Analysing the Nexus of Sanitation and Agriculture at Municipal Scale

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To better understand the linkage between sanitation and agriculture at municipal scale, a study was carried out that addressed the following research questions:

- ***How does a larger investment in flush toilets affect water quality and urban farmers?***
- ***How much of the nutrient demand of urban farmers could be covered through waste composting?***

Modelling is required to answer these questions at municipal scale. A common approach is to quantify water and nutrient flows, for example, via material flow analysis (MFA) (see box). MFA has been used extensively to quantify the flows of food and other materials passing through cities, the related consumption and amounts of waste generated, as well as the fate of that waste. Once the pathways and quantities are known, the same flows can be broken down into streams of nutrients, biomass, energy, etc. This analysis allows researchers to identify points in the system at which interventions to reduce the environmental burden or increase resource efficiency would be most appropriate. The analysis becomes **decision support** when scenarios are calculated to see how the flows will be affected by population growth or certain investments in infrastructure or transport capacity.

The International Water Management Institute (IWMI) and SANDEC/EAWAG applied MFA twice in Kumasi, Ghana, first with emphasis on solid waste and options for co-composting for urban agriculture, later to understand nutrient flows in the household wastewater systems, focusing particularly on urban and periurban farmers exposed to highly polluted water.
Several scenarios were modelled to

- quantify the amounts of nutrients which could be recovered from the system before they are lost on landfills or the environment,
- quantify future urban water needs and wastewater generation and
- identify the impact of changing sanitation practices on water pollution and nutrient availability for farming.

The scenarios considered various types of investments that are planned in Kumasi as part of efforts to achieve the Millennium Development Goals (MDGs). The modelling showed interesting results (Leitzinger, 2000; Erni, 2007; Erni et al., 2010), some aspects of which are highlighted here to illustrate the application potential of MFA:

- The planned investments in urban water supply would largely be outpaced by population growth in the same period resulting in a much smaller improvement in per capita supply than officially aimed at. It also showed that if the expansion work was delayed (as often happens), per capita water availability in Kumasi would actually decrease. In all scenarios, the amount of water per capita would not surpass the minimum for conventional sewer operation.
- Even if the city does not aim at sewerage and opts for more flushing toilets connected to septic tanks, as is common now, more toilets in certain better-off districts would strongly compete with other household water needs and drastically affect water supply to the average household in Kumasi.
- From the nutrient perspective, the toilets would decrease the amount of nutrients directly entering surface water via gutters, but to a much larger extent increase the nutrients entering groundwater from the septic tanks, which are hardly ever emptied. This would result in a net increase of nutrients released to the environment.

The MFA showed that due to the continuing scarcity of drinking water, Kumasi, like many other African cities, can achieve the sanitation MDG better through investments in water-saving toilet systems. A higher fraction of dry sanitation systems would not only have a positive impact on water demand but also reduce the nutrients released into the water cycle (as has also been shown by Montangero and Belevi (2007) for Vietnam).

What happens to the nutrients released to the environment? The majority find their way into the streams passing through the city. Compared to the nutrient levels upstream of Kumasi, the nitrogen (N) and phosphorus (P) concentrations downstream of the city are approximately 14 and 6 times higher, respectively. In absolute figures, the amounts correspond approximately to half of the annually generated human excreta in Kumasi, and indeed the largest N and P input into water bodies derives from domestic sources, i.e. failing sanitation.

This nutrient load moves downstream passing hundreds of farmers who use the water to irrigate their vegetables. More than 50 per cent of the farmers in urban and periurban Kumasi are aware that their irrigation water contains nutrients, but only a small percentage showed a high level of awareness and indicated that they regularly consider this while managing crop nutrient needs. The reasons for this are two-fold:
a) Farmers use the water first of all to irrigate highly perish-

able crops; thus irrigation frequency depends on crop water needs and not nutrient needs.

b) Without options for water, soil or crop analysis, farmers' nutrient management depends on observations that they make of the crops and their own general experience. As water nutrient loads also vary, farmers prefer to stay on the safe side and apply e.g. poultry manure or chemical fertiliser according to their own experience.

Farmers do not tend to reduce their manure application rates over time. This results easily in over-fertilisation and nutrient imbalances, which was verified in this case using the NUTMON model (see box). This situation can strongly affect crop growth. Fortunately, in contrast to most cereals, leafy vegetables love excess nitrogen.

The MFA is only one of several methods needed to answer questions like those posed above. Looking only at already collected and transported solid waste and excreta, the Kumasi MFA showed that the amount of N and P that could be recycled through co-composting would be sufficient to cover the demand of all urban farmers and even some farmers in Kumasi's periurban fringe (see the previous article). However, even if all nutrients were available at one or more compost stations, a detailed analysis would be needed to determine how many farmers are actually interested in the product (or already have a cheaper fertiliser, like poultry manure), how many of those who are interested would be willing to pay for the product at a price that covers the cost of operating the compost station, and how much they are willing to pay in addition for the transport to reach the product. In the case of Kumasi, the answers to these questions showed that the final target group would be so small that composting only the urban market waste would already cover their demand. This again was an important message as it means that to reach the target group, there is no need to introduce waste sorting (organic – inorganic) at household level to have enough organic waste for composting. To reach a larger group of users, the above constraints will have to be removed.

References

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Analysing nutrient flows and balances

There are various ways to analyse nutrient flows and balances in urban or rural systems, on farms or for whole cities, these are two examples.

NUTMON is an integrated model which allows farmers and researchers to jointly analyse nutrient flows and balances at the farm or plot level to improve soil fertility management. NUTMON software is easy to use and a free global public good. It can be used to analyse nutrient balances at village, regional, national, and supra-national levels and to better understand the effects of current and alternative land use options on productivity, farm finances and sustainability. NUTMON looks primarily at in- and outflows, rather than internal processes, to determine whether there will be a nutrient deficiency or a surplus. In addition to major nutrient inflows and outflows (erosion, leaching, harvest, fertilisation, atmospheric deposition, etc.), the NUTMON Toolbox considers interactions with livestock and human activities such as household waste recycling. It can also link the nutrient flows with financial assessments.
More information: http://www.nutmon.org
Examples of the use of NUTMON in periurban vegetable farming: www.vegsys.nl

Material flow analysis or flux analysis (MFA) goes beyond NUTMON and allows researchers to capture all flows in and out of the black box as well as between different components or transfer points in the box. It describes the fluxes of resources used and transformed as they flow through a city or region, using a defined space and time frame. In industrialised countries, MFA proved to be a suitable instrument for early recognition of environmental problems and development of solutions to these problems. The scientific basis is more complex than that of NUTMON and based on the law of conservation of matter and energy.
One commonly used MFA programme is SIMBOX, which was developed at the Swiss Federal Institute for Environmental Science and Technology (EAWAG), Zürich, Switzerland. Licenses for its use can be obtained from EAWAG
More information and application examples:
www.eawag.ch
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