sustainable sanitation alliance

SuSanA factsheet

Productive sanitation and the link to food security

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1 Summary

This factsheet provides information on the link between sanitation and agriculture as well as related implications on health, economy and environment. It shows examples of treating and using treated excreta and wastewater in a productive way and describes the potential for urban agriculture and resource recovery in rural areas. Institutional and legal aspects, business opportunities and how to manage associated health risks are also discussed.

Productive sanitation is the term used for the variety of sanitation systems that make productive use of the nutrient, organic matter, water and energy content of human excreta and wastewater in agricultural production and aquaculture. These systems should enable the recovery of resources in household wastewater, minimise consumption and pollution of water resources, support the conservation of soil fertility as well as agricultural productivity and thereby contribute to food security and help to reduce undernutrition.

2 Background

Food security and the access to safe water and sanitation are fundamental human rights that for many people remain a promise unfulfilled. Globally still some estimated 2.6 billion people do not use improved sanitation facilities (WHO, UNICEF, 2010) and around 925 million worldwide are chronically undernourished (FAO, 2010).

To meet the dietary demands from a growing world population, projected to reach 9 billion by 2050, the world food production in 2050 would need to increase by 70% (FAO, 2009). A great deal of the population growth will take place in urban areas leading to a substantial increase in urban food demand and which needs the volume of organic waste, human excreta and wastewater from cities to be managed in a safe and productive way.

Facing the number of people to be fed and the existing resource limitations, it is important to approach the food security issue from a perspective of resource preservation and recovery, in which productive sanitation systems play a key role.

At present farmers worldwide use around 164 million tons of synthetic fertiliser[1] in terms of N, P_2O_5 and K_2O annually (IFA, 2011). The production of the most important and commonly used fertiliser ingredients i.e. nitrogen (N), phosphorus (P), and potassium (K) is energy-intensive. Furthermore, the minable phosphorus and potassium reserves are finite. The crop yields today depend to a large extent on mined phosphate rock and potassium, a significant departure from historical food production methods (UNEP, 2011).

How long exactly the phosphorus and potassium reserves will last is hotly disputed as estimates depend on many factors, like the potential discovery of new reserves, increasing population growth and demand, increasing difficulty to extract reserves, and related market price developments (Cordell et al., 2009; UNEP, 2011;). One additional concern is that lower grade phosphorus which might increasingly be mined in the future, is often contaminated with radioactive uranium.

Recent phosphorus fertiliser price increases and the uncertain phosphorus future stress the need for resource recovery on a global level (Rosemarin et al., 2009). It is estimated that the globally available phosphorus from urine and faeces could account for 22% of the total global phosphorus demand (Mihelcic et al., 2011).

Figure 1: Left: Greywater towers in Arba Minch, Ethiopia (source: Wudneh Ayele Shewa). Right: Urine applied on petchay crops in Cagayan de Oro, Philippines (source: William Repulo).

Nitrogen can be extracted from the surrounding air but the industrial Haber-Bosch process is energy-intensive and today strongly based on fossil fuels. Furthermore, human activities now convert more nitrogen from the atmosphere into reactive forms than all of the earth´s terrestrial processes combined (reactive nitrogen is ammonia, ammonium, nitrate, nitrite and nitrous oxides, i.e. NO and NO_2) (Gruber and Galloway, 2008). This is four times the rate proposed as the planetary boundary for human modification of the nitrogen cycle, in order to avoid large-

[1] The term "synthetic fertiliser" in this factsheet equates more or less to other terms used colloquially for this type of fertiliser, namely industrial, chemical, commercial or inorganic fertiliser.

scale ecological impacts, such as oceans becoming eutrophic due to nitrate (Rockström et al., 2009).

This results in a *triple driver* for treated excreta use in agriculture in terms of nitrogen – to reduce fossil fuel use, reduce emissions of gases responsible for climate change and to reduce the input of reactive nitrogen in ecosystems.

Another essential resource in food production is water. Agriculture is a highly water demanding process and consumes 70% of the total water withdrawn (FAO, 2011). The supply and availability of water is increasingly diminished and unevenly distributed throughout the globe. Already today, large parts of Asia, Africa and the Middle East face either physical or economic water scarcity.

a.) Environmental consequences

As urbanisation has outpaced sanitation infrastructure in many countries, today only a small part of the human excreta receives appropriate treatment, and generally resource recovery is not intended. The way we produce our food uses 70–90 per cent of the available fresh water, returning much of this water to the system with additional nutrients and contaminants (UNEP/UN-HABITAT, 2010).

Continuous and excessive use of synthetic fertilisers on farmlands can lead to serious environmental consequences such as eutrophication of surface waters, “dead zones” along coastal estuaries and high nitrate concentrations in groundwater with a potential negative impact on human health.

Although in conventional agriculture the loss of the most important macronutrients is being compensated through application of synthetic fertilisers, these fertilisers cannot replace the loss of organic matter, microorganisms and many micronutrients equally important for fertile topsoils. In many parts of the developing world the “mining” of soil nutrients is severe and crop yields are falling, as nutrients removed by the crops are often not replaced. Many soils have been depleted or damaged by inappropriate agricultural practices leading to erosion, fertility losses, reduced productivity and hence decreased food security especially for people living in poverty.

b.) Health impacts of undernutrition

Undernutrition causes weakness and fatigue, inhibits mental and physical development particularly in children (where it also causes stunting), and makes people susceptible to other fatal diseases such as pneumonia and diarrhoea. In fact, it is estimated that the underlying cause for around *one third* of all deaths of children under five years old is undernutrition[2]. Diarrhoea and intestinal worm infections like ascaris, trichuris and hookworm rob children and adults of calories and prevent food from properly nourishing its consumers. See for example DFID (2009) and Humphrey (2009) for more information on these health issues.

Productive sanitation could lead to higher crop yields, leading to less undernutrition and hence less susceptibility for disease, growth stunting in children and death. In addition, preventing diseases caused by lack of sanitation, such as diarrhoea and helminth infections, would lead to a more efficient use of available nutrients in food.

3 The historical link between sanitation and agriculture

Food production is historically strongly linked with using liquid and solid waste from human settlements in agriculture. In former centuries the removal of organic matter and nutrients from the soil through harvested crops was compensated through application of animal manure, human excreta, compost or long fallow periods (see for example Lüthi et al., 2011). Only after the introduction of phosphorus mining in the mid 19th century, and industrial ammonia production in the beginning of the 20th century it became the prevailing practice to replace nutrients removed with the harvest with synthetic fertilisers instead of nutrients from human excreta.

In the same era the water based sanitation systems with flush toilets and sewers was installed as a response to the acute health crisis in large cities at that time. Although these new sanitation systems did improve public health significantly, they also contributed to polluted water resources and broken nutrient cycles.

The idea that human excreta is a waste with no useful purpose can therefore be seen as a modern misconception: Pits, water bodies and landfills are used nowadays as sinks for nutrients, organic matter and pathogens.

4 Economic implications

A high percentage of the population in areas affected by the sanitation crisis carry out subsistence farming (IAASTD, 2009), and struggle to maintain an income for feeding their families. Workdays and income won through improved water and sanitation services are thereby also a contribution to food security.

Many farmers are nowadays facing higher prices of fertilisers, due to increasing demands, higher energy and transport costs as well as rising production costs (IWMI, 2011). Food and fertiliser prices have been particularly unstable since the beginning of 2008 (see Figure 2).

When fertiliser prices rise, developing countries which are dependent on fertiliser imports for agricultural production, are particularly vulnerable. Poor infrastructure and high costs of transport, particularly to remote areas, adds to the problem and will further increase the market prices for synthetic fertilisers.

Synthetic fertilisers are often not affordable for small-scale farmers in developing countries unless they are subsidised. Recycling of nutrients and organic matter from human and animal excreta, wastewater and organic waste can therefore make a big difference to local crop yields.

[2] See also www.childinfo.org.

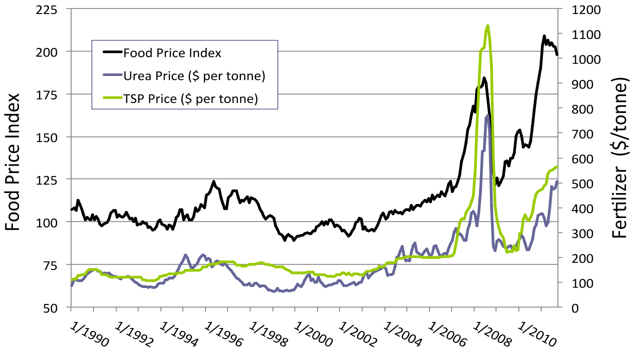

Figure 2: Food price index and fertiliser prices during 1990 to 2010 (source: FAO, 2011). Urea is a nitrogen fertiliser and TSP stands for trisodium phosphate.

There is nearly a mass balance between nutrient consumption and excretion since – "what we eat is what we excrete". Therefore, the protein consumption of a person can be used to estimate the nitrogen and phosphorus content in his or her excreta (Jönsson et al., 2004).

An estimate of the value of plant nutrients in human excreta can be made based on the local cost of an equivalent quantity of nutrients as synthetic fertilisers. Such an estimate for Burkina Faso was 6.2 EUR per person per year (Dagerskog and Bonzi, 2010) and in the case of the Philippines around 4.6 EUR per person per year (Gensch, 2011). To give another example: the average rural family of 9 in Niger excretes the equivalent of 100 kg (2 bags) of synthetic fertilisers (Dagerskog, 2009).

Figure 3: Fertiliser bags brought along to illustrate annual nutrient amount present in excreta from one rural family in Niger (source: Linus Dagerskog).

The resource reuse in agriculture can boost yields considerably. For example vegetables fertilised with urine produce 2-10 times the amount of crop per weight compared to those grown unfertilised (Jönsson et al., 2004). Fertilisation with urine can achieve comparable results as synthetic fertilisers (Gensch et al., 2011).

The increase in crop yield improves the availability and affordability of food and can result in higher food security. The increased agricultural yields can have a significant impact on the household income for the poor population, even if only subsistence farming is practised. Within the poor population in developing countries an estimated 40-80% of all generated household income is used for food (Viljoen, 2006). Where there is space for gardens, productive use of sanitation products can reduce household expenditures for the purchase of food.

5 The productive sanitation approach

Productive sanitation is a general term used for the variety of sanitation systems that make productive use of the nutrient, organic matter, water and energy content of human excreta and wastewater in agricultural production and aquaculture. These systems enable the recovery of nutrients and/or energy in household wastewater, minimise consumption and pollution of water resources and support the conservation of soil fertility as well as agricultural productivity and thereby contribute to food security. Productive sanitation systems can be considered sustainable if technical, institutional, environmental, social and economical aspects are appropriately addressed, according to the Vision Document of SuSanA.

Treated human excreta and wastewater, animal manure and organic solid waste can serve as important sources for soil amelioration, as they deliver relevant micro and macronutrients, organic matter and water needed for plant growth.

Some technologies out of a great number of options for treating and using excreta and wastewater in a productive way include[3]:

- **Use of source-separated urine:** Separately collected and treated urine is a complete fertiliser rich in nitrogen that can replace or complement synthetic fertiliser. Urine can be applied on fields, beds, vertical or container gardens, school gardens, or rooftops. This can be done on household or community level without sophisticated transport and application, but it is more difficult at city level due to high transport costs.
- **Struvite production:** Struvite is a mineral powder with high fertiliser value that can be produced from urine. Volume and weight are reduced compared to urine, it can be stored in a compact form and is easy to handle, transport and apply. Industrial struvite precipitation reactors exist (see www.saniresch.de/en).
- **Arborloo:** The Arborloo is a shallow pit latrine filled over time with human excreta and ash or soil added after each defecation and is only suitable for rural areas. As soon as the pit is full, the superstructure can be moved to a new area while a tree (such as fruit trees like banana or mango) can be planted on top of the nutrient-rich substrate of the old pit.
- **(Co-)Composting:** Organic solid waste can be collected from households and composted at community-based or centralised composting plants. Pre-treated faecal sludge can be co-composted together with organic solid waste
- **Short rotation plantations:** Short rotation plantations are an integrated agro forestry land-use system combining biomass production with wastewater use. Fast growing tree species are managed in short cropping cycles. These non-food crops have a high demand for nutrients and water, which may alternatively

[3] For more information see respective SSWM technology sheets under: http://www.sswm.info/category/implementation-tools/reuse-and-recharge.

be met by using pre-treated wastewater and sewage sludge. The biomass produced can be used as renewable fuel for heat/power generation.
- **Biogas plants:** This process produces biogas and fertiliser under anaerobic conditions (absence of oxygen) from organic inputs. Biogas production from organic waste is interesting, as the revenue generated in that market might offset some of organic waste the costs for transport and treatment (IWMI, 2011).

Flow streams

Wastewater and human excreta consist of different streams. Due to their different characteristics, it can be advantageous to consider separate collection with adapted treatment processes and application methods according to the flow stream's properties:
- **Human urine** contains essential plant nutrients like N, P, K and smaller fractions of micronutrients, in plant available form. On average, an adult person produces around 500 litres of urine per year. Human urine, when leaving the body, is essentially pathogen-free and can be considered a well-balanced nitrogen-rich liquid fertiliser.
- **Human faeces** contain lesser amounts of nutrients than urine and are rich in organic matter but also contain a high number of pathogens especially when a person is sick. On average an adult person produces around 50 kg of faecal matter annually although this figure varies widely depending on diet. Faeces are a valuable soil conditioner and can improve pH, nutrient content and water retention capacity of the soil and the ability of plants to withstand insects, parasite attacks and pests.
- **Greywater** is the wastewater from kitchen, baths and showers. It contains a low nutrient load compared with excreta or wastewater and hardly any pathogens. After appropriate treatment or other risk reduction measures greywater can be safely reused for irrigation.
- **Wastewater** is a term used for all kinds of wastewater and storm water mixed together. Due to its high nutrient and water content it can also be used as a fertiliser and irrigation source. However, due to the high pathogen load in domestic wastewater, treatment and appropriate risk reduction measures should be applied before use in agricultural production.
- **Organic solid waste** consists of organic kitchen waste, leaves, grass etc. that accumulate in households. Organic waste can also be used for gardening after a treatment process such as composting.

Benefits of productive sanitation include:
- The efficient resource reuse minimises uncontrolled excreta discharge in surface and groundwater with less environmental degradation.
- The use of treated wastewater as irrigation water can lead to a more economical use of potable water.
- In terms of soil fertility the nutrient loss through the harvest is almost completely compensable with excreta-based fertilisers.
- The organic matter from human and animal excreta improves the water retention capacity of the soil reducing irrigation water requirements and the vulnerability to droughts. Moreover the organic matter balances the soil temperature and enhances the buffering capacity of the soil.
- It can reduce health costs due to a better nutritional status of the population and less exposure to pathogens.

6 Cities as hot spots for resource recovery

The current global urban population is expected to double by 2050, with 90% of urban growth taking place in developing countries (Drechsel et al., 1999). We need a transition to sustainable and resilient cities, which requires enhancing quality of life while minimising resource extraction, energy consumption, waste generation and safeguarding ecosystem services. This is directly related to city planning: to the development of city-based energy, waste, transportation, food, water and sanitation systems (Lüthi et al., 2011).

Urban and peri-urban agriculture (UPA) is the production of food and related services within and around cities. UPA includes urban horticulture, livestock, (agro-) forestry, aquaculture and related processing and marketing activities. Production of food by poor urban households can supply up to 20-60% of their total food consumption (De Zeeuw and Dubbling, 2009). Urban households that are involved in farming or gardening have in many cases a better and more diverse diet and are more food secure than households not involved in urban agriculture. UPA also increases the availability of fresh, healthy and affordable food for a large number of other urban consumers.

Urban centres are hubs of consumption of all kind of goods including food, which makes them major waste generation centres, and, if this waste remains in the urban area, vast sinks for resources such as water, nutrients and organic matter, posing environmental and health challenges, as well as an economic challenge. But, water demand for food production is increasing due to rising populations as well as due to changes in urban food consumption patterns.

Urban producers and farmers have a variety of motives for using untreated or partly treated wastewater. In semi-arid and arid areas it is often the only source of water available all year round. It is also an inexpensive source, not just of water but also of nutrients. Irrigated urban agriculture provides livelihoods and has an important niche function (Drechsel et al., 2010).

Management of urban wastes is a high-cost concern for many cities. Instead of flushing waste out of the city or bringing the waste to heaps in landfills, illegal dumps or transfer stations, there is growing understanding that composting and local reuse is an environmentally attractive way to manage parts of these otherwise wasted resources.

Decentralised safe reuse of wastewater and composted organic waste in UPA will help to:
- Adapt to drought by facilitating year-round production, making safe use of wastewater and nutrients in water and organic waste;
- Reduce the competition for fresh water between agriculture, domestic and industrial uses;

- Reduce the discharge of wastewater into rivers, canals and other surface water and thus diminish their pollution;
- Make productive use of the nutrients in wastewater and organic wastes.

UPA contributes to local economic development, poverty alleviation, social inclusion of the urban poor – women in particular – and to reduced vulnerability of cities and their inhabitants. Nutrient loops can be closed and the environmental benefits of urban agriculture can be enhanced.

7 Resource recovery in rural areas

Almost 50% of the world population still live in rural areas, where local reuse can be relatively simple and make a big difference, especially for smallholder farmers. The resource potential of human excreta needs to be emphasised, and a close collaboration with the agriculture sector established.

Two recent productive sanitation projects in Burkina Faso and Niger were financed from the agricultural sector (EU food facility and IFAD), where treated urine and faeces have been termed “liquid and solid fertiliser”, and toilets and urinals are promoted as “fertiliser factories” (see Dagerskog and Bonzi, 2010). Agricultural extension workers were at the forefront of these projects, using farmer field schools to show the effect of treated urine and faeces as fertilisers. This created demand for toilets and urinals that transformed dangerous raw excreta into safe fertilisers. There are examples of villagers selling and buying treated urine and faeces, as well as households in surrounding villages that construct toilets or urinals on their own initiative to obtain the safe fertiliser.

Figure 6: Increased vegetable crop yields when using urine as fertiliser in “Productive Sanitation in Aguié Project” (source: Linus Dagerskog, 2010). More photos: http://www.flickr.com/photos/gtzecosan/sets/72157627175906041.

8 Institutional and legal aspects

Weak, non-existing or sometimes prohibiting legislation on reuse of excreta and wastewater makes it difficult to implement and scale up productive sanitation systems. Ideally, a regulatory framework should facilitate the safe reuse of resources from sanitation systems. Resource reuse may require changes to existing sanitation, environmental and agricultural policies, or the development of new policies. Effective laws and regulations establish both incentives for complying as well as sanctions for not complying with the requirements.

The “Guidelines for safe use of wastewater, excreta and greywater in agriculture and aquaculture” (WHO, 2006) can be used as a reference when national policies and legislations are developed. These guidelines aim to protect the health of individuals and communities by recommending safe practice requirements and supporting the development of risk management.

It is necessary to develop relevant legislation along the sanitation chain, from excreta treatment and transport to application of fertiliser, produce restrictions, occupational health, food hygiene and other preventive measures.

A legal framework that focuses on desired functions of the sanitation system rather than specific technologies, stimulates innovation and is not out-dated as fast as technology prescriptive regulatory frameworks. This is described by Kvarnström et al. (2011) using Sweden as an example where in 2006 national guidelines for on-site sanitation were developed.

The Swedish guidelines are not focussing on technology per se but on the function of the sanitation technology instead. They guide local authorities on what kind of expected results from the sanitation system they should impose on the house owner. The national guidelines especially emphasise the need to reduce the phosphorus loads to the recipient water bodies and the importance of nutrient recycling.

In a setting with large-scale recycling of excreta (or “sanitation products”), it is important to guarantee the quality from both a hygienic and an agricultural point of view to maintain trust between stakeholders. This could be achieved with a system of certification, including permits for professionals who work in the sanitation chain, as well as quality control of the sanitation products. It is important not to over-burden the control system as the regulations should be feasible to implement under local circumstances.

Allowing treated excreta as fertilisers and organic matter sources in organic and conventional agriculture would certainly boost recycling. The International Federation of Organic Agriculture Movements, restricts the use of human excreta on food crops, but exceptions may be made where detailed sanitation requirements are established by the standard setting organisation to prevent the transmission of pathogens (IFOAM, 2005). However, if the use of sanitised excreta in agriculture is prohibited in the food importing country, the exporting country will not use it except for own consumption. An example is the EU legislation on organic farming, which is not allowing the use of sanitation products as fertilisers for organic crops to be sold in the EU (Richert et al., 2010).

9 Management of health risk

Sanitation related health risks occur mainly through persistent pathogenic organisms in excreta such as bacteria, viruses, protozoa and helminths. If not collected, treated, transported and applied properly this can lead to transmission of infectious diseases such as diarrhoea and the proliferation of intestinal worms. The purpose of every

sanitation system is therefore to protect human health and install effective barriers against possible exposure to pathogens.
In this context the WHO has set up guidelines to protect the health of individuals and communities regarding the productive use of excreta, greywater and wastewater and recommend a flexible multi-barrier approach for managing the health risks. The guidelines give recommendations for adequate use in agriculture and offer management solutions if effective wastewater treatment is not possible. It is stated in these guidelines that wherever the use of wastewater, excreta and greywater "contributes significantly to food security and nutritional status, the point is to identify associated health hazards, define the risks they represent to vulnerable groups and design measures aimed at reducing this risks" (WHO, 2006).

The WHO recommends that the additional disease burden arising from wastewater and excreta use in agriculture should not exceed 10^{-6} DALYs (disability-adjusted life years). This means that only one year out of a million human life years should be lost because of disability or death from a disease caused by the use of wastewater or human excreta. This high level of protection was adapted from the recommendations used for WHO drinking water guidelines and is currently under discussion as possibly begining too strict (Mara, 2011).

Partially treated or untreated wastewater can be used provided that barriers are applied at various stages of the process, like crop restrictions, application techniques, and food handling by vendors and consumers. This requires awareness raising, advocacy and changes in attitudes of a wide variety of stakeholders, both rural and urban.
In addition to the WHO guidelines the Stockholm Environment Institute recently published a support tool for practitioners, planners and engineers to allow for a rapid assessment of health risks associated with the components or functional groups of sanitation systems (see Stenström et al., 2011).

Hormones and pharmaceutical residues do occur in wastewater and sludge as human beings excrete them with their urine and faeces. There is a theoretical possibility that if wastewater is reused in agriculture, but even more in aquaculture, these micro-pollutants can enter the human food chain. However, these risks are small compared to pathogens and diarrhoea as the main challenges where sanitation is lacking, but also compared to pharmaceutical residues contained in animal manure, or risks resulting from pesticide use. Soil is considered a more suitable medium for natural degradation of pharmaceuticals than water. Pharmaceuticals can be degraded better in aerobic, biologically active soil layers with high concentration of microorganisms and longer retention times than in the more sensitive ecosystems of water bodies (Richert et al., 2010).

Contamination of wastewater with heavy metals from industrial wastewater should be avoided through introduction of cleaner production approaches keeping apart industrial from domestic wastewater and imposing proper treatment processes within industries.

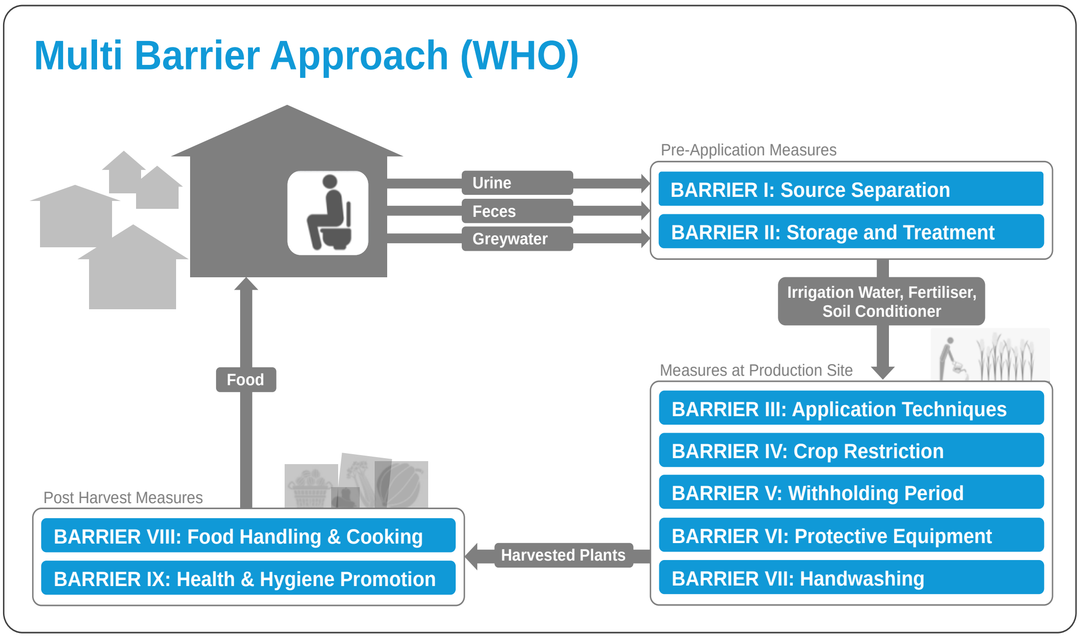

Figure 7: WHO multi-barrier approach to safe use of excreta and greywater in agriculture.

10 Business opportunities

The water, nutrients and energy recovered could enable cost reduction or recovery in the sanitation service chain and could offer market opportunities[4].

Increasingly there is agreement on the need to move from "treatment for disposal" to "treatment for reuse" (Drechsel et al., 2011). Successful involvement of the private sector in providing sanitation services and recovering resources in waste materials will directly enhance the livelihoods of millions of households in rural and peri-urban areas of developing countries (ibid.).

In low-income countries, sanitation and waste management traditionally have been either neglected or subsidised by public-sector agencies, with service quality varying across locations and income levels resulting in notable health and environmental problems. This reliance on public-sector provision has partly prevented development of markets in sanitation services that might be best provided by private companies. The market analysis and business planning needed to promote private sector or public private activities has not been conducted, although interest in developing viable business models is increasing among donors and international organisations (ibid.).

11 Challenges and way forward

Despite all known and convincing benefits of productive sanitation, a number of challenges and problems still need to be overcome which differ largely between countries and regions. These concern cultural barriers and perceptions; political will; missing knowledge on economics of waste management and reuse; development of appropriate regulations and legal frameworks; and technical aspects of making reuse profitable.

In most parts of the world, the productive sanitation concept has not been fully embedded in legislation. The cultural barriers, fear of health impacts, and the neglect of sanitation and wastewater management in general might explain the lack of clear policies in support of safe reuse options.

Reversing current trends and patterns requires the adoption of holistic and integrated approaches. Multi-stakeholder consultation, joint planning and decision-making will be needed to adapt existing policies or develop new ones. More applied research is also needed to assess risk management options in the agriculture and sanitation interface in support of policy dialogue at the local and national level.

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