running costs?

Which (economic) benefits for the society at large are possible?

Can these justify municipal subsidies?

What is the best mixture of waste from different sources?

How to realise co-composting?

Institutional, legal and communal framework

Are there constraints/support related to official plans, programmes, regulations, by-laws or policies and how could we make best use of them?

Are there constraints to the set-up of compost stations related to land availability?

What are the official attitudes and recommendations e.g. at institutional/municipal/communal level?

Could inter/intra-sectoral cooperation be improved (platform building)?

How can local key groups/stakeholders become involved (community based stations)?

What are the implications of composting for these groups and what kind of commitment/input would be necessary from them?

What management settings and instruments (M&E, accounting, O&M, etc.) would be

Annex Table 8.1

Name and Location of Compost Facility	Teshie-Nungua, Accra, Ghana	Zogbo and Houeyiho Cotonou, Benin	Hèvié Compost Plant, Benin	Bodija Plant, Ibadan, Nigeria	Lome and Tsévié ,Togo	Wogodogo, Ouagadougou, Burkina-Faso
Year of Establishment	1980	1994	1998	1985	1998	1998
Realistic production capacity (tons compost)	up to 11,000	360	1200-2000	3000	900	3000
Access to Sources of Organic Material	Easy Access to Organic Waste	No easy access to MSW	Easy access to MSW	Easy access to Bodija market waste, and slaughterhouse Waste.	Easy access to MSW	Easy Access to MSW
Method of Waste Collection	House-to-house collection system Communal containers	House-to-house collection system	Curb-side collection system	Curb-side collection system (communal containers)	House-to-house source separated waste collection system & communal containers.	House-to-house collection system & Curb-side system.
Technology Employed	Capital intensive Mixed MSW Composting	Labour-intensive, Waste separated before composting	Labour-intensive, Manually separated waste composting	Labour-intensive, manually separated waste composting	Labour-intensive, source separated composting	Labour-intensive, manually separated composting
Problems facing Compost Facility	-Lack of spare parts, water, training and public education programmes, and reliable energy sources. - Poor funding of maintenance -No clearly defined marketing strategies - Persistent public complaints about location - No collaboration & networking amongst stakeholders	- Poor Quality of Compost. - Low priced Competing products such as poultry droppings, "black soil", animal anure, raw waste etc. - Lower market prices of compost than production cost. - Lack of training programmes for operator. - Difficulty in accepting the value of compost.	- Complaints about bad odour. - Cheaper priced competing products such as black soil, poultry droppings, animal manure, etc. - Poor marketing strategies. - Located far from farmers and other compost Users.	- Political bickering over ownership of facility. - Inadequate working capital. - Poor quality of compost. - Lack of skilled personnel to manage the plant.	- Problem of replicating technology elsewhere in Togo. - Inadequate funding. - Poor marketing strategies. - Poor quality of compost. - Higher prices of compost products.	- Cheaper priced competing products. - Lack of public education on the benefits of compost and source separation - Poor marketing strategies.