Developing Typologies for Resource Recovery Businesses

Alexandra Evans, Miriam Otoo, Pay Drechsel, George Danso

The idea of closing the nutrient and water cycles by using municipal organic waste, fecal sludge, and wastewater for urban and periurban agriculture is nothing new. Not only has it been practised for generations in many countries, it has also been proposed and tried on a small scale as a green solution for modern cities (Smit and Nasr, 1992).

There are, however, limitations to nutrient and water recovery that have prevented scaling up in many locations. These include economic feasibility, administrative frameworks, socio-cultural perceptions and acceptance, environmental issues and, to a lesser extent, technology (Rijswijk and Dada, 2001). Following a range of analyses, we suggested that the fundamental factor that could result in the scaling up of resource recovery and reuse (RRR) efforts is the introduction and implementation of “business thinking” in the sanitation sector, to generate value and allow cost recovery—or even profits, if well designed (Drechsel et al., 2011; Otoo et al., 2012).

**Box 1: What do we define as business cases?**

In our definition, resource recovery and reuse (RRR) business cases are any practices that we observe taking place that utilize the resource value in waste to support waste management and/or a healthy environment. For our purposes we limit that resource value to that of water, nutrients and energy.

Because sanitation, including urban solid waste management, is still predominantly financed by the public sector with limited attention to cost recovery, we consider any improvement that RRR can support, from partial to full cost recovery, as a step in the right direction and as business models worth our attention.

To better understand what drives nutrient and water reuse and recovery in the sanitation sector, and to identify limiting factors, our research approach was to identify and analyse existing and emerging reuse examples, which we have termed RRR business cases (see Box 1). The RRR cases identified in this study can be categorised into typologies to enable consideration of the key components of the businesses: principally, how value is created and by whom, and whether that value can be returned to support the sanitation value chain. Based on this analysis, “business models”, which could be replicated and scaled up, can be extracted or designed.

There are of course many options to sort and cluster business cases in the sector, based on such factors as the type of waste, type of recovered resource, type of partnership or ownership, or modes of income generation. In the example presented in this paper we will reflect on the value addition for the recovery and reuse of nutrients, water and energy from faecal and wastewater, a form of resource recovery which has received less attention than other forms, such as nutrient recovery from municipal waste through composting.

**Typologies for Nutrient Use**

Inappropriate management and reuse of waste containing faecal matter can cause contamination of water, soils and crops, and endanger human health and the environment. This situation is a common reality in many low- and middle-income countries.

A controlled resource recovery approach can reduce the negative impact on the environment and have positive public health impact—not only through removal of contamination, but also through the potential use of well-treated waste resources for the production of nutritious food. Depending on the context, the type of business model and the market for produce, reuse offers opportunities for employment, income and cost-recovery. Waste can be an alternative source of nutrients for low-income farmers, or
energy for poor communities. When the business model goes to scale it will eventually reduce the waste challenge as we know it by catalysing waste entrepreneurs to seek the resources they need.

Faecal sludge (FS) is an abundant and valuable resource, similar to other organic manure such as farmyard manure. For the reuse of excreta or FS from on-site sanitation systems, such as septic tanks and latrines, we can observe a pathway of value proposition for agricultural reuse:

- **Direct land application of raw FS for agricultural purposes**: value addition occurs in the form of collection and transportation to the field, usually followed by solar treatment (sun drying).
- **Composting of FS or co-composting of FS with organic solid waste before sale**: value addition by removing pathogens, reducing the volume, and concentrating the nutrients. Some value loss may relate to nitrogen loss during composting.
- **Pelletisation and blending of FS-based compost**: value addition through nutrient addition and product structure improvement to improve competitive advantage, marketability and field use.

### Direct land application of FS for agricultural purposes

With a limited number of functional wastewater collection and treatment systems in many parts of the developing world, on-site sanitation systems remain crucial. Often, the entities that empty latrines or cesspits discharge the waste indiscriminately onto open lands or into watercourses. In areas where resources for agricultural production are limited and fertiliser prices are increasing, smallholder farmers frequently resort to the use of FS for crop production. For example, farmers in West Africa and South India are redirecting cesspit truck operators to their fields to provide them with the nutrient-rich manure. In Northern Ghana, this typically occurs after cereal harvest in the dry season. Due to the aridity and heat, the sludge dries over several months and is then incorporated into the soil. Most pathogens die during sun exposure, so health risks for consumers of cereals grown on this land are minimised (Seidu, 2010). To further mitigate associated health risks, farmers working with raw sludge are required to use protective gear.

However, in most developing countries, faecal sludge as a source of fertilizer has not received much recognition, due to both the informal nature of reuse and consumer perceptions of agricultural products grown with human excreta. Also, the disposal of FS onto land, particularly agricultural land, is often prohibited by law—or is, at least, a grey area governed by “tacit approval”. “Culprits” have not been punished, especially where engineered, official dumping places are still an exception and the authorities are left with little choice. Where official dumping sites exist, cesspit truck owners pay to use them.

The observed reuse business model is reversing the cash flow, as farmers pay the drivers for farm-gate delivery. In an optimised business model, the revenue would support the operation and maintenance costs of the cesspit operation, supplementing the FS collection fees. A drawback to the sustainability of the system in West Africa is the seasonality in demand for FS; the contrary exists in India, with plantation crops requiring FS throughout the year. Another difficulty that must be overcome is that farmers in some places currently receive raw sludge for free or a low fee, and will require field demonstrations to appreciate any other form of sludge with a higher price tag.

### Composting or co-composting

To explore business opportunities in agriculture, horticulture, landscaping and gardening, both public and private sector entities across Africa and Asia have adopted commercial strategies to add value to FS. The main approach is composting, usually in an aerobic process, which sanitises, dries, and reduces the volume of the FS. The FS may be processed alone or combined with solid waste (co-composting) to improve the properties of the resultant compost (Cofe et al., 2009).

However, composting also adds additional capital and operation and maintenance (O&M) costs. Many governmental, community and non-governmental organizations (NGOs) in Asia and Africa have introduced composting with varying degrees of success, cost recovery and sustainability. Key reasons for failure were often a lack of market research and poor institutional linkages (Evans and Drechsel, 2010). To address market-related constraints, some businesses adopt strategic partnerships with the local government, private enterprises and community-based organizations (CBOs) to optimise the allocation of resources and activities, reduce risk associated with high capital investments, and establish an assured market for their product. On the one hand, CBOs are contracted to do the collection and separation of waste, which ensures a consistent supply of high quality input (waste) and income for the CBOs. As part of their marketing strategy, these businesses sell their compost product through the established marketing and distribution system.
of other private companies, providing an assured and large market base for their product.

Additional financial leverage for these entities might be created by using anaerobic digestion to produce biogas with a higher commercial value than the compost, as well as nutrient-rich slurry.

**Pelletisation and enrichment**
While value-added waste products such as composted FS represent alternative nutrient sources for cash-constrained farmers cultivating on poor lands, nutrient levels of composted FS are comparatively lower than those of alternative products such as poultry manure and chemical fertiliser. This gap represents additional costs to farmers, as they are often required to invest in supplementary inputs. Additionally, the bulky nature of composted FS acts as a barrier to the transportation of the product to markets, increasing distribution costs to the producers that are often borne by the end-user.

Opportunities to increase the accessibility and usability of value-added FS products in agriculture are emerging, with cases identified in Nigeria, Ghana and South Africa. Various entities have adopted innovative value-addition techniques such as fortification and enrichment of FS with nutrients to boost its fertiliser value. Another option is pelletising composted FS, resulting in an easy-to-handle, safe, high-value product. These commodity-value based approaches represent opportunities for both public and private entities to increase their income-generating options by gaining market access to agricultural producers, giving them a competitive advantage.

**Water reuse related typologies**
Urban wastewater is produced from a number of sources, including urban drainage, domestic sewage, grey water, and industrial and commercial liquid waste streams. In many cities across the developing world, the effluents flow through open drains, canals or sewers into natural water bodies or onto irrigated land; less frequently, they are received by functioning treatment plants. As on-site sanitation systems prevail in many low-income countries, the wastewater flowing to fields or treatment plants will predominantly be grey water, contaminated by septic tank overflow, illegal connections or open defecation. It is not uncommon for domestic waste streams to be mixed with untreated industrial waste, despite laws to prevent this. This poses a particular problem for RRR options, and care should be taken to utilize those streams that contain only domestic waste, or to treat or handle other wastes appropriately before use.

Typologies for wastewater use have been proposed before; for example, Van der Hoek (2004) has defined typologies for agricultural reuse (Figure 1).
- **Direct use of untreated wastewater** — the application to farmland of wastewater taken directly from sewers or other purpose-built wastewater conveyance systems.
- **Direct use of treated wastewater** — use of treated wastewater where control exists over the conveyance of treated wastewater to the point of irrigation.
- **Indirect use of wastewater** — the application to farmland of water from a wastewater-receiving water body (e.g., stream). The pollution level can vary, as can farmers’ awareness of it.

![Urban wastewater reuse types](image)

**Figure 1: Urban wastewater reuse types (After Van der Heijden, 2004).**

<table>
<thead>
<tr>
<th>Type</th>
<th>Value addition to the resource</th>
<th>User pays for</th>
<th>Value addition through resource use</th>
<th>Reuse-based business model</th>
<th>Examples of business cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct or indirect use of untreated wastewater for agriculture, forestry or aquaculture</td>
<td>None, except for facilitation of access (canals) or some dilution and natural treatment depending on distance from source to use.</td>
<td>Farm land (with water access) or fish ponds; or water fee where water access is regulated and this water is the only source.</td>
<td>Growing crops, trees, aquatic plants or fish benefiting from water and (diluted) nutrients. Natural treatment (soil infiltration, stabilization in ditches and ponds).</td>
<td>Where resources are scarce, farmers might pay for access to land or water (which could support wastewater collection, basic treatment or health care).</td>
<td>Mexico, India, Pakistan, Cambodia, Vietnam</td>
</tr>
<tr>
<td>Direct use of treated wastewater for agriculture, forestry or aquaculture</td>
<td>Provision of safe water for agriculture, forestry or aquaculture</td>
<td>As above. In this case, the added safety value could justify a higher fee than for untreated wastewater.</td>
<td>Growing crops, trees, bio-fuel, aquatic plants or fish benefiting from water and nutrients. Products sold directly or processed, e.g., duckweed for fish feed.</td>
<td>Paying for resource access contributes to recovery of O&amp;M costs at various scales.</td>
<td>Syria, Tunisia, Egypt, Morocco, Pakistan (agriculture and forestry), Bangladesh, Peru, Ghana (aquaculture)</td>
</tr>
<tr>
<td>Exchange of wastewater (treated or untreated) for fresh water</td>
<td>None</td>
<td>Farmers swap their freshwater allocation for a regular supply of wastewater for cropping out of season and greater income generation.</td>
<td>Release of fresh water for other sectors with high demand. Off-season crops for farmers.</td>
<td>Reduces water supply costs incurred by the city. Higher income for farmers.</td>
<td>Mexico, Spain, Bolivia, Iran</td>
</tr>
<tr>
<td>Groundwater recharge</td>
<td>Water treatment</td>
<td>Water supply</td>
<td>Greater access to fresh water for drinking or other high-value purposes</td>
<td>Lower treatment (and pumping) costs</td>
<td>India, Mexico</td>
</tr>
<tr>
<td>Use of treated sludge from wastewater treatment processes (with or without wastewater use)</td>
<td>Provision of organic fertiliser (nutrients) for agricultural use, alongside water recovery</td>
<td>Treated biosolids (and water)</td>
<td>Growing crops or trees</td>
<td>Paying for multiple treatment products supports the recovery of O&amp;M costs. Reduces water-supply and fertiliser costs.</td>
<td>India, Uganda</td>
</tr>
<tr>
<td>Production of energy (with or without sludge or treated water use)</td>
<td>Provision of bioenergy with or without safe water and fertiliser recovery</td>
<td>Treatment plant saves on external energy needs or sells energy (and water and/or biosolids).</td>
<td>Energy may be used for productive purposes by the treatment plant or external small businesses or households. Growing crops or trees.</td>
<td>Model for multi-resource recovery for cost reduction or revenues even exceeding O&amp;M costs.</td>
<td>India, Jordan</td>
</tr>
</tbody>
</table>
The typology that we initially worked with drew on elements of Van der Hoek’s classification, particularly with respect to the division between treated and untreated wastewater. Some of the most commonly practised forms of wastewater use take advantage either of the regular supply of wastewater, for example for growing crops or breeding fish, or of the nutrient value of the wastewater (Table 1). However, from a reuse business perspective the situation is more complex, and other systems emerged, such as groundwater recharge as well as “sub-systems” of the initial use types. Some examples showing different cases are described in Table 1.

**Direct or indirect use of untreated wastewater for agriculture, forestry or aquaculture**

This is the most common scenario across Asia, Sub-Saharan Africa and Latin America. The dominant type is the use of polluted streams (indirect use of untreated wastewater). Where natural streams are lacking or are not perennial, wastewater can also become the only water available, resulting in direct use. In both cases, there is no planned value addition to the wastewater that could increase its market value, except if authorities provide canals for water access. However, where water is scarce or supply is irregular, farmers might still be willing to pay for access to water or to the land which allows access. Depending on geology and soil characteristics, other market segments could also be accessed if the wastewater is used for groundwater recharge and farmers/households pay for aquifer access.

How much could be charged for untreated water will depend on the local understanding of water as a free commodity, and on national water quality standards. Since authorities have to dispose of the wastewater anyway, it can be difficult to charge for it. This is seen in Pakistan, where farmers have paid for untreated wastewater for many years but have fought against these fees in courts of law (Weckenbrock et al., 2012). In this situation, it may be better to base a business model on income generation through leasing of land rather than sale of water; however, barriers still exist and local land-use rights need careful consideration. In all cases, value is generated as a direct result of the use of wastewater to grow cash crops or wood, or to raise fish. Capturing part of that value—e.g., through water fees, land rent or a product tax—can provide an opportunity to support the sanitation service chain through funds for wastewater collection or primary treatment, or for safety measures from farm to fork.

**Direct use of treated wastewater in agriculture, aquaculture or urban greening**

This type represents the most common business model, in which payment is received in direct exchange for the use of the resource. Most examples are from drier regions such as the Middle East, North Africa and Latin America, for example, in Egypt, Morocco, Tunisia and Peru treated wastewater is sold to farmers. Cost recovery appears to increase where there is no fresh-water alternative. Cost recovery can exceed O&M costs where the treatment system is cheap (e.g., pond systems) and productivity high (duckweed, fish). In some cases, part of the water is deliberately returned to streams or rivers to protect the environment, or may be used to generate hydropower before being used again.
Exchange of wastewater (treated or untreated) for freshwater

Where farmers currently use freshwater and where domestic water is in short supply, “water swaps” can take place. In this situation, farmers do not pay for the water but get paid to accept the swap, as the city can make a significant profit from a greater freshwater supply (FAO, 2010). Depending on the geographical location, the exchange might have advantages for the farmer in terms of additional nutrient supply, or disadvantages if the wastewater will increase soil salinity. In some cases, the farmers may not need payment because the result is a more reliable overall water supply, often outside the normal growing season, which allows farmers to generate more income. However, pumping is required to either gain the freshwater or return the wastewater, which adds a cost.

Groundwater recharge

In this reuse type the authorities may dispose of the water to a pond or land in a location that allows groundwater recharge. The hydrogeology must be understood well so as to prevent contamination of the aquifer. The desired quality of the groundwater may differ depending on its use (e.g., agricultural, industrial or domestic), but in many cases the aquifer may have multiple uses and thus drinking water standards will need to be the aim. In certain circumstances—in Mexico, for example—farmers may also be part of the solution. In this particular case the farmers are provided with wastewater, and their land acts as a recharge field. The groundwater obtained is of drinking-water quality and is used by the authorities to pump water back to the city.

Use of treated sludge or biosolids

Examples have been recorded of wastewater treatment plants (WWTPs) providing (in addition to treated wastewater) sludge from aerobic treatment processes—such as activated sludge—to farmers for landscaping. This usually occurs after anaerobic digestion to ensure that pathogens have been removed from the sludge. Combined treatment systems are increasing the opportunities for nutrient- and cost-recovery while reducing the burden of finding alternative uses or deposits for the ever-increasing amounts of organic residues. Problems may occur if the wastewater is combined with industrial waste, or if the origin of the waste is not known. In Bangalore, for example, there is anecdotal evidence that the farmers are unwilling to use WWTP sludge because of perceived heavy-metal contamination. More advanced models could use waste valorisation options as discussed above for FS, such as pelletisation.

Energy production

This model adds energy recovery to the previous one. Multiple-resource recovery, particularly considering energy, offers the best value and opportunity for cost recovery. There are, so far, limited examples where treatment plant operators run “businesses” based on all three recovered resources (water, biosolids, energy). Usually, recovered energy is used internally. Some treatment plants are able to operate (nearly) entirely on the energy generated, providing a major cost reduction and protection from fluctuations in energy costs (Lazarova et al., 2012). Depending on the type and running costs of the WWTP and the market for water, organic fertiliser and energy, a WWTP that recovers all three products has a high probability of covering its O&M costs.

Alternative Typologies

The typology shown in Table 1 is just one way of classifying different reuse options. As our understanding of reuse systems grows, flow charts or organograms might allow a better visual representation of larger and smaller differences between reuse types, value propositions and business models. An alternative typology could be proposed based on the ownership of the “business” and the motivation of the owners. For example, the public sector may seek cost recovery rather than the generation of profits (Figure 2). The schematic is not exhaustive but represents another mode of classification which is likely to be more appropriate when converting the RRR cases observed into generic business models that could be selected and implemented by private sector organizations or by authorities responsible for sanitation.
**Work in progress**

Screening the sanitation-agriculture interface around the globe results in the daily discovery of interesting approaches for commercial RRR. The RRR team at IWMI is reviewing these cases, and the most promising ones will be reported in a compendium. Each new case will be used to refine the typologies and to develop business models for replication. The conditions in which the business models function are critical to the analysis. In addition to nutrient and water recovery, energy business cases are also being analysed across the domestic and agro-industrial waste sector, as they are likely to contribute significantly to the viability of water and nutrient recovery models.

Alexandra Evans, Miriam Otoo, Pay Drechsel, George Danso, IWMI, Colombo, Sri Lanka
Email: Corresponding author: p.drechsel@cgiar.org

**References**