Sustainable water resource management in sanitation

An overview

by Lucas Dengel

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Abstract

Modern sanitation makes liberal use of water to achieve its goals, i.e. hygiene of living conditions and disposal of liquid and solid wastes including human excreta. It is recognized that conventional approaches to these issues, on the one hand, contribute to environmental stress, and, on the other hand, are wasteful in water use, and hence non-sustainable.

This presentation introduces concepts of sanitation, hygiene, and wastewater treatment that aim at conserving water resources and an ecologically responsible water use. This includes technologies which require little or no water, which do not burden the self-cleaning mechanisms of soil, groundwater or natural water bodies, and which recycle water maximally.

Ecological hygiene management dispenses with the use of biocides and disinfectants and thus reduces toxic pollutants in water and soil. It aims at creating a beneficial microbial environment which spontaneously controls pathogens and provides full hygienic and aesthetic benefits, while facilitating treatment of wastewater downstream.

At the upstream end of human waste disposal the eco-sanitation concept favors flush-free urinals, minimal-flush toilets or water-less composting toilets, separation of urine and feces for the retrieval of nutrients for farming and gardening and for recycling of liquid and solid wastes.

Conventional wastewater treatment favors a centralized approach with extensive sewerage lines, highly engineered treatment plants requiring chemical inputs, constant energy supply and high maintenance. Decentralized treatment systems decrease the need for sewers, maximally utilize natural slope for flow, operate without chemical inputs, and are low in energy and maintenance requirements.

(1) Introduction: A historical perspective

Human waste disposal and disease control

The historical period of the European Middle Age lasting from around 500 to 1,500 AD evokes, in regard to public hygiene and sanitation, pictures of filth and stink. The dark ages of bad sanitation lasted well into the 19th century, and technical progress initially did not at all counteract ill-health, but rather contributed to its spread. Cholera has always been an endemic of South East Asia, it has always been at home here. In 1817 an epidemic wave of cholera moved to the West, with pilgrims to Damascus, Mekka, Alexandria. From the

Middle East northwards and westwards, in 1830 killed 4,500 people in Moscow, and went with the soldiers of the tsar to Prussia. In 1831/32 Hamburg and Berlin were badly affected, the disease reached Duesseldorf at the Rhine in 1832. The next epidemic wave of cholera hit Germany in 1848, Prussia counted 85,000 cases and Berlin 5,000 dead. While Hamburg and Munich suffered, Nuernberg which is not situated at a major river had had no contact with the disease. This changed when the railway track from Munich to Nuernberg got built in 1852. From now on a travel between these towns took less time than the average incubation time of cholera i.e. two days. Passengers entering the train infected in Munich manifested and spread the disease in Nuernberg.

The great bacteriologists of the 19th century, such as Virchow (1821-1902), Pasteur (1822-1895) and Koch (1843-1910), not only engaged in research and clinical medicine, but in public hygiene, policy, and in the engineering of sanitation facilities.

Amongst medical historians it is acknowledged that it was not the development of medicines that halted spread of diseases and epidemics, but improvements in sanitation including water toilets and sewerage systems, and improvements in nutrition made widely available. Vaccines, antituberculotics, antibiotics etc. were developed when infectious diseases were statistically already on the decline.

Nowadays the affluent West (or North) is proud of its living standard, its public hygiene and control of epidemics, and its civil engineering for transport and treatment of human wastes. It has not yet become a common realization that conventional sanitation systems regardless of their efficiency are always extremely wasteful, wasteful in material investments, in water use, and in energy use.

What is true for the disposal and treatment of human waste (and for the disposal and treatment of other liquid and solid wastes as well) – i.e. wasteful and non-ecological use of water and resources – is also true for hygiene management.

Breakthrough in hygiene for surgery

Only when chemists and physicians discovered disinfectants (Semmelweiss, Lister), surgery had a chance to develop. In 1850 a caring and conscientious physician was obliged to advise his patients not to undergo surgery as more patients died from surgery than from the diseases for which surgery was applied. With the discovery of biocides and the development of disinfectants surgery became safe and an actual treatment option. Modern surgery developed from about 1880 onwards and is definitely a post-Listerian affair.

Swabbing a patch of skin with a disinfectant to allow the surgeon to invade the body without causing an infection has been a breakthrough for surgical history and can obviously be a beneficial procedure for the individual patient. However, if applied to our bodies in general, to our households, to urban environment, and to the environment at large, the same procedure becomes completely nonsensical and positively harmful.

The use of antibiotics and disinfectants in hospitals has led to the development of the most virulent pathogens against which medicine has no cure. The use of disinfectants and detergents in households and human environment has led, or at least greatly contributed, to the development of allergies and diseases that are difficult to treat. And, outside the realm of sanitation and public hygiene, the use of biocidal chemicals in industrial processes and agricultural practices has lead to a deadening of the soil and to pollution of groundwater. Not only have we massively increased the pollution load that rivers and oceans are expected to take care of, we have also to a large extent actively destroyed nature's capacity to treat our wastes.

Present scenario – summary

Currently about 2.4 billion people lack access to basic sanitation, but actually most of humanity is affected by a global sanitation crisis: 70% of the sewage systems in the world, serving about 1 billion people, are dysfunctional. Even of 540 European Union cities, only 79 have advanced sewage treatment and 45% have either no or incomplete treatment. In 2002 the European Commission took legal action against France, Greece, Germany, Ireland, Luxembourg, Belgium, Spain and the United Kingdom for failure to implement various environmental laws for water quality protection. The city of Brussels was one of the worst defaulters. In developing countries 80% of all diseases and 25% of all deaths can be attributed to polluted water. The need for hygiene and sanitation is indisputable and is being made focus of various international and national campaigns and programs.

The present scenario of sanitation and hygiene is characterized by
- the use of biocidal hygiene inputs which are a burden on the environment,
- wasteful use of water,
- unncessary use of fresh drinking water,
- energy-intensive and expensive wastewater treatment,
- waste of plant nutrients and organic matter,
- due to capacity constraints of the operators, frequent breakdown of systems resulting in transfer of pollution instead of elimination, and
- due to discharge of ill-treated sewage into rivers and water bodies, massive pollution down-stream by nutrients (leading to eutrophication), organic matter, and hazardous substances.

This presentation introduces concepts and technologies that offer solutions to the above-described problems, which need to be made part and parcel of a sustainable management of water resources:
1) decentralized ecological wastewater treatment,
2) ecological sanitation, and
3) hygiene management with beneficial micro-organisms.
The presentation does not address the issue of industrial water pollution specifically.

(2) Dewats – decentralized wastewater treatment systems

Centralized wastewater treatment – its disadvantages

In conventional water-borne disposal of human wastes and treatment of wastewater, large amounts of clean water are used to flush and transport human waste to distant sites for treatment. The disadvantages of centralized large sewage treatment plants and extensive sewerage are as follows:

- Investment costs are high, in particular in regard to sewerage which can cost up to five times more than the central sewage plant itself.
- Energy requirements are high, either for pumping sewage uphill in the course of extensive sewer lines, or for the operation of the treatment plant.
- Accordingly operation and maintenance costs are high, not only because of energy requirements, but also because treatment systems depend on a range of technical gadgets that require attention and skilled labour.
- The longer the sewer lines, the more chances for leakage, i.e. for contamination of groundwater or piped drinking water, and hence for the spread of disease.
- Like water-borne sewage systems in general, it depends on large volumes of water, and mostly uses water of drinking water quality for the flushing of toilets: it wastes clean water.

First corrective measure for water-borne sewage systems: segregated supply system for water of different qualities

A first corrective measure to counteract waste of high quality water is the installment of separate plumbing for the supply of water that need not be of drinking water quality, e.g. for floor washing, toilet flushing, gardening. Theoretically segregation may be into more than two water qualities, in practice two are more easily feasible and affordable.

Further corrective measures will be shortening of the sewer lines, and treatment of wastewater with lowered investment costs, lesser energy requirements, lesser operational costs, and appropriate re-use of treated water. If this is implemented by setting up a decentralized wastewater treatment plant, it will be easy to re-use treated water on site and in the households via segregated plumbing. Treated wastewater can not only be used for gardening, but, depending on treatment quality, also for toilet flushing, general room hygiene, laundry and bathing.

Decentralized wastewater treatment – advantages and technical components

Decentralized wastewater treatment offers a range of technical and ecological advantages, and additionally addresses the crucial factor of decentralization of responsibility. While enormous funds are being spent on setting up central treatment plants, and the same plants often become sources of pollution, and governance systems are overwhelmed by their upkeep and operation, dewats play a major role in passing on the control over disposal of human waste to groups and associations of citizens, in institutions, hostels, hotels, residential blocks and areas, and villages.

- Decentralized wastewater treatment systems, short "dewats", provide treatment for wastewater flows from 1 to 500 m3 per day, from both domestic and industrial sources.
- Dewats are based on a set of treatment principles the selection of which has been determined by their reliability, longevity, tolerance towards inflow fluctuation, and because they dispense with the need for sophisticated control and maintenance.
- Dewats work without (or minimal) technical energy, and cannot be switched off intentionally. Thus they guarantee permanent and continuous operation. However, fluctuation in effluent quality may occur temporarily.
- Most dewats modules require little space, are inexpensive in investment and extremely cheap in operation and maintenance.
- Dewats facilitate re-use of treated water on site and are ideally combined with segregated water supply.
- Dewats can be well integrated into an aesthetic pleasing rural and urban landscaping.
- Dewats are not everywhere the best solution. However, where skilled and responsible operation and maintenance cannot be guaranteed, they are the best choice available.

Technically, dewats involve four treatment steps and systems:
- Sedimentation (and primary treatment) in ponds, septic tanks, or Imhoff tanks.
- Secondary anaerobic treatment in fixed bed filters or baffled septic tanks (baffled reactors).
- Secondary or tertiary aerobic / anaerobic treatment in constructed wetlands (subsurface flow filters).
- Secondary and tertiary aerobic / anaerobic treatment in ponds.

Of these, constructed wetlands require the largest area (i.e. 1 m2 per m3 daily flow), are the most expensive to construct, and may loose large amounts of water by transevaporation. Wherever space availability is a constraint or land prices so high that land use for wastewater treatment is regarded as prohibitively uneconomical, dewats modules of lesser space requirements should be considered.

(3) Ecosan – ecological sanitation

For many years the United States Census measure of progress was the number of flush toilets in the country. Any departure from this was looked at as a step backwards. Water-borne disposal of human waste depends on large volumes of water – 20 to 25 percent of indoor wastewater generation is from toilet use – and, as said above, in general water of drinking water quality is unwisely taken for toilet flushing and other uses which do not require this water quality. Conventional toilets use 15 to 20 liters for one flush, i.e. to transport 200 g of feces (average amount per capita per day). Presently available water-saving toilets use volumes in the range of 5 to 7 liters.

Speaking of human wastes and toilet facilities, the issue is not only one of health and hygiene, and of environmental sustainability, but also one of human dignity. This presentation, however, deals with technical aspects mainly. It starts from the assumptions that maximal benefits of hygiene, water conservation, and nutrient recycling, are to be matched, and that at every socio-economic level appropriate technical solutions can be developed.

The ecological challenge

Additionally to the above-said disadvantages of water-borne sewer systems and centralized treatment plants, the conventional approach generally does not make use of the nutrients in human waste and thus contributes to the impoverishment of soils. Neither do conventional pit latrines – the “drop-and-store” type – rectify this deficiency. Pit latrines and seepage pits are also not appropriate in areas of high water tables and increasing population density. The approach of ecological sanitation – short “ecosan” – is an effort to replace a linear end-of-pipe technology aiming to get rid of waste with a system that closes material-flow cycles.

Handling of human feces poses health risks and hence requires thorough treatment. There are basically two options: Either it is used for generation of biogas from anaerobic digestion. Or it is dehydrated and/or composted and then, like other types of compost, is easy to handle, provides small amounts of nutrients, improves soil structure and increases water retention capacity.

Urine contains the highest proportion of nutrients in human excreta, directly available to plants and as effective as mineral fertilizers without having their disadvantages. It contains about 90% of the total nitrogen, 55% of the total phosphorus, and a similar portion of the potassium in human excreta. The urine produced by one person per year contains 4kg N, 0.365kg P and 1 kg K. As urine is a sterile product of the human kidney, there is, in contrast to feces, little need for its sanitisation. Urine can be collected separately with the help of separation toilets or waterless urinals.

The nutrients in human waste per capita per year are sufficient to produce 250 kg of cereals. One person can provide enough nutrients for 200 to 400 sq.m. agricultural production area.

Greywater from washing, rinsing, showers etc. is the largest fraction of the total wastewater flow. It has only a very low nutrient content and needs to be treated to a quality at which it can be used for irrigation or for groundwater recharge.

Ecosan remedies two unsustainable defaults of conventional wastewater treatment: waste of water, and waste of nutrients and organic matter.

Ecosan – technical options

Waterless urinals operate without flushing and do not generate any unpleasant odor. They either are equipped with a trap filled with a sealing agent, or with a simple curtain-device of material closing against odors from the sewers. The first type is more expensive and difficult in maintenance, the latter type is practically free of maintenance and hence extremely cost-efficient. Cleaning of the urinals is being done in the usual way, as in the case of flushed urinals. (Naturally, it would be wise to combine the system with a more ecological hygiene input – see below.) Waterless urinals have been installed in many parts of the world, the curtain-seal model has been developed in South Africa and is in use in several hundreds of toilets, in universities, restaurants etc. without any complaints.

Separation toilets separate feces from urine in order to treat the two waste products separately. Feces may be composted, and urine, after minimal treatment, channeled to agricultural use. Rustic low-cost models of this type have been successfully set up in villages in Tamilnadu, and the users enjoy odor-free toilets and green kitchen gardens, and demonstrate their appreciation of the benefits of hygiene and garden productivity by maintaining their toilets clean.

Bringing urine to agricultural production sites requires transport. Considering the energy consumption for this transport compared to wastewater treatment and production of mineral fertilizers, it is still economical to transport urine 200 km.

Composting toilets can operate if fed with urine and feces (and small amounts of washwater), or they receive feces only and composting becomes a simple operation manageable by a willing user. Fully composted human feces can be handled like any other compost. Composting toilets make sense where compost is desired or welcome, or where collection of compost is feasible and makes economical sense. In South India there are several examples of composting toilets, at the level of individual households as well as of public facilities. (In Auroville we have a few composting toilets in individual households.)

Vacuum flush toilets are used in aeroplanes and on ships. (Vacuum flush system is a misnomer as it does not operate with a vacuum, but with suction from negative pressure.) They operate with minimal amounts of water (1 or 2 liters per flush), but require energy supply. Actual energy requirements are minimal, and wherever energy supply is assured (for reasons different from flushing toilets), vacuum sewerage has great advantages: It needs small-diameter sewer piping only; and, as operation does not depend on gravity flow, in old buildings to be retrofitted or in conditions where continuous downward slope of sewers is not feasible, the technology is an ideal option.

Presently Scandinavian countries are leading in design and development of ecosan equipment, manufactured in porcelain (for the toilet bowls) and high-quality plastics (for composting chambers etc.), but similar equipment in simpler versions and cheaper materials has been developed in other parts of the world, including China and India. Indian sanitary ware manufacturers have expressed their readiness to go into serial production of ecosan toilets if and when informed about the demand of the market. Plastic manufacturers are also ready to enter the market.

(4) Ecological hygiene – the use of Effective Micro-organisms (EM)

Medical science, in the course of the last decades, has realized that wide-spread use of disinfectants and biocides in hospitals has provoked the evolution of the most virulent and treatment-resistent pathogens imaginable. A pneumonia caught on the road might be well treatable with an antibiotic, a pneumonia caught in hospital is likely to be untreatable by any antibiotic and might kill the patient.

EM stands for Effective Micro-organisms. It is a product developed by Japanese agriculturist Prof. Teruo Higa in the seventies and eighties and presently used in over 150 countries. It is produced in about 50 countries including India. EM contains lactobacilli, yeasts, and photosynthetic bacteria. These organisms are sourced from food processing and nature, are safe to handle, harmless to human health if ingested, and beneficial to man and environment. The breakthrough of EM does not consist in finding or identifying particular microbes, but in the discovery that a symbiotic culture of these organisms attains new capacities beyond expectation, and in finding an appropriate culture medium that makes the product into a marketable product with several months of shelf life.

Originally EM was developed for agri- and horticulture, and then it was found to be effective also in animal husbandry, aquaculture, composting and solid waste management, sewage and effluent treatment, and environmental regeneration. The capacity of EM to control odors, in particular if generated by bio-degradable substances, fast and efficiently, and thus to eliminate or drastically decrease all nuisance and risks affiliated with putrefying organic debris, such as flies, cockroaches, rats, spread of pathogens etc. make EM an ideal agent for hygiene management.

We have observed that a sewerage inspection manhole – which usually is the ideal habitat for cockroaches – after two weeks of EM use in the kitchen drain was completely free of cockroaches. A household that used to call a pest control agency for spraying against cockroaches every three months has, after several weeks of EM use for floor hygiene, become cockroach-free while neighboring households left and right continue to engage chemical warfare against the same pest.

EM – and potentially similar products – could well replace the use of detergents, disinfectants, pesticides etc. in the hygiene management of toilets, bathrooms, tiled walls, shelves, cupboards, floors, floor mats and carpets. Its use would result in the desired hygiene benefits, be cheaper than conventional inputs, safer to handle – even beneficial to the skin of the handler –, and generate multiple benefits downstream: enhance sewage treatment, stimulate beneficial micro-organisms in soils, revive damaged environment and stimulate biodiversity in water bodies.

Basic practical steps are as follows:
One volume part of stock solution (the product available from the manufacturer) is mixed with one volume part of molasses or jaggery and 20-30 parts of water. Fermentation for about one week under anaerobic conditions – and till a pH of 3.5 has been reached – makes activated EM solution ready for use. For practical application activated EM solution is

diluted with water in the range of 1 into 100 for hygiene management, 1 into 1,000 for agriculture, and mixed into effluents at a dilution of one into several thousand for sewage and effluent treatment.

Naturally, EM technology is an ideal combination with dewats and ecosan technologies. Independent of this, EM can assist any sewage treatment and reduce COD, BOD, dissolved and suspended solids; it decreases sludge formation and the need for desludging; it may decrease the need for aeration and thus energy consumption; and it counteracts corrosion of sewer systems and thus decreases maintenance costs. EM has been used for sewage treatment from 1990 onwards and is successfully used in a growing number of treatment plants in India.

(5) Conclusion

Following the stream of human waste disposal from downstream to upstream, this presentation has introduced concepts and technologies that have great potential to transform the field of hygiene and sanitation into a more ecological and sustainable scenario. Some of these technologies are well developed, others are in development. Research and development, and implementation and utilization of these technologies require courageous collaboration of innovative players, architects, engineers, builders, municipal authorities and citizens. In an overall strategy for water resources management, they should be utilized as widely as possible.