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**Water Resources Management in Tropical and Sub-tropical Regions
Department of Civil Engineering**

-ecosan-
**A Possible Approach to Sustainable Sanitation
And Food Security**
(M.Sc. Thesis)

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DECLARATION

I, Mr. Kalidas Neupane, state and declare that to the best of my knowledge and belief, I have prepared this thesis “ ecosan- An Approach to Sustainable Sanitation and Food Security” independently using only means and sources as cited.

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Suderburg, 8th March 2004

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Dedicated to Beloved Parents, My Wife Tara and Daughter Astha

Abstract

ecosan-“An Approach to Sustainable Sanitation and Food Security. is the descriptive analysis of current sanitation and ecological sanitation (ecosan). Efficient and equitable water resources management and provision of safe water supply and sanitation are essential for poverty reduction, ecosystem protection and sustainability. Clean water is essential for human health and survival. Safe drinking water and adequate sanitation and hygienic practices are preconditions for overall reductions in malnutrition and child mortality.

A paradigm shift from current flush and forget or drop and store type of management to sanitise and reuse type of excreta management approach is a current need to protect the world’s precious water resource and people health. A work towards integrated and holistic approach is needed which promotes the co-ordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. In this regards ecosan a new emerging sanitation approach could be an optional best concept.

It describes a whole range of technologies and institutional arrangements, which address both the issues of water scarcity and better sanitation. “ecosan” covers closed-loop systems of wastewater management, which concentrate on the principles of recycling water and extraction of nutrients.

Properly sanitised human excreta and urine can be used as an effective fertiliser and soil conditioner. By collecting the nutrients found in urine and faeces through ecosan and returning them to the environment through agricultural use,

With the implementation of ecosan an environmentally beneficial holistic cycle could be created, which stresses the link between people, soil and food production, and attempts to separate sanitation cycle from the water cycle.

Increasing crop yields through the use of sanitised urine and faeces would certainly be cost effective. Nutritional status could definitely be increased through higher crop yields, thus it could be an approach towards food security and poverty alleviation.

Key words: water crisis, poor sanitation, health hazard, lower life expectancy, closed loops, ecological sanitation, wastewater composition, urine diversion, nutrient recycling, wastewater reuse and food production.

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Abbreviation Units and Exchange Rate

BBC	British Broadcasting Corporation
BC	Before Christ
BOD	Burden of Diseases
BOD ₅	Biological Oxygen demand
CBS	Central Bureau of Static
CITA	Centro de Innovacion Tecnologica
COD	Bio- Chemical Oxygen Demand
DENET	Development Networks
DWSS	Department of Water Supply and Sanitation
ENPHO	Environment and Public Health Organisation
ESAC	Espacio de Salud AC
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GTZ	German Technical Corporation
HMG/N	His Majesties Government of Nepal
INGO	International Non-Governmental Organisation
IRC	International Water and Sanitation Centre
IWA	International Water Association
MGDs	Millennium Developments Goals
MSBH	Massachusetts State Board of Health
M&E	Monitoring and Evaluation
NEWHA	Nepal Water for Health
NGOs	Non-Governmental Organisation
NPC	National Planning Commission
O&M	Operation and Maintenance
PEM	Protein Energy Malnutrition
pH	negative logarithms of hydrogen concentration
R&D	Research and Demonstration
SIDA	Swedish International Development Cooperation
SODIS	Solar Disinfection System
SWMRMC	Solid Waste Management & Resource Mobilization Centre
TSS	Total Suspended Solid

UASB	Up-flow Anaerobic Sludge Blanket
UK	United Kingdom
UN	United Nation
UNDP	United Nations Development Projects
UNICEF	United Nations International Children's Fund
US	United States
USA	United States of America
VDC	Village Development Committee
VIP	Ventilated Improved Pit
WDR	World Development Report
WECS	Water and Energy Commission Secretariat
WFP	World Food Programme
WHO	World Health Organization
WSSCC	Water Supply and Sanitation Coordination Council

Units

g/l	Gram per litre
ha	Hectare
KJ	Kilo Joules
GJ	Giga Joules
l/s/ha	Litre per second per hectare
NRs	Nepalese Rupees
€	Euro
\$	US Dollar

Exchange Rate

1\$ = NRs 74

1 € = NRs 92

1 INTRODUCTION

1.1 Background

“Sanitation is more important than independence, “said Mahatma Gandhi. It is clearly a critical issue, which links to human health and dignity. The health costs are enormous. Polluted water kills more babies than any other substance in the world. More than five million people, mostly small children, are dying from polluted water, the main reason being that sanitary technologies are still mixing faecal matters into the water. If all households would have clean fuel, private (clean) water, private toilet it would reduce infant child mortality by roughly 1 million.

Sanitation is a double-edged sword. It is a vital part of the solution of human wellbeing but it is also a part of the problem of human health. This is because the modern sanitation is based on excessive use of water as a carrier medium for disposal and adds to the problems of water scarcity and water pollution.

Many efforts have been made in the past years to provide adequate sanitation. Despite of these efforts almost half of the people are still without these services. Centralised wastewater treatment systems do not represent a universal solution for all situations and places. Conventional systems are usually cost-intensive, and quite often proper operation of the sanitation system poses problems due to capacity constraints of the operators. Hence it can be concluded that the sanitation systems which we are using now (so called conventional systems) are not sufficient to solve current as well as future sanitation problems. Therefore, a new paradigm of thinking is required in all earnestness. But it must be made sure that the new technologies take into account cultural constraints, otherwise they are unlikely to succeed. In this regards Ecological Sanitation (ecosan), a new emerging sanitation approach, could be an optional best concept which could couple scientifically sanitation and health problems.

The term “Ecological Sanitation” stands for ecologically and economically sustainable sanitation systems. It does not refer to a specific technology. It is used to rather describe a whole range of technologies and institutional arrangements, which address both the issues of water scarcity and better sanitation. “ecosan” covers closed-loop systems of wastewater management, which concentrate on the principles of recycling water and nutrients as well

as reducing the need for fresh water, being a holistic alternative to conventional sanitary systems.

The basic concept of ecosan is to look wastewater in a different way. It is a resource rather than a waste. The faecal matter is the smallest part and if kept separate and treated in the appropriate way, it is a simple material to handle and can even provide renewable energy and restore soil fertility. Mixing this into water creates a hazard, and brings difficulties to treat at the other end of the pipe. The urine is the major nutrient resource, a natural fertilizer, in principle easy to collect and to use. Subsidies for commercial fertilisers are reduced around the world. Therefore, farmers are in search of cheap and suitable alternatives, and urine could be the answer.

ecosan systems direct the excreta flow in the correct direction, closing the nutrient loop and diverting the hormones to arable land, just as in ancient evolution time. Closing local nutrient cycles by retrieving and using nitrogen, phosphorus, potassium, other trace elements and organic components contained in the excrements, are even more important considering the disadvantages of chemical fertilisers. They are too expensive in many parts of the world or are unavailable to local farmers, and their effects on soil and food quality are in dispute. Additionally, large amounts of energy and finite fossil resources are used to produce them. An example of this is phosphorus: It is currently estimated that reserves will be exhausted in about 60 years if the present rate of consumption continues. Also in this regard, ecosan is a decisive factor

Box 1 Millennium development Goals and Johannesburg Plan of Implementation

The Millennium Development Goals aim to:

- Eradicate extreme poverty and hunger
- Achieve universal primary education
- Promote gender equality and empower women
- Reduce child mortality
- Improve maternal health
- Combat HIV / AIDS, malaria and other diseases
- Ensure environmental sustainability
- Develop a global partnership for development

With particular regard to water issues the goal of ensuring environmental stability has set itself the target of halving the proportion of people without sustainable access to safe drinking water by 2015.

(The World Bank Group: United Nations Millennium Declaration – September 2000)

Johannesburg Plan of Implementation

In the Johannesburg Plan of Implementation the goals of the United Nations Millennium Declaration were reaffirmed and further elaborated. With respect to the MDGs and water supply and sanitation they aim to:

(1) Halve, by 2015, the proportion of people without access to safe drinking water – thus reaffirming the target set in the Millennium Development Goals.

and

(2) Halve, by 2015, the proportion of people who do not have access to basic sanitation.

(United Nations: Key commitments, targets, and timetables from the Johannesburg plan of implementation, 2002)

for environmental protection and resource conservation, sustainable food production and a stable future in food security and health.

ecosan can be a dry or flush (little dilution) system. It can even be the conventional flush system upgraded by urine diversion as long as it does not disrupt the ecological loop.

The ecosan-concept fits perfectly into the Millennium Development Goals for 2015 set at the UN Summit of 2000 and Johannesburg Commitments on Sanitation. The goals most relevant to water are to stop the non-sustainable exploitation of water resources and to develop strategies, which enable an affordable and reliable water supply at a regional, national and local level.

1.2 Introduction

ecosan-“An Approach to Sustainable Sanitation and Food Security. This thesis is a comprehensive study of different literature; especially ecosan’s first and second international symposium proceedings along with its International Internet dialogues. Different experiences of ecosan pilot projects and outcomes of different national and international workshops.

The thesis is focused on managerial as well as technical aspect of ecosan. A chronological development and approaches within the ethnic groups towards the ecological sanitation in Nepal is also included.

This thesis also traced out the historical development of wastewater treatment and agricultural use of wastewater. The thesis is further focusing on nutrient values of faeces and urine and their consequences in soil enrichment and food security. Types of wastewater according to their colours and nutrients, appropriate treatment, nutrient extraction and reuse are also presented with ecosan principles and technologies.

1.3 Objectives of Thesis

In the spirit of systematically investigating new and effective approaches to address world-wide sanitation problems, current measures are very limited to specific areas and affordable community and do not serve all. Hence an alternative sanitation is the current need of today. In this context this thesis focuses on the study of ecological sanitation, an alternative to conventional sanitation.

The goal of this thesis work is “To contribute to the body of knowledge of ecological sanitation (ecosan) for sustainable sanitation as well as to increase food security” with the following specific objectives

- An approach is made to describe world sanitation situation and their effects on health as well as environmental impact and need of new paradigm shift in current sanitation
- Study of the chronological historical development and achievements towards the sanitations and health conditions.
- To evaluate the trend of wastewater treatment technology and give overview of their consequences in ecological balance.
- Comparison of different types of conventional sanitation systems and their shortcomings
- To describe ecological sanitation its different aspects, advantages, disadvantages and promotional terms.
- Comparative evaluation of ecological sanitation against the traditional systems in terms of cost and environmental impacts.
- To classify different types of household wastewater according to their colours and their nutrient contents and their suitability of application.
- To classify and describe different types of utensils of ecosan depending upon the available technology and resources.
- To describe the different technologies for excreta treatment and their use in decentralised units for food production and soil fertility enrichment.
- To evaluate the current sanitation practices of Nepal and their consequences in terms of health and food security.
- To study the chronological development of ecosan practices in Nepal.
- To conduct case studies of different on going ecosan pilot projects in Nepal.
- To propose potential strategies to address sanitation problems in Nepal.
- Discuss the relevance of lessons learned based on pilot ecosan projects and further development in context of Nepal.

1.4 World Water and Sanitation Crisis

Water covers about two-thirds of the Earth's surface, admittedly. But most this is too salty for use. Only 2.5% of the world's water is fresh water, and two-thirds of that is locked up

in the icecaps and glaciers. The rest, about 20% is in remote areas, and much of the rest arrives at the wrong time and place, like monsoons and floods. Hence less than 0.08% of all the Earth's water is actually available for productive use. Yet over the next two decades water demand is estimated to be increased by about 40%. It is necessary to provide safe drinking water to all the people living in the world, but the water is being far away from being sufficient to the world population. The question arises, how much water is needed? And how much is available? And how it can balance? There are only two options to balance it- either to increase the source, which is impossible or to reduce the demand, which can be done.

Under the pressure from population growth, rapid urbanisation's, and extra consumption of water for higher standard, are threats to freshwater supplies. A tendency to see plentiful supplies of water for flushing as a key to effective sanitation is increasing. This is no longer realistic. In the large part of world, the availability of fresh water is scarce. Already some more than 80 countries with over 40% of world's population are suffering from water shortage either for few months or whole year. Partly or fully the chronic scarcity threatens the Middle East, Northern China, Central America, Western USA, Sub-Saharan countries and many Asian countries.

Today nearly half of the world's population has no access to safe drinking water and proper sanitation. As far as remaining 50% is concern it relies on such sanitation approaches, which falls into one of the two categories: water borne system (Flush and discharge) and pit latrines (drop and store). Both flush and discharge and drop and store technologies were built on principle that the nutrients we excrete have little value and waste is suitable only for disposal. Consequently, the environment is polluted, nutrients are lost, and wide array of health problem aroused.

In the studies made by many worlds organisations including WHO has brought following fearful facts faced today in health and sanitation.

- 80 % of all diseases and 25 % of all deaths in developing countries are caused by polluted water (WHO),
- Almost 2,5 billion people do not have access to adequate sanitation and wastewater treatment facilities,
- 6000 people die everyday as a result of coming into contact with contaminated water,

- More than 90 % of wastewater world-wide is discharged into the environment either uncontrolled or after unsatisfactory treatment,
- Between 1.2 and 1.5 billion people do not have access to safe drinking water. The estimated mortality rate in 2000 as a result of illnesses caused by contaminated drinking water and poor sanitation and hygiene in developing countries was approximately 2.2 million. Worldwide, over 2 billion people were infected with schistosomiasis and intestinal helminths, of which 300 million suffered serious illness, most of them children under the age of 5.

All the above indicators show that they are getting worse and that we are facing a serious world water crisis, which will affect all, particularly the poor. They suffer most from this decrease in fresh water resources, and bear the brunt of water-related diseases and damaged environment. This water crisis is a direct result of the sanitation crisis, which, more or less often discussed, is causing huge adverse effect on health and environment around the world. The intricate interdependence of current sanitary systems with the water cycle requires both these issues to be considered together, before we can consider how both these problems can be de-coupled from one another.

1.5 Food Security situation

Sanitation, Hunger and poverty are the three daunting development challenges confronting the world to day. Of the world population of around 6 billion about 1.3 billion people in the developing countries live on a meagre income of less than US\$ 1/day (WDR 1996). About 800 million people are food insecure and about 500 million are chronically malnourished. It is not the production, but the distribution and access to food for healthy and active life is the critical challenge (IFAD). The hunger and poverty situation is more alarming in the developing world.

Food security can be defined as sustained access of adequate and safe food supply for an active, healthy and productive life. The FAO indicator for subsistence level is 2250 calories/day/cap (0.8 gm/kg body wt. protein and other essential fats and vitamins) food requirement. Food insecurity is growing over time. Broad trends in food production and prices indicate an improvement in food security, but the aggregate picture masks variations in food security among regions, countries and income groups. A recent report of 67 countries indicates that while some regions are improving, others are getting worse (FAO). Nearly half of all the deaths of children occur because of malnourish. Even a

mildly underweight child has an increased risk of dying. WHO estimates that of the 10.4 million deaths of children less than 5 years of age that occurred in developing countries during 1995, about half were associated with malnutrition. Malnutrition not only increases mortality, but it also reduces the quality of life, impairs immunity against diseases, and hinders cognitive development. Certain nutrient deficiencies lead to blindness, decreased work capacity and increased morbidity. All of these conditions financially drain families, communities, and countries.

Food security is greatly influenced by physical, economic, natural resources, socio-cultural, gender and ethnic factors; and could be chronic or transitory. Many children and women “the most vulnerable groups who are at risk of becoming malnourished and food insecure” suffer from “hidden hunger” or micro-nutrient deficiencies. The most common micro-nutrient deficiencies are in iodine, Vitamin A and iron, and in some locations zinc, selenium or other nutrients may also be deficient. Urban agriculture can help supply these needed nutrients.

Food security is linked to food intake at the individual level, and food availability at a higher level. Food security will be achieved when poor and vulnerable households living in the marginal areas, have physical and economic access to food, and will be achieved when they have sustainable livelihood.

There are three basic approaches to correcting nutritional deficiencies and malnutrition: food supplementation, control of public health diseases, and food-based approaches. Food supplementation provides nutrients in some form (e. g., Vitamin A capsules). Public health measures prevent and/or treat diseases that lead to specific nutritional problems (e.g., through de-worming or improved sanitation). Because ecological sanitation seeks to sanitise faeces prior to releasing them in the environment, it should be a powerful public health tool not only to reduce disease and death, but also to improve nutrition status through improved diets. Food-based approaches include dietary diversity, food fortification and genetic alteration of seeds/plants.

Sole reliance on food produced in rural areas will not achieve food security among urban poor. Hence urban agriculture is needed. Urban agriculture is the growing of food and non-food plant and tree crops and the raising of livestock (e.g., cattle, poultry and fish) both within the city limits and on the fringe, in peri-urban areas. Urban agriculture is

ubiquitous. One of the most important considerations for urban agriculture is food security, and this is one of the strongest arguments used to accommodate the rise of farming in cities.

Production of food in urban areas can contribute a considerable share of a household's total food intake. Urban and peri-urban food production was found to be 60% in Kampala, Uganda and 80% in Nairobi, Kenya (SIDA publication on water resources No 18). Urban agriculture has the potential to invigorate the urban economy, possibly eliminating income transfers from food subsidies, which amount to 15-25% of real income in low-income households. In Bolivia, urban food products supply women producers with 25% of their income. In African cities, urban agriculture increased income by 67% in Dar es Salaam, and in Addis Ababa, the incomes of urban co-operative farmers were well above the median, and half were earning more than the city's employed population.(SIDA publication on water resources No 18). This is even true for the farmers in urban areas of Nepal.

By applying closed nutrient loop (ecosan principle), improving soil fertility and structure of the limited areas in urban and peri-urban, yields could be increased per unit space. This could be achieved even with the lower external inputs including water. It should also be noted here that production of food closer to consumers also strengthens local communities. This closed loop approach is suitable both in rural as well as urban area to overcome the food insecurity.

1.6 Sanitation Situation in Developing Countries

At present more than 18 mega-cities in developing world have population more than 10 million each. Central to the urbanisation phenomena are the problems associated with providing sanitation services. Currently, providing housing, health care, social services, and access to basic human needs infrastructure, such as clean water and the disposal of effluent present major challenges in these areas to engineers, planners and politicians. Safe water access and adequate sanitation is crucial here, this makes the difference between life and death. These services are heavy cost intensive and people should be capable to pay an economic price for it. But in the developing countries people are rarely ready to pay economic price for health and sanitation. People are often poor to pay for the supply

of complete safe water, government is not strong and has several other obligations rather than sanitation, and the fund available for ideal sanitation choice is very limited.

It is estimated that in developing world 300 million urban residents have no access to sanitation and it is mainly low-income urban dwellers that are affected by lack of sanitation infrastructure. Approximately two third of the population in developing world have no hygienic means of disposing of excreta and even greater number lack adequate means of disposing of total wastewater. Open defecation in field and water bodies is still common in developing world. Even the limited sewer facilities that are provided in the city discharge into the nearest water bodies. Improper construction (watertight) of septic tank, which rather functions as a soak pit, leaches the harmful elements and pathogens into the ground threatening the ground water quality.

If adequate sanitation is taken to mean a toilet connected to a sewer, there is a significant lack of adequate sanitation through out the developing world- even in large cities. The sanitation coverage is much worse than water coverage in every region. Today, Approximately 1.1 billion people have no access to safe water and twice as many (2,4 billion people) have no access to adequate sanitation. Among them 80% live in Asia. In south Asia only 37% of the population has access to adequate sanitation (Figure 1). Some 1.4 million people of this region still either defecate in open areas or use unsanitary bucket latrines.

Furthermore the rural coverage even lacks remarkably behind the urban areas: 2 billion of the total 2,4 billion live in rural areas. In the 1990s the number of children killed by diarrhoea as a result of unsafe water and sanitation

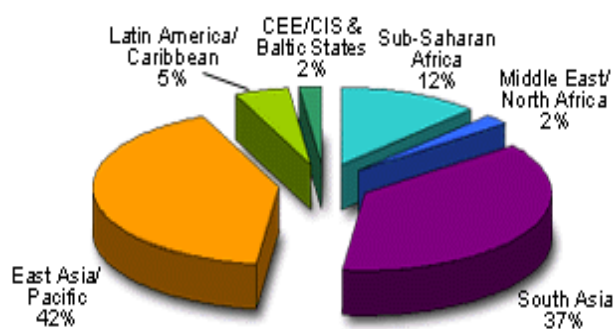


Figure 1 Distribution of regions with access to improved sanitation - in % from total 2,4 billion
(<http://www.childinfo.org/eddb/sani/current.htm>)

exceeded the number of people killed in armed conflicts since the Second World War. Moreover half the world's hospital beds are occupied by patients with water – borne diseases, for expensive curative services that could easily have been prevented.

2 WASTEWATER

The word “wastewater” is combination of waste and water. Wastewater is originated from use of water. The practice of managing wastewater is from the beginning of civilisations. As the density of population is increased the problem of feeding and supplying water as well as problem due to wastewater has also increased consequently. There are many epidemic outbursts due to the lack of its proper management and it is still evident many part of the world. Many practices have been adapted to manage wastewater in the past and even today. History shows that change comes in cycles first and the practices come back into use and this may come in different time in different places. Perhaps the problem that was in London 300 years before could be same today in many cities of the developing countries. Therefore knowledge of the chronological development of sanitation management from the past is essential for a student of wastewater management.

In the following subheadings an overview in different time trends of wastewater treatment practices, classification of wastewater according to their colour and its use around the world is tried to present. The time trend is given in Annex 1.

2.1 Historical Development of Wastewater Treatment Practices

The use of sewers is not new. In the Mesopotamian Empire (3500 to 2500BC) some homes were connected to storm water drain system to carry away wastes. In Babylon there were latrines, which were connected to 18-inch (450mm) diameter vertical shafts, lined with perforated clay pipes leading to cesspools. In the Indus city to Mohenjo-daro (located in Pakistan) the wealthy as well as some of the peasants used latrines and cesspools. These were connected to drainage systems in the streets from where the liquid flowed to cesspools or through drains to the nearest river.

The ancient Greeks tackled the problem of waste in different way. They had public latrines, which were connected to sewer, the system was combined with storm water to a collector basin out side the city. Form there bricked lined conduits took the wastewater to agricultural fields, used for irrigation and to fertilise crops and orchards. The sewers were periodically flushed with wastewater. (Wolfe 1999)

2.1.1 Roman Times: 800 BC to 450 AD

In about 800 BC Romans constructed the Cloaca Maxima, the central sewer system, to drain the marsh upon which Rome was later built. The system took surface water to the river Tiber. By 100 AD the system was almost completed and connection had been made to some houses. Water was supplied by an aqueduct system which carried away wastewater from the public baths and latrines to the sewers beneath the city and finally into the Tiber. The streets were regularly washed from the aqueduct system and the waste washed into the sewer (Wolfe 1999)

The Romans knew the need of clean water and need to dispose wastewater away from the source of drinking water. In UK they built their villas on the side of hills where springs emerged from the hills side, and dispose of their wastewater away from their villas. It has long been known the Romans had build brick lined sewer in London, which they called Londinium.

2.1.2 The Sanitary Dark Ages: 450 to 1750

During this period the main form of waste disposal in European cities such as in Paris and London was simply to dispose it off in the street. Waste was just thrown from windows and God helps anyone who happens to be passing.

Around in 360 AD waste in Paris was put into the streets where rainfall and heavy traffic help it to decompose and it was picked over by pigs and wild dogs or collected by scavengers for fertiliser (Wolfe 1999). In the thirteen century King Philip Augustus orders the city's roads to be paved to reduce the stench of the mixed garbage and sewage. In 1348 king Philip VI formed the first corps of sanitation workers to clean the streets. He also issued an ordinance that required all citizens to sweep in front of their houses and dispose of garbage in dumps. The first covered sewer was built in 1370 which dump sewer into the river Seine near the Louvre. The French monarchy only took action over the sewers if affected by the smell. King Francois I ordered house owner to build cesspool for sewage collection in new house. These constructions were used until the late 1700s.

In London cesspool were in existence in 1189. The first mayor of London, Henry Fitzalwyn, ruled that they be located no less than 2.5 feet (75 cm) from the neighbouring buildings if made of stone or 3.5 feet (105 cm) if constructed of other materials (Wolfe 1999). Cistercian monks in the south of Scotland build stone lined sewers to drain latrines

in the monks cells to the near by watercourse. The sewage of the city was to be collected in cesspool and their contents conveyed into the countryside for the application to land. “Racker”, who removed the foul sewage from the cesspool and sold it to the farmers just outside the city wall. By the 1300s the city of Norwich, was selling night soil to the farmers outside the wall of city as fertiliser (Campbell 2000). Seven hundred thousand Londoners died from cholera, typhoid, plague and pestilence before the city realised that its own waste was causing the problem (Wolfe 1999).

In 1596 Sir John Harington had designed two water closets (called the Necessary) for Queen Elizabeth I but these did not achieve popularity until adopted by Londoners late in the 1700s (Thomas Crapper 1861).

2.1.3 The Age of Sanitary Enlightenment and the Industrial Revolution: 1750 to 1950

This period is characterised by high population growth in the new industrial cities, leading to high population densities. In this period growths as well as death rates were increased rapidly. The increasing death rates were related to water and waste-borne diseases.

2.1.3.1 The Age of Miasmas

The early part of the nineteenth century (1820 to 1850) saw great debate as to how disease like cholera, typhoid was spread and what would be done to prevent it. This was the era of Miasmas. The belief was that that Miasmas (noxious gaseous emanations and infections derived from the rotting waste which abounded in streets and public places) led to disease. In other words people were made ill as a result of poisoned air. This idea was put forwarded by “Miasmatists”, including Florence Nightingale and Edwin Chadwick. Another rival group, the “Contagionists” believed that disease was passed by physical contact, weather from human to human, or through the consumption of infected food or water. Drs John Snow and William Budd were amongst those who saw that infected drinking water seem to be likeliest source of disease particularly cholera (Chartered Institute of environmental health 1998).

Further more Chandwick proposed a hydraulic system that would bring portable water into the homes equipped with water closets and than carry effluent out to the public sewer lines to be deposited as ‘liquid manure’ onto neighbouring agricultural fields (Melosi 2000). He also proposed the ‘backyard tubular drainage’ system in which sewage was

drained from the backs (where the privies, latrines and water closets were placed) of back-to-back houses (being built in the proper areas in the rapidly expanding cities) rather than putting sewer connection through the front of houses as usual (General Board of health 1852). He claimed that it would reduce the cost of sewer run by two third to four fifth and allows the use of smaller sewers. This idea was successfully taken up 130 years later in Brazil (Mara 1999).

The water closet, which began to be adopted by Londoners in the late 1700s, gained tremendous popularity in the 1800s because of its ability, once connected to sewer, to immediately remove human waste from house. This improved the living conditions in homes but transformed the river.

Major contribution at this time was made by Drs John Snow who provided the link between disease and sanitary conditions. In 1849 he wrote an article 'on the mode of Transmission of Cholera'. He believed that it was transmitted by water contaminated by the vomit and faecal matter of cholera patient. He was able to prove the theory in 1854 when a severe bout of cholera occurred in London (Binnie 1999). He carefully documented the number of cholera death occurring in house served by two of the cities water companies, which served a total of about 300,000 people (BBC 2001)).

At this period industrialisation was in Europe, particular in the German states. Epidemics of cholera had periodically caused heavy losses of life in large European cities (Evans 1987). The English engineer William Lindley began the first comprehensive sewer network in Europe in Hamburg in 1848 (Melosi 2000, Evans 1987). He proposed a sewerage network for the central city of Hamburg in 1843 and this was finally accepted with construction starting in 1848. The system came into operation in 1853 and the district of St Pauli was connected in 1859. By 1860 there were 48 km of sewers in the city but this network did not cover the new suburbs (Evan 1987).

2.1.3.2 Land Treatment

The first treatment process applied for wastewater was land treatment. This is a process, which went back to Roman times, and even in to the pre-historic times (Wolfe 1999). One of the first organised users was James Smith, a Stirlingshire cotton mill owner. He found that taking the excrement from his factory privies to his farm improved crop yield (Stanbridge 1976). In 1942 he moved to London and adopted the ideas of James Vetch for

distributing sewage on the land by hoses and jets. Edwin Chandwick enthusiastically followed these ideas. He was greatly encouraged by Justus von Liebig, the eminent German chemist, who argued that the fertiliser value (particularly the phosphate content) should be used on agricultural land (Stanbridge 1976). A whole range of idea modifications and process designs were used over the next fifty years. The large towns and cities bought more and more land for their sewage farms. Until now many sewage treatments works are referred to in common parlance as sewage farms. The system was gradually abandoned because of large area requirement. The lands suffered from clogging and water logging and were unable to achieve the higher hygiene standards required.

2.1.3.3 Chemical Treatment

The first Chemical treatment of sewage discharges had been used in Paris in 1740 using lime as the precipitant (Wardle 1893). Between 1850 and 1910 there were several hundred patent applications for recipes for treating sewage. The purpose of this was

- To treat the sewage in removing enough of the pollutant concentration to get safely disposed, and
- To provide artificial guano

It had been shown that sewage could improve fertility but the sewerage was diluted and it needed large areas to apply. By using chemicals to enhance the settlement rate and recover more of the solids in a much smaller volume the sludge produced could provide the concentrated fertiliser. Hence it was thought that two problems could potentially be solved at once. Chemical treatment was helpful in removing some of the polluting load but it had two main disadvantages:

- It could only remove suspended pollutants and this left about one third of the total pollutant load present in the treated sewage, and
- It produced a much larger quantity of sludge, which was difficult to dispose.

When the biological processes came alone at the end of the 1800s then chemical treatment gradually went out of use. It underwent a revival in the 1970s for the removal of phosphates, and continues in this role today (Culp and Culp 1971).

2.1.4 Development of Basic Treatment Process 1870 to 1914

In this period the thoughts of „process development “come in different literatures, at the beginning it was gradually brought into practice. People thought that the sewage could also be filtered as the practice was for drinking water. Primary settlement and Biological filter concept are major development of this period. Further more the development of Royal Commission on sewage disposal (discussed later) is remarkable outcome of this period.

2.1.4.1 Primary Settlement

In land treatment practices, trenches/ pits were dug to reduce the load on the land and to sediment heavier solids prior to application. After filling of one trench next trenches were dug one after the other. This led to development of primary settlement.

The next development consisted of flat- bottomed tanks, which were sometimes clay-lined. It seems that these were operated on a fill and draw basis, with the removal of water by siphoning. In this patent of 1846 for the lime as a precipitant William Higgs mentioned ‘tanks or reservoirs in which the content of sewers and drain from the cities, towns and villages were to be collected and the solid animal or vegetable matters therein contained, solidified and dried’ (Stanbridge 1976).

Horizontal flow tanks seem to have been invented in the 1850s and Radial-flow tanks in 1905. Many of these systems had to be manually de-slugged with scrapers and squeegees. There were some bucket-and-winch operated systems for de-slugging in the 1850s and 1860s but true power operated mechanical system did not make an appearance until the 1900s.

In 1960, L.H. Mouras of Vesoul in France designed a cesspool in which the inlet and outlet pipes dipped below the water surface thus forming a water seal. This so called ‘fosses Mouras’ was described by the Abbe Moigno in ‘Cosmos les Mondes’ in 1881 as it had been found that liquefaction of the solids took place, which was attributed to anaerobic action (Stanbridge 1976). This is a pre cursor of modern septic tanks (Melosi 2000).

The Imhoff tank designed in 1906 by Karl Imhoff of the Emscher Drainage Board in Germany. This improved upon the design of septic tanks by using two chambers, which

allowed the separation of the settlement and sludge digestion processes (Wolfe 1999). The system was successful and is still in worldwide use.

2.1.4.2 Biological Filter

Up to 1900 virtually all the sewer treatment, where it existed, was carried out by land treatment. But these methods were not always successful, as water logging was a major problem. As the population continued to expand it became more and more difficult to find sufficient areas of land on the fringes of the towns and cities. The idea that there might be better ways, using 'organisms' was gradually emerged. In 1870 Sir Edward Frankland established the fundamental principle of filtration through soil on which much of future developments depended (second royal commission on river pollution 1870). In one of his experimental filter containing coarse porous was found that a rate of application of $0.045\text{m}^3/\text{m}^2$ of bed per day produce a well nitrified effluent. This filter showed no sign of clogging after four month of operation (Stanbridge 1976). In 1882 Warrington suggested the first idea of filter bed, which would have great oxidising power (Nicoll 1988). He also suggested that the use of filter containing more porous medium than natural soil is essential for better efficiency (Stanbridge 1976).

The dramatic breakthrough in biological filter design for more reliable performance was made in the US at the Lawrence Experimental Station for the Massachusetts State Board of Health (MSBH), established in 1886 (Melosi 2000). They confirm that gravel was the best filtering medium and in November 1890 first Trickling Filter was commissioned (Stanbridge 1976).

The contact beds developed in the 1890s were, essentially tank containing broken stones, slate or other coarse inert substances, which provided a relatively large specific surface area for microbial growth. They were operated on a 'fill and draw' basis, bacteria on the filter bed decomposed the organic matter in the sewage. When the filter was empty, bacterial growth would be stimulated by the flow of air through the voids between filter-material (American Public works Association 1976).

Between 1895 and 1920 many biological filter were installed to treat sewage. From this time it was a case of gradual development of the biological filter process, which does not look different today that it did in 1900. Many of the early 20th century systems are in operation throughout the world with this process.

2.1.4.3 First Standard on Sewage Disposal

In 1898 an important event occurred in the formation of the Royal Commission on sewage Disposal by the UK government. The commission was to write a series of ten reports between 1901 and 1915. The royal commission's eighth report in 1912, had significant outcome towards sewage treatment as it was concerned with the standards (and testing methods) to be applied to the sewage and effluent being discharged to the rivers. It recommended the so-called 20:30 standard, 'Royal Commission Standard' or 'General Standard' which was copied by many other countries. This is the general standard of 20mg BOD₅/litre, 30 mg suspended solids/litre for effluent specific to a dilution of at least eight folds being achieved in the receiving water.

2.1.5 The Age of Process Development (Activated Sludge) 1914 to 1965

In 1913 activated sludge process was discovered and organised by W.T. Lockett in the course of some bottle experiments in the laboratory of the Manchester sewage treatment works. In 1938, the activated sludge process was in operation in hundred of full-scale sewage treatment works and more than a billion gallon of sewage were treated every day. Activated sludge plants are now operated all over the world. This astounding growth in the past twenty-five years is unparalleled in the history of sewage treatment. Sewage treatment works in our modern cities can no longer be obnoxious or insufficient. They must be free from odour, occupy limited area, and be amenable to scientific control (Federation of sewage work association, US).

The development of the process was held up due to the World War II until late 1948 and later the search for a better control plan performance began. This search was to occupy many workers over the next forty years in many different countries. The activated sludge process and its many variants are now is the main engine of secondary sewage treatment and has the biggest impact of all process upon environmental improvement in the past century.

2.1.6 Process Refinement Towards Standards and Environmental Protection

In this period the emphasis has been made on: wide spread application of known techniques for BOD and TSS removal, Environmental protection and improvement by the removal of nitrate, phosphate and ammoniac nitrogen and disinfecting. More fixed film

process variants of the original biological filters have gradually been developed. Examples of these such as submerged aerated biological filters and plastic media biological filter systems are now common.

2.1.6.1 Nutrient Removal

One of the major problems with activated sludge systems in this period was that the oxidation of ammoniac nitrogen (nitrification) was not reliable or predictable. The solution to this was discovered by an investigation by Downing et al. (1964). The result of that work is now incorporated into design methods and computer models. Biological de-nitrification had been known about since the late 1800s but de-nitrification first took place in sewage treatment in the late 1930s (Edmondson and Godrich 1947). They use the nitrate as a source of oxygen for an overloaded biological filter. In 1962, in the US, Ludzack and Ettinger put forward the use of anoxic zones achieve biological de-nitrification in an activated sludge process. This concept is now standard practice in all Activated Sludge process and some fixed film processes.

The problem of how to remove phosphorus in activated sludge process was solved by James Barnard (1974) and his colleagues in South Africa. This technique is now applied worldwide. Nutrient removal processes to help prevent eutrophication and to protect water sources from high nitrate concentrations have developed rapidly in this period.

2.1.6.2 Standards

In the 1970s, a move started to raise standards and improve environmental protection, to some extent driven by public opinion and greater public awareness. The first step in this direction was the clean water act in the US in 1972. As the European union expanded from the original five states to the present fifteen there have been a series of directives aimed at the prevention of water pollution and protection of cross border water resources. This began with the surface water Directive in 1975 followed by the bathing water directive in 1976, the fishing Water Directive in 1978, the Shellfish Water Directive in 1979 and the Drinking Water Directive in 1980. The Urban Waste Water Treatment Directive (CEC 1991) has had a very significant impact upon operators in the last decade since it provides European-wide standards and introduces more stringent standards for nitrogen and phosphorus level.

2.1.6.3 Sludge Treatment and Disposal

Little has been said about sludge treatment and disposal in the earlier periods. It has become more significant problem in the last twenty years, as easy disposal routes have been gradually closed. It is no longer permissible in Europe to discharge sewage to sea, a common practice until the 1990s. Standards for disposal on agricultural land have also become tighter. Many new processes have been proposed and developed. The most common used in the UK is still on agricultural land but incineration and drying are becoming more popular. *The sludge treatment and disposal route should be considered at the earliest stage in any process design.*

2.1.6.4 Computer Modelling and Control

The advent of industrial electronic computers and electrically controlled valves in the late 1970s made automatic control of process units a possibility for the first time, and this has progressed apace since that time. In the late 1980s when the first affordable first personal computer (PCs) becomes available, there was another change with respect to the development of the computer models of the treatment processes, in particular the activated sludge process, which had previously required powerful mainframe computers. The IAWPRC model (based on COD) (Olsson and Newell 1999) and the WRc STOAT model (based on BOD) (Smith and Dudley 1998) have led the way. They are particularly helpful in allowing a dry run of weather conditions and checking how outside factors, such as storm conditions will affect the treatment process (Smith et al. 1998).

2.1.6.5 Reed Beds/Constructed Wetlands

Over the past twenty years there has been a rise in interest in less sophisticated drainage and treatment system such as pond and wetland treatment systems. This has been derived in Europe by the desire to safe treatment in lower cost.

The use of reed beds also known as constructed wetlands came in 1980s. These systems are particularly useful for small rural decentralised wastewater treatment systems.

2.1.6.6 Anaerobic Treatment of Wastewater

Over the past fifty years a number of attempts have been made to apply anaerobic processes to the treatment of wastewater. There has been a considerable success in treatment of agricultural and industrial wastewater largely based upon the UASB (up-flow

anaerobic sludge Blanket) reactors pioneered in the Netherlands in 1970s (Zeeman et al. 2001). These process systems have been successful where wastewater is usually warm or concentrated (or both) organic wastes. Municipal domestic sewage is usually cold and weak and so efforts to apply anaerobic treatment have not yet been successful. Recently considerable research effort has been devoted to the anaerobic treatment of the concentrated wastewater that results from the separation of 'grey' and 'black' waters from houses. This looks to be promising possibility for localised decentralised treatment, but will not be the solution to treatment of the present weak domestic sewage.

2.1.6.7 Membrane System

One of the most important developments relates to the use of membranes. This is possibly the most novel process of the past forty years. Tertiary or Quaternary treatment using membranes for removing bacteria is already carried out in Europe, Australia and the US. The potential for use of membranes in reverse osmosis, Micro filtration and Ultra filtration has been known since 1990s but research and development has only recently resulted in membranes that are cheap enough to allow for their use with concentrated waste such as sewage.

2.1.7 Concept of Closed Loop Sanitation

Closed loop sanitation concept is emerging these days. Urine diversion, composting and ecological sanitation are major feature of this concept. No single person can be credited with inventing this concept. They have been practised in China and elsewhere in Asia for hundreds, maybe thousands, of years. But since the emergence of the environmental movement in the 1960s and 1970s, try to combine these old concepts with present day science and technology and adapt them to modern urban living. This means attractive design, freedom from odours and flies, easy operation, effective pathogen destruction, cost-effectiveness, which create the institutions required to manage ecological sanitation systems on a large scale.

Today's ecological sanitation is the beginning of last century. it is still in the early stages of the development and the concept is unknown and likely to be misunderstood. It cannot be imagined what ecological sanitation may look like 50 or 100 years from now. So far the emphasis has been on the design of on-site or in-house devices and how to operate

them. But in the future it will be able to apply ecological principles to towns, big cities and whole metropolitan areas.

2.2 Reuse of Wastewater

Many communities in developing countries do not have reliable access to clean water. As the demand for water increases, making more efficient use of water becomes more important. Water reuse should be seriously considered before water availability is matched by water demand. All water doesn't need to be treated to potable standards. Most water reuse is informal and goes largely unrecognised by the public and by many professionals.

The reuse of wastewater may be in two forms either direct or indirect. **Direct** re-use is the planned and deliberate use of treated wastewater for some beneficial purpose, sometimes including drinking. Direct reuse is generally unacceptable to the public because of both the expense and the attitudes of the community. Normally people will drink wastewater from an indirect source unless there is evidence to suggest that it is unsafe to do so. People will not, however, drink water from a direct source unless it is proven to be safe. **Indirect** re-use refers to water that is taken from a river, lake, or aquifer, which has received sewage or sewage effluent in some way. However, till now the most efficient use of wastewater is found in agriculture sector.

Water scarcity, household wastewater/ excreta as resource, population growth and urbanisation, and food securities are the driving forces for using household wastewater in agriculture. In many arid and Semi-arid countries, household wastewater is becoming an increasingly important source of irrigation water. The demand of growing urban communities for both food and water requires the agricultural sector not only to increase food production but also to reduce the use of natural water resources. At the same time the volume of sewage effluent is increasing, and safe disposal can be difficult. The use of reclaimed household wastewater for irrigation is the obvious solution.

In a separate system where only the grey water flows, another most use of wastewater is for recreational purposes. Many examples are found in the use of wastewater in park and such public places as a fountain or small pond.

2.2.1 Current Situation on Reuse of Wastewater

The use of wastewater is found in two ways either treated or untreated. Untreated are common practices in developing countries and they reflect indirect use in most of the cases. Treated are used in both developed as well as developing countries where the facilities of treatments are provided. According to World Health Organisation (WHO) more than 10 % people around the world are thought to consume foods that are produce with wastewater in irrigation however the trend is increasing day by day. Further more 20 million hectares in 50 countries are irrigated with raw or partially treated wastewater. If we see the use of treated water in agriculture, it is quite harassing, only around 40% of treated wastewater is use in agriculture or other productive use other wise it is simply discharged to the water bodies. Apparently North America is found to be the most prominent continent to use treated wastewater in agriculture with more than 90%. As compare to this no use of treated wastewater found in Africa with an exception of South Africa. The use of treated wastewater in agriculture in Europe is satisfactory with 60%, Asia with 35% and 14% in Latin America and Caribbean. From this information it could be concluded that effective utilisation of wastewater is found in developed countries and only the little amount is used in developing countries, which means there is still a big potential of using wastewater for agriculture/other purpose in developing countries.

The re-use of wastewater for irrigation is more successful near cities, where wastewater is easily available and where there is a market for agricultural produce. The storage may be requiring sometimes when the demand does not match with the supply.

Wastewater may be the important resource in urban agriculture. Different Studies in South America, Asia, and the Middle East have shown that farmers prefer to grow produce in the following order of priority:

- Vegetables (to earn a regular income);
- Fruit (to earn a regular income or foreign exchange);
- Cereal crops (of lower value);
- Fodder crops (of low value);
- Other crops for which there is a demand (herbs, spices, flowers, etc.)

2.2.2 Constraints in using Wastewater

Although the use of wastewater is beneficial in many respects but there are many constraints to use it widely due to its pathogen content and lack of technology and the perception of people towards it. Till now no extensive research has been carried out as far as use of wastewater is concern. There are no proper guidelines so far as how and when the wastewater should be used. Handling wastewater is also an important factor for the health.

Wastewater contains many harmful pathogens and there are many exiting examples, which causes outbreak of serious diseases and epidemics. Further more wastewater may contain chemicals, which may have adverse effects on growth and yield of the plants. Apart from risk of outburst of different diseases lack of technology and fund availability, Perception and cultural barrier, Lack of appropriate legislation and quality standards are the major constraints to the use of wastewater.

3 SANITATION

There are three types of sanitation systems according to sewage/excreta management technologies. One is flush and discharge, second one is drop and store and third one is sanitize and reuse. The first two belongs to conventional one where as the latter one is more or less belongs to ecological sanitation. In this chapter conventional systems are described and the ecological sanitation is described in chapter 4.

3.1 Conventional

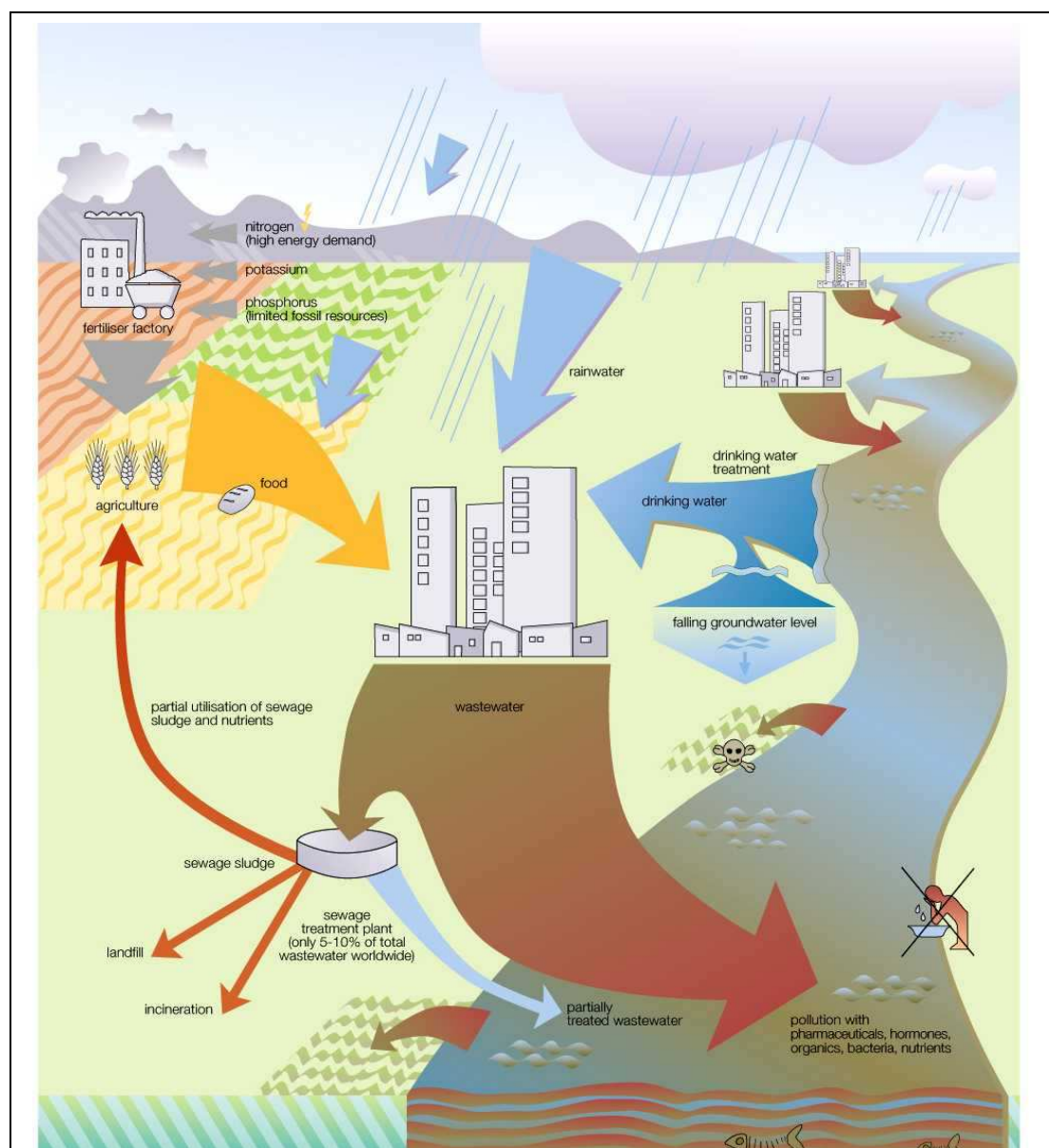


Figure 2 Shortcomings of conventional sanitation systems (Source: gtz ecosan)

Figure 2 represents the conventional sanitation system and its shortcomings. “Modern” water-carriage sewer systems are relatively new technology, which only began to spread in European cities from around the end of the 19th century, as a result of piped water supply systems which lead to an increased water consumption and subsequent wastewater production. This first caused stagnant pools and streams of wastewater in the streets of the cities that led to outbreaks of cholera and other diseases. Sewer systems were then gradually introduced. Later, when this resulted in heavy water pollution, mechanical wastewater treatment plants, biological treatment for the degradation of the organic and tertiary treatment for the removal of nutrients were added in order to reduce the pollution and the eutrophication of the receiving water bodies. This now represents the present state-of-the-art in wastewater treatment and popularly known as conventional sanitation system.

3.1.1 Flush and Discharge

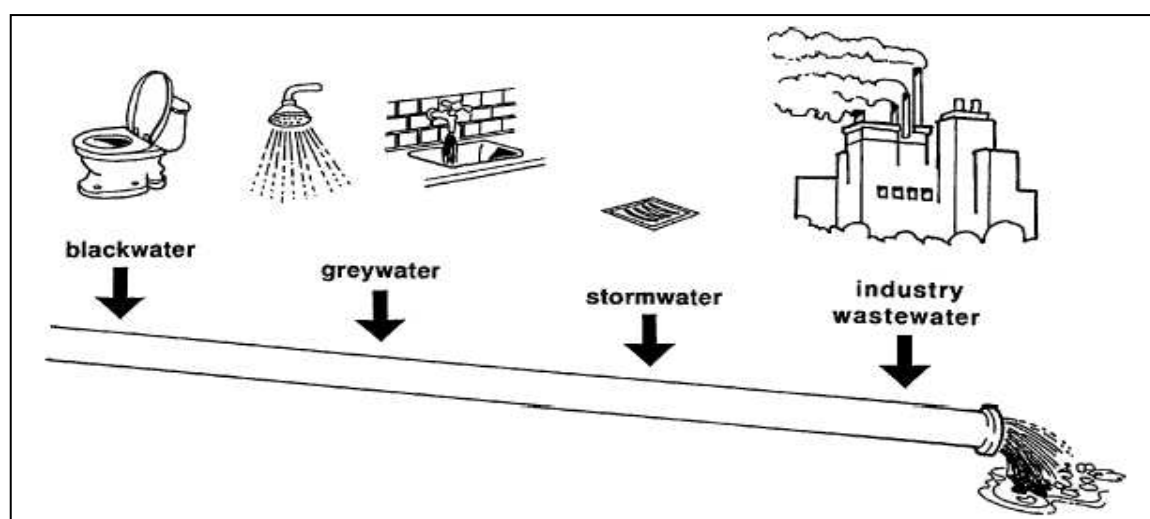


Figure 3 In a flush-and-discharge system. (Source: SIDA publication)

Flush and discharge is such a technology of wastewater management in which the excreta is flushed through water and transported by means of sewer or discharged into other water bodies or made septic into septic tank. The design of this system is based on the premises that the excreta is a waste and that waste is only suitable for disposal. Further more this technology does not consider the effects of waste at the end of other side of pipe due to which it is also called as flush and forget technology.

Flush and discharge is popular among the user due to its easiness and relatively low problematic to the first user. It is universally regarded that this technology is the ideal one for wastewater management in urban areas. And almost without giving the second thought

it has been promoted in cities and towns around the world, even in poor countries where people cannot afford it and in arid areas where there is hardly enough water for drinking. But in reality it is making the problem of sanitation much worse rather than solving it in totality. Here a relatively small amount of dangerous material especially human faeces/brown-water is allowed to pollute water bodies such as rivers, lakes and ground water as shown in Figure 3.

The flush and discharge technologies is based on following assumptions

- Fresh water is unlimited resource,
- At the end of pipe the sewage is treated
- The environment can take care of the discharge from the treatment plant

However, none of these assumptions are correct: The basic problem is the disposal of human faeces and urine, not sewage.

- Fresh water is never be the unlimited resource; outright shortage of it will become very soon, a major problem for most of the developing and arid countries.
- Sewage are rarely treated- only a tiny fraction of the sewage production in the developing countries is treated.
- The environment cannot take the load of all discharges from treated wastewater- all over the world we can find examples of natural ecosystem destroyed by the discharge of untreated or partly treated sewage.

3.1.2 Drop and Store

The alternative to flush and discharge is drop and store. It is a system where excrements are hides into the earth by means of pits. Such system can be simple a relatively low cost and they are easy to understand and to operate. But they have many drawbacks: smell, fly breeding, and risk for pit collapse, and obtain a relatively short life. From time to time new pits have to be dug. This may be difficult on crowded sites. In many cases drop and store system cannot be used at all: on rocky ground, where the ground water table is high and in areas periodically flooded. Recent experiment using bio-tracers indicate that the risk of ground water contamination from pits latrines is greater than generally assumed (Stenström 1996).

In theory, these pit latrines should be emptied when they are filled, with the content being treated before being put to any other use (e.g. in agriculture). In practice however, old pits are often simply abandoned, with users generally preferring to build a new pit latrine than to attempt the extremely unpleasant job of emptying the old one. However, it can prove to be relatively expensive for a household to dig a new pit, and provide a new superstructure each time when the old pit is full. This is added to by the difficulty faced by house owners living in densely populated areas, where plots are small and tend to already be crowded with old, previously abandoned pits.

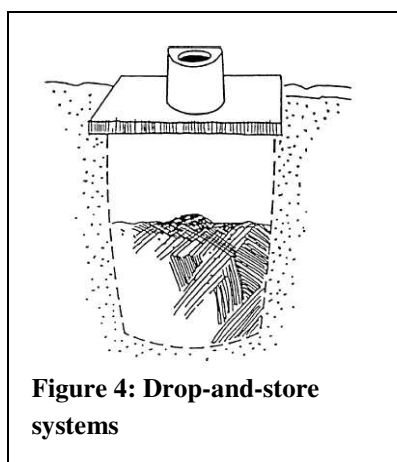


Figure 4: Drop-and-store systems

Drop and store system resulting in large numbers of excreta field pits is not feasible in densely built up urban areas. Nor is the Japanese Jokaso system (Jokaso: a Japanese technology for collection and treatment of nightsoil) realistic option for poor countries. With manual collection the Jokaso system is unacceptable for health reason.

3.1.3 Limitation of Conventional Sanitation Systems

Conventional sanitation systems both flush and discharge or drop and store both have proven to be unable to make a significant impact on the backlog of nearly half of the world's population. Even if conventional sanitation systems could be provided to address the enormous backlog, the problem of sanitation would not be solved, as these conventional solutions today already pollute ground and surface waters. Further more they bring with them a whole range of problems, which could lead to an actual deterioration of the situation. At the Luebeck Symposium on ecological sanitation in April 2003, this issue has been raised by most of the presenters asking participants to imagine the environmental consequences of flush toilet.

At first glance, conventional centralised sanitation systems would appear to be extremely advantageous, as, when functioning correctly, they allow a relatively well assured hydraulic transport of excreta, used water and rainwater away from urban areas. Polluted surface waters in urban areas are also avoided. The hygienic situation of the inhabitants of

urban areas being served by well functioning sewer systems is thereby improved. This practice is however not correctly applied in many countries, with improvements in the sewerage of wealthy areas of towns often leading directly to a deterioration of the sanitary situation in surrounding, poorer neighbourhoods, as sewage is discharged with little or no treatment into water bodies. Furthermore poor communities are often exposed to these contaminated waters in their daily life, during flooding or even as a drinking or washing water source, increased contamination of this water directly affects them.

These conventional centralised technologies require a huge financial investment, as well as required high maintenance and operation costs. The problems of expense do not only problematic to developing nations from correctly operating centralised sanitation treatment systems, industrialised nations also face huge problems in the operation of their plants. Of 540 major European cities, only 79 have advanced tertiary sewage treatment, 223 have secondary treatment, 72 have incomplete primary treatment and 168 cities have no or an unknown form of treatment of their wastewater.

A closer consideration shows conventional waterborne sanitation to have shortcomings of even greater importance than their high costs. As water is necessary to transport the wastes, the high water-consumption connected with these sanitary systems makes them generally unsuitable in the long term for regions with water scarcity and arid countries and is already leading to an irreversible exploitation of non-renewable water resources. Drinking water is therefore becoming an expensive good. Clean drinking water is clearly too precious a resource to be flushed down the toilet, and it is not the most pleasurable experience to operate a water flush toilet, when the water supply only operates a few hours per week. Additionally, even if these systems do contribute to a healthier environment in the cities located upstream, they actually do the opposite for those living downstream. Even when functioning correctly, the discharge from conventional wastewater treatment plants is not even of bathing quality. Conventional treatment plants result in only a small reduction in the bacteriological content of wastewater before discharge, concentrating rather on the removal of large solid elements, the degradation of organic substances and on eliminating the water's nutrient content. The effluent from these plant also contains many other potentially dangerous substances. For example, research has shown an increasing awareness of the effects of endocrine substances, which are contained in human excreta and that have an effect on reducing the fertility of fish and even on altering the sex of male trout. The effects of pharmaceutical residues in the

effluents and their impact on environment and humans living downstream and obtaining their drinking water from the same river are also the question.

A further problem, for combined sewer systems (carrying both storm water and wastewater), is that a sudden heavy rainfall generally leads to the diluted wastewater being discharged directly into rivers as treatment plants are only designed for a limited influent.

Conventional on-site wastewater disposal systems such as pit latrines or septic tanks are also not a viable alternative, due to the resultant groundwater contamination, which increases with increasing population densities. In many densely populated areas, the nitrate contamination of groundwater, for example, far exceeds the maximum level recommended by the WHO for drinking water and therefore represents a particularly serious mortal danger to babies. Shallow groundwater is still a major source for local and reliable water supply especially for the poor in rural and peri-urban areas. The design of the conventional “drop and store” pit-latrines (and of most other on-plot systems) however deliberately aims to retain only the solids in the pit and to infiltrate as much of the liquids into the subsoil as possible. As these liquids contain all the soluble elements of the excreta as well as viruses and pathogens, this type of sanitation is very obviously a highway to groundwater contamination.

Many conventional latrines also smell quite badly, are a breeding place for flies, insects and other vectors and are very inconvenient to use, especially for children, women and girls, as they have to be built at a distance from the house, making night-time visits highly undesirable. Added to this are the problems of pit construction in areas with a high groundwater table, or where the ground is rocky, making the use of a pit extremely impractical. Pits are also susceptible to both flooding during heavy rainfall and subsequent collapse.

Further more the fundamental problem with all types of conventional wastewater disposal systems is that they directly impair soil fertility as the valuable nutrients and trace elements contained in human excrement are very rarely re-channelled back into agriculture. Even if sewage sludge is used in agriculture, only a very small fraction of the nutrients contained in the excrement are reintroduced into the living soil layer. Most are either destroyed (e.g. by nitrogen elimination) or enter the water cycle, where they pollute the environment, causing the eutrophication of lakes and rivers.

The use of sewage sludge from central wastewater systems is also frequently restricted as it contains high concentrations of heavy metals and other hazardous substances, due to the mixing of domestic and industrial wastewater with storm-water run-off from contaminated streets. The consequence of this is that agriculture now has a huge demand for chemical fertilisers, which are regarded as the only solution to address the problem of falling soil fertility. In order to produce these fertilisers large amounts of energy are needed along with the exploitation of finite mineral resources such as phosphorous.

In fact, our conventional wastewater systems are largely linear end-of-pipe systems where drinking water is misused to transport waste into the water cycle, causing environmental damage and hygienic hazards. If we continue to promote these technologies in order to meet the MDGs, the overall result would be worse than our present situation as the hygienic situation of our waters would be further deteriorated and even more resources would be dissipated and introduced into water bodies. The limitation of conventional sanitation system is summarised in Box 2.

Box 2: summary of short comings of conventional systems (source: gtz ecosan)

- Unsatisfactory purification or uncontrolled discharge of more than 90 % of wastewater worldwide
- Pollution of water bodies by organics, nutrients, hazardous substances, pathogens, pharmaceutical residues, hormones, etc.
- Unacceptable health risks and spread of disease
- Severe environmental damage and eutrophication of the water cycle
- Consumption of precious water for transport of waste
- High investment, energy, operating and maintenance costs
- Frequent subsidisation of prosperous areas, and neglect of poor settlements
- Loss of valuable nutrients and trace elements contained in excrement through their discharge into water bodies
- Impoverishment of agricultural soils, increased dependence on the chemical fertilisers
- Predominance of combined central systems, resulting in problems with contaminated sewage sludge
- Linear end-of-pipe technology

3.2 Ecological

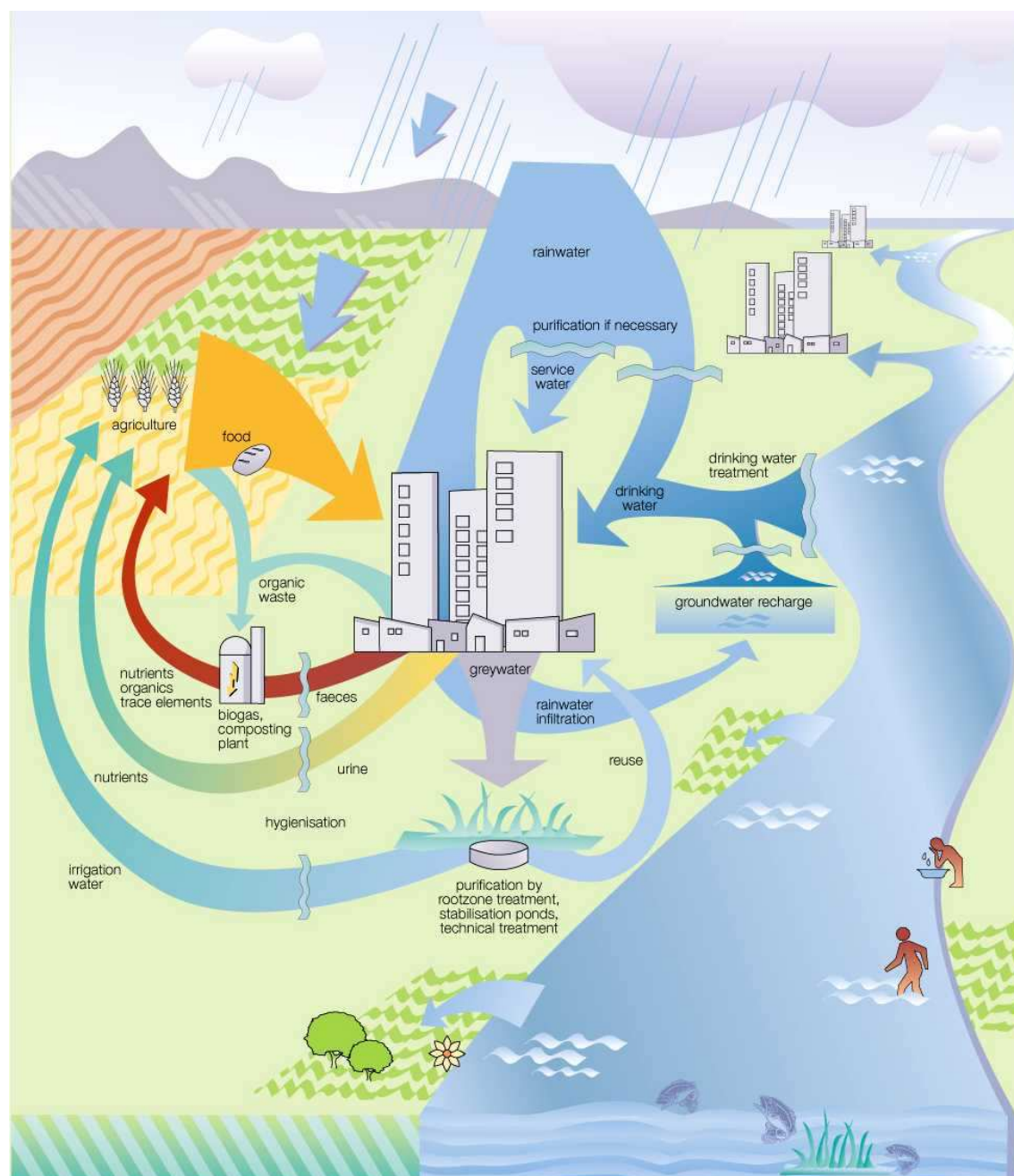


Figure 5: ecological sanitation

Figure 5 shows the concept of ecological sanitation. Sanitation within the ecological cycle is ecological sanitation. There are those who claim that ecological sanitation is “just another technology” - like ventilated improved pit latrines or small bore sewers. But that is to miss the point and misunderstanding of ecological sanitation. Conventional sanitation is based on hiding human excreta in deep pits or diluting them with water and exporting them to the neighbouring downstream. Ecological sanitation stands for another way of thinking – a completely different approach to sanitation. Ecological sanitation is

based on the insight that the Earth is a closed ecological system where nothing permanently disappears.

Ecological sanitation is only possible with “Sanitise and Reuse”. Ecological sanitation is the Sanitation system, which is based on fundamental ecological principles: zero pollution, water conservation and recycling. These systems are based on accelerated pathogen destruction through different technologies and applying the end products for food and non-food plants. Ecological sanitation systems are relatively unknown outside East Asia and many attempts to introduce them in other part of the world have failed because the lack of knowledge of the principles involved and the design and management options available.

As an integrated alternative, a hallmark of ecosan is its interdisciplinary approach that goes beyond the narrow disciplines of domestic water supply and technological aspects to address issues such as agriculture, sociology, hygiene, health, town planning, economics and small business promotion, the administration, etc.

3.2.1 Definition of ecosan

ecosan is a system approach to sanitation and short form of Ecological Sanitation. According to Steven A. Esrey- ecosan represents a shift in the way people think about and act upon human excreta. It is ecosystem approach that recognises the need and benefit of promoting human health and human being. At the same time it is an approach to recover, recycling of nutrients along with conserving and protecting water sources. It represents a close loop approach, and is an attempt to move away from linear solutions of waste disposal towards a circular flow of nutrients. The system is quite effective to provide sanitation economically and increase food security.

A similar definition is described in GTZ-ecosan sub project. This project realises ecosan as a holistic and alternative approach to avoid the disadvantages of conventional wastewater systems. This is based on an overall view of material flows as part of an ecologically and economically sustainable wastewater management system tailored to local needs. It does not favour a specific technology, but constitutes a new philosophy in handling substances that have so far been seen merely as wastewater and water-carried waste for disposal. Further more the project realises ecosan-concept fits perfectly into the

Millennium Development Goals for 2015 set at the UN Summit of 2000 and Johannesburg Commitments on Sanitation.

Hakan Jonshon Co-chairman of specialist Group of ecological sanitation described ecosan as system directing excrement in the correct direction, closing the nutrient loop and diverting the hormones to arable land, just as previously during evolution. He also added, ecosan is designed to support the natural cycles of plant nutrients and other natural components of excreta, e.g. hormones. When fully implemented, all excreta are returned to arable land in a hygienically and chemically safe way.

Similarly First International Conference on ecosan in Nanning China concludes ecological Sanitation is a term used to describe a sanitation approach which respects ecological integrity, conserves and protects freshwater, promotes healthy and dignified living, and recycles nutrients from human excreta for the growing of food and non food tree crops. Its closed loop thinking is fully compatible with the principles articulated at the WSSCC (Water supply and sanitation coordination council) meeting in Bellagio in 2000, and falls within the framework of its approach to environmental sanitation.

With this different views and definitions it can be concluded that 'ecological' a sanitation system should fulfil the following criteria.

- Prevent Pollution,
- Destroy pathogenic organisms, and
- Recycle human excreta as fertiliser.
- Material-flow cycle instead of disposal
- Provide better sanitation in economical way
- Better health and environment

A system that fulfils only one of the above criteria does not fall into ecosan. Hence to fulfil an achieve ecosan all the above criteria should be met.

Zero discharge is an essential part of ecosan principles. Prevention is better than cure this concept should be applied in ecosan. A main characteristic of the ecological sanitation is to prevent the problems at the origin rather than dealing with them at the end of a pipe.

Further more Kyoto Resolution concluded the following statements regarding ecosan.

- It is an environment-friendly and Safe Approach to sanitation.

- It save water, prevents water pollution, sanitises and recycles the nutrients and organic to restore soil and soil fertility.
- It includes low as well as high cost solutions for rural and urban settings. Ecosan can be more cost-effective than conventional sanitation and thereby offering a greater chance of meeting the Millennium Development Goals and the Johannesburg Commitments on Sanitation.
- It is applicable to a wide array of local physical, cultural and economic conditions providing permanent installations.
- Its concepts and techniques can also be used to upgrade conventional pit latrines and flush systems.

3.2.2 Principles

The basic principle of ecosan is to close loop sanitation with the objectives of:

- Reducing the health risks related to sanitation,
- Reducing contamination of water and consequently improving the quality of surface and groundwater
- Improving soil fertility
- Optimising the management of nutrients and water resources

An essential step in this process is to maintain hygiene and appropriate handling of the materials throughout the entire treatment and reuse process in order to ensure a complete containment and sensitisation of the excrement and protection of the public health. Unlike conventional sanitation systems, ecosan systems take care that bacteria, viruses and parasites do not endanger the environment, or pose no hygienic risks to the population.

ecosan systems restore a remarkable natural balance between the quantity of nutrients and excrements. Ideally, ecosan systems enable an almost complete recovery of nutrients, trace elements and energy contained in household wastewater and organic waste and their reuse in agriculture. It helps to preserve soil fertility and safeguard long-term food security.

From both natural and human ecological point of view, the fundamental principles for ecosan could be understood as:

Totality: geographical continuity, hydrological circulation, ecological integrity and cultural consistence.

Harmony: between structure and function, internal and external environment, implicit and explicit layout, nature and man, objective being and subjective value, material and spiritual goals

Mobility: constant wind and water flowing, vertical and horizontal flow, meandering streams, undulating and far stretching

Vitality: luxuriant, flourishing and productive fauna, flora and soil and aquatic biome

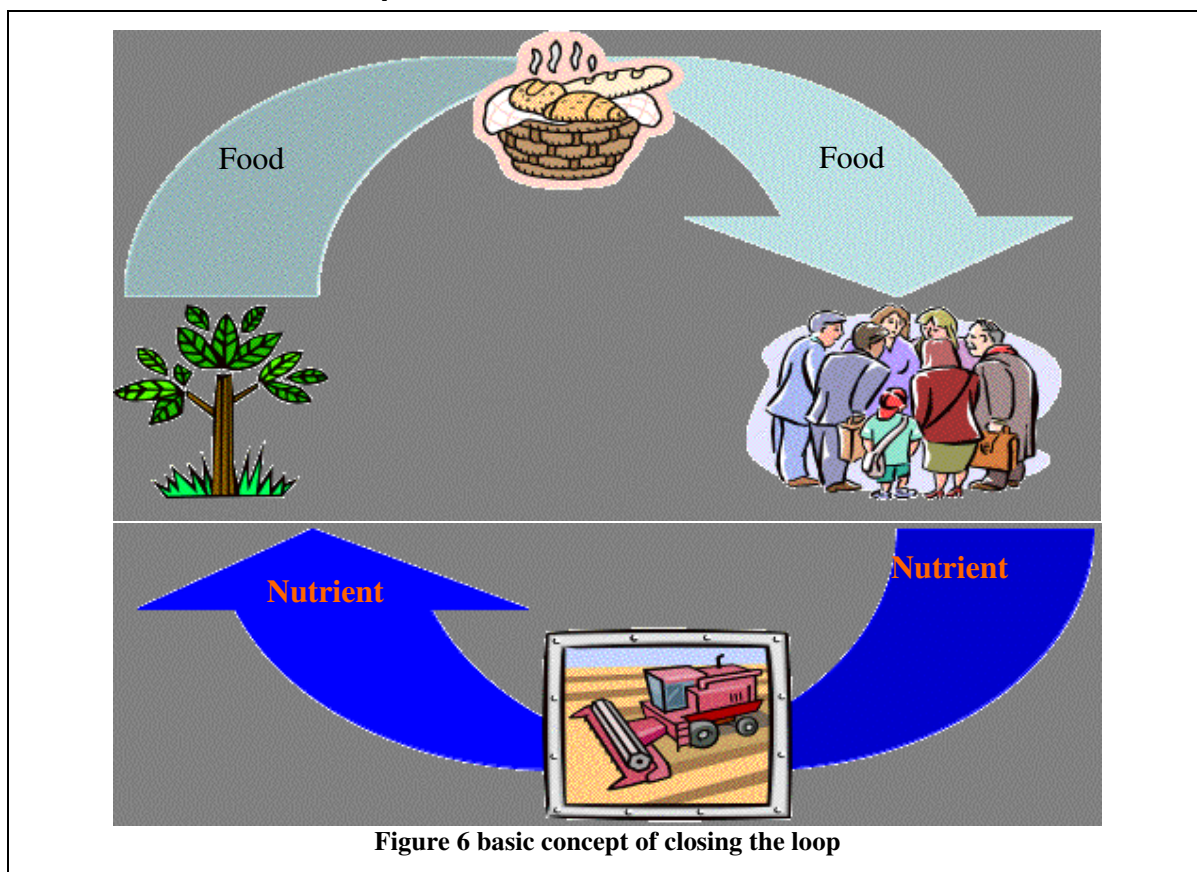
Purity: clean and limpid water, clean and transparent atmosphere, quiet and secluded surrounding, never overloading its carrying capacity

Safety: backed by hill, enclosure, and explicit, openness, easy to disperse and defence, disaster resistance

Diversity and heterogeneity of landscape, ecosystem, species, society and culture

Sustainability: negative and positive interlocking feedback, self-reliance, self-maintenance, sufficiency and efficiency, appropriate exploitation and development.

3.2.3 The Basic concept



The basic concept of ecosan is to consider so called waste as resource and close loop between sanitation and agriculture and to achieve environment friendly sanitation conditions. The message that ecosan disseminates - let us not produce sewage or sludge by adding valuable water into it and make it more difficult to handle. It also recommends to consider faeces and urine as resource and should be handled with most economical procedure at the source of the production itself. The source could be household, community, town, and catchments etc.

ecosan concept is a holistic approach with win-win solution considering different aspects, which are beyond traditional wastewater engineering. It saves water, prevents water pollution, sanitises and recycles the nutrients and organic to restore soil and soil fertility. In traditional engineering practices only on the spot sanitation is considered where as ecosan consider the sanitation of whole environment.

The basic concept of ecosan originates from the classification of wastewater according to their colour.

3.2.3.1 Types of Wastewater According to Colour and Their Nutrient Contents

It is simple to define household wastewater; it is just water + waste of household. But what is waste? Although there are many definitions regarding waste, but evidently there are no such things as waste. Nature has created no waste; it is a concept of humans. All so-called waste is food for another living organism. Therefore conventional definition of household wastewater is wrong. A new thought of defining household wastewater is a current need. A classification of household water through different colour given by Henze et Ledin, 2001 is quite progressive classification of household water towards it. According to him household wastewater is originally a mixture of different components, and it can be divided into different streams, which are described by one specific colour. Table 1 describes much more about this.

Table 1: Description of household waste water components (Henze et Ledin, 2001)

Name	Colour	Source
Classic	-	Toilet, bath , kitchen, washing
Greywater		Wastewater from kitchen, bath, shower, washing machine
Blackwater		Toilet water (combined yellow+ brownwater)
Yellowwater		Urine
Brownwater		Faeces

Table 2 Characteristic of the main components of household waste water (Otterpohl, 2001 ;Esrey, 2001)

	Total	Greywater	Yellow	Brown	Black
Daily loads g/(person*d)	Volume l/(person*d)		1.200	70-140	1.200-1.400
N			11.0	1.5	12.5
P			1.0	0.5 - 0.8	1.5
K			2.5	0.6 - 1,0	3.5
COD			6.6	21.4	30.0
Yearly loads kg/(person*a)	Volume l/(person*a)	25,000- 100,000	~ 500	~ 50	~ 550
N	~ 4-5	0.7	4.0	0.5	4.5
P	~ 0.75-0.9	~ 0.07	0.4	0.2	0.6
K	~ 1.8	~ 0.6	1.0	0.2-0.4	1.2
COD	~ 30- 47	~ 25	5.5	22	27

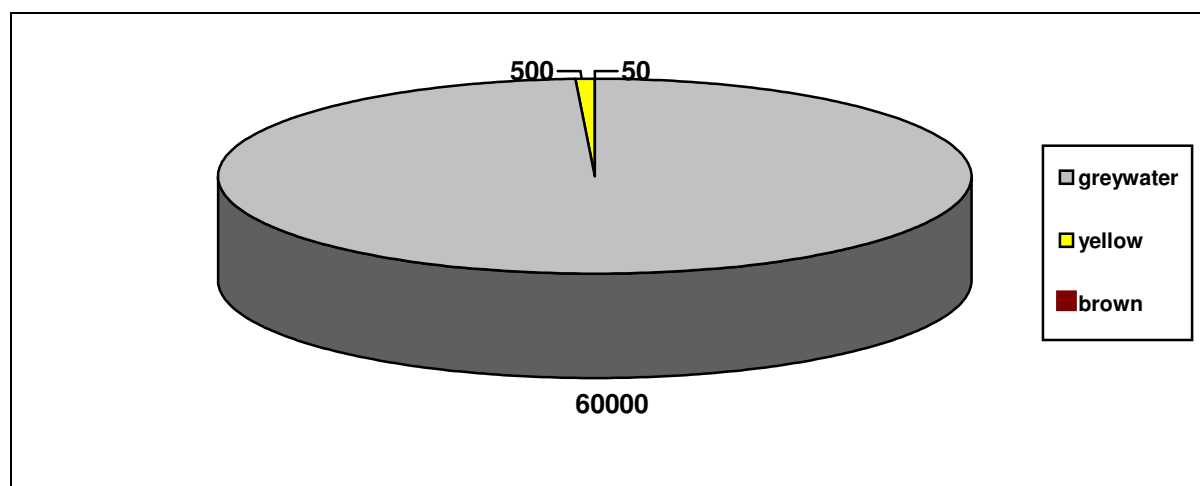


Figure 7 Graphic Representation of wastewater components (l/person*a)

Table 2 gives the main components and quantity of household wastewater. As the volume of water concern, nearly 99% is Grey water and only 1 percent is black water among which around 10% is brown and the rest one is yellow water. The detail is shown in Figure 7. In different research it is found that yellow (urine) contains most of the nutrient. Faeces are the smallest part and if kept separate and treated in the appropriate way, it is a simple material to handle and can even provide renewable energy and restore soil fertility. Throwing this into water creates a hazard, making it very difficult to treat the water at the

other end of the pipe. The urine is the major nutrient resource, a natural fertilizer, in principle easy to collect and to use. Subsidies for commercial fertilizer are reduced around the world, many farmers are indeed of cheap local fertilizer, and urine could be the answer.

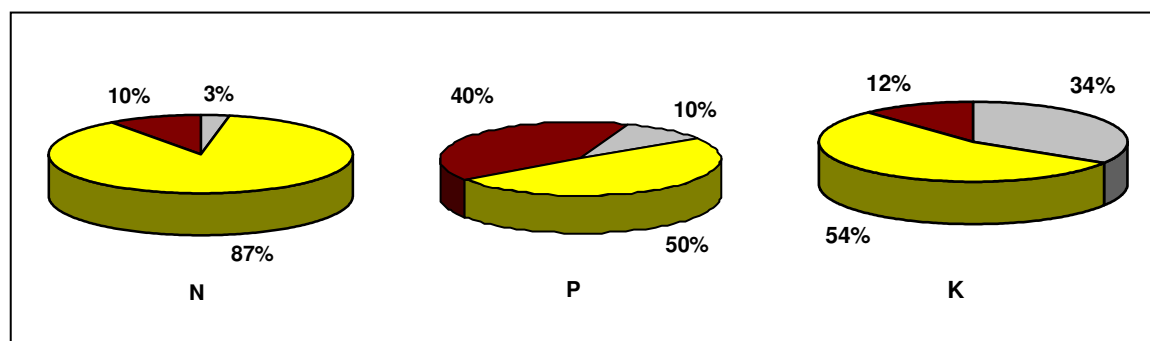


Figure 8 Nitrogen, Phosphorus and Potassium loads of wastewater in percentage of total loads

3.2.3.1.1 Yellow Water

Urine alone is called as Yellow Water. Urine comprises 90 percent of human excreta, the quantity of urine varies from person to person but from different experiment it is estimated that one person normally urinate around 500 litre per year. The yellow water alone contains about 80 percent of nutrients from the total excreta. It contains 87% of nitrogen, 50% potassium, 60% of sodium and contains only 12% COD of total nutrient excreted from human being. Studies indicate this amount of nutrient is sufficient to provide enough nitrogen, phosphorous and potassium to grow a year's supply of wheat and maize for one person. Yellow water can be applied to field crops without treatment because it is generally sterile. "Fresh urine" does not contain any bacteria, unless the person has a urinary tract infection, so you could even use it to wash out wounds without causing any infections.

3.2.3.1.2 Brown Water

It is the product of faeces and water. Here the quantity of water depends on the habits of people and the system adopted. A detailed composition of this water can be calculate based on the amount of food that is consumed daily in the fraction that is normally found in physiological solid waste (excreted, not digested). Brown water contains bacteria, digestion liquids and others. The composition of this water doesn't vary much in relation to the eating pattern.

The nutrient content value of brown water is significant in terms of phosphorous, a very non-accessible, expensive and essential nutrient of plant. Around 300 gram of phosphorous is found into the portion of one persons brown water per year. Further it contains 10% of nitrogen and 17% sodium. The COD contain is maximum in this water in regard to yellow and grey water It contains 47% of COD.

3.2.3.1.3 Grey Water

Any used water not containing urine and faeces or except water from toilets is called grey water. Dish, shower, sink, and laundry water comprise 50-80% of total household wastewater. As shown in the Table 2 this water may vary from 25,000 to 100,000 litre /person per year. The chemical contents of grey water depends on the source of water, whether it is household or commercial laundries, and what type of installation is draws the water in kitchen sink, bathroom, hand basin or laundry wash. Furthermore, life style, costumes and use of chemical product (detergents) will be of importance. Biological growth with in the transport system is another source of microorganisms and chemical substances. During storage and transportation of grey water biological growth may lead to increased concentration of microorganisms including faecal coliforms. This may also cause new organic and inorganic compounds to be produced: metabolites from partly degraded chemical present in the grey water. The presence of nutrient nitrogen, phosphate and potassium will promote this microbial growth. Chemical reaction could also take place during storage and transportation of grey water and they're by cause changes in the chemical composition of this water. In this regard it is always better to treat grey water as near as by the source of production.

This water contains very less amount of nutrient. The content of potassium is quite high (~34% of total) but compare to its concentration it is negligible. The COD contain is quite high (~41%) Figure 8.

The nutrient in this waste can be used for growing products in constructed wetland systems or (fish) ponds. Organisations or private persons deriving benefits from the products can do management of such treatment plants. Should wastewater flows become too big or when insufficient space is available oxidation ditches can be considered. Treated water can be recharge to groundwater or to irrigate land. If this water could be collected at individual household level it could fulfil the requirement of small kitchen garden.

3.2.3.1.4 Black Water

The water from Flush toilets is known as black water. It is product of urine faeces and water. Normally the separation of urine and faeces are very limited, perhaps the separation term may be quite funny for some people as they are practising combine system. In this regards the production of black water is common everywhere. Although separation system reduces drastically the amount of treatment cost but due to cultural practices and norms black water borne system is unavoidable.

Normally from different practices and experiments it is found that the amount of urine is ~500 l and faeces ~50 l which gives black water in total ~550l per year per person. But in water borne system only this quantity is not sufficient to represent black-water it also accounts of flushing/transporting water. More than 15000 litre of water is generally needed to flush/transport the above actual black water. Hence in actual practice the quantity of black water is nearly 28 times more than of actual excrement, i.e. nearly about 15000 litre (this quantity depends upon the system and customs of the people) per person per year.

As concern of nutrient content of black water, it contains most of all nutrient excreted from human. Detail is given in Table 2.

3.2.3.2 Technologies

In practice a frequently applied strategy in ecosan is to separate the different flows and treat faeces, urine and grey water with different technologies near the source as far as practicable. The separation of the flows make eco-solutions easy and cheaper, however, it is not a prerequisite in ecosan systems, and ecological sanitation is also possible in centralised and combined flow systems, if there is a demand for more diluted recycled products. The practice should minimises the consumption of valuable drinking water need to flush away excreta, and treats the separate wastewater flows at low cost for subsequent use in soil amelioration, as fertiliser or as service or irrigation water. The treatment of organic domestic and garden wastes and of animal manure may also be integrated into ecosan-concepts.

Diverse technologies can be used in ecosan systems, from simple low-tech to sophisticated high-tech solutions. These currently range from compost toilets or urine-separating dry toilets, to water-saving vacuum sewage systems, possibly with separate

collection and subsequent treatment of urine, faeces and grey water through membrane technology for material separation and hygienisation. Generally, precedence is given to appropriate modular and decentralised facilities, but in very densely populated areas centralised systems may still be needed. The essential advantage of the modular components is the optimal adaptation to the local social, economic, ecological and climatological conditions. As a result, they represent a comparatively rapid and more economically realisable alternative to conventional systems.

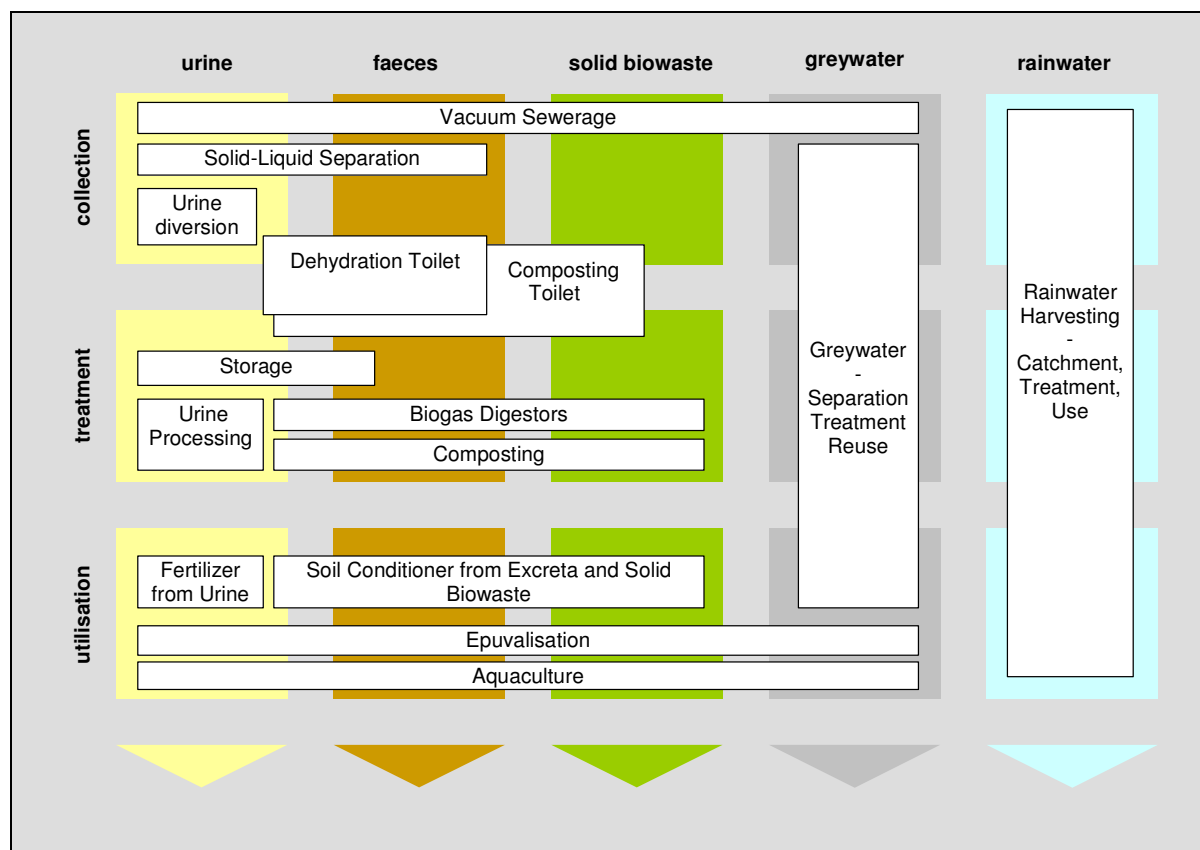


Figure 9 different wastewater flow their treatment and utilisation

Of particular importance in ecosan approaches are innovative logistics to return nutrients to farmland, marketing strategies for the recovered nutrients and directions for their safe application in agriculture. New ecosan schemes may also entail setting up service enterprises and hence kick starting income generating measures for the construction and easy and safe operation of the installations as well as the collection, treatment and marketing of the recyclates.

The split-stream collection, treatment and reuse of different wastewater flows offers new possibilities for more specific and cost-efficient solutions Figure 9. The partial flows can be characterised as yellowwater (urine with or without domestic wastewater), brownwater

(blackwater with no urine), greywater (domestic water without faeces and urine) and rain water as discussed earlier.

The human faeces obtained after separation, show valuable soil improvement qualities (structure and rise of the water retention capacity). They are treated if necessary together with organic waste and according to local conditions (climate, power demand and socio-cultural acceptance etc) using the processes of dehydration, composting, stabilisation, socialisation or fermentation. Thus, the organic and nutrients contained in faeces can be used in concentrated and hygienically safe form as a dry fertiliser, compost or fluid fertiliser. Dependent on the type of treatment energy can be produced if necessary in the form of bio-gas after anaerobic digestion.

The urine, or yellow water, contains the highest proportion of natural nutrients (nitrogen, phosphorus and potassium), which are directly available to plants and equally effective as mineral fertilisers. Urine contains approximately 90% of the total nitrogen, 55% of the total phosphorus and a substantial portion of the potassium contained in human excrement. A partial flow separation and use of the urine is particularly advisable due to its low volume and the high concentration of nutrients it contains. In order to obtain the yellow water fraction devices such as urine separation toilets or waterless urinals can be used.

The grey water from washing, rinsing, showers etc., while representing the largest fraction of the total wastewater flow, has only a very low nutrient content. Therefore, it can be treated to a high quality using simple techniques such as gravel filters, constructed wetlands, ponds, bio-film or activated sludge procedures. For high-tech applications more sophisticated treatments, such as membrane filtration or activated carbon filters, may eventually be added. The treated grey water can be put to particularly good use in agricultural irrigation (especially in water scarce regions), but may also be used for groundwater recharge, industrial or urban reuse or discharged into surrounding watercourses.

3.2.4 Basic Project Types





Basic types of ecosan-projects				
Project-type	A	B	C	D
Characteristics • User of sanitation facilities • User of the end products (Range: in house / other) • Level of initiative and Decision (min / max) • Considered resources (minimum / optimum) • Service provision for operation, transport, treatment and marketing (Range: in house / other)	 rural upgrading	 urban upgrading	 new urban development areas	 non-residential (tourism, schools ..)
	household	household / neighbourhood	household / neighbourhood	tourists, employees, pupils ...
	household	household (partly) farmer, external user (partly)	household (partly) farmer, external user (partly)	user-institution (partly) farmer, external user (partly)
	micro / macro	micro / macro	macro	micro / macro
	faeces + urine only	faeces + urine + greywater only plus rainwater harvesting, stormwater management, organic waste	faeces + urine + greywater only plus rainwater harvesting, stormwater management, organic waste	faeces + urine + greywater + stormwater-management plus rainwater harvesting, organic waste
	household	household / public/private service provider	household / public/private service provider	user institution / public/private service provider

Figure 10 The characteristics of the 4 basic types of ecosan project (source: GTZ ecosan)

ecosan is not a technology it is a process hence it is not easy to categorise a process. But for the convenience ecosan projects can be broadly classified into four categories according to the basic features such as Rural upgrade, Peri-urban and urban upgrade, New urban development and Non residential and tourist places. The category and the classification and their size may also depend upon definition of different terms like rural and urban from country to country. Even the disparities could be seen with in the county itself. The four basic types are therefore mainly intended to provoke reflection of stakeholders, their roles and information needs, and tools foreseen to encourage their participation. These four broad categories of ecosan projects are quite general in their description. Projects in reality may not fit so neatly into one of the categories and individual projects may lie somewhere in between two types. The types presented here are hypothetical types and it is hoped this type will give overview of ecosan concept introduction in different project types and areas. These probable four types can be clearly seen in the Figure 10.

3.2.5 Different Aspects

In order to conceive a full-fledged ecosan system one must give due respects to the different aspects. These aspects, which are discussed below, are most important to achieve the good function and minimise health risks.

3.2.5.1 Technical

The important factor that influences the proper function of any ecosan system is the technical aspects. It should be chosen or adopted in line with the surroundings and the available material.

3.2.5.1.1 Durability

Durability is a function of material, technology, workmanship, and size itself. Strong material could be chosen for ecosan system. The technology may differ from place to place depending upon the available material, fund and manpower but the main aim however remains same. The principle of small is beautiful can be also applied in ecosan projects- smaller in size (household level) may function better than larger ones.

ecosan is a system approach which functions in a closed cycle (closed loop). But there could be problem with durability of appliances in the system. For example in urine diverting pan or commode, or vacuum toilet, or Aquatron may have different life span and need regular maintenance as well as they may require to be replaced. If the handling of the system is assured the system is more durable than conventional.

3.2.5.1.2 Construction/ low tech

ecosan is quite easy to understand. Every one can understand the loop between sanitation and agriculture. ecosan has verity of construction choices, which can be low tech appropriate for small village to high tech appropriate for big cities. As the system can deal with the situation of locality there is no doubt of easiness of construction with the available local material, but the designer must be quite aware of ecosan principles.

3.2.5.1.3 Flexibility/ adaptability

ecosan has varieties of technology from low to high. The system even works without electricity. The flexibility of the system may be simple technology like compost toilet to the high tech vacuum as in aeroplane. The choice of technology depends on the available

materials and fund without compromising the quality and close looped philosophy of work. Hence technological choices in ecosan are flexible, only the adoption may be difficult if the consideration of social dimension and awareness of the people are not taken into account. Closing the loop and zero discharge to the receiving stream cannot be achieved unless all the users are aware about it and ready by heart to follow the proper use of the system.

There is no fixed formula in ecosan, which give more choices but may lead difficulty in monitoring. ecosan system are designed according to their local need and constraints following the bellagio principle (household centred approach). Hence it starts from the need of user and the solutions are adopted considering appropriateness, which definitely assure the adaptability of the system.

3.2.5.1.4 Maintenance and handling

Maintenance plays a major role in ecosan. The size of maintenance in ecosan is similar as in conventional system. Many examples are found where very high tech systems are not functioning well due to lack of maintenance and similarly low-tech systems are functioning very well because of well-developed maintenance systems. Hence the maintenance system should cope with the knowledge of users and available options. In case of ecosan the system is designed by considering all the social dimensions and the knowledge of people. The project is lunched after users are fully aware about maintenance and risk of diseases outbreak due to lack of maintenance and handling.

In case of ecosan skill and knowledge of maintenance are very important as the end products are handled and reused with in the very vicinity of the system itself. The user must be made aware of the consequences that may lead due to un-proper handling and reuse of the end products.

3.2.5.1.5 Reliability

For the reliability the technology must be robust, that must work in any variations of temperature or other natural phenomenon. In ecosan system has various choices of technology from ancient Greek methods to modern membrane technique, which can assure the reliability of the system.

3.2.5.2 Socio- Cultural Aspect of ecosan



Cultural norms about waste treatment are universally similar to those on diet. The norms toward both inherent and learned are deeply rooted in psychology, gender and religion. However, the ecosan starts from the defecation and a defecation process is guided with socio cultural behaviour. The adoption of the particular system depends upon the socio cultural aspects of the users. Hence before conceiving a system the designer should be well aware of the socio cultural behaviour of the community.

3.2.5.2.1 Psychology

As we know ecosan generally starts with defecation of excreta, nutrient extraction and safe use of it. For efficient ecosan system we need a special toilet rather than the conventional one. When developing an alternative toilet system, formulating a psychological contract with the potential users is just as important as designing the system itself. A system often fails, not because of technical reasons rather, because it simply is not used. Therefore, it is vital to understand the psychological processes of waste treatment as much as the biological, chemical and physical processes of the system.

In the course of human evolution, those unfortunate to come in contact with excreta were exposed to a plethora of pathogens, and consequently less likely to survive than those who did not come into contact with excreta. Therefore, some assume that this instinctive repulsion is almost genetic in nature. Furthermore the attitude consists of three basic components: perception, cognition and behavioural tendency.

Perception: Essentially it is our emotional response(s). The common perceptions about excreta are emotionally charged associations, which vary from culture to culture, but are essentially negative. Similarly the universal perceptions about water, which also vary with culture; however, they tend to be positive in nature. The developments of water-based toilet systems have a deep-seated psychological link, with water providing a mental barrier of protection.

	Perception <i>image</i>	
<ul style="list-style-type: none"> • Excreta • dark • defiled • Evil - dangerous • bad • repulsion 		<ul style="list-style-type: none"> • Water • clear - reflecting light • pure • God/heavenly - safe • good • attraction

Cognition: The second element of attitude is *cognition*, which deals with our rational thoughts. Similar to perceptions, generally speaking, universal notions about excreta are threatening and harmful, whereas attributes about water are healthy and helpful.



Behavioural tendency: The third element of attitude is *behavioural tendency*. Although there is a link between how one feels and thinks about a subject, there is no direct cause-effect relationship between these elements and specific behaviour. Rather, there is a tendency, to behave in a specific manner, which explains why some cultures are more disposed to handling excreta than others. Our behavioural tendencies toward excreta are inherent. We all eliminate wastes: that is a basic fact of life. How we actually perform the elimination act, and what we do with the waste, is partly dependent upon one's sex, religion, age, health, diet, and most significantly what facilities, we are accustomed to.

Although little research has been devoted to these issues, however, Prof. Alexander Kira, Cornell University (USA), conducted a study to determine peoples' tolerance towards offensive body waste. Not surprising, those who are exposed to excreta – such as mothers of infants and health care professionals had a higher tolerance. The implications for ecological engineers are far-reaching. There is no right or wrong behaviour or attitude, except within a given cultural context. But even within the same culture, our behaviour can be influenced by a number of factors – and these develop over time.

3.2.5.2.2 Gender

Another social aspect is *gender*. Gender plays a universal role in privacy, but equally important are the physical differences between men and women. Women urinate more frequently (especially when pregnant), and use more time to eliminate wastes.

It is noted that women tend to have a greater tolerance towards handling waste; use public toilets more often, longer and for more purposes, yet have fewer facilities than men. Another generalization is that women tend to manage the home toilet more than men. In

cultures where women stay at home, the toilet becomes a primary management issue, because their primary responsibilities of cooking, housekeeping, family hygiene, and care giving to infants and the elderly are toilet dependent.

But studies have shown, that in many regions of the world there are far fewer facilities for women than men. Ecological engineers should be acutely aware of gender issues associated with public toilets, because in the future many public facilities adopt ecosan systems. The success or failure of an alternative treatment system might well hinge not on system performance, but on system use – or lack of. System design should not necessarily be based upon existing cultural conditions, because, in fact, the current cultural context might well be flawed from the point of hygiene.

For ecosan projects involving compost or dehydration toilets, this is a vital concern, because these systems require at some time – and usually often – the handling of excreta.

3.2.5.2.3 Religion

Until the 19th century, cleanliness was not a scientific concern. Our understanding of water and excreta was not associated with molecules but myths, and the terms *hygiene* and *sanitation* were not part of the popular vocabulary. Nevertheless, many cultures did – and some still do – make a distinction between *clean* water and *cleansed* water. (The former being perceived as pure and potable, the latter being neither.)

Common assumption is that science and religion are always in conflict. Both share a common concern about human excreta – namely, human health. Science's interests in wastewater treatment stems from two issues: the transmission of faecal related diseases and the conservation of water and nutrients in the waste. Religion's interest in wastewater is also two-fold: the promotion of health (although most religious doctrines lack medical explanation for disease), and the observation of rituals associated with purification (in the broadest sense of the word).

The interests of science and religion are neither incompatible nor contradictory. The heart of the conflict is that science and religion deal with human *behaviour* differently. Science tends to introduce new concepts and modifies behaviour, whereas religion generally preserves old beliefs and maintains traditions. Thus, conflict arises when science tries to alter religious behaviour, including behaviour that is related to health and hygiene. **ecosan**

mitigates potential conflict by integrating science and religion into a system that is as sensitive to social concerns as the physical environment .

The heart of ecosan is a *holistic* approach towards treating human waste, which implies sustaining the human ecology. Consequently, the key to a successful ecosan system is its adoption to specific cultural requirements.

Water has always had a special significance in religious purification rituals. But the use of water for sanitation – in the broadest sense of the word – generally has less to do with physical hygiene than spiritual cleaning, i.e. ablution. Spiritual cleansing is not limited to the Judeo-Christian heritage. For example in Hindu religion one has only to see and smell the Ganges to know that the mass immersion in that holy river has no connection with hygiene.

Moslem doctrine, however, prescribes strict procedures to limit contact with faecal material, because – by Koran edict – it is considered impure (*najassa*). A Muslim must use water to clean parts of the body through which *najassa* pass. The hygiene behaviour of Muslims varies because the Koranic edicts are interpreted differently among different movements. In Iran's Shiite society, for example, the use of excreta in agriculture and aquaculture is not condoned. In West Java, however, direct application of excrement for aquaculture is an ancient practice that has altered little under Islamic rule.

Similarly, the Malaysian Cabinet has directed local authorities to incorporate the water requirements of Muslims in the design of public toilets. Also note, although Islamic law requires the use of water for anal cleansing, waterless toilets are a tradition in Yemen and Zanzibar.

Waterless ecosan systems (i.e. dehydration toilets) have been successfully introduced in water-based Hindu cultures. The principal Hindu text that details the code of conduct for rituals, the Artha Veda (500-200 BC), clearly specifies the use of water for sanitation. The feet are to be washed after elimination and the anal region is cleansed with water before. The end of the ritual is symbolized by rinsing the mouth eight times with water. But note: there is an obligation to wash one's hands after defecation.

Nowhere do we find excrement included more in a social context than in Buddhist cultures. An integral dimension of Buddhism is reincarnation, which preaches the natural process of recycling human energy – birth, growth, decay, death, and re-birth. Since

reincarnation promotes the harmonious concept of recycling life's treasures, it is not surprising that Buddhist cultures treat earthly resources similarly. But bear in mind that the unenlightened had been applying excreta to crops 3000 years before Buddha first began preaching about spiritual composting.

3.2.5.3 Economic

For ideal system the sanitary solution chosen should be economically reasonable, both in investment and maintenance. The ecological sanitation solutions are economical than the conventional one as the cycle is small and end products possess positive economic value than conventional. The end product of ecosan could drastically reduce the consumption of chemical fertilizer. Poor farmers may get rid of buying expensive fertilizer. Further ecological sanitation saves fresh water and also reduces the cost of wastewater treatment.

Furthermore ecosan is the most energy saving option because it emphasises on on-spot sanitation and tries to close the loop with as small as possible route. As a result it leads to reduce the enormous transport and pumping cost as well. It has been estimated that on-spot sanitation loop is 47% economical than conventional ones.

Nutrient removal has become a central element in wastewater treatment in developed world, but nitrogen, phosphorus and sulphur removal requires relatively large amount of resources (energy as well as chemicals) in conventional systems where as in ecosan these nutrients are aim to extract with in the source itself and the cost is drastically low.

3.2.5.3.1 Additional benefit

A part from saving the cost of transportation and energy consumed in pumping the ecosan provides the safe guard to the nutrients. These nutrients of high value for the plants could be used by saving huge amount of money invested in chemical fertilizer. The extent of environmental protection, ecological balance of the nature, and enrichment of soil fertility that can be achieved by ecosan however cannot be evaluated in terms of money.

3.2.5.3.2 Impact on equity

In a particular community such as farmers groups adaptation of ecosan and its end products may be as assets to such a group. This end product used to increase the crop yield may result into the financial gain to this group. The farmers group may overcome

from the financial burden of chemical fertilizer, which is becoming expensive day by day, particularly in the developing countries.

3.2.5.3.3 *Cost economy and benefit*

Cost estimation is difficult in the case of alternative systems, but nevertheless the cost savings and expenses are summarised in Table 3. Alternative systems are still more expensive, because they are limited to pilot projects. There is a low degree of economy in the production of new components. But in future, especially with serial production of components, the expenses are expected to decrease. The main cost advantages are water saving (reuse, reduction in flushing water, etc.) and for sewage network (construction of smaller pipes, decentralised system). Fertiliser products from excrements can be sold and/or substitute the artificial fertiliser. Additional cost benefits can be gained with energy production in Biogas treatment. Other benefits are hard to be calculated, for example soil improvement by the compost or groundwater recharge. Increased agriculture yields. For each selected technology there are differences in specific operation and maintenance and personal cost.

Table 3: Cost estimations for alternative systems

Cost beneficial	Cost effective
Water saving	Pilot projects (new components)
Smaller pipes	Higher costs for sanitary equipment
Energy gain (biogas)	- vacuum toilets, separation toilets
Household waste reduction	Higher installation costs for separated pipes
Higher agriculture yields	
Selling fertilizer	
Substitution of artificial fertilizer	
Not measurable	Further costs
oil improvement	Operation and Maintenance costs
Groundwater recharge	Personal costs

3.2.5.4 **Health**

The handling of human excrement as well as use of wastewater is essential in ecosan. When untreated wastewater is used for crop irrigation, intestinal nematodes and bacteria present high actual risk. Crops fertilised with raw excreta may cause excess infection with intestinal nematodes to both consumers and field workers, if not properly handled. Fertilisation of rice paddies with excreta may lead to excess schistosomiasis infection among rice farmers. Cattle may be infected with *Cysticercus bovis*.

ecosan systems are prone to expose the public to potential health risks if not properly handled because they deal with recycling excreta and wastewater. In developing countries, excreta-related diseases are common, because excreta and wastewater contain correspondingly high concentrations of excreted pathogens. It is important to understand the transmission routes of these diseases, and health-risk factors involved, in order to design and implement (or modify) ecosan systems effectively.

Improving water and sanitation facilities does not necessarily lead to a decrease in faecal-related diseases. To bring about real improvements in health, the installation of ecosan facilities has to go hand in hand with their proper use and maintenance. Hygiene promotion aims to ensure the proper use and maintenance of facilities by motivating people to change their behaviour. ecosan gives emphasis both on facilities as well as in promotional terms (awareness and motivation) which also includes hygiene promotion.

Hygiene promotion goes beyond hygiene education. It recognises that it is not only the potential users of facilities who need to change their behaviour; behavioural changes are also needed at other levels. Politicians need to recognise the importance of improving hygiene and work to create a favourable political environment. Implementing agencies need to recognise the need to allocate adequate resources to put policy into practice. Field workers need to be willing and able to understand people's hygiene behaviour and to build on existing motives to encourage people to change if needed.

Available measures for protecting health can be grouped under four main components: Waste treatment, Crop restriction, Waste application methods, Control of human exposure.

The goals of ecosan include: Human, Settlement, Farmland and Environment health. The sanitary system in ecosan should not cause sanitary risks or nuisances in form of odour or plies in any part. When closing nutrient cycles, one has to be careful not to establish a "cycle" of infectious matter, which will increase hygienic risks and re-circulate an inferior nutrient fraction (due to the presence of environmentally harmful substances and undesired products). Neither residents nor farmers will accept exposure to increased hygienic risks, and farmers are obviously not interested in fertilizers with low nutrient content or high levels of environmentally harmful substances.

Hence diseases transmission routes and pathogen removals are essential factors that a designer of ecosan must know before hand.

3.2.5.4.1 Diseases transmission

Humans themselves are the main reservoir of most diseases that affect them. Transmission of excrete-related diseases from one host to another normally follows the routes shown in the Figure 11. Most routes for faecal related diseases are similar to those for water-related diseases.

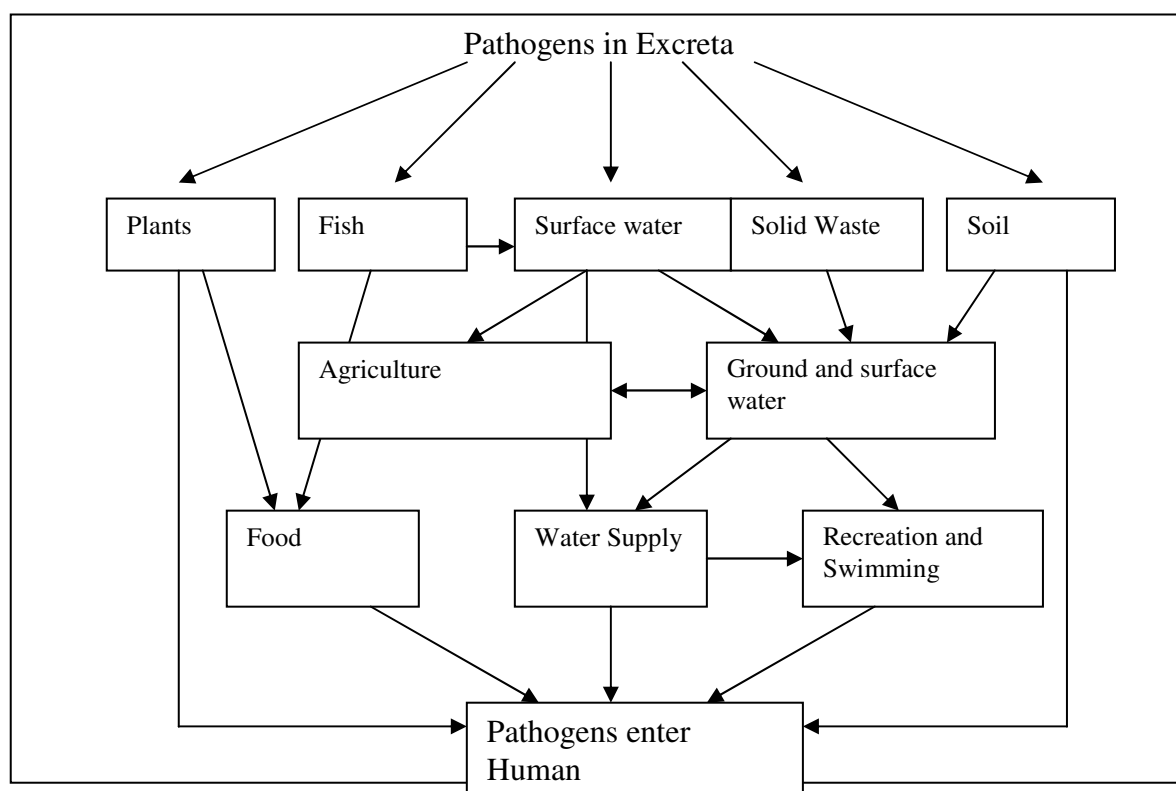


Figure 11 Transmission routes of pathogens (Marra & Cross, 1989)

3.2.5.4.2 Pathogen Removal

Excreta must not be stored or disposed of with risk of leakage of nutrients and pathogens to the ground water. Many conventional wastewater treatment systems depend on chemical or thermal disinfections however, ecologically engineered systems kill or immobilise pathogens in a variety of ways:

Suppression: Human pathogens have specific lifetimes, and many cannot survive long once they have left the human host. Containing excreta for an extended period, say, two years, is one method.

Competition: When carbon and nutrients are consumed, the microorganisms begin to consume their own protoplasm for cell maintenance. When these die, other organism digests their cellular matter.

Antagonism: Some organisms produce toxic substances, which harm or kill other microorganisms.

Adverse environmental factors: pH, temperature and ammonia content and retention time also destroy pathogens.

3.2.6 Advantages and promotional terms

It is advantageous in terms of both economy and ecology. ecosan serves both the requirements of indoor services as well as outdoor production and better environment. Dry ecosan toilets can be constructed directly indoors, as these toilets, unlike traditional on-plot sanitation, do not endanger the stability of the houses, as they do not require a pit, and have no flies and no odour unless well managed. Indoor toilets contribute to the security of the user, particularly women and girls using the toilet at night. They also save a good deal of time, as adults, normally women, can help children to the toilet with only a minimal delay in other activities.

It has been evaluated that when a urine separating system is introduced, nitrogen discharge into water bodies is reduced by about 60% and phosphorous by 60%.

The amount of water saved may vary between 5 — 40 litres per person per day depending on individual habits and the toilet with which the comparison is made.

When the hygienic conditions are met, excrements can be a good source of fertiliser. It is cheap and abundant, and especially favourable for local utilisation. Excreta not only serve as fertiliser; with its high organic matter it also serves as a soil conditioner. The main advantages of ecosan are given in Box 3. Furthermore ecosan:

- Provide organic fertiliser and/ soil conditioner and substitute artificial fertiliser.
- Minimise the consumption of fresh water.
- Economise the treatment of the separate wastewater.
- Provide Service and/or Irrigation water.
- Require no/low energy demand.

Although the necessity of ecosan is all around the world however it could be more reliable and adoptable in following situations as listed below.

- The areas facing water scarcity (arid, semi arid)
- Places where a water born system may not be economically viable (low income community)
- New Town planning areas.
- Existence of agriculture Practices (also in the urban/ peri-urban areas).
- Places where utilisation of urine, faecal is already in practice (easy adoption).
- Areas where availability of water is of high price.
- Areas with unsuitable geological conditions such as rock outcrop, and areas with high ground water table.
- Areas demanding irrigation water in order to develop Greenbelts and parks. (Grey water and yellow water).
- Areas with nitrogen and phosphorus demand for agricultural.
- Areas where availability and affordability of artificial fertiliser is low.

Box 3 Advantages of ecosan (source GTZ)

- Improvement of health by minimising the introduction of pathogens from human excrement into the water cycle
- Promotion of recycling by safe, hygienic recovery and use of nutrients, organics, trace elements, water and energy
- Resource conservation, through lower water consumption, substitution of chemical fertilisers and minimisation of water pollution
- Preference for modular, decentralised partial-flow systems for more appropriate cost-efficient solutions
- Possibility to integrate on-plot systems into houses, increasing using comfort and security for women and girls
- Contributes to the preservation of soil fertility
- Improvement of agricultural productivity and hence contributes to food security
- Promotion of a holistic, interdisciplinary approach (hygiene, water supply and sanitation, resource conservation, environmental protection, urban planning, agriculture, irrigation, food security, small-business promotion.)
- Material-flow cycle instead of disposal

3.2.7 Disadvantages and Constraints

Although an ecosan concept tries to find appropriate, sustainable solutions and has various advantages compared to a conventional sewage system, it also has some drawbacks if not properly handled and managed. Besides the risks for public health by using human faeces and urine (see chapter 5- the health aspect of using excrements.), several hindrances for implementation, operation and use have to be considered.

For the implementation of closed-loop systems there could be several constraints:

- Existence of a relatively new sewer system
- Cheap or subsidised prices for fresh water
- Installation and operation of treatment and recycling options are too expensive compared to installation of conventional system.
- Poor financial conditions.
- Technology and know-how deficit.
- Cultural and traditional constraints (Urine and excrements and their utilisation are a “prohibited” in some cultures).
- Social constraints regarding for example gender issues: only men are allowed to use the toilet, or women are responsible for cleaning the toilets.
- Political will and institutional capacity. As the most governments still tend to conventional sewage and central system, mostly because of ignorance of better local solution. Lack of motivation, advocacy and participatory in planning processes.
- Missing community participation.
- Missing or restrictive legislation.
- Separation of substances but no further utilisation or treatment.

For the operation and maintenance:

- Technology and know-how deficit
- Misusing of the toilet (in particular with urine separation toilets). Also throw away of contraries into the toilet bowl and reactor.

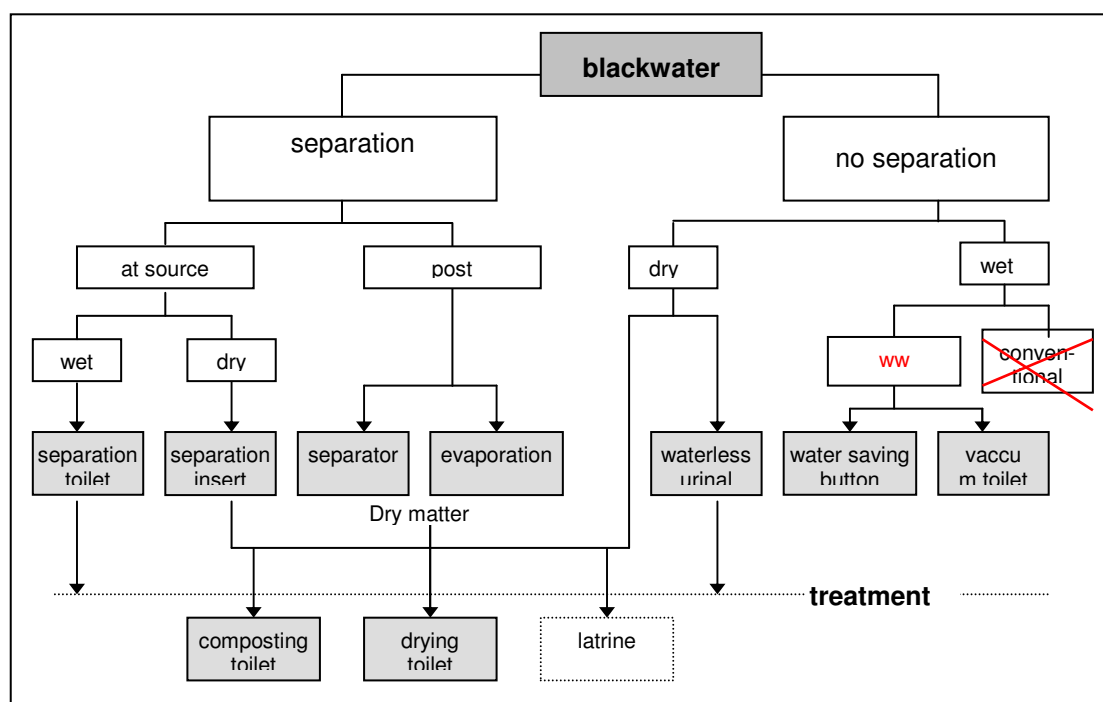
Farmers may face some of the discrepancies from this system as follows:

- Availability cannot be guaranteed at the required time (Six month storage)
- Quality variations due to climatic conditions and Handling.

3.2.8 Commonly used Sanitary Utensils

Sanitation is a very personal topic. Especially when introducing a new toilet or equipment for this proposes, it has to consider and respect cultural and social practises, beliefs and taboos. The functionality for the toilet is supposed to fail, if it ignores the persons and community habits. Due to these regions different sanitary equipment are developed and used around the world. Here only that equipment which is related to ecosan is discussed. Figure 12 shows the different sanitary options.

Figure 12: Options for sanitary equipment



Ideally for ecosan concept the sanitary equipment is constructed with urine and faeces separation devices but if it is locally and economically more feasible in the whole concept, the toilets can also be constructed as a water saving system. They do not separate the substances, but have advantages in remarkable water saving and further in the low dilution of the blackwater with flushing water. Table 4 shows how the aim of water saving can be fulfilled with different toilet systems.

Table 4: Comparison of water consumption for different toilet systems in litre

(litre)	Conventional toilet	Composting toilet	Vaccum toilet	Separation toilet
Water per flush	9	0 - 0,5	1	0,2 for urine flush 9 for full flush
Water per person per day*	45	0 - 1	5	10

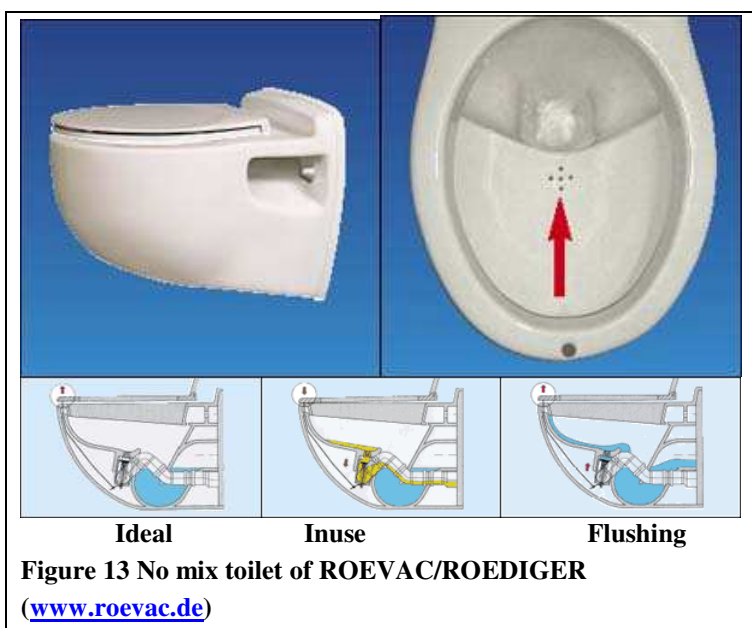
* assuming 1 “faeces flush” and 4 “urine flush” per day

3.2.8.1 Urine diverting toilet

The principle of the separation toilet is to separate urine and faeces directly at source in the toilet bowl, and drain both components in two independent systems. The idea of separation is very simple and the design of the toilet bowl range from very low cost to modern, high tech. The common designs are just different parts in the bowl that catches the urine and faeces separately from each other. Although the separate collection was common in some cultures, like in china and Vietnam but it is a new concept for the most countries.

The design of toilet has to full fill modern and high aesthetic design claims and personal hygiene and social constrains. A part from this urine separation toilet demands for a respectful toilet behaviour - some say even a cultural change - because men have to sit when urinating. To avoid this disadvantage, a good idea is to offer an additional urinal for men.

The toilet shown in Figure 13 is the no-mix toilet of German Company Roediger/Roevac,. The upfront opening (see arrow) is for the branching off the urine that will flow without water (undiluted!). Paper and faeces will be flushed away with a small amount of water into the back part of the bowl. The opening for urine is closing with a mechanical device, combined with the toilet seat. If the user is sits the urine vent opens automatically and closes when the user leaves the seat. This prevents the mixing of urine and flushing water.



In the model “Dubbletten” by the Swedish company *BB-Innovation &Co Inc.*, shown in Figure 14, the bowl is well separated into two parts: a small urinal in the front, and a bowl for faeces at the back, that has a bulge to prevent overflows. Both bowls have independent flushing systems, for urine 0,12 – 0,15 l flushing water is required where as the faeces

bowl is flushed with 4 - 6 l. The Bowl of the Swedish company *Wost Man ecology AB* (see Figure 15) functions similar to the previous one although it has a little different design.

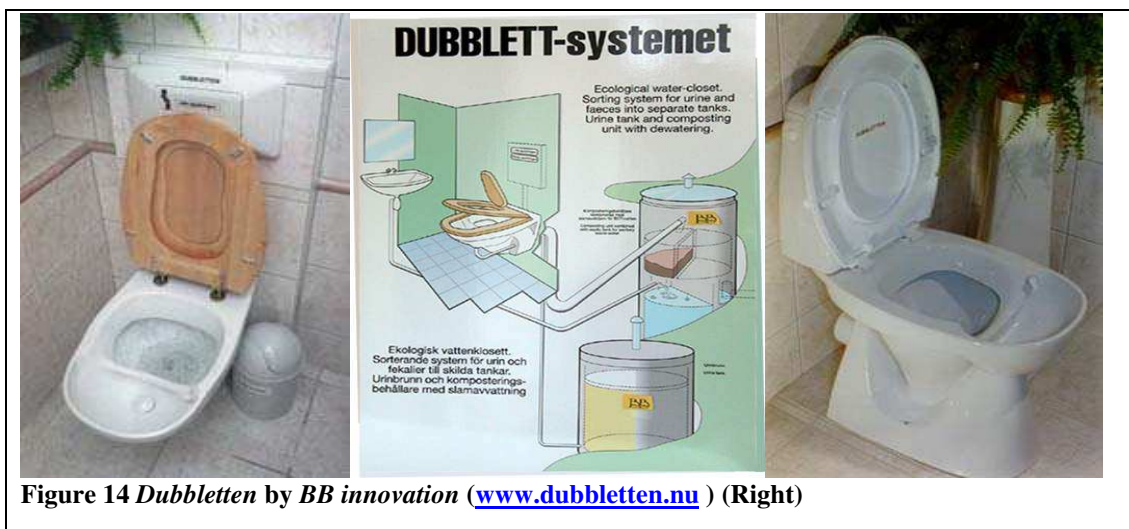


Figure 14 Dubbletten by BB innovation (www.dubbletten.nu) (Right)



Figure 15 Separation toilets from left- double flush, single flush, WM-barrel and WM-Privvy from left by *Wost Man ecology AB* (www.wost-man-ecology.se)

3.2.8.2 Separator

The second possibility of separating urine and faeces, is the post separation. This is popularly done with Aquatron. In this system the urine and faeces are drained together in a chamber and with mechanical devices the liquids and solids are separated. The major disadvantage of this system is that the liquid (grey water and urine) already mixed with the faeces. As a result the sterile urine can be polluted by faecal pathogens. This affords a superior hygienic treatment, like sterilisation, before utilising as fertiliser.

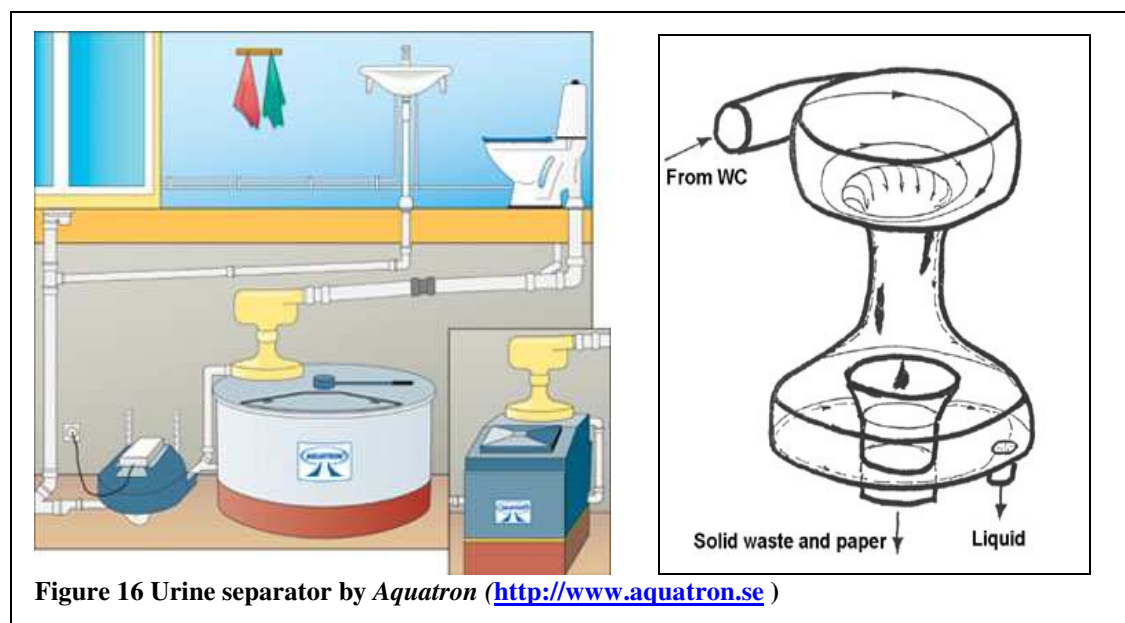


Figure 16 shows the separator of the Swedish Company *Aquatron*. It's a small plastic unit in the shape of an hourglass. The device uses the momentum of the flushing process to divide the liquid and solid components by centrifugal forces and gravity. The more heavy solid waste and paper drops in the middle, while the liquids are pressed on the outside surface and drops into the outlet pipe. The separator is connected to a composting chamber for treatment of solid wastes. Combined draining water from the base of the chamber and the toilet water are passing an UV-unit for sterilization before it is piped to a grey water collection tank.

3.2.8.3 Water less urinal

The looks of these toilets do not vary from normal urinals. But in order to save the flushing water the toilet bowl is specially designed to guarantee a well urine discharge. Some toilets are operating with additional chemicals and with special ceramic surface coating. In South Africa the outlet of this urinal are moulded with material like latex to protect further clotting into pipe due to segregation of urine. The important advantage of water saving urinal is, that it does not demand for water network and the collected urine is undiluted and could be efficiently used in agriculture as fertiliser.

3.2.8.4 Separation inserts

Separation inserts are designed with the same function as separation toilets, but with the difference, that they don't demand for flushing water (=dry system). The faeces fall into a composting and drying chamber, while urine is piped away. For cleaning small amounts of water is used. To keep the toilet odourless the adding of absorbing materials after defecation are recommended. The insert can be further installed to upgrade conventional toilets with a urine diversion and collection.



Figure 17 Set of urinal and separation insert by Senforce (South Africa)



Figure 18 Squat pan with urine diversion from Palestine

The Figure 17 shows an insert developed by South African Company *Senforce*. It is made out of recycled plastic and is light. The company offers a set of urinal (for men). There are also squatting inserts panels with urine and faeces separation. An example is shown in Figure 18. It is provided with the cover to prevent from foul and fly nuisance. However in China the pan cover is different from this it is slide sideways instead of flapping up to open as in this case.

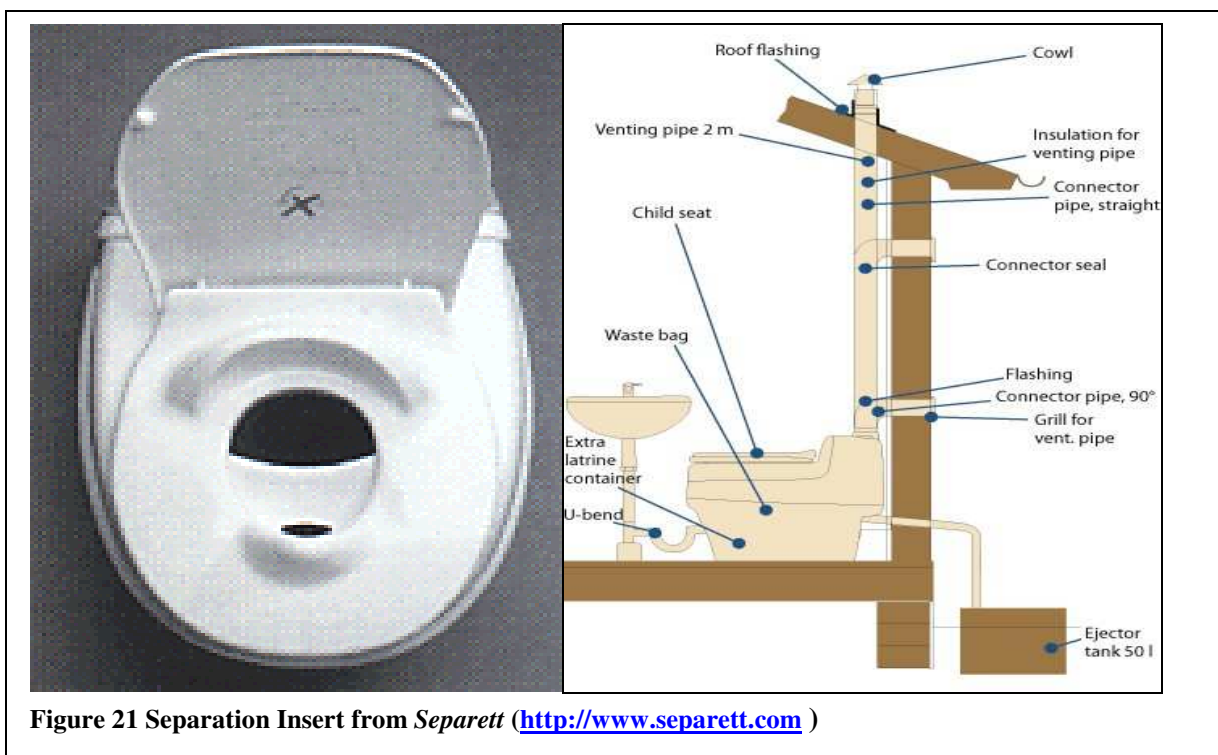


Figure 19 *Eco-latrine* Africa
(<http://www.ias.unu.edu/proceedings/icibs/ecosan/eg-nnt>)

Low-tech solutions, like latrines, can also be equipped with urine and faeces separation. The Figure 19 shows a hand made concrete defecation pedestal and toilet.



The insert, shown in Figure 20 was developed in Mexico, which is a very easy and cheap device to put on the toilet bowl. As for kids the utilisation of a separation toilet is more



difficult, some manufactures offer child seats as shown in figure Figure 21 model given by Separett.

3.2.8.5 Vacuum toilet

In the vacuum toilet systems the components are installed within the toilet body (an example is shown in Figure 22). The toilet is connected to a vacuum tank that generates

the necessary pressure for vacuum. With this pressure only 1 liter of water is needed per flushing.

Benefiting from water saving and low wastewater amounts, the vacuum toilets are now common in trains, airplanes and ships. Noise is a concern, but modern units are not much louder than conventional toilets. Vacuum toilets are high tech solutions, and the installation is costly and requires high technology skills. But on the other hand it obviously reduces the water consumption and as a matter of fact the black water can be collected relatively undiluted. Additionally the pipe diameter is drastically reduced, hence saving the cost of pipe.

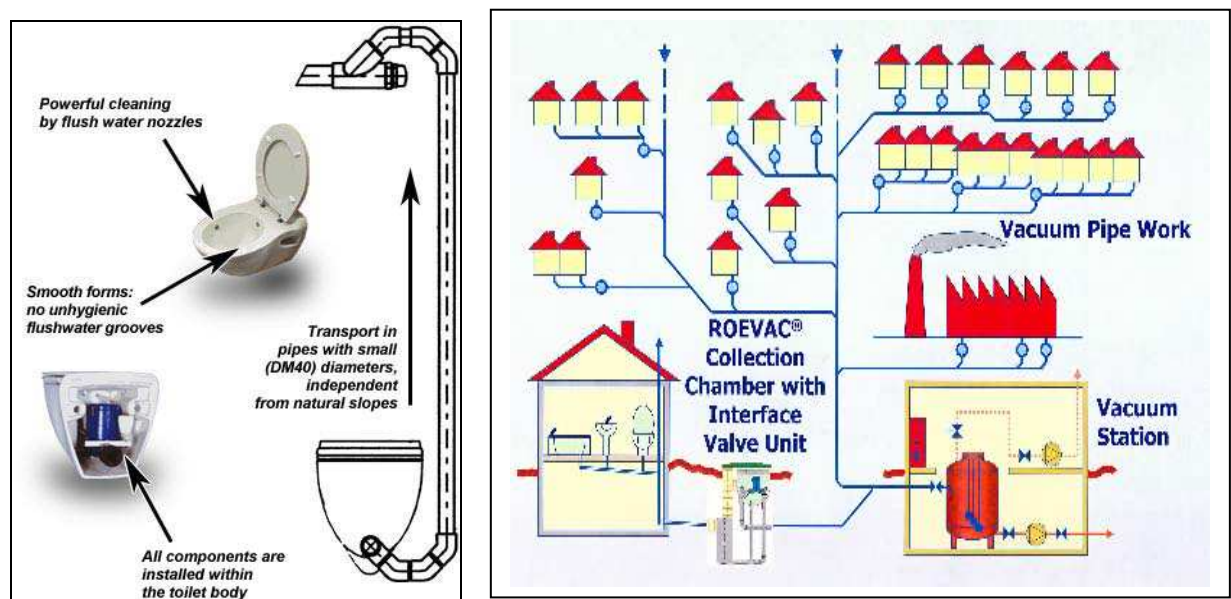


Figure 22: Vacuum toilet for household installation by Roediger (www.roevac.de)

3.2.8.6 Composting Toilets

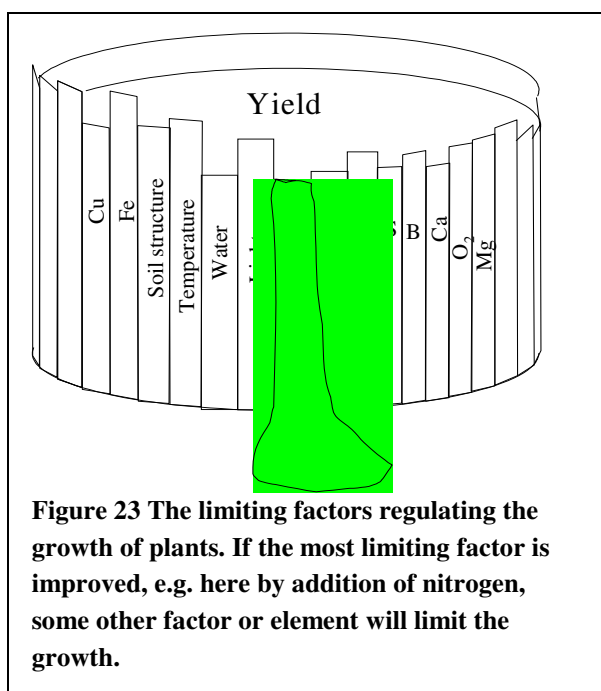
Composting and drying toilets are a special toilet system that can be considered as treatment technology to process the human waste into fertiliser. The detailed descriptions of these types of toilets are given in chapter 5.

4 Utilisation of Excrement in food Production

Many of the nutrients used today are produced either from fossil resources or consume large amounts of fossil resources during their production. During food production, nutrients are removed from the soil and these nutrients have to be replaced by plant-available fresh nutrients. The main nutrient source is manure either compost or chemical fertiliser. Further more toilet waste and together with organic household waste fractions also contain more or less the same amounts of nutrients removed from the field during food production. Hence the utilisation of excrement in case of food production is quite important for the sustainability of food security.

4.1 Nutrient requirement of plant

Elements essential for the growth of plants are normally called nutrients. There are two types of elements non-mineral and mineral nutrients. The nutrients used in the largest



amounts are the non-mineral elements, i.e. carbon, hydrogen, and oxygen. These substances are mainly derived from carbon dioxide (CO_2) and water (H_2O). All other nutrients are mainly taken up from the soil by the roots. Increasing the supply of light, CO_2 , water and mineral nutrients from the deficiency range influence the photosynthesis process, which ultimately increases growth rate and crop yield. The yield response of a particular mineral nutrient can be illustrated as in Figure 23.

When the supply of one mineral nutrient or growth factor is increased, other mineral nutrients or growth factors then become important as limiting factors. Hence nutrients supply should be optimal as far as possible.

Further more nutrients can be divided into the two category macronutrients and micronutrients. From different researches it is found that the total uptake of macronutrients is about 100 times that of micronutrients. Six elements nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca) and magnesium (Mg) are

known as the macronutrients. Among these, yearly additions are usually needed of the first four (N, P, K, S), while the soil itself supply sufficient Ca and Mg at reliable pH value (i.e. when it is not too low). Nitrogen is frequently the most limiting nutrient for plant growth. The main natural sources of plant-available N are degradation of organic matter in the soil and N fixation by microorganisms living in symbiosis with the roots of legumes.

The natural supply of Phosphorus comes from mineralisation of phosphates and from degradation of organic matter in the soil. In acidic soil the availability of Phosphorus is often low, due to strong bonds between phosphates and metal ions at low pH. The high water solubility of Potassium often results in a good supply of plant-available Potassium. However, many crops such as vegetables need large amounts of potassium and therefore additional fertilisation improves plant growth. Sulphur is also highly water-soluble and normally crops need it in smaller amounts as compare to Phosphorous. Even so, on many soils yearly additions of Sulphur are sometimes needed.

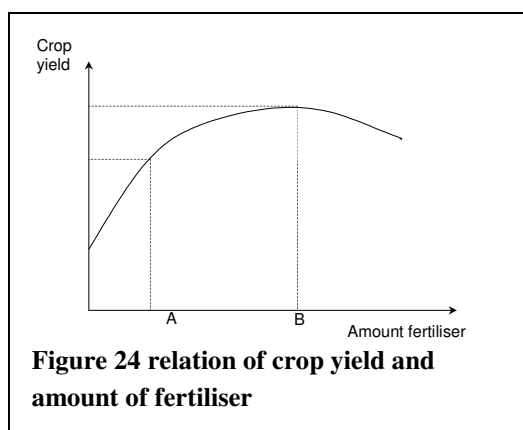
Micronutrients are also essential for plant growth, but the uptake of these elements is in small (micro) amounts. The elements normally considered to be micronutrients are boron, copper, iron, chloride, manganese, molybdenum and zinc (Frausto da Silva & Williams, 1997). Most micronutrients are needed for formation of different enzymes. These nutrients mainly come from degradation of organic material and erosion of soil particles.

Only in special circumstances does scarcity of micronutrients limit plant growth. When human excreta are used as a fertiliser, the risk for such deficiency is minimal as excreta contain all the micronutrients.

Fertilisation only increases crop yield if the plant nutrients supply are in optimal balance as well as supply of adequate water and reasonable

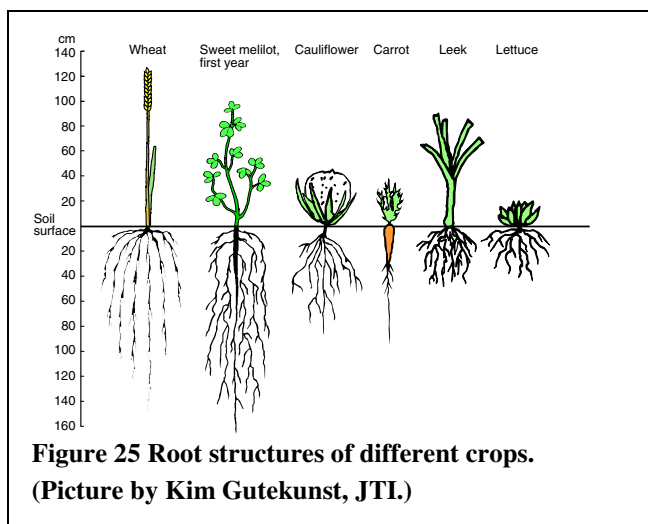
other factors. No yield increase is to be expected when fertilising crops are mainly limited by factors other than nutrient supply, e.g. lack of water, too low or too high pH, etc.

There is enough space to utilise all of the nutrients to their full potential if the average application of available nitrogen is below dose A in Figure 24. Dose A is the point up to



which the yield increases linearly with the increase in the application of fertiliser. However this may differ between different crops, regions and climate.

When the space is limited the best fertilising efficiency is that the average dose should be above A. this can be obtained by keeping the dose even over the whole available space, if all the crops have the same nitrogen demand. In this case the yield increases according to the increase rate of dose from A to B in Figure 24. However, both the quantity and the quality of the yield are important and high doses of available nitrogen (i.e. urine) can also affect the quality. For example, the quality of wheat is generally improved by a high nitrogen dosage, while the quality of, Irish potatoes may decrease since the tubers can become watery.



Vegetables are normally harvested before they reach their reproductive stage and therefore fertilisation can be continued until some time before the harvest. As a rule of thumb, fertilisation should stop after between 2/3 and 3/4 of the time between sowing and harvest. The amount of nutrients and the intervals depend mainly on nitrogen usage by the plant

and root size. Root size varies between different crops (Figure 25). Plants with inefficient or small root systems, e.g. carrots or lettuce, could possibly benefit from several applications of nutrients throughout the cultivation time (Thorup-Kristensen, 2001.)

4.2 Fertilising value of Excrements

As discussed in chapter 4 excrements contains most of the nutrients required for the growth of plants. Often when human excreta are used for fertilisation, the available amount is very limited in relation to the amount of plant nutrients needed. Therefore, it is important that the excreta should be used in the most efficient way and this differs depending on the amount of available nutrients in relation to the available space as well as the type of crop.

The major proportions of the nutrients in excreta are come from urine. According to the amounts consumed in food, about 70-90% of the nitrogen, 45-80% of the phosphorus and 70-95% of the potassium are found in this fraction while the rest is found in the faeces (Lentner et al., 1981; Guyton, 1992; Vinnerås 2002). The urine nutrients are water-soluble and relatively available for plants to take up or easily transformed into plant-available compounds (Kirchmann & Pettersson, 1995).

Faeces are the smallest of the biodegradable waste fractions by weight. Between 30 and 110 kilograms wet weight of faeces is produced per person and year. This corresponds to 10-15 kilograms of dry matter (Lentner et al., 1981; Vinnerås 2002). The volume produced per person depends upon the composition of the food consumed. Meat and other foods low in fibre produce smaller volumes than food high in fibre (Guyton, 1992). Faecal nitrogen is mainly found as organic nitrogen and has therefore to be mineralised before it becomes available for plants. Phosphorus is mainly found as small grains of calcium phosphates in the faeces (Frausto da Silva & Williams, 1997) and this phosphorous is available to plants. Potassium is mainly found in soluble ionic form in water (Berger, 1960) and is therefore easily available to plant. Faeces are high in phosphorous and potassium, but also contain low amount of nitrogen. The amount of nutrients found in excrements depends on the nutrient content of the food consumed. This varies from person to person and region to region. The nutrient content of excrements and nutrient demands for crop is given in Table 5.

Table 5 Nutrient content of excrements and nutrient demand for crops

Nutrient	Nutrient content of urine in kg per person per year*	Nutrient content of faeces in kg per person per year*	Nutrient content of Blackwater in kg per person per year**	Nutrient need for 200kg crops**	Nutrient need for 250kg crops**
N	4	0.5	3.8-4.7	5.1	5.6
P	0.4	0.2	0.6-0.7	0.6	0.7
K	1	0.2-0.4	1.2-1.3	1.0	1.2
Total N+P+K	4.5	0.9-1.1	5.6-6.7	6.7	7.5

Source: (**Drangert, 1998; West, 2001 and *Otterpohl, 2001 ;Esrey, 2001)

4.2.1 Urine

As shown in Table 5 and discussed in chapter 4, the fertilising effect of urine is similar to that of a nitrogen-rich chemical fertiliser. Therefore, urine can be utilised as a best

fertiliser to nitrogen-demanding crops and vegetables. If crop- and region-specific recommendations are available for the use of such a chemical fertiliser, a good starting point is to translate this recommendation to urine. This translation is simplified if the nitrogen concentration of the urine is known. If it is not, then as a rule of thumb, a concentration of 3-7 grams of nitrogen per litre of urine can be expected, or approximately half that concentration if flushed urine-diverting toilets are used (Vinnerås, 2002, Vinnerås & Jönsson, 2003).

4.2.1.1 Application technique

For best fertilising effect, the urine should be mixed into the soil as soon as possible after the application, instantly if possible. This can be done by applying it in small furrows and covered after application. It can also be done by adding water after the urine application so the nutrients are washed into the soil. When applying the urine, spraying over the leaves with urine should be avoided as this can cause foliar burning due to high concentrations of salts. Spraying urine in the air should also be avoided as the nitrogen in the urine is partly lost as gaseous emissions of ammonia (Rodhe et al, 2003).

It is not necessary to dilute the urine before application. However, the whole root of the plants should not be thoroughly soaked with undiluted urine, as this might be toxic and even lethal, especially for small plants. Instead, the urine should be applied either prior to sowing/planting or at such a distance from the plants that the nutrients are within reach of the roots.

The application of urine is depends upon the space available for plant growth as shown in Figure 24. If the space is unknown than as a thumb rule the application of the urine from one person during a full day per square metre (approx 1.5 litres of urine/m²) can be used with out any calculations. This corresponds to application of approximately 40-80 kg N/ha. When space is not a limiting factor, the full fertilising effect can easily be gained from urine, by applying required dosages in required space. If space is even more limited, then the dose should be limited as additional dose may be toxic. In such cases the amount of urine that cannot be utilised as a fertiliser and should be disposed of in some other way, i.e. as an accelerating agent when composting (Shelter waste, Kitchen waste).

4.2.2 Faeces

As shown in Table 5 and discussed in chapter 4 the nutrient content in faecal matter is considerably lower than that in urine, especially the amount of plant-available nitrogen. The main contribution from the faecal matter is the content of phosphorus and potassium and the increase in buffering capacity of the soil.

Faeces are rich in phosphorous and potassium and should therefore preferably be used on crops that have a high demand for potassium and phosphorous. The dose can be based on the recommended dose for use of phosphorous in chemical fertilisers. The risk of over-application is small, but toxic effects can occur at high application rates if the faeces are mixed with large amounts of ash.

4.2.2.1 Application technique

To gain the maximal effect from faecal matter it should, just as urine, be applied close to the roots of the plants, but not in such a way that it is the only growing medium available for the root. The easiest way to do this is by application in holes or furrows close to the plant. Faecal material should be cultivated into the ground and covered as soon as possible after application, to prevent unwanted contact with potential remaining pathogens. For best effect, it should be applied before sowing/planting. Care should be taken to prepare a proper seed bed.

4.3 Economical aspect of excrement use

Human excreta contain major plant available nutrient Nitrogen, Potassium, Potassium and others. Using proper treatment and applying appropriate technology these nutrient can easily be made available to the plant. Hence the economical value of excreta is quite mentionable in terms of increasing crop yield, reduction of chemical fertiliser and environmental protection.

4.3.1 Increase Crop Yields

Each person produces per year about 6 kg of Nitrogen, phosphorus and potassium and this is almost the amount of nutrients that is needed for growing his or her own food (Drangert, 1998) - equivalent to 200-250 kg of crops. Table 5 shows a detailed comparison of the nutrient content and the nutrient demand for crops. If all the nutrients can properly extracted no artificial fertiliser is required. But in reality, a part of this

potential is lost during storage and treatment, e.g. nitrogen loss through ammonia volatilisation (Strauss, 2000). One person can fertile approximately ~200m² in Europe or ~400m² in sub-Saharan Africa agricultural area with excrements nutrients (ecosan Presentation, 2002; Mang).

4.3.2 Comparison with artificial /industrial fertilizer

As it is already state that the fertilising effects of urine for crops have been found out to be very close for nitrogen (~90%) and almost equal for phosphorus. Compost from excrements can be used in the same way as inorganic, industrial fertiliser. But in some cases, depending on the raw material mixture, some elements are in lower concentrations. A nutrient comparison to the commercial fertiliser is presented in Table 6. As a result, compost is considered in some cases more as soil conditioner and low-analysis fertiliser.

Table 6 Nutrients in human waste compare to commercial, chemical fertiliser (Mid 1990s's)

Country	Nutrient equivalentent (%)*
Kenya	136
Indonesia	49
Zimbabwe	38
Mexico	31
Colombia	31
South Africa	29
Egypt	26
India	26
Tunisia	25

Source: World water Institute (Gardner, 1998)

*assumes a loss of 50% of nitrogen through volatilisation

On the other hand, compost has a quality close to humus. This can be of benefit in areas where the humus content of the soil is depleted as a result of excessive agriculture and soil erosion. Compost can replace lost humus (Obeng, 1987) and improve the general soil quality. Furthermore, organic fertiliser made out of human excrements can compensate for the following disadvantages of artificial fertiliser:

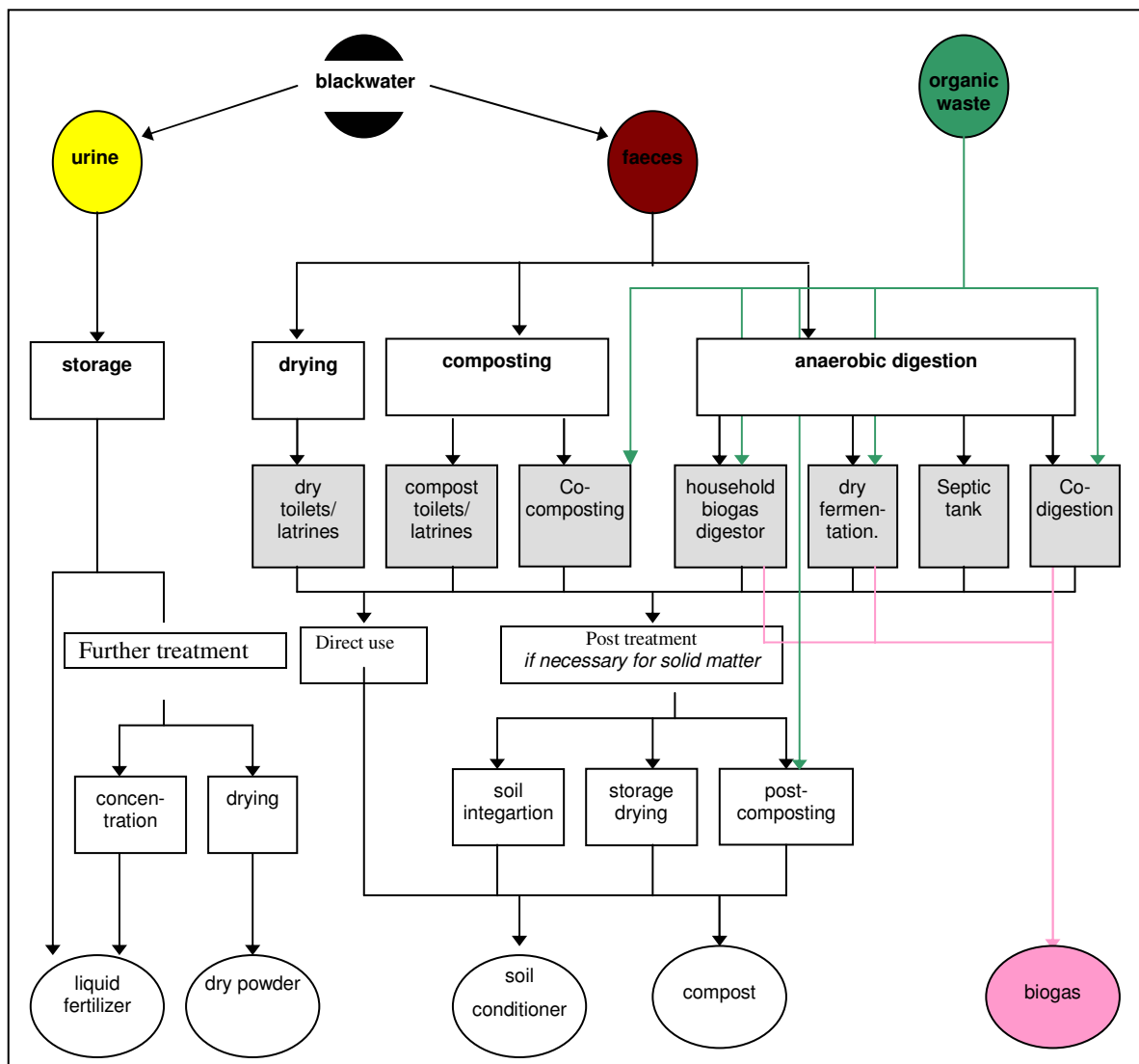
- In some parts of the world, artificial fertiliser is too expensive or unavailable to local farmers.
- Large amounts of energy and fossil fuels are needed to produce artificial fertiliser. Organic fertiliser conserves energy, further lowering CO₂ emissions, and extending the life of phosphate mines.

- Urban nutrient recycling programs may lower both operating costs to farmers and food prices for the consumer.

4.4 Treatment Technologies for Excrements

Normally a treatment technology for excrements must fulfil destruction of pathogens. In case of ecosan concept only destruction is not sufficient but also the extraction of nutrient and use of treated water should come simultaneously. In ecosan all the possible wastewater treatment technology can be applied. Dealing of all possible types of treatment is beyond the limit and aim of this thesis. In this thesis the decentralise systems particularly dealing with black water is considered. The common technologies/processes for treatment of excrements are: storage, drying, composting and anaerobic digestion. Figure 26 gives schematic diagram of different possibilities. The suitability of treatment process depends on sanitary equipment used, outflow from these utensils and moisture content of initial material.

Figure 26: Treatment options different household used water



4.4.1 Storage

Enclosed storage is an approved technology for urine treatment. Generally urine is taken as sterilize liquid from the healthy personal. However the healthiness of the person cannot be ensured. Hence there is always a chance of pathogens content in urine. A storage period of 6 month at 20°C is recommended for urine storage. This storage period destructs pathogens and eventual medicament residues by increasing pH value inside the tank assuming that there will be no contamination by faeces or soil from leakages. In order to stabilize the ammonium, acid (e.g. vinegar) can be added. The storage capacity of the



Figure 27 Urine tank in Lambertsühle Material HDP, storage tank (www.lambertsuehle.de)

tanks must be dimensioned according to the expected amount in the discharge quantity from designed person at least for a six-month period considering safety factor. The tank can be constructed from various material, preferable light durable plastic, but also concrete is possible. Any metal components should be avoided, because urine is very corrosive when fresh, and the metals can cause contamination in the almost heavy-metal free urine. Typical tank is given in Figure 27.

4.4.2 Drying

Drying means an extraction of water and volatile components. The objective is to dehumidify the excrement until they reach a dry consistence. In this process the excrements are treated in a dehydration process and not in degradation processes. The process can be supported and accelerated with extra heat, ventilation and if necessary with the additive of drying material (ash, sawdust, soil, husks, etc.). Drying systems are especially feasible for arid areas, because the drying can be achieved with ambient temperatures of the region. A drying may not necessarily destroy the pathogens; they are inactivated in the dry product. But if the material is wet again, the pathogens can be released. To guarantee a hygienic product a post-treatment should be considered. There are several methods of drying however dry toilets are most commonly used around the world.

A dry toilet or dry latrine stores the faeces in a vault, where they can dry out with help of heat, ventilation and additives. The end product is more a kind of mulch than compost.



Figure 28 Drying toilet from ESAC/CITA with two vaults. (<http://www.laneta.apc.org/esac/index.htm>)

The principle of a dry toilet is to reduce the moisture of the faeces under 25%. Under this level, the destruction of pathogens is more effective, and further more there will be no odours and fly breeding. In dry toilet urine should be separated and water for anal cleaning also should be as low as possible, otherwise the moisture content would be high and may disturb and hinder the process. For the generation of heat and ventilation some toilets require an external power supply (for cold regions), others work with solar heat (for arid regions). Additives should be regularly poured onto the faeces (depending on the model after defecation) for the reduction of moisture, smell and to increase the pH value.

A more simplified dry toilet was invented in Mexico by the NGO ‘Espacio de Salud A.C.’ (ESAC) and the ‘Centro de Innovacion Tecnologica’ (CITA). (Figure 28) It is in use since last 15 years and is simple to build only by using local materials. The dry toilet consists of

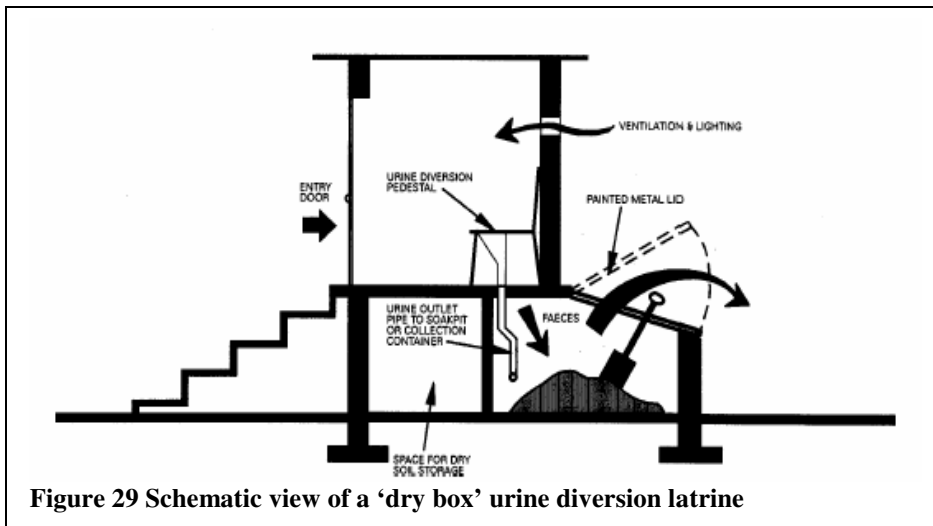


Figure 29 Schematic view of a ‘dry box’ urine diversion latrine

two vaults referring to a batch process: one in use and the other inactive.

The Model shown in the Figure 29 is designed as a

“dry box” toilet. The faeces are collected in a vault under the toilet where they are treated with a mixture of ash and soil. To enhance the heating in the chamber and therefore to accelerate the dehydration process, a metal lid on the outside of the latrine is painted in dark colour. The dried material can be derived from the opening.

4.4.3 Composting

Composting is the process of mineralising organic substances by microorganism and transforming it into compost. It is a multistage degradation process where pathogen viruses and bacteria are also destroyed. But composting is only possible in aerobic condition. As a reason of the intensive microbiological degradation processes the organic material will be heated, which also supports the destruction of pathogens. Therefore a well managed and designed composting process can also handle human faeces for safe compost. The effecting composting required following conditions (Windberg, 2001):

- Optimum moisture content range from 50-60% , <70%
- Temperature below 70°C, optimum between 35°C –55°C
- C/N ratio approximately 30:1
- pH Value 5,5-8,5
- Oxygen concentration >10%

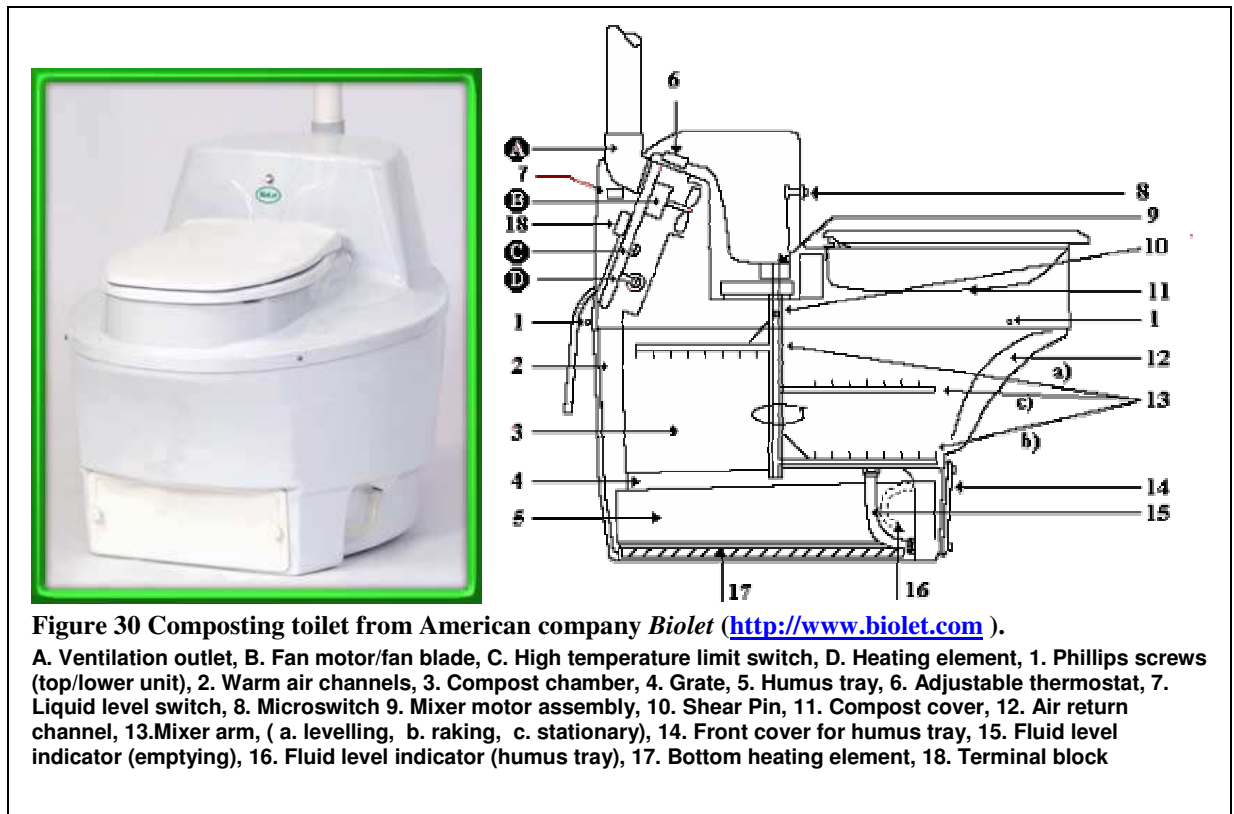
For the composting of human excrements, urine is preferred to be separated. Urine contains too much nitrogen to allow an effective composting process and additionally the substrate get too wet (Jenkins, 1999). The high nitrogen content of excrements can be balanced by adding more carbon material such as sawdust or ashes in non-separating system. Faeces are wet with less structure and they have a low C:N ratio: it is 6:1 (compared to fresh vegetable 20:1, dry straw 100:1). The optimum of 30:1 can be reached with the addition of carbon rich material, like straw dust, kitchen waste, toilet paper, and grass. It should be added in the same amount as that of faeces (Jenkins, 1999). The added carbon material also absorbs the excess liquid and will cover the refuse sufficiently to eliminate odour completely.

Depending on the initial material, the process conditions and the achievable pathogen removal rates the retention time can vary from 3-12 months. For receiving a high quality and marketable product, the material has to compose over a longer period. There are two major technical possibilities for composting: Composting toilets and Co-composting with organic wastes.

4.4.3.1 Composting toilets

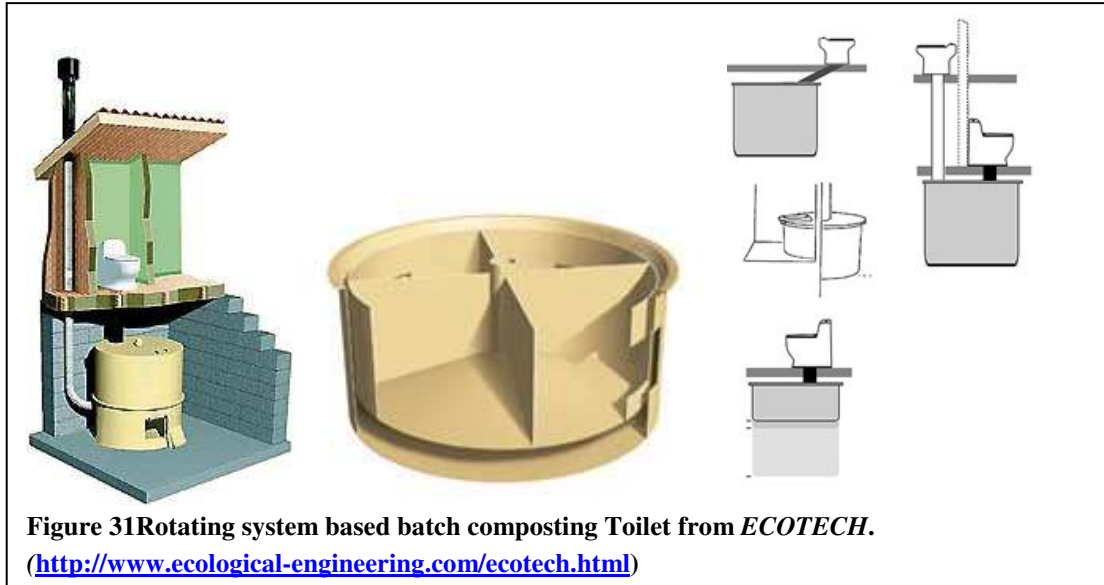
Basically a composting toilet consists of the toilet seat and a well-ventilated container. In the composting container underneath the toilet seat the excrements are treated together by

composting, worm processing, micro and macro - organism breakdown, and by dehydration. For the composting container itself there are a variety of shapes and designs, but the system can broadly divided into two types: continuous process systems and batch systems.

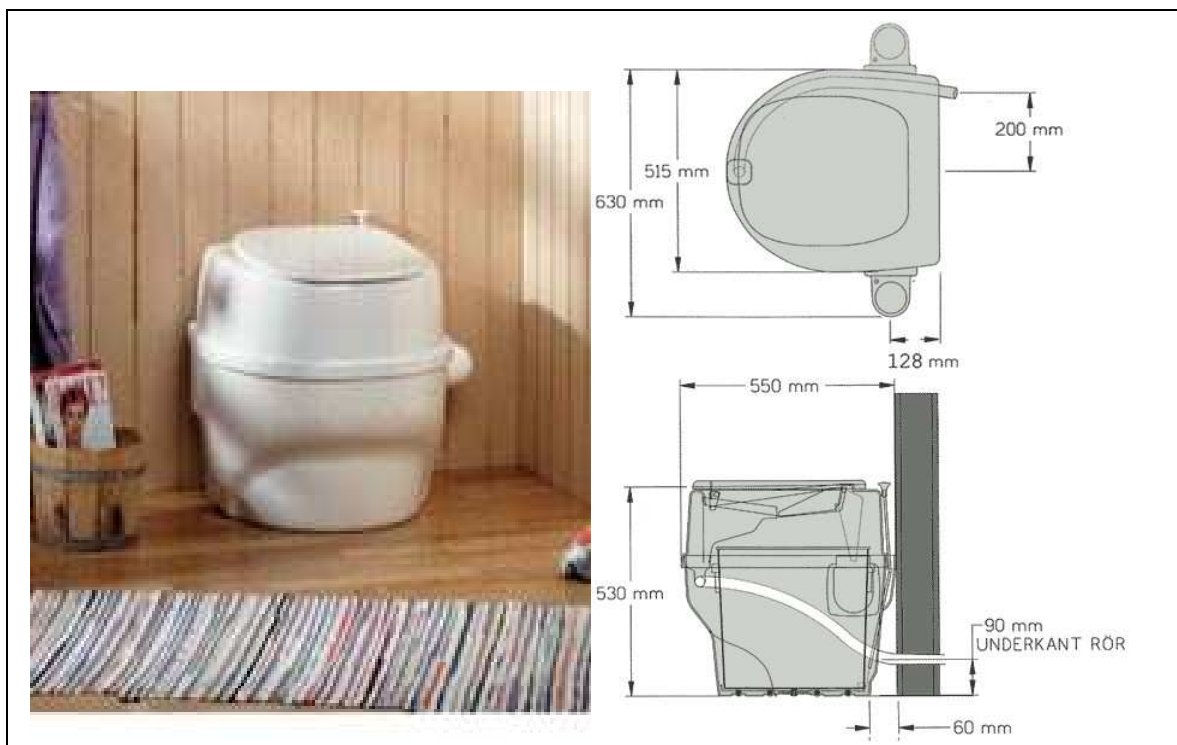


Continual process systems: These systems are in a constant state of composting. Here excrements are put into the system and can be removed after 6-12 months. These systems take advantage of the fact, which during composting the volume of the excrements in the toilet will be reduced by 10-30%. The Figure 30 is an example made from American company Biolet

Batch systems: With the batch systems, a container is filled and then replaced with an empty container. Inside the sealed container the composting process can finish undisturbed from new material input. The system may have a single, replaceable container, or it can be designed as a carousel system where 3 or 4 containers are mounted. After the cycle is completed, the first container is fully composted and ready for emptying. Figure 31 is an example of such composting toilet by American company ECOTECh



Most models combine the two elements toilet seat and container in one complete toilet , but there are also models that have separate seating -with a choice of different seats- and with the composting chamber installed in the basement of the house (see Figure 31). Urine diversion makes compost process very easy by reducing moisture content so the models with urine diversion are common now a day. A typical model is given in Figure 32.



Evaporation is assisted by heat and airflow and every composting toilet must have a vertical vent pipe to carry off moisture. As standard equipment most of the toilets are equipped with a small heating element. This demands for electricity, whereas non-electric models use batteries or solar energy (in case of cold climates).

Compost toilets are especially feasible for remote areas (e.g. in national parks), areas with difficult or no access to sewage, etc. Another advantage of the technology is the possibility of adding organic household wastes to the chamber, where it decomposes together with the faecal sludge.

4.4.3.2 Co-composting

The C:N ratio and the moisture of night-soil is not suitable for a single treatment, hence it requires some bulking agent and organic matters. This can be fulfilled with the organic fraction of household wastes or separately collected municipal solid waste. This process can benefit from the approved technology of organic waste composting. And further from the reduction of total waste generated. There are two main possibilities: Household orientated composting in a tank with the household wastes and Pile Composting.

Household composting tank

This household orientated composting, usually practices in a tank outside in the garden, a solution for larger households. A separation of liquid/solid, preferable urine/brownwater is necessary in this process. Organic household wastes are added manually direct into the container.

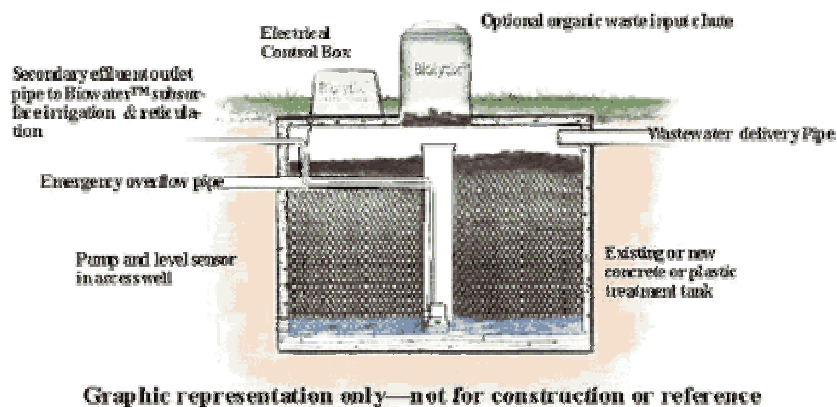


Figure 33 Composting tank by *Biolytix* (<http://www.biolytix.com>)

The household composting tank model shown in Figure 33 is designed by *Biolytix*. The process is called filtration, although it is a worm composting process. The specific composting is done by special organism, mainly earthworms, beetles and mites. A filter is designed to separate liquid and solid waste while reaching the chamber/tank, where the solid content decomposes.

Pile composting

In this process night-soil is arranged together with organic wastes and bulking material on a composting pile. For the composting the human excrements should be mixed with the wastes to reach an optimum moisture content with 2 –3 times the volume with organic wastes, (Jenkins, 1999). Calculations from Obeng (1987) to mix 1 ton waste with 80kg night-soil (3% solid), or 140 kg settled pit latrine sludge.

The shape of the pile with maximum height of 2 metres and sides slope of 45°. (AID, 1982). For continuous aeration and steady conditions in the pile, it should be turned several times in the first weeks. Aeration can additionally be supported by extra vent pipes (e.g. a low cost option used in China are bamboo poles). Various types of compost piles are illustrated in Figure 34.

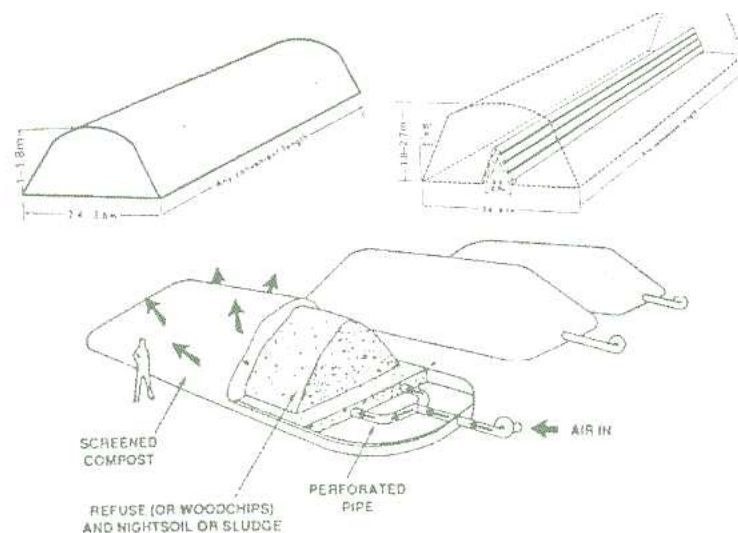


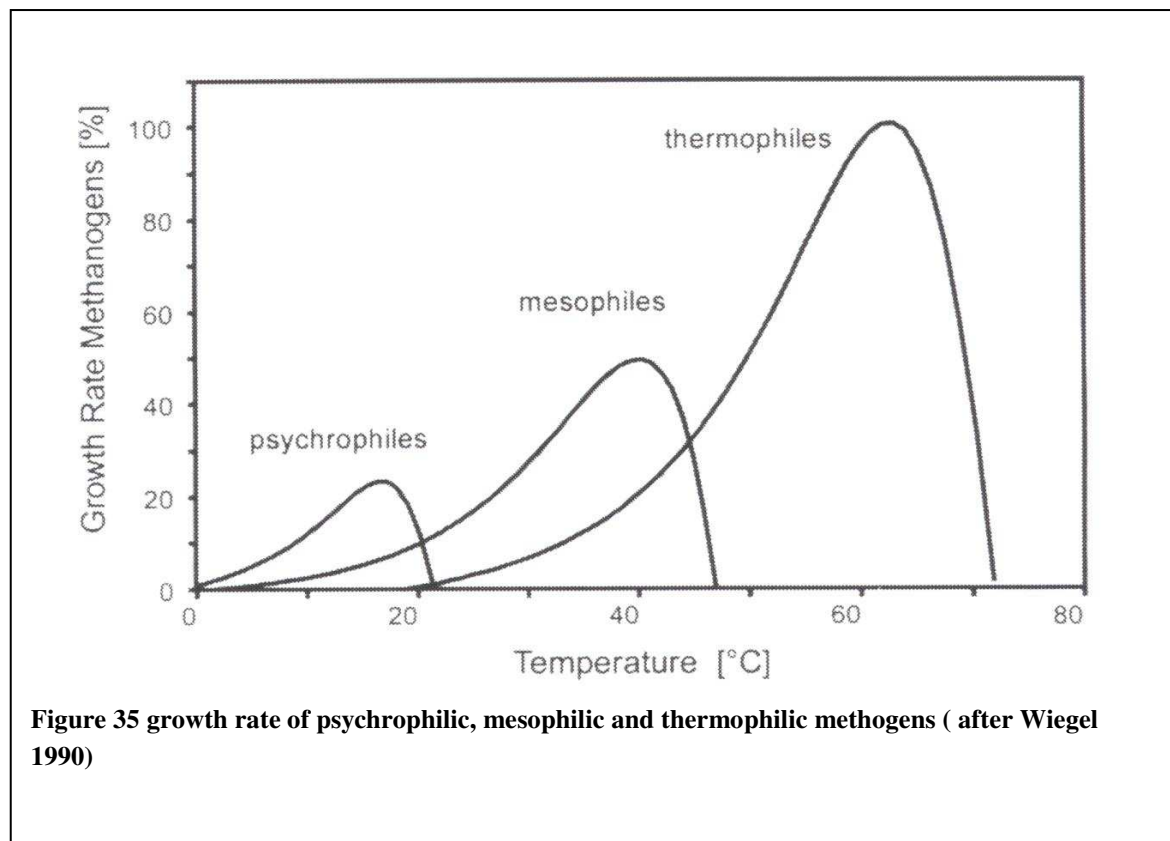
Figure 34 Different types of composting piles for refuse and night-soil or sludge. Without aeration (top left), passive aeration (top right) and forced aeration (bottom) (GTZ, 2002)

This process started in the early 70s with the co-composting of municipal wastes together with sewage sludge in western society. China, India and Haiti made the first experience with night-soil. A processing with night-soil seem to be preferable because it does not contain heavy metals like sewage sludge (Obeng, 1987).

For gaining a marketable product, a pre-separation of disturbances (plastic, glass, etc.) and a sieving of the end product should be included. The process can be divided into a main composting, with strong degradation activities (1-2 months) and a post-maturation, with decreasing activities (2-4 months). Pile composting can be carried out as a low cost options for developing countries.

4.4.4 Anaerobic digestion

An anaerobic digestion is the process of degrading organic matter in the absence of oxygen. Anaerobic digestion is considered to be possible under three ranges of temperatures- psychrophilic, mesophilic and thermophilic. The optimal temperature of psychrophilic micro-organism is around 17°C (Edeline 1997). Low temperature conditions generally lead to a decrease in the maximum specific growth rate. Psychrophilic microorganisms take approx 35 days for digestion which is 3.5 and 9 times higher than that of mesophilic and thermophilic respectively. The different ranges are given in Figure 35.



It is a fermentation process with the help of specific bacteria and under controlled in temperatures. In the fermentation process different gases and sludge are produced. The

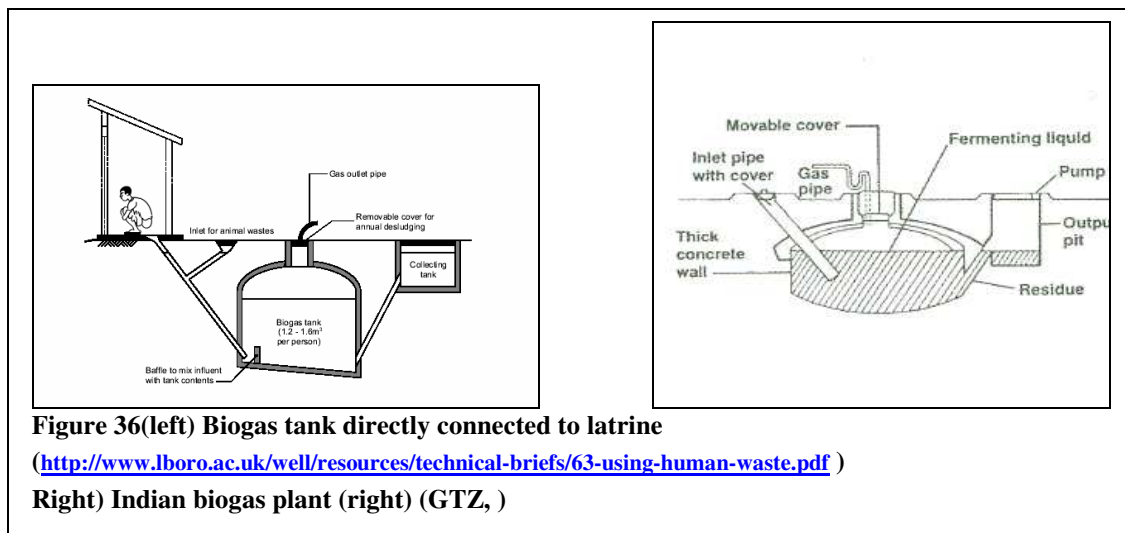
gas can be used for energy (in case of bio gas) and remaining sludge can be used as fertiliser. Generally this sludge has higher nitrogen and phosphorus content than normal compost. Additionally a post composting of the sludge, to stabilise the compost can also be integrated. If the anaerobic digestion process aims to produce fertiliser a hygienization by high temperature of the substrate before processing or a post maturation on a compost pile would be appropriate.

Anaerobic treatment is widely applied technology for municipal wastewater, industrial wastewater, animal manure and solid wastes in developing as well as in industrial countries. The processing of blackwater is quite more practised in developing world rather than developed. Centralised anaerobic digestion as well as decentralised both can be equally applied in ecosan concept.

The scope of this thesis covers only the decentralise anaerobic digestion of faeces/blackwater are which are most helpful in introducing ecosan concept in developing countries and they are:

- Household biogas plant
- Household septic tank
- Co-digestion in agricultural biogas plant

4.4.4.1 Household biogas tank



Household biogas tanks are small-scale biogas plants, usually installed for the purpose of getting energy (cooking gas). They may directly connected to the toilet or the latrine (see Figure 36). They can be designed for a single household, or larger apartment blocks,

schools, hospitals, market areas and other institutions. There are a variety of designs, depending on the required standard and climate.

Typical design is shown in Figure 36. For larger settlements semi-centralized plants can be constructed with the same principle.

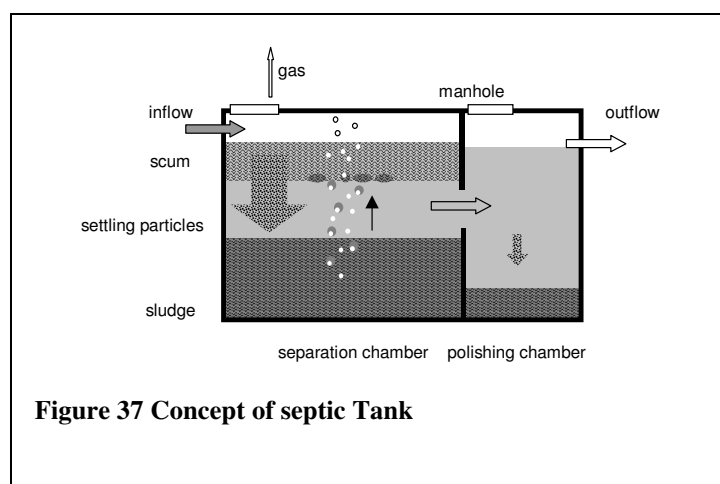
The retention time and the organic load of the substrate are the most important factor in determining the volume of the digester, which in turn determines the cost of the plant. This retention time depends on the ambient temperature in unheated plants or the adjusted temperature. The following table gives recommendations for the retention time according to the temperature.

Table 7: Retention time in biogas plants without heating

Average ambient temperature	Retention time (days)
> 20° C	30
15-20	40
>15	55

Source: <http://www.teriin.org/renew/tech/biogas/about.htm>

However, biogas cannot guarantee 100% sanitation. Since fresh faeces are mixed with old ones, and the retention time is not enough to kill the pathogens, therefore the effluent from the tank should be treated before using as fertiliser, e. g. composting.



4.4.4.2 Septic tank

A septic tank is a specially designed vault connected to the toilet. Commonly the tank consists of two compartments as shown in the Figure 37.

In the septic tanks liquid components of the wastewater are separated from solids. The solids are allowed settle at the bottom of the tank and they form a layer of sludge. In this layer the sludge digestion takes place under anaerobic conditions, which reduces the volume of accumulated solids in the septic tank. The sludge has to be withdrawn in regular intervals, depending on the size of unit, location, and household habits. The frequency of withdrawal is approximately 2-3 years. The liquid

effluent flows through the outlet to the soak pit. The capacity must be chosen according to a retention time and frequency of withdrawal.

The septic tank can be designed for a single household or for several households, depending on water consumption and location. Sludge has to be carefully handled as it requires secondary treatment before using as fertiliser.

4.4.4.3 Possibility of Co-digestion

Co-digestion, or co-fermentation, is the simultaneous digestion of a homogenous mixture of 2 or more substrates. Anaerobic digestion was a single substrate, single purpose treatment (Braun, 2002). However, co-digestion is done with manure, sewage sludge, and co-substrates like organic wastes, (industrial, municipal) residues, but only a few experiences were made with night soil. As it is similar to sewage sludge and manure, the co-digestion with human wastes should be not difficult. Co-digestion in general can provide an improved nutrient balance and therefore better digestion process, and higher biogas yields (Braun, 2002).

4.5 Regulations for the use of excrement

Although total destruction of pathogens is naturally, technically and economically unrealistic, a significant amount of pathogen destruction must be done for safe utilisation of excrements. This safe utilisation are guided by different regulations and guidelines.

As health concern World Health Organisation (WHO) is responsible for preparing such guidelines although there are many regulations that are practiced locally.

Extensive research has been carried out on the effluent quality of (wet) faecal sludge treatment processes and various guidelines have been developed over the past years. But reuse of urine and compost from human excrements has not been investigated to the same extent (Austin, 2001) and guidelines are missing to address these issues.

WHO guidelines for the safe use of wastewater and excreta in agriculture and aquaculture were published in 1989. The purpose of this was to guide designers and planners and to set worldwide quality standards. The guidelines levels were derived from the results of available epidemiological studies, along with a consideration of achievable results by wastewater treatment processes. (Strauss, 2000) Similar principles were applied to the

derivation of guidelines for the use of excreta in agriculture and aquaculture. The standard set by this guideline mostly applicable to both wastewater (for reuse) and faecal sludge treatment. However, it is seen commonly that effluent standards are neither controlled nor enforced. This guideline doesn't cover safe use of different colour aspects of household wastewater, which is very important in order to benefit from wastewater. However, such guidelines are expected to be published by 2005.

The commonly practice and adopted guidelines for the utilisation of wastewater in irrigation as fertiliser and use of urine and faecal compost are discussed below.

4.5.1 Wastewater as irrigation water/liquid fertilizer

ecosan concept aims to reuse and not to discharge the treated excrements and faecal sludge into the waterways, the hygienic characteristics are more important in this respect, than the discharge relevant COD factor. In tune to this the following Table 8 presents the quality standards promulgated by the World Health Organisation. In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account.

Table 8 Hygienic quality standard for treated faeces of the WHO (Strauss et al, 2000)

Category	Utilisation	Recipient	Intestinal Nematodes ⁺ (eggs/kg) (eggs/l) ⁺⁺	Faecal coliforms (number/100g) (number/100ml) ⁺⁺
A	Irrigation of crops likely to be eaten uncooked, sport fields, public parks*	Worker, consumer, public	≤ 1	≤ 1000
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture trees**	Worker	≤ 1	No suggestion
C	Local application to crops of B without contact to persons	None	Not relevant	Not relevant

+ Ascaris and trichurus species and hookworms

++ During irrigation period

* A more stringent guideline is appropriate for public lawns with which the public comes into direct contact: ≤ 200 faecal coliforms/100ml

** In the case of fruit trees irrigation should applied 2 weeks before harvesting and no fruits should be picked off the ground

4.5.2 The utilisation of urine

There is no any specific Guideline by WHO concerning use of urine in agriculture although it is being used since many years in developing as well as developed countries.

Hence regulatory standards have yet to be determined by the responsible agencies for the use of urine worldwide. Some guidelines and regulations are found, based on the inactivation of micro-organisms, which are mainly come from the risk assessment. The Table 9 gives recommendations related to storage of urine for different use.

Table 9: Relationship between storage conditions and pathogen content, and the recommendation (Schönning, 2001)

Storage	Storage time	Possible pathogens still available	Recommended crops
4°C*	≥ 1 month	Viruses, protozoa	Food and fodder crops for processing
4°C*	≥ 6 months	Viruses	Food crops for processing, fodder crops
20°C	≥ 1 month	Viruses	Food crops for processing, fodder crops
20°C	≥ 6 months	Probably none	All crops

* cold storage

From this it can be concluded that storage of 6 months at 20°C is sufficient to destroy the pathogens, and to guarantee a safe spreading.

In countries where the utilisation of urine is common, national standards adapt this storage period, e.g. Sweden. For the spreading of urine the following recommendations can be summarized:

- Spreading during the period of vegetation
- Spreading not closer than 100 m from a source of water supply, or 50 m from a watercourse
- Concentrated urine should be diluted 1 part urine to 8 parts water when spreading on vegetation
- Spreading during rain and late evening reduces evaporation.

4.5.3 The utilisation of faecal compost

Quality standards for the product (compost) from composting or anaerobic digestion are initiated in some European countries, but no international standard is available. Nevertheless the standards only consider the processing of animal manure and other organic wastes and not human excrements.

Compost from human excrement at least has to comply with the national standard of manure compost and must prove hygienic harmlessness, in the means of a limited number

of pathogens. If the hygienic quality of compost cannot be guaranteed, a further option is to use the compost not over ground. It would be better to incorporate it into the soil, where the degradation processes can continue. The following recommendations can be made from Chinese and Vietnamese practices

- No application within 2 months of harvesting
- Application only to industrial and fodder crops
- Use only to prepare the ground prior to planting

4.6 Health Aspects of using Excrements

Sanitation and human health are closely connected. There are many evidences that poor sanitation and the utilisation of untreated excrements, lead to direct or indirect transmission of diseases. A closer understanding of the processes will help to prevent from health risks associated with the use of human excrements.

4.6.1 Existence of pathogens in excrements

Human excrements, even from healthy people, contain naturally a number of viruses, bacteria and organism. Some of these microorganisms can cause infections and illness. In fresh excrements four categories of pathogens can be found: bacteria, protozoa, viruses and helminths eggs and worms. There are approximately thirty excreted infections of public health importance (Strauss, 2000), with the major ones listed in Table 10. Faecal coliforms, especially escheria coli, and helminths eggs are used as indicator organisms for excreted pathogens.

Table 10 Appearance of pathogens in faeces and urine and provoked diseases (Windberg, 2001)

Pathogen	Disease	Urine	Faeces
Virus			
Polio	Infantile paralysis (polio)		X
Bacteria			
Escheria coli	Diarrhea	X	X
Salmonella typhi	Typhus	X	X
Vibrio cholerae	Cholera		X
Protozoa	Dysentery		X
Helminths	Worm infestation		X

As it can be derived from the table, faeces contain the predominant number of pathogens in the human excrements rather than urine. Hence major transmission source for

infectious diseases is faeces. Urine is hygienically less critical. A higher risk arises if the urine is mixed with faeces or comes from an infected person. The potential health risk associated with urine is related to pharmaceuticals consumed by people, because chemical components contained in the medicine are shed in urine. However, effects and accumulation in soils and crops and its affection is still unknown and not sufficiently researched. A separation or low dilution of urine and faeces offers an excellent option for specific hygienisation measurements.

4.6.2 Survival of Excreted Pathogens

In principle, all pathogens die off upon excretion (Strauss, 2000). However, with varying climate, as shown in Table 11 for faecal sludge, Helminths have the longest survival period. Bacteria and virus die-off in the same range. Flies require about a minimum of one week to develop from egg to adult (Feacham et al ,1983). It has to be considered that faecal sludge is an optimum ambiance for pathogens: it is rich with organic matter, wet and anaerobic conditions simulate the conditions of the intestine.

Table 11 Pathogen survival period in wet faecal sludge (Strauss, 2000)

(Days)	in temperate climate (10-15°C)	in tropical climate (20-30° C)
Viruses	< 100	< 20
Bacteria:		
Salmonella	< 100	< 30
Cholera	< 30	< 5
Faecal coliforms	< 150	< 50
Protozoa:		
Amoebic cysts	< 30	< 15
Helminths		
Ascaris eggs	2-3 years	10-12 months
Tapeworm eggs	12 months	6 months

The main factors affecting the survival of excreted pathogens are time, temperature and moisture content. As shown in the Table 11, pathogens are less frequent at higher temperatures. The organism can survive until a certain temperature, above which they perish. Some bacteria have even the potential to multiply “outside” on food and with warm temperature. The pathogen survival on soil and crops is shown in Table 12.

Table 12 Pathogen survivals on soil and crops in warm climate (Strauss, 2000)

(Days)	soil	crops
Viruses	30	17
Bacteria		
salmonella	80	27
Protozoa	15	6
Helminths		
Ascaris	180	30

A further important factor is pH. The pH limits for the survival of escheria coli, for example, are between 4,4 and 9,0, with the optimum between 6,0 and 7,0. In general, with pH values greater than about 9,0 all microbial growth is detrimental (Austin, 2001).

4.6.3 Transmission of pathogens

The complexity of “excreta-related” infections is illustrated in Figure 38. The actual risk for the recipient and a breakout of an illness is a combination of the transmission path and barriers (sanitation, habits, pathogen factors, and host factors). The major paths for pathogen transmissions are:

- Direct contact (faecal oral transmission)
- By insects
- Through water-way
- Through Soils and Plants
- Secondary transmission from food

The highest health risk that exists for the recipients are direct contact to the excreted pathogens in the bathroom or especially in latrine (user risk). Worse latrine design or leaking pits promotes the spreading of pathogens by insects, and the contamination of the nearest water resources. While using the excrements on the fields, further health risks exists for the persons who are working with the excrements and product (worker, farmer

risk), for the population nearby the reuse location (nearby population risk) and for the end-user of the crops grown with the waste (consumer risk).

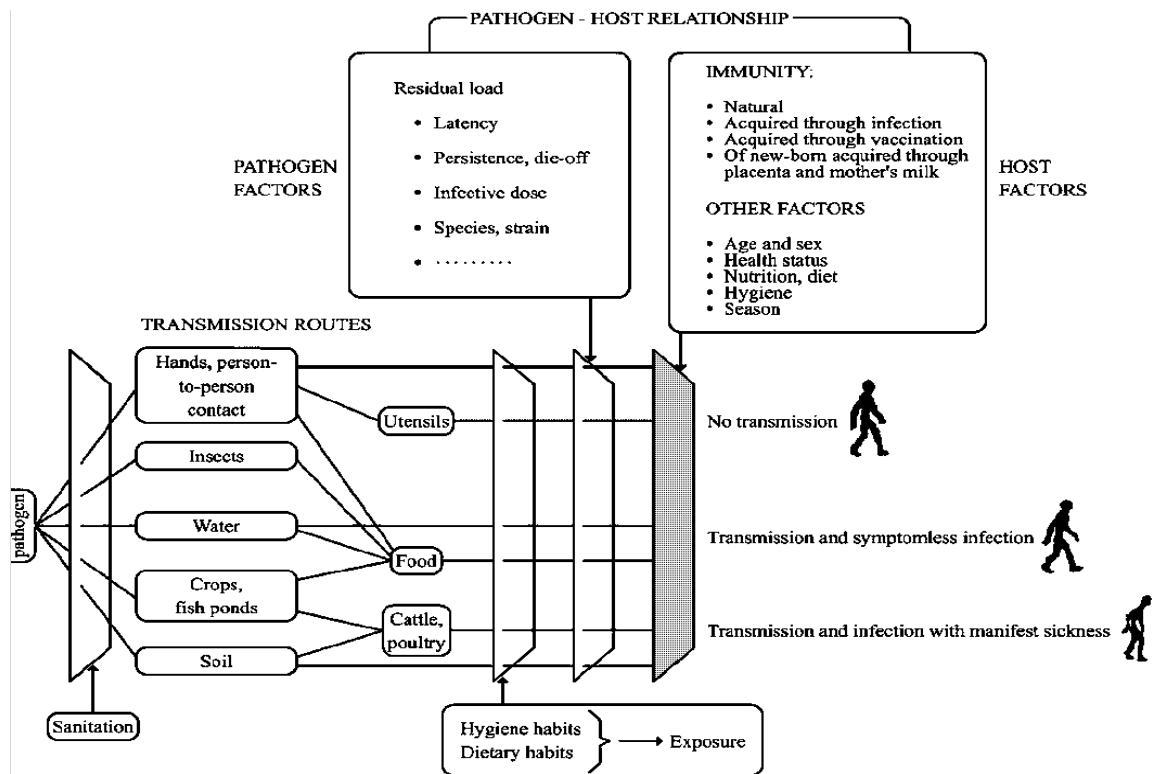


Figure 38 Transmission paths of excreted pathogens (Strauss, 2000)

Another important factor is the infective dose: it corresponds to the dose required to create and evoke a disease in the human host. For helminths, protozoa and viruses the infective dose is low (<100 No/l) for bacteria it can be medium ($\sim=10^4$) to high ($> 10^6$) (Strauss, 2000). Often it is not only a matter of a single infection, but also the chronic and long-term health impact from consuming food irrigated with faecal sludge and wastewater.

4.6.4 Measures to Minimise Health Risks for the Recipient

With regard to the transmission paths there are basic options for health protection:

- Improve personal and household hygiene and sanitation
- Isolate the user from their own excreta
- Appropriate treatment of faeces, urine and faecal sludge
- Safe handling for the workers/ related persons
- Restriction of the applied crops

- Choice of methods and amount/rate for the application
- Isolate communities from exposure to excreta, e.g. through contaminated drinking water

The different measurements should be applied in a combination, with different conditions (technical, socio-economic, cultural, institutional) and needs/demands (fertilizer, nutrition, sanitation) of the specific locality.

4.6.5 Treatment for pathogen reduction

Worldwide, and especially in less developed countries, it is still common to use the excrements untreated, a practise that can strictly be condemned because of the health hazards. There is scientific evidence that a well-designed sanitation, storage and treatment of excrements reduce the transmission of pathogens. There are a variety of technical options that, if properly designed, constructed, operated and maintained, can guarantee a save product and environment.

The most important factors to achieve pathogen reduction and destruction are control of temperature and moisture of the treatment process and a sufficient retention time. Table 13 shows the time for pathogen destruction in different temperature. From this table it can be concluded that time is inversely proportional to the temperature to destroy pathogens.

Table 13: Time for pathogen destruction dependent on temperature (Jenkins, 1999 after Faechem)

Temperature	Time for pathogen destruction
62°C	1 h
50°C	1 d
46°C	1 week
43°C	1 month

Further Figure 39 points out the relation between different pathogen destruction, time and temperature. From this it can be concluded that *Ecentric Viruses* need more temperature

to destruct where as *Vibro Cholera* need less temperature. It also clearly indicates the safety zone.

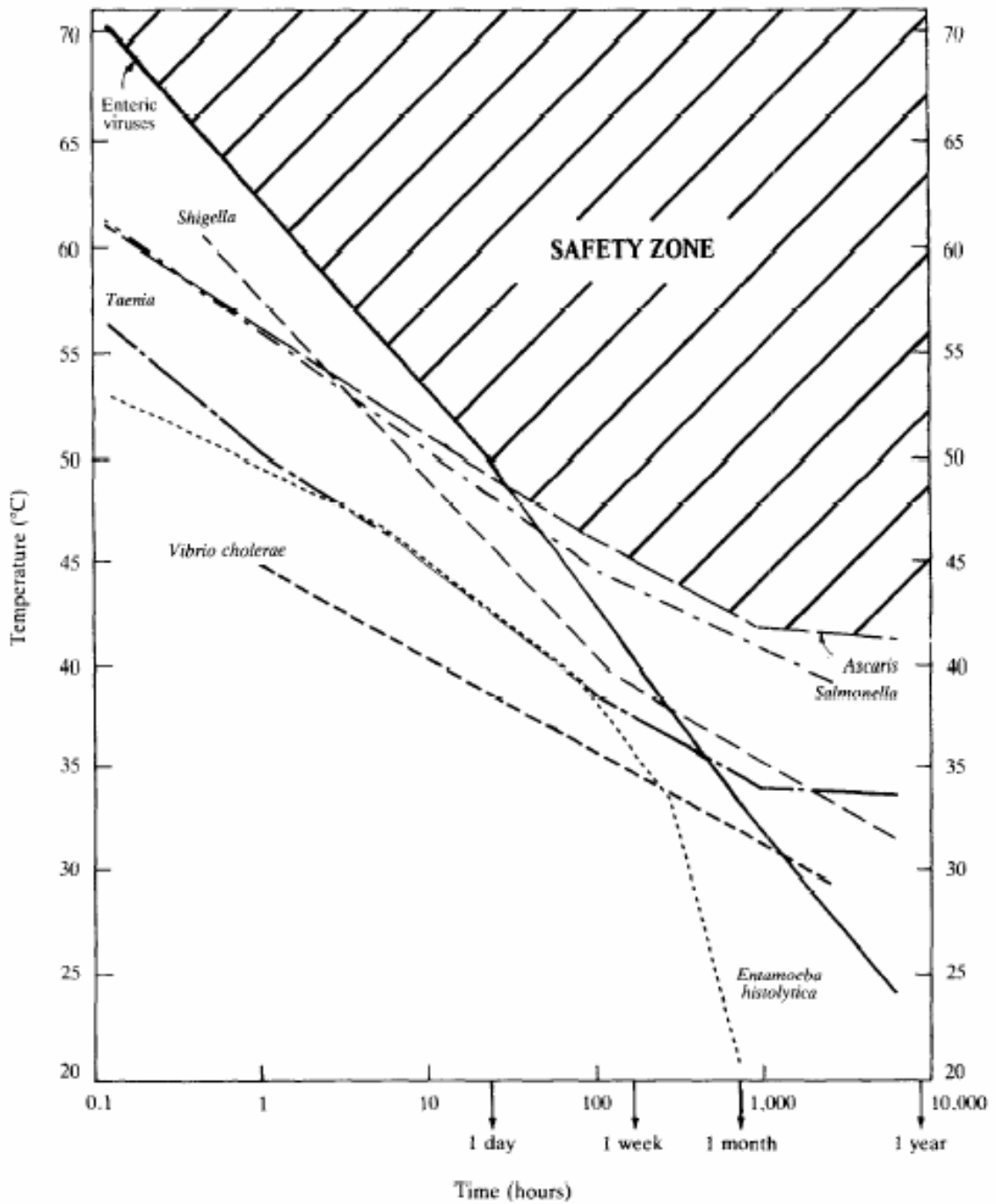


Figure 39 Influence of time and temperature for selected pathogens in night soil (Feachem et al, 1983)

5 Specific Situation of Nepal

5.1 General Introduction

Nepal is located between the latitude 26°22' to 30°27' North and longitude 80°4' E to 88°12' East, and elevation ranges from 90m to 8848 meters. The average length being 885 km east to west and the average breadth is 193 km from north to south. The country is landlocked bordering between the two most populous countries in the world, India in the East, South, and West, and China in the North. The Northern range (Himalayas) is covered with snow over the year. The middle range (Hill) is captured by mountains, high peaks hills, valleys and lakes. Southern range (Terai) is the gangaitic plain of alluvial soil and consist of dense forest area, national parks, wildlife reserves and conservation areas. The temperature and rainfall differ from place to place. In the geographic diversity and varied climatic conditions 26 million people of more than 60 caste/ethnic groups are accommodated in this country.



Figure 40 Map of Nepal

Geographically, the country is divided into three regions; Mountain, Hill and Terai accommodating 7.3, 44.3 and 48.4 % of the population respectively. There are 5 development regions and 75 administrative districts. Districts are further divided into smaller units, called Village Development committee (VDC) and Municipality. Currently, there are 3915 VDCs and 58 Municipalities in the country. Each VDC is composed of 9 wards, Municipality ward ranges from 9 to 35. Kathmandu is the capital city.

Economic growth of the country has not improved substantially over time to overtake population growth. As the current population growth is 2.26 percent per annum, growing population has overshadowed the gain achieved by development activities. Little over half (56.7%) of the population of working age reported usually economically active. Contributions of non-agricultural activities are gradually increasing in the GDP. Per capita GDP is estimated in the order of US \$233(Revised estimate) for 2001/02.

Energy is indispensable for all socio-economic development. It is obtained from various sources, which can be divided into two categories in Nepal: traditional and commercial. The traditional category includes firewood, agricultural residues and animal dung. These provide about 85% of the total energy in Nepal. Commercial fuels such as petroleum, coal and water (hydropower) are in use, but their contribution is only about 15%.

The per capita energy consumption in Nepal is 14.65 Giga Joules per annum, which is one of the lowest in the world. The contribution of electricity to the total national energy demand is less than one percent. 80% of the total electric energy is obtained from hydropower and the remaining comes from thermal power plants. About 89% percent of the total electric energy is consumed in urban areas. Attempts have been made to generate electricity through micro-hydro schemes in rural areas. But very little has been achieved. As of present, only 11% of the total population uses electric energy. On the other hand, about 95% of total domestic energy requirements are met by fuel wood. This has exerted pressure on limited forest resources, resulting in environmental degradation.

The Tenth Plan (1-97) placed due importance on the promotion of alternative sources of energy. It planned to install about 1,30,000 units of biogas plants during this period, and to increase hydropower through the extension of existing plants and the development of new plants. The achievements in this area are, however, not very encouraging.

5.2 Health, water supply and Sanitation

Health is related to the sanitation, as most of the health problems arise from lack of sanitation. Sanitation only is the important programme, which can drastically upgrade the health situation of the people. A number of aspects of health and sanitation programmes make implementation problematic and consequently more difficult to support than water programmes as the awareness of people regarding sanitation is not sufficient. These critical aspects are the fact that the effectiveness of a health and sanitation system to a

large extent is determined by sanitation behaviour. It is not so much important that people have a latrine, but whether people wash their hands after defecation, whether people dispose of their solid waste in a hygienic way, whether people consistently use their latrine and whether people are aware of their health problems their causes and remedies. Counting latrines is easier than changing behaviour. Other critical aspects are the need for consumer demand, the interest for implementation, the availability of technical and logistic support and an extensive hygiene promotion programme. At present, these concerns are realised and practised in Nepal since last decades with the help of various NGOs and INGOs and the Government it self.

5.2.1 Health

The burden of disease (BOD) study, conducted in 1996 indicates that the overall pattern of morbidity in Nepal is dominated by infectious disease, nutritional disorders, and problems related to reproduction. In addition there are important newly emerging and re-emerging diseases.

Although it is not a easy task to measure the health situation, it can be realised from some indicators such as life expectancy, infant mortality rate, nutritional status of children etc. To reduce health problem two measures can be taken either preventative or the curative. The government strategies and efforts are mainly concerned in curative rather than preventative. In line with national and international commitments, the Government is committed to making health services available to all by the year 2000. It is against this background that the National Health Policy 1991 has been adopted. The policy aims to deliver effective health services at the local level. As a result of the efforts made during different periodical plans, diseases like malaria, tuberculosis, leprosy and other vaccine-preventable diseases have been controlled to a large extent. In order to support its programmes, the Government has created a network of organisations at the national and local level. The most important of these networks are the Health Posts, which have been established down to the Ilaka level. The Government has also adopted the policy to set up at least one Sub-health Post in each VDC. Arrangements have also been made for the services of Female Community Health Volunteers at the ward level. The Government's Integrated Primary Health Services program seeks to provide preventive and promotive services at the community level.

The nutritional aspect of health has also been included in Government programmes. People of all age groups, especially children, suffer from malnutrition in Nepal. The main reasons are scarcity of food grains, inappropriate food habits, and imbalance in the distribution of resources, poverty and illiteracy. Various empirical studies have indicated that the majority of Nepalese children suffer from protein-energy malnutrition (PEM). Together with this, micronutrient problems like vitamin -A and iodine deficiencies, and the conditions of anaemia have also assumed serious dimensions. Consequently, poor people, women and children are the victims of low weight, blindness and goitre.

5.2.2 Water Supply

Nepal, though rich in water resources, its history of supplied drinking water is not very old and enthusiastic. Planned development of water supply and sanitation was started in the Fourth Five-Year Development Plan (1970-1975). The national coverage of water supply system was only about 4 % in 1970. A separate institution the Department of Drinking Water Supply and Sewerage (DWSS) was established during that period. The major thrust of the development of drinking water sector only came with the UN call of 1977. By the end of Water supply and Sanitation Decade (1990), the coverage substantially increased to 36 % of the total population, with the rural population and urban population at 33% and 67%, respectively. The recent Census Between Household Information, Monitoring and Evaluation System report-2000 indicates water coverage at 78.1% for rural and 92.3 % of urban population (WHO, 1995, HMG/NPC/UNICEF, 2001).

Most of the population still relies on decentralised water supply systems such as tube wells, open wells, springs, and stone taps connected to local reservoirs. While some of these water sources may be relatively clean, many are not, and those that may be now are still quite vulnerable to contamination in the future as development proceeds and stress on the environment and water resources persists. To fulfil Millennium Development Goals of those un-served with the safe drinking water by 2015 additional 700,000 must be served each year. To achieve this target requires both better uses of existing resources as well as additional resources. A part from this more sustainable and functional systems are to be built.

The target set by National Water Supply Sector Policy, 1998 and in Ninth five-year plan could not be achieved due to various reasons. Rural communities continue to use the most convenient sources of water irrespective of quality. Regular outbreaks of water borne epidemics, increasing number of patient being admitted in the hospital due to water related diseases indicates that only supplying of drinking water is not sufficient to improve public health status unless the concentrated effort is made both on quality water supply and proper sanitation.

The Draft Water Resources Strategy 2001 further set new targets and proposed to provide the entire population with access to reasonable safe water by 2012. It also targeted for establishment of necessary infrastructure and human resources for implementing drinking water quality standard. In line with this strategy, the 10th five-year Plan has proposed to reach total water coverage of 85 % by 2007. (HMG/WECS, 2001).

5.2.3 Sanitation

Nepal lags behind all the other nations of South Asia as well as most other developing countries in sanitation. It has been estimated that only 27% of the population of Nepal has access to sanitation (Human Development Report, 2003), while the average is 44% among developing countries worldwide (UNICEF, 2003).

Despite significant progress over the past 30 years in improving access to safe drinking water, the situation is still not satisfactory – 75 Nepalese children die each day from diarrhoea and millions of women and girls waste thousands of hours fetching water to their homes. According to the World Health Organization's 2000 "Global Water Supply and Sanitation Assessment Report", nearly five million people in Nepal lack access to safe drinking water and nearly eighteen million lack access to improved sanitation.

Sanitation is a process of collection, treatment and disposal/reuse of human excreta and domestic waste in a safe and hygienic manner (behaviour), which is affordable and sustainable. In view of the growing population, expanding urbanisation and the socio-cultural habits of the people, sanitation has emerged as a severe problem in Nepal. Sewage and waste disposal facilities are tremendously lacking in Nepal. According to government sources sanitary latrines are being used only by about 5% percent of the rural population. Even in urban areas only about 50% of the population use toilets. Major urban places like Kathmandu are provided with water borne sanitation system. Dilution is the

solution to pollution, the concept is applied whole around the country polluting most of the fresh water bodies around and near the cities. The sewers are openly discharged in water bodies and no treatment is given to this fresh sewer.

Even the simplest pit latrines are rarely found in rural areas. Open defecation is normal in rural hills, plain Terai, and peri-urban area. In dry season the faeces are dried with the help of sunlight but it is quite vulnerable at the time of rainy seasons. This mainly contaminates the water bodies of downstream, which are the main sources of drinking water in lower settlement areas.

There is no doubt that fresh water is a finite and vulnerable resource, essential in sustaining life, development, and the environment. Although theoretically the rural areas are connected with the pipe system some of them never receive flow of water through them, most of the systems do not function. Leakage and soaking of polluted water is normal in these systems.

The problem is more acute in the Terai region where open defecation is very common as a result of social behaviour. It is thought to be nuisance to use Toilet by most of the Terai living people. This as a result pollutes the ground water, which is at shallow depth. The situation is more disastrous during rainy seasons due to the inundation. During or soon after rainy seasons every year there is out break of epidemics mostly water borne.

However, the problem of solid waste is becoming more acute everyday. Haphazard waste disposal results often in the pollution of water, air and soil. The overland flow may carry toxic chemicals to the canals, streams and other water-bodies. The major sources of solid waste in urban areas are domestic, industrial, commercial and institutional. Among them, domestic, industrial and hospital wastes are creating threats to the water population.

It is estimated that approximately 557 metric tones per day, per municipality, of solid waste is generated in the 33 municipalities (NPC/CBS: 1994). There are many methods of waste disposal (e.g. composting, landfill and recycling). Efforts have been made in Kathmandu to sort waste before disposal. The Solid Waste Management and Resources Mobilization Centre (SWMRMC) has been doing this. In addition to this, the municipalities have also their own programmes for waste management. These institutions have, however, not been able to cope with the problem.

In the above scenario the crucial question in rural Nepal is not, what kind of sanitation is the best, but how to introduce sanitation at all. Water is still one of the best and culturally accepted means to keep personal hygiene, which is essential in a country with high rates of water borne and food related diseases. From different practices of rural development it is known that community management concepts are an option for reaching sustainable services, if a clear financial responsibility is included. For sanitation concepts individual users need to finance the facilities. Consequently, only such technical options are sustainable (or appropriate) here if they can be financed and operated by the users. The direct benefits of any measure must be made visible or known to the users. Therefore, establishing means for income generation, before any infrastructure can be built or operated, may be a good start of improving water supply and sanitation at community level.

5.2.4 Problem due to lack of adequate sanitation

Outbreak of infectious diseases, adverse health and environmental situation, downfall in economy, adverse effect in gender equity, fresh water contaminations are the major problems in Nepal due to lack of adequate sanitation.

5.2.4.1 Environmental

Lack of sanitation would cause vast environmental problems. The open defecation not only spread foul smell around its vicinity but also made unpleasant environment. Similarly discharge of untreated sewer to the water bodies cause foul smell to the stream and eutrophication problems. Water contamination results in environmental and wildlife damage and pollutes the food chain. Water scarcity and bad water management cause losses in agricultural crops, fisheries, and livestock populations.

5.2.4.2 Social and gender

The lack of sanitation facilities compounds the trauma of displacement and loss. The men can manage somehow and relieve themselves whenever they want, they can walk around and locate some place behind a bush, but women cannot do that. Due to this many women reduce food and water intake, which ultimately causes many diseases like anaemia and others.

Given the existent cultural constraints on women, women do not relieve themselves in public the way men do. Educated and well-dressed men will get out of a car and urinate by the roadside without feeling abashed – a state of mind few women, rich or poor, young or old can reach. Women tend to hold on, control and force their bodies into punishing (and often harmful) restraints because that is what the gender discrimination speak about.

5.2.4.3 Adverse effects on economy

The lack of sanitation cause adverse effects on economy. There are lots of means to raise economic condition of people among which tourism is on of the most in Nepal. Lack of sanitation drastically reduces the nos. of tourists, which could directly effects on the economy of the country. Furthermore the lack will increase the havoc of disease which would required a lot of amount for the curative treatment as a result people are forced to pay sanitation cost with out sanitation.

5.2.4.4 Adverse effects on health

Lack of adequate sanitation contaminates surface as well as ground water, which is the source of drinking water and as a result threatens human health. More than 80% of all diseases in Nepal are caused by contaminated water and sanitation-related problems. Many people die each year with water borne diseases through out the country as a result of poor sanitation and unsafe water. Due to lack of sanitation people are forced to take bath and drink water from rivers whose banks are often polluted due to the open defecation.

Diseases commonly associated with contaminated water include schistosomiasis, trachoma blindness, cholera, guinea worm, malaria, elephantiasis, typhoid, cholera, hepatitis, yellow fever, and diarrhoea. Diarrhoeal disease is the major cause of child malnutrition, and stunts physical and mental health. In the poor community of Nepal open defecation is well known practice. Most of the people defecate in the open field and often they move barefoot, giving access to the pathogens through the space between the fingers. These pathogens such as tapeworm, hookworms grow into the human body and cause ill effect.

5.2.4.5 Contamination of fresh water

All water is susceptible to contamination. It may accumulate contaminants from the above, under or surface of earth. Some of these contaminants, such as low levels of certain minerals or compounds, are not harmful to health, whereas others, such as pathogens and heavy metals like lead and others are harmful to the health. Empirical studies of drinking water throughout Nepal have found that faecal coliform contaminations in the water consistently exceed WHO guidelines for water considered fit for human consumption. A report by international consultants concludes, "Kathmandu's drinking water is hosting disease-causing microbes and hazardous chemicals." According to the same study, when tap water from representative locations of Kathmandu's urban areas was analysed in the laboratory, almost 90% of the sample were not potable.

The contamination may be from different causes. Among them lack of sanitation is the main one. Contamination of fresh water is major problem due to lack of proper sanitation. Although Nepal is a country with rich in freshwater resources, but most of the cities including Kathmandu has a serve problem of getting fresh water.

Surface water in the Kathmandu Valley is severely polluted by industrial effluence, waste dumping, and by the discharge of untreated sewage from residential areas. Rivers in the valley, including the Bagmati, Vishnumati, Manohara and Hanumante are all seriously fouled for this reason. Because human and other wastes are routinely discharged in the ponds, still water in the valley is even more polluted.

Ground water in most of the urban areas is contaminating due to seepage from septic tanks. Private septic tanks are built by virtually all the Kathmandu home owners in their generally tiny land plots - often covering just 60 squared metres - without sufficient room for soak pits. The semi-treated effluent, which is still toxic from the tanks, cannot find adequate area for dissipation, and becomes concentrated in residential yards and ground water.

Piped drinking water in Kathmandu is also polluted due to various reasons. Firstly, the water at the intake storage itself is not properly treated. Secondly, because the urban water supply is intermittent, (supplied only a few hours a day), suction is created in the water pipes during the run of water. Waste from ground sources and leakages from the sewage

lines, which run side by side, frequently enter the water supply system, contaminating the drinking water.

5.2.5 Present Sanitation Systems

Sanitation systems are very limited to Nepal. Most of the places have lack of adequate sanitation means. Pit latrine is generally understood by most of the people. VIP latrine is also introduced in some places by different NGOs. Poor flush latrine and septic tank are common in peri urban area and water carriage sewerage systems are found in cities without treatment plants and are directly discharged into the water bodies.

5.2.5.1 Sewerage system

Theoretically sewerage systems should collect excreta and domestic wastewater and transport them away from homes to a treatment and/or disposal point through the network of pipes. All sewerage systems require water for flushing waste away. This is the common water borne sanitation system in urban areas of Nepal. Most of these systems are provided with no treatment plant and easily discharged to the nearest water bodies whatever the environmental as well as health concern it poses.

5.2.5.2 Pit latrine

This is the most popular means of sanitation in rural areas in Nepal. It is simply a pit Figure 41. The use of this latrine suddenly increased among the community after national sanitation policy adopted compulsory construction of toilet (at least pit latrine) for the introduction of new water supply system project. In pit latrine faecal matter is stored in a pit and left to decompose. Unless specifically designed, pit latrines do not require periodic emptying; once a pit is full it is sealed and a new pit is dug. If faecal matter is left to

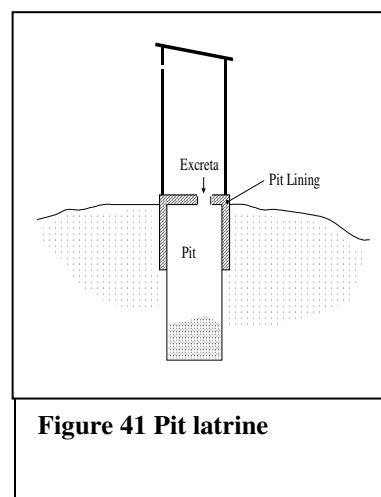


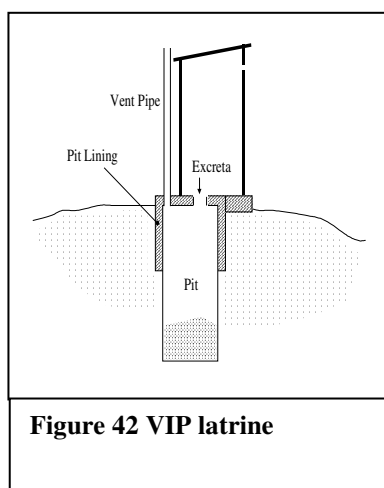
Figure 41 Pit latrine

decompose in dry conditions for at least two years, the contents can be safely emptied manually and the pit could be reused theoretically. Some of the pit latrines are found to be designed to allow faecal matter to compost and be reused in agriculture. Furthermore two alternating pits could be found in some places, especially in official building in rural

areas. Most of the pits function completely dry, while some use small quantities of water. Ventilation to remove odours and flies is incorporated into certain designs, while others are very basic and use traditional materials and approaches. In most of the cases additive (ash) is used to reduce fly breeding and odour removal.

5.2.5.3 VIP latrine

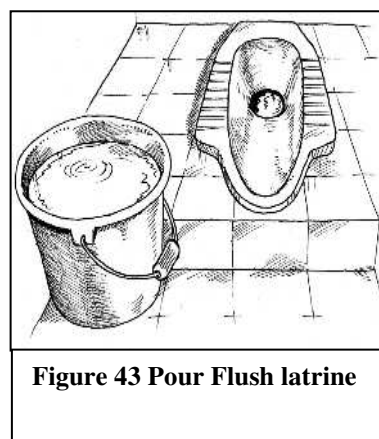
The VIP (ventilated improved pit) latrine is designed to overcome some of the problems with traditional latrine designs, but it is more expensive than a pit latrine. This type of latrine can be seen in office buildings and rural hospitals of Nepal. It has a vent pipe from the pit to above the roof of the building as shown in Figure 42. When air flows across the top of the vent pipe, air is drawn up through the pipe from the pit and fresh air is drawn into the pit from the building. Offensive odours from the pit thus pass through the vent



pipe and do not enter the building. The location of VIP latrines is important: unless a clear flow of air is maintained across the top of the vent, the ventilation system may not be effective. VIP latrines should therefore be located away from trees or high buildings that may limit airflow. A dark vent pipe also helps the air to rise. The top of the pipe is usually covered with mosquito meshing. If the inside of the building is kept partially dark, the flies will be attracted to light at the top of the pipe, where they will be trapped and die.

5.2.5.4 Pour flush latrine

A pour-flush latrine is a type of pit latrine where small volumes of water (commonly 1-3 litres) are used to flush faeces into the pit. They are most appropriate where people use water to clean themselves which is a common practice in Nepal after defecating. Solid materials should not be disposed of into pour-flush latrines, as this could block the pipe and even cause it to break.



A pour-flush latrine has a small collection pan set in a slab (Figure 43). Wastes are disposed of through a section of pipe bent into a U shape (a

U-bend) to maintain a water seal for reducing fly and odour problems. A vent pipe may also be added to the pit to overcome fly and odour problems. The pit of a pour-flush latrine may be located directly beneath the slab or set to one side, but offset pits may require more water to prevent blockages. Pour-flush latrines can also be designed to be connected to small-bore sewers at a later date.

5.2.5.5 Septic Tank and soak pit

A septic tank is a form of on-site sanitation that provides the convenience of a sewerage system. It is usually linked to flush toilets and can receive domestic wastewater. Since flush toilets tend to use large amounts of water, septic tanks are usually appropriate only for households with water piped into the home. The tank is offset from the house and linked to the toilet and domestic wastewater by a short drain. It is designed to hold solids and is linked to a soak away to dispose of liquid waste (effluent).

Septic tanks generally require relatively large amounts of land and periodic emptying by vacuum tankers. This is often expensive and the vacuum tanker requires easy access to the tank. Septic tanks thus tend to be high-cost solutions for improving sanitation. Communal septic tanks may be feasible if a large number of households close to the tank can be connected with very short lengths of sewer pipe. For such a system to work, however, each household needs sufficient water to flush faeces into the septic tank effectively. This kind of practice can only be seen in some of the cities and towns of Nepal.

5.3 Agriculture and Food security

5.3.1 Agriculture

Nepal as an agricultural country, agriculture remains the backbone of economic development in which the majority of country's population is dependent. Till today this is the main employment sector in the rural areas and also major source of production to livelihood and income generation. Despite this, the development of this sector has not been as envisioned in the past plans and programmes. For sustainable economic change and employment generation agriculture development and its professional enhancement is very important in every region of the country. Mainly agriculture can play a significant role to improve the lives of the poor and uneducated families in the rural areas, so the plan should give top priority to modernise agriculture and increase productivity. Difficult

geographical settings, dependence on monsoon, traditional farming, use of old and less productive tools, seeds, pesticides and fertiliser, insufficient irrigation, lack of proper market, lack of transportation facilities have been the main problems for the sustainable development of this sector.

Majority of Nepal's population engaged in subsistence agriculture. 93% of the labour force involved in this sector. The quality of earth in which they farm is of great importance for every Nepalese. Soil fertility and soil erosion are being current issues of concern in this sector.

According to the land use pattern the land can be divided into the following usage: agricultural land (26.5%), pastures (11.8%), forest and woodlands (42.4%), and others (rocks, rivers, towns etc.) 19.1%. **Mountain region** is at the north part of nation, which occupied almost 35% surface area nation. This part is characterising with high Hill Mountains with steep slope. Only gentle slope areas at the bottom of mountains are used for cultivation. One crop per year is common in these areas although some of the farmers grow two crops per year. Livestock such as goat, sheep, and yaks are commonly reared and meadows are used for grazing. **The hills**, which occupy 42% of the total land area, are intensively terraced for agricultural purposes. The dominant crops are rice, maize, and millet. **The Terai** is the grain belt of Nepal despite comprising only 23% of Nepal's total land surface. Three crops per year are grown in this region.

5.3.2 Food security

Due to many of the reasons **food insecurity in Nepal has been gradually increasing** day by day. In 1991, for instance, per capita cereal grain availability was estimated at 198 kilograms; by 1997, this had declined to 186 kilograms. Although cultivated land as well as efforts on irrigation is increasing reasonably. The food insecurity is not only due to population growth but also due to low productivity of soil. Due to population growth crop intensity is being increased without adding nutrient. Chemical nutrients (fertiliser) are quite expensive and not easily available, furthermore practices of traditional nutrient recovering through night soil are forgotten due to which the fertility of soil is being degraded and production is being lowered. As a result, many people are denied their right to food and suffer from chronic hunger. In fact, a recent estimate by the WFP (1997) found that 36 percent of all Nepalese consume less than the minimum daily caloric intake

notably hill households consume 47 percent less, mountain people 31 percent less and urban residents 40 percent less than the recommended daily caloric intake.

Food is an essential component for human growth and development. For normal human development the assured and regular intake of balanced food in adequate quantity and quality is essential. While under nutrition and malnutrition are the result mainly of inadequate and low quality food intake, over-intake of food or over-consumption of some components of food or nutrients may also cause severe problems of malnutrition with long-term and lasting consequences of ill-health. Harmful contaminants may cause severe malnutrition due to liver damage and interference in digestion and absorption. The major threats due to the food insecurity can be summarised as below

- 'Poor' nutritional value
- Deteriorating terms of trade
- Selling-off permanent household assets
- Increasing temporary and permanent out-migration
- Decreasing general health situation
- Changing eating behaviour
- Increasing number of beggars for relief
- Increased relief food requirements
- Increments in Rebel groups
- Political instability

5.3.2.1 Nutrient Cycle of Nepalese community

Most nutrient balance studies follow a fairly simple routine of dealing with nutrient flows across the farm 'boundary'. The difference between the sum of the inputs and the sum of the outputs gives the nutrient balance of the farm. A positive balance can indicate the potential for losses to the environment, while a negative balance indicates that there may be problems with sustainability of the system. More detailed treatments include components within the system and flows between them.

Brown *et al.* (1999) Calculated nutrient balances for fields in a watershed in the Middle Mountains 40 km east of Kathmandu: They showed that overall soil fertility is poor, particularly under forest due to biomass removal by local inhabitants for animal fodder, etc. Nutrient deficits were relatively low for the traditional irrigated rice-wheat systems

(on *khet* land) due to nutrient inputs from sediments and irrigation waters, but the current trend towards triple cropping (maize-rice-wheat) on these fields is causing negative nutrient budgets at the field level. Calculated balances were negative for 57% of irrigated rice fields. Similarly, large deficits were shown for rain-fed maize production (on *bari* land) due to the relatively high yields of maize, with 94% of the fields showing a negative balance. Current management practices are, therefore, mining the soil nutrient pool, and if continued may have long-term negative impacts on productivity. They concluded that integrated nutrient management is crucial to maintaining soil fertility, as compost alone will be insufficient to meet the nutrient demands of increasing cropping intensities and vegetable production, due to its relative shortage.

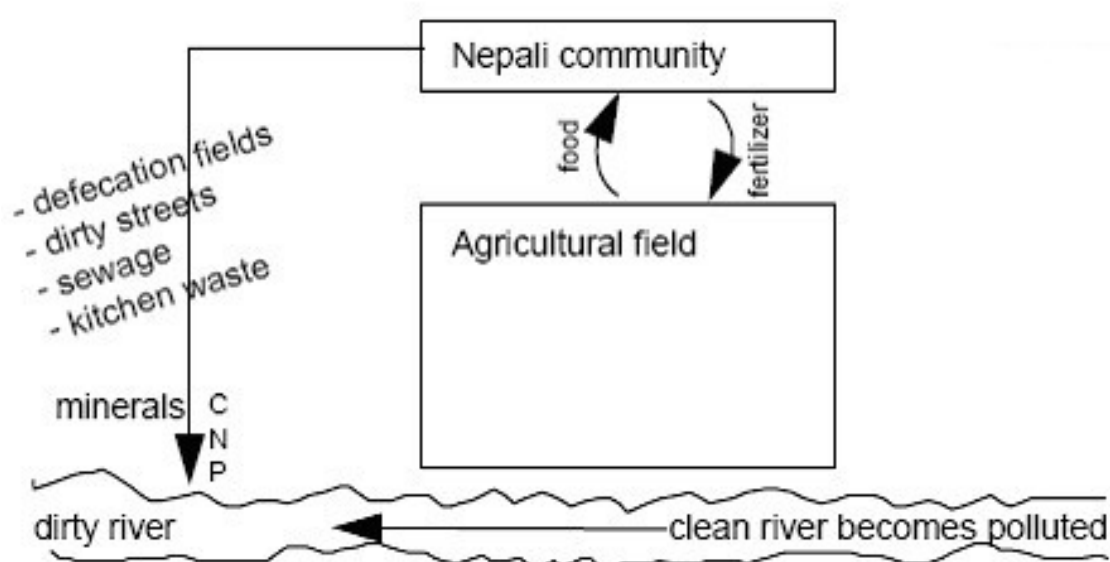


Figure 44 Current Nutrient cycle of Nepalese Community

The situation in other parts of the country doesn't differ than this. The land after extraction of nutrient i.e. harvesting crop is recharged only through chemical fertiliser and organic compost. The nutrient value of excrement is rarely considered. These human excreted nutrients are mainly discharged either directly or indirectly to the nearest water bodies as in Figure 44. Furthermore the waste from kitchen and other household are simply thrown into the streets neglecting their nutrient value and other chemical consequences. This ultimately reaches to the nearest water bodies by means of rainwater. In this way the current nutrient flow of Nepalese community is in the backlog direction of ecological sanitation polluting surface as well as ground water. If the present trend is continued the period of food scarcity and chaotic hunger is not far from now. Hence the

need of new thought to change present nutrient flow cycle with ecosan concept is shown in Figure 45.

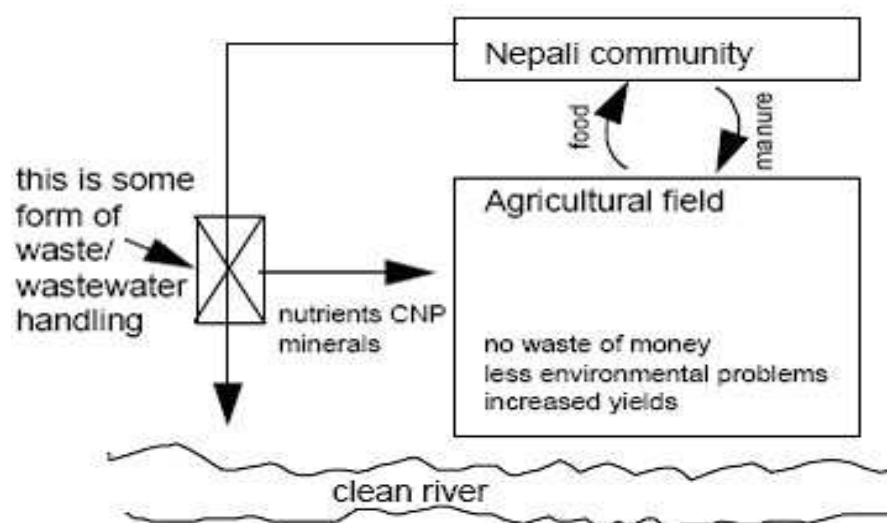


Figure 45 Proposed Nutrient cycle for Nepalese community with ecosan

5.4 Practices of wastewater and excreta management

As a traditional agricultural society, Nepal paid more attention to water-land sustainability. To survive from the marginal water and land, people have to plan, design and manage their environment in accordance with nature by resorting to making efficient use of resources from their native ecosystem. There were no waste problems in ancient Nepal, either in towns or countries; all wastes were degradable and used as fuel, forage or fertiliser for local ecosystem. Nepalese people had a long ecological tradition of efficient resource use including wastes recycling and goods repairing. Wasting grain, paper, and clothes, no matter how plentiful they are, is considered immoral behaviour that will be punished by God according to ancient tradition.

The faeces and urine collection system were adopted from Chinese society of 5000 years ago in Nepal. At the Lichhabi and Malla period night soils were collected door to door in the early morning by a night-soil cart then sent to suburbs for crop fertilising. Further more practice of complete separation of human and animal metabolism from water cycling without using chemical fertiliser was found in the ancient time. Surplus food and agro-wastes were used as fodder for livestock without polluting watershed, clothes were cleaned by plant cleaners rather than chemical detergents, bio-diversity was maintained to control pests ecologically without using pesticides.

There were many villages in Nepal where agriculture was sustainable for centuries and people were sharing their sanitation system with nature, with cities and with each other. Human and animal wastes were usually dried or fermented for fertiliser.

However, along with the intervention of modern development destroyed the traditional practices. The philosophy of "man and nature be in one" is transformed into "Man could conquer nature", the reductionism is substituting holism, diversified human ecosystem is being substituted by mono-production and mono-culture, self-reliant life style is being substituted by modern life style characterised by high-energy consumption and high environmental impacts. The sanitation change is one of these transitions. Night soil cart disappeared, Poda don't want to introduce them as Poda (Person who use to collect excreta).

General speaking, the present human society is a somewhat inefficient, immoral, unhealthy, counter cyber-nautical and less ecologically viable habitat. Its efficiency of resource using is much lower than that of a natural or agricultural ecosystem. It exploits resource through degradation of hinterland ecosystem and imposes environmental impacts on its surroundings. Its people are estranged and competitive rather than intimate and co-operative. Its artificial living and working environment is far away from the real needs of human health. People more and more rely on electricity, water, car and chemicals to survive themselves, more and more depart from nature.

In order to jump out from this ecologically decaying culture, a refinement of people's concepts, thoughts, values, manners, emotions, tastes, customs and habits should be encouraged. And an eco-cultural revolution in production mode, life style and consumption behaviour is necessary. Only when the life style is harmonious with nature in metabolism process, structural pattern and functional development and human activities could be enhanced rather than depleting the life supporting system, then a sustainable development can be expected.

Still we can find such traditional examples of wastewater and excreta management in several parts of Nepal. Sherpa of Helambu still feed their faeces to pigs, Jayapu of Kathmandu valley still use faeces in producing vegetables, a farmer in middle hill still uses grey water in his kitchen garden.

5.4.1 Grey water in Kitchen Garden

This is relatively new approach of managing wastewater by small farmers in their kitchen /vegetables gardens. Kitchen Garden in Nepal is small plot where mainly vegetables are grown rather than flowers. It is thought that a good kitchen gardening practice adds so much spice to one's life, with the motto- if we grow our own greens, we will gain our health and happiness. Giving emphasis on



Figure 46 JUTHELNU

the importance of garden produce for good diet will reduce/ eliminate the consumption of chemical vitamins, minerals, and fibre. For kitchen gardening water and manure is essential, with out water the garden cannot be imagined in the country like Nepal where the country has uncertain climate. The practices of using grey water in kitchen garden are very popular among those who are aware of the above facts. The practices are commonly seen in the middle hill as well as in high hill settlements. Normally they make traditional washbasin made up of wooden planks and a ditch below it (JUTELNU) see Figure 46 in front of the house. The water after wash is diverted with small canal towards vegetables/ kitchen garden. In some places the water is collected into a small pot and the water is transported time to time to the garden. Furthermore in some cases a small pond is made to collect water, which is later transported, to the garden.

5.4.2 Faeces as Animal food

This is very traditional practice of managing excreta and adopted from Chinese culture. Here the excreta are taken as good food for pigs. The toilet is made above the pig shelter. Defecation is made through a hole made above the shelter and is consumed by the pigs. For children a open pit of nearly 30cmX30cmX30cm (size may differ) in the corner of room of the house or near by the pig shelter is constructed and they are forced to defecate in this pit which is later thrown in the pig shelter by the parents. In some places it is found that parents beat their children in case they defecate elsewhere.

In mountainous regions where open defecation is difficult due to the very cold weather condition toilets are made inside the house, generally in the ground floor, which is connected with the pig shelter in the basement. These so-called toilets are made up of thin

wooden planks. By removing one plank a place is created to defecate. In such cases water is not used but special green grass or leaves are used.

5.4.3 Excreta as Manure

Using human excreta as manure is a popular method among the farming communities in many parts of the world. Where as it might not have been a new practice as in the case of Nepal. This method is becoming absolute because of the gain of the increasing use of modern water closet systems.

An interview conducted by national daily news paper Kathmandu Post with a Farmer shows the view of the farmer on the use of human excreta as manure, which is as follows:

Panna Ratna Maharjan, an elderly Kirtipur farmer, often worries that the vegetables he grows these days are not "as big and tasty" as they used to be two decades ago. He says that's because he no longer uses human excreta as manure. "In the earlier days, we used to use human excreta and kitchen waste as manure. That was a productive way of doing agriculture," he says. He further adds the old practice of mixing human faeces; urine and kitchen waste in the soil to make it more fertile is now being regarded as "unhealthy" in the face of so-called modern scientific ways of agriculture. The only farmers who are still sticking to the old ways are the Sherpas in high-altitude districts like Dolpa and Solukhumbu. "Our grandfathers were much more scientific, they used to manage solid waste in such a way that it became an essential resource in agricultural production," says farmer Maharjan. In those 'grandfather times', the human faeces in public toilets were collected by sweepers in buckets and deposited in pits dug beside the fields. Then the farmers would add other types of manure to it before pouring it into the field. Maharjan says pouring human excreta "directly on the earth is a sin". He says the vegetables grown in such fields have better colour, are more tasty and bigger.

Similarly, In Bhaktapur district of the Kathmandu valley an interesting event was happened in the past when the government of Nepal with the supports from donor agency constructed a sewer system there. The farmers had broken the sewer of the project and taken the raw sewer to their farmland with bucket. Even these days, farmers used direct fresh sewage to their farm in different places.

The practices is not only limited to the surrounding of Kathmandu valley but the farmers of high hill (normally Sherpas Gurungs and others of high hill) use human excreta as manure to the fullest advantage for mountain farming. Local people are apprehensive about the use of chemical fertilisers, as they believe that these fertilisers cause soil compaction, which hinders other farming operations. Although cows, sheep, goats, and donkeys are the main sources of manure, in most of the cases, human excreta and poultry manure is also collected. Human excreta, called chaksa, are considered to be the richest manure and are collected in a special dry latrine pit. In some areas, kitchen ash and manure are mixed together and are used for kitchen gardening and for improving the size of potatoes.

5.4.4 Biogas

This is the new practice of managing organic waste including human excrement. History of biogas is not old in Nepal. The pioneer of biogas in Nepal was father B.R Sauboll, a Belgian teacher at Godavari St. Xavier's School. He built a demonstration plant in 1955. Now biogas has been found very successful technology to reduce the pressure on bio mass resources. Furthermore it provides the means of clean cooking gas, which help to maintain the health of cook person specially woman and children.

Biogas technology is efficient and cost-effective method methods of disposing organic waste and produces energy and fertiliser. At the beginning only cattle manure is used in this technology. But letter the use of toilet (excreta) is found very effective and BSP (Biogas Support Programme) Nepal introduce toilet with biogas plant. This technology is being popular in the rural areas. In this process toilet wastewater is discharged into biogas reactor and treated an-aerobically with organic kitchen waste, cattle manure and garden waste. Anaerobic bacteria degrade organic matter into methane, carbon dioxide and sludge. The methane can be used as source of energy and the sludge, which is reach in nutrient, is used as fertiliser after composting.

5.5 ecosan in Nepal

The ecosan system is reviving the traditional yet forgotten art of applying night soil to the agricultural fields. It is an ecosystem approach to excreta disposal that can be defined as a system that prevents diseases, protects the environment, conserves the waste and recovers and recycles nutrients and organic matter. Knowingly or unknowingly ecosan concept has

been practiced for the past many generations in Nepal in different forms there are many places where farmers have used excreta as well as urine for feeding pigs and for growing crops and vegetables. Average people have faecophobia i.e. they do not like to hear the word excreta, but few farmers are still using raw (fresh) excreta from latrine to their vegetable gardens and grow good quantity of vegetables.

Use of night soil in agriculture is not new in Nepal. There are many examples found around the country of using night soil in their field. Either the farmers of Kathmandu valley (Japu commune) or farmers from Mongolians commune in high and middle hill are practising the use of night soil with the combination of animal waste, kitchen and other decomposable waste. This is considered as the main fertilisers in the agricultural fields in above said regions and community. Although it is a good practise, it is performed in an unscientific and unhygienic way.

5.5.1 Chronological development of ecosan

The actual ecosan practices starts in Nepal in 2000 after Water Aid conducted a workshop to its partner agencies for implementation of ecosan in Nepal. This workshop had a good impact on the organisations those were working in the field of water supply and sanitation. Now a days these organisations are setting up their programmes with the view of achieving ecological balance in sanitation. After 2002 the chronological development towards the ecosan practices in Nepal can be summarised as follows.

1. Water Aid conducted a workshop to its partner agencies for the implementation of ecosan in 2000.
2. Participatory Intensive Training course on ecosan with partial support from Water Aid , UNICEF and SIDA in 2001.
3. Environment and Public Health Organisation (ENPHO) organised a talk Program on ecosan in Jan 2002.
4. Promotion of ecosan through national media's from 2002
5. Analysis of preliminary design criteria proposed by ENPHO with Lumanti, NEWAH, DWSS, DENET in early 2002.
6. Implementation of pilot projects in three peri urban communities – Siddhipur, Thimi, and Khokana- mid 2002
7. ecosan pilot project in urban setting in early 2003

8. Public Demonstration of these systems on the occasion of World Water Day and Earth Day 22 march 2003.
9. Research and Development is under progress.
10. Recognition of ecosan by National Sanitation Document
11. First National Conference on Ecological Sanitation (ecosan) November 2003

5.5.2 Feature of ecosan pilot projects in Peri-urban areas of Kathmandu

Till now ecosan in Nepal is limited into ecosan urine diverting toilet. ENPHO, Water Aid, NEWHA, DNET, Lumanti and DWSS five organisation are directly involved to promote and implement ecosan through pilot projects. Four locations of Peri-urban area around the Kathmandu valley were selected to implement the pilot projects. All the projects are were implemented in early 2002. More or less the general features of these projects are similar to each other. Urine diversions, Specific Anal cleaning place, two chamber composting, and Awareness and Training are the basic features of these pilot projects.

5.5.2.1 Urine diversion

Toilet is the basic element of ecosan. Although urine diversion is not compulsory as per ecosan concept but the treatment process may definitely be simple and economical if the diversion can be done. The concept behind urine diversion is that the urine contains most of the nutrient, and contains no pathogens if it comes from healthy persons where as faeces contain pathogens and require appropriate



Figure 47 Ceramic urine diverting squatting pan

treatment. During the early conceptualisation it was realised that the urine diversion



Figure 48 Locally casted urine diverting pan

would be a better way of implementing these projects.

The adopted toilet model is Double vault urine diversion. In this model urine and Faeces are collected separately by means of separation pan as shown in Figure 47 and 48. The separated urine is diverted through a pipe to the urine storage tank outside the toilet, which is later used as

fertiliser. A thumb rule has been developed with the help of agronomist for the doses and interval of application of the urine as per the crop type and growing pattern. Effects of

urine application and the crop yield are being observed and studied at present at various experimental plots at Khokana area.

5.5.2.2 Anal cleaning place

Anal cleaning with water after defecation is habitual, customary and social practices among the people of Nepal. Hence only introducing urine-diverting toilet doesn't serve the comfort of defecation to the people unless easy place and method of anal cleaning is provided. Considering this fact

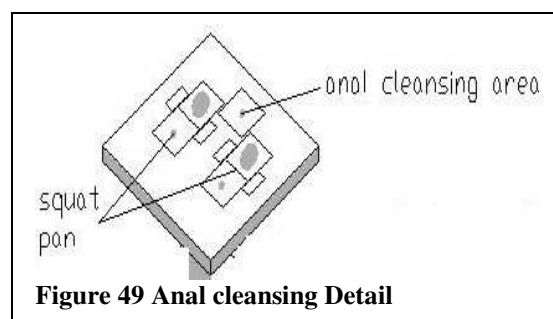


Figure 49 Anal cleansing Detail

an anal cleaning place provided in front of defecation (see Figure 49) pan and small water storage tank serves the purpose



Figure 50 Use of Reed bed

Generally the water (Brown water) which comes from anal cleaning pan and which contains pathogens is required to be handled carefully. Realising this fact the brown water is diverted to the small reed bed outside of the toilet. In this reed bed farmers are suggested to plant such vegetables like bitter (KARELA) which is eaten only after cooking at high temperature. This could be clearly seen in Figure 50.

5.5.2.3 Two chamber composting

Faeces contain many harmful pathogens as well as nutrients. Hence appropriate treatment is required to destruct pathogens and maintain the content of nutrient. Composting is the most appropriate and economical technique in case of decentralised system. Realising this fact composting of faeces is adopted in these ecosan pilot projects. This is achieved by constructing two chambers. Each

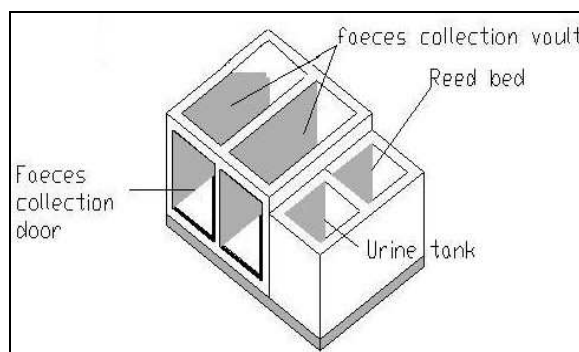


Figure 51 Arrangements of two chamber composting, reed bed and Urine tank

chamber is provided with urine diverting defecation pan over it. It is assumed that one chamber is sufficient to accommodate the faeces from a family of 5-6 people for six month see. The purpose of providing two chamber is to decompose the faeces in the first chamber during the use of second chamber for second six months.

The faeces are dropped into the chamber constructed right below the defecation pan. After each defecation the users are suggested to drop a small amount of ash over it. Some times when the toilet papers are used they are also dropped into this chamber. This reduces not only the foul smell but also maintain the solid water ratio for the decomposition of the faeces. The arrangement of the chamber can be seen in Figure 51.

5.5.2.4 Awareness and training

Although ecosan is new development of old practices, it requires awareness and training to the users as old practices are forgotten and if proper handling is not done it may give negative message. Furthermore ecosan starts from the defecation, which depends on the behaviour of the person it is really a personal matter. Hence without personnel awareness ecosan can never be applied as better sanitation. Therefore awareness and training among the users is essential before launching the projects. In order to disseminate the basic concept and information of ecosan, consultation with the users, local organisations and key persons in the community is also essential.

Realising the above facts awareness and training programmes are designed and being conducted among the users before, during and after the implementation of the pilot projects. In this process local bodies and the users are made aware about the ecological cycle, their advantages and adaptability through different training and non-formal educational classes and seminars. After the completion of the ecosan units, the user groups were trained to properly use the toilets. They also acknowledged with features of the system.

Furthermore ecosan installed households are being closely monitored for application of end products. Periodic community meeting, consultation, monitoring and sharing the innovative ideas for future plans are also being done regularly. The teams of experts comprising water and sanitation expert, sanitary engineer, agronomist, sociologist etc are provided for ideas and knowledge in terms of cleanliness, managing the collected urine and proper storage of faeces in the vault for required time periods.

5.5.2.5 Cost of the project and subsidy

The cost factor is very important in case of any projects. Normally the starting cost of the project is always high and for the pilot and demonstration projects the acceptability and efficiency of the project is the first priority then comes the cost function.

The ecosan system is quite new to Nepal and all the efforts are being limited to pilot scale till now. If we see different pilot projects the cost of one unit ecotoilet construction varies from 18000 to 25000 Nepalese rupees. In comparing to the pour flush and VIP latrine these toilet poses the more or similar cost and with water borne system either sewerage or septic tank it is one third cheaper, here the cost of water is not considered.

5.5.3 Peri urban setting ecosan Pilot Projects case studies

5.5.3.1 Khokana

Khokana is a traditional Newar farming community with a population of about 4700 with about 800 dense households, located in southern part of the Kathmandu Valley at an elevation of around 1300 m above sea level. Majority of the population in the village are farmers by occupation and are economically as well as socially backward.



Open defecation, special open toilet for women near water collecting places (Figure 52) and 500 sanitary pit toilets build by UNICEF more than one decade back are the means of sanitation utensil in this area. Most of these toilets are not functioning well due to high water table, lack of proper using knowledge, people habits and perceptions towards it. Among those, which are still in function, have problems of overflow, foul odour, and have become breeding place for the fly. These are even contaminating ground water, which is the main source of drinking water.

People of this region have now realised that pit latrines are not suitable in their area due to high water table and they are in search of better options. In this context ecosan could be an answer to their search. Sewer lines are incomplete and insufficient. Therefore, all the surrounding ponds and dug wells are now extremely polluted due to the seepage from pit latrines and surrounding runoff.

Most of the farmers here use animal manure and chemical fertiliser. Although not practised extensively today, human waste was one of the main sources of fertiliser in the fields. With this background, Khokana is chosen as an ideal setting for the introduction of ecosan by host organisation (ENPHO). The village people have heartily welcomed this system and are very eager to see its success in their community.

The project is run by ENPHO, under financial assistance from Water Aid. 10 ecosan toilet units had been constructed in this village development committee to find the reliability of ecosan concept and disseminate its message through demonstration. The concept of ecosan was quite new at the first time and it was not possible to convince and install ecosan unit in each and every household. It was believed that the ten units would be scattered to these 9 wards in the village So that these households will be demonstration houses and encourage the other households to install the units. A local welfare committee assists host organisation to select those ten households, irrespective of social status. An agreement is made among local organisation, host organisation and house owner before implementing the project. Each household unit is desired to share the cost in terms of cash and kind.

The units at Khokana are based upon double vault urine separation model. The capacity of each collection chamber is 0.45 m^3 . Each chamber has been estimated to be used for 6 months by an average family size of 5-6 members. The urine collection tank has a capacity of more than 100L. The units are being constructed with active participation of the community.

5.5.3.2 Siddhipur

Siddhipur VDC is one of the 41 VDCs of Lalitpur District and is located about 20 km to the south east of Kathmandu. It lies at an altitude of 1500 m from mean sea level. The village occupies an area of 4.13 square kilometres sharing 80% in farming and rest 20 % has been used as public land and residential purposes. There are about 1200 households in Siddhipur giving shelter for around 7000 people. Ethnically, 99.99% of the total population are Newar.

The water and sanitation situation of village is poor, although sufficient water is available in the village. A water supply system from the Godavari stream the boundary between Thaiba and Godamchaur VDCs, is serving the village. The water is collected in an intake

tank from where it is transported to a reservoir tank having a capacity of 50,000 liters. The water from the tank has been distributed in the Siddhipur community through 50 public taps. A part from this 8-10 dug-wells and one spring is also serving community to fulfil their water demand. Open defecation, blocked drainage channels and poor drinking water quality from taps and wells, are the main causes of diseases.

In this village also the same programme as that in Khokana was implemented by UNICEF some eleven years ago. Only 20-25 percent people use private toilet whereas others use open spaces and riverbanks for defecation. Unmanaged wastewater has adverse effect on both public health and crop yield (over dose) as well.

Realising the grief of poor sanitation condition of this region, with a good intension a seminar was held in Nov. 1998 organised jointly by ENPHO, NEWAH and IRC. During the seminar a strong voice was raised by some of the experts as probable solution by closing the nutrient cycle.

As a consequence similar approach to Khokana was adopted with ten units of pilot projects, under the financial assistance from DWSS. These pilot projects are considered as of demonstrative nature in order to attract others after its successful implementation.

As a part of pilot project the comparative efficiency study of urine over urea is also implemented in the field trails, which are still under observation. In these field trail the dose of application are based on the annual report of soil science programme (1998/99). According to which application @154kg of urea/ha or 70kg of N/ha for potato and 132kg of Urea/ha or 60 kg of N/ha for maize is considered in field trail. The effect of this application is yet expected.

5.5.3.3 Thimi and Shankhamul

A break through workshop organised by Water Aid in early 2000 drew the attention of NGOs and others organisations working in the field of sanitation and environmental protection. As an impact of this workshop few NGOs tried to launch ecosan projects in the peri urban areas of Kathmandu valley. In this hurdle Lumanti is one of the NGO, which lunched such projects in Thimi and Shankhamul.

After several consultations with community as well as consultant (ENPHO and Water Aid) the organisation chose to launch the project in three different communities Layeku Thimi, Kamitole Thimi and Sankhamol Kathmandu.

It has tried to accommodate communities such as farmers in Layeku, Lower caste ethnic group Kami and dalit in Kami Tole and squatter (Group of people living unlawfully in governments land) in Sankhamol. After several efforts and full subsidy 10 units' urine diverting toilet in Layeku, 2 units in Kamitole and 4 units in Sankhamol were built.

Several series of meetings and orientation among the interested families especially with woman was done at the first stage of programme introduction. After the community willingness the technical consultation with Water Aid and ENPHO were taken and the design of the toilet were finalised. Training was also arranged for the mason with the consultation of consulting organisations. The basic design concept resembles to the Khokana pilot project.

The toilets are performing well in Layeku where as in Kamitole and Sankhamol the purpose is not fully achieved. Farming community, high involvement of women, acceptance of ecosan from heart, necessity of end product in agriculture, curiosities of community to learn and share experience are the main reasons behind the successful function of toilets in Layeku. Where as just opposite to this in Kamitol Thimi and Sankhamol Kathmandu the community has no interest in the end product as they are not involve in agriculture.

5.5.4 ecosan in Urban setting

Today Kathmandu, the capital of Nepal is facing major water scarcity; the supply of water is always less than required demand Figure 53. Furthermore the sanitation situation is much worse than water supply. All the surface as well as ground water is contaminated through different hazardous elements. The quality of drinking water is beyond the standard set by WHO. The situation is not seems to be progressed unless new thought of managing water is introduced.

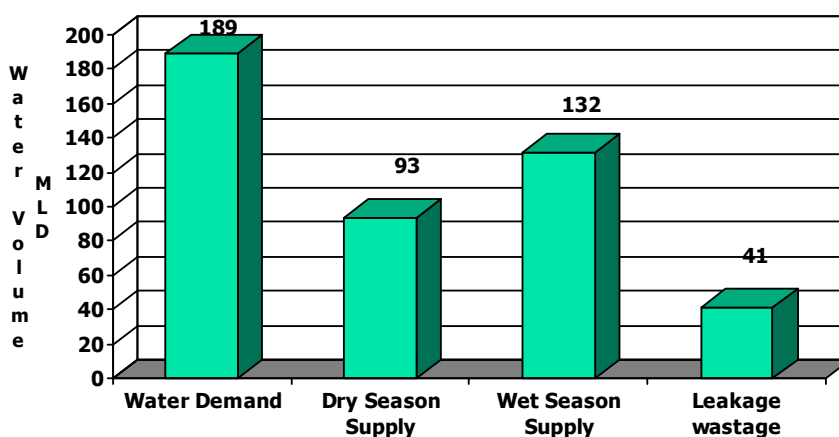


Figure 53 Drinking Water Supply and Demand in Kathmandu

Most of the people have no enough water, those who have access to enough water flush a huge amount of fresh water for flushing their toilets. The flush system is doing nothing but wasting fresh water in flushing away the excreta, thereby polluting a much larger volume of river water. In this background, ecosan could be realised as the best solution to overcome these problems.

Considering this fact ENPHO tried to construct the first ecosan system in modern residence in the Dallu Housing Area of Kathmandu. Dr. Roshan Raj Shrestha, the director of ENPHO's house was taken as model house for this, which now known as eco home at present.

Dr. Roshan Raj Shrestha, one of the initiator of ecosan in Nepal has built ecosan system in his own house to demonstrate ecosan concept, its technology and feasibility of it in modern houses. He along with his family has been using this system since March 2003. Rainwater harvesting and ground water recharge, SODIS and solar heating, Dry toilet (urine diversion), Grey water recycling and Application of urine for crop production are the basic features of this house.



Figure 54 Eco-home

The urine-separating commode Figure 55 with a bucket collection bin of 80 litre for

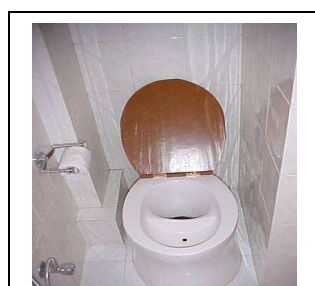


Figure 55 Urine Separating commode



Figure 58 Use of Urine for vegetables and flowers

faeces in the basement of the house is arranged Figure 56. The urine collected from the system is used in the kitchen garden and orchard Figure 58. Faeces have been emptied at every four-month's interval. Apart from

urine diverting and composting system, a small reed beds

system (see Figure 57) is also provided to recycle grey water (wastewater from shower and kitchen). The recycled wastewater is used for many purposes other than drinking like gardening, cleaning vehicles, flushing toilets.



Figure 56 Urine and Faeces Collection by means of polythene tanks



Figure 57 Reed bed for Gray Water Treatment

Furthermore the house is provided with Rainwater harvesting system. The need of water in this house is compensated for more than 7 months by rain water harvesting and remaining four months water is tapped from dug-well.

Solar water dis-infection (SODIS) Figure 59, is another fascinating effort being practised to disinfect water for drinking purpose.

In urban area like Kathmandu suffering from shortage of drinking water and untreated wastewater loads to the Source Rivers Vishnumati and Bagmati are acute problem of water scarcity. Hence in such context, the Eco-Home demonstrates the aspiring efforts to optimise the household water management.

Dr. Shrestha is very proud of this system in his house. The success of this system has proved that such a system could be implemented in urban settings and should be introduced in the upcoming urban settlements both in and outside of Kathmandu.



Figure 59 SODIS Treatment

5.6 Lesson learned from pilot projects

Lesson learnt from the different pilot projects can be summarised as follows

- Most demonstration projects have shown that ecosan could be socially accepted in Nepalese society.
- There is no problem of using urine, people are ready to handle urine but don't know proper application dose.
- During rainy season urine is not applied therefore need either big urine collection tank or some storage facilities.
- Need regular motivation, supervision and monitoring to change their attitude and behaviour of the users.
- Still economical approach and design is needed.
- Demonstration site to show the best agricultural practice with application of end products is needed
- Empowering people in decision making with demand driven approach can promote ecosan concept.
- Making aware of high resources within their wastes
- Entrepreneurship development and Using indigenous styles rather than replacing by modern ones
- It can safely increase agricultural production
- It is Sustainable solution to the total waste Projects are successful in farmers communities where as it seems failure in squatter areas

5.7 A Comparative Study of Sanitation Systems

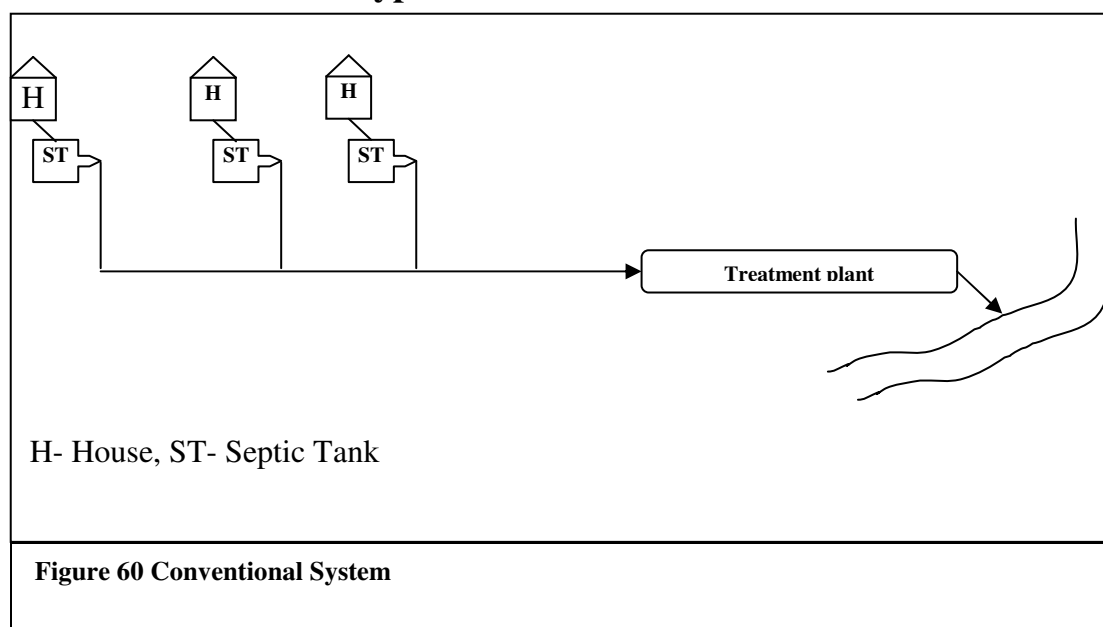
What type of sanitation is suitable? The question arises and the answer may be either conventional system as current practice or with ecosan concept. Normally people prefer to have the conventional one as it is well understood in all level but for the future ecosan is only the viable option as the concern of environment, sustainability and affordability. Regarding this background hereunder two different hypothetical project scenarios are considered more or less compatible to Nepalese context.

In Nepal still 40% of the population lack in proper sanitation in this scenario ecosan definitely would be an economical and sustainable approach towards attaining appropriate sanitation and better health.

5.7.1 Peri-urban Scenario

Here an approach is made to compare a peri urban area of 12000 populations with conventional centralised system of sanitation and decentralised ecosan sanitation system. It is assumed that the cost of toilet construction is same for both systems as this cost mostly depend upon the finishing of the toilet.

5.7.1.1 Conventional Type



Here it is assumed that each house has septic tank. The average distance between household and mains is 30 Mtr. and the length of main sewer is 1000m. The end sewerage

is treated with activated sludge process before discharging to the water bodies. The arrangement of septic tank and sewer is shown in the figure 60.

Design of septic Tank

Assuming Retention period = 3 days and family size 6 persons, water demand 100lpcd, sludge cleaning period 3 years and sludge production 40l per person per year

$$\text{Detention volume} = 3 * 6 * 100 = 1800 \text{ l}$$

$$\text{Sludge volume} = 3 * 6 * 40 = 720 \text{ l}$$

$$\text{Total} = 2520 \text{ l}$$

Hence proposed size of the Tank is 3m*1m*1m

The dimension of the pipe from household to mains is assumed to be of dia.150mm and mains of dia 450mm.

Construction Cost

Septic tank

SN	Type of work	Length (m)	breadth (m)	height (m)	Quantity	Rate	Amount (NRs)
1	E/W excavation	3,5	1,5	2	10,5	80	840
2	Soling	3,5	1,5	0,2	1,05	1000	1050
3	(1:2:4)PCC	3,5	1,5	0,1	0,525	3200	1680
4	Brick work in 1:4 cement sand mortar	8,92	0,23	1	2,0516	2500	5129
5	1:4 cement sand plaster	(3+3+1+1=8*1= 8m ²)			8	110	880
6	RCC	3,46	1,46	0,1	0,50516	4200	2122
7	Backfilling	1s					1000
Total							12701
Total for 2000 nos							25401344

Sewer

SN	Type of work	Length (m)	breadth (m)	height (m)	Quantity	Rate	Amount (NRs)
From house to mains (150 mm dia NP6 cement concrete pipe)							
1	E/W excavation	1	0,45	1	0,45	80	36
	150 mm dia pipe	1			1	500	500
	Backfilling and compaction	1	0,45	0,45	0,2025	120	24
SubTotal							560
Fitting and placing @ 7% of total cost							39
Total							600
Total for 2000 *30 = 6000mtr							3597126
mains (450 mm dia NP6 cement concrete pipe)							
1	E/W excavation	1	1	1,5	1,5	80	120
	450 mm dia pipe	1			1	1000	1000
	Backfilling and compaction	1	1	1,5	1,5	120	180
SubTotal							1300
fitting and placing @ 7% of sub total cost							91
Manholecovers @ 5% of sub total cost							65
Total							1456
Total cost for 1000m							1456000

Total cost for sewer = NRs.(3597126+1456000)
= NRs.5053126

Construction cost of Activated sludge system

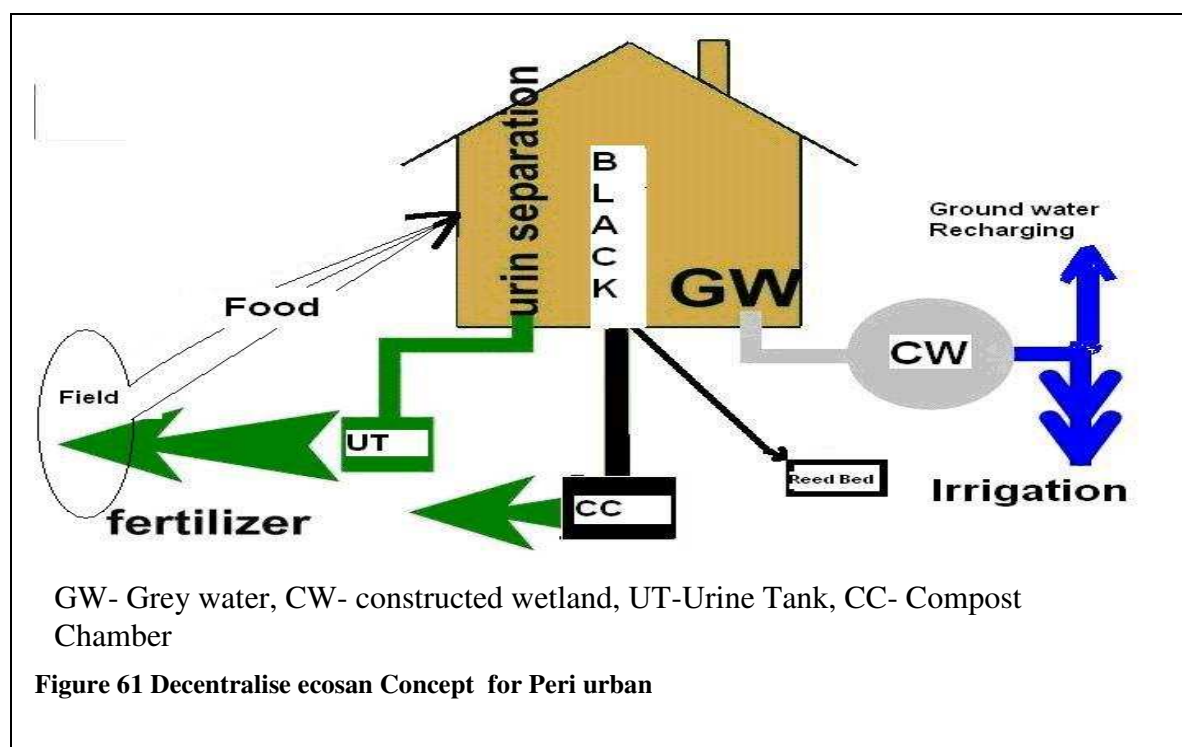
= 74* \$660* 12000 (Rate see Appendix 2)
= NRs.586080000

Total Construction cost = NRs.(25401344+5053126+586080000)
= NRs.845,144,470
= 9,186,353 Euro
= 766 Euro/ person
= NRs 70,428/person

Operation and maintenance cost

= \$0.7* 74* 1200 (Rate see Appendix 2)
= NRs. 62160/ day
= 676 Euro/ day
= NRs 5.20/ person/ day

5.7.1.2 ecosan type



It is proposed to provide one ecosan double vault toilet in each house and Grey water is treated with reed bed in each house and the water is used in irrigation as shown in Figure 61.



Figure 61

Construction Cost

Double vault urine diverting toilet

SN	Type of work	Length (m)	breadth (m)	height (m)	Quantity	Rate	Amount (NRs)
1	E/W excavation	2	1,5	0,4	1,2	80	96
	Soling	2	1,5	0,2	0,6	1000	600
	(1:2:4)PCC	2	1,5	0,1	0,3	3200	960
	Brick work in 1:4 cement sand mortar				0,0		
		6,18	0,23	0,7	1,0		
		7,6	0,1	2	1,5		
		Total			2,5	2500	6287
	1:4 cement sand plaster				14,7	110	1613
	RCC				0,5	4200	1949
	Door and outlet chamber	Ls					2000
							Total
							13505

Grey water treatment

A simple reed filter bed of 8m by 4m is considered for the treatment of Grey-water in each household.

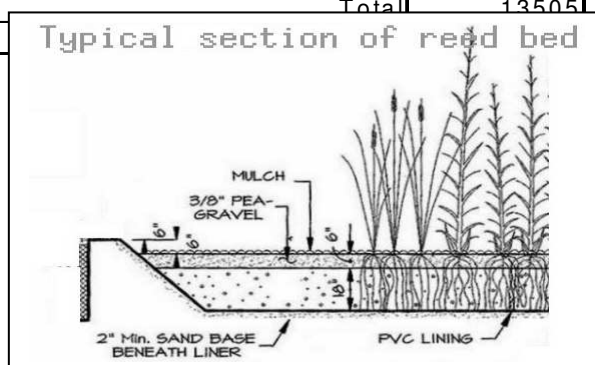


Figure 62 Typical Section of Reed bed

SN	Type of work	Length (m)	breadth (m)	height (m)	Quantity	Rate	Amount (NRs)
1	E/W excavation	4,3	3,2	0,7	9,6	80	771
	sand filling	7,5	1	0,1	0,8	800	600
	Gravel filling in three layer	4,3	3,2	0,25	3,4	800	2752
	Stone filling	4,3	3,2	0,4	5,5	500	2752
	Grass carpetting	5	3,9	0,25	4,9	100	488
	Pipe 90m m dia	20			20,0	80	1600
	Plastic sheet LS (sq m)				60,0	25	1500
Total							10462
Total for 2000 nos							20924120

Total = NRs.20924120

Grand Total = 27009700 +20924120= NRs.47933820

~ NRs 4000/ per person

= 521020 Euro

~43,41 Euro/ Person

Operation and maintenance cost

= 0.4* 74* 600 (Rate see Appendix 2) (further it is assured that the water consumption will be reduced by 50% of conventional one)

= NRs. 22200/ day

= NRs 1.85/ person/ day

Further, NPK Extraction = 5*12000 = 60000kg per year@ NRs. 32 per kg total value of NPK will be NRs.1,920,000. Assuming life period of system is 20 years and rate of interest 10% the present value of NPK will be NRs. 16,865,280.

The comparison of cost is shown in Figure 63. The ecosan options are cost effective, however efforts should be made to minimise the maintenance cost in Nepalese context.

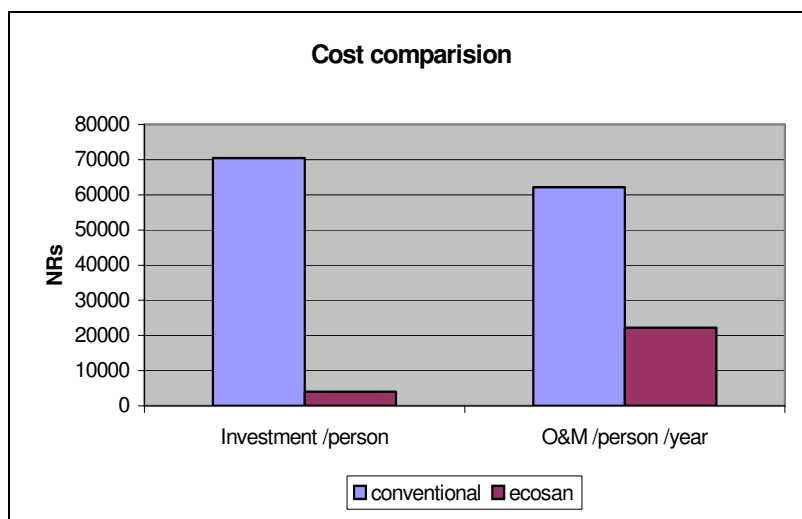


Figure 63 Cost Comparisons

5.7.2 Village Scenario

Nepal is a country of 34,000 villages. 80% of the population of this country live in villages. Any development activities without considering the people of villages have no meaning.

Here a small village of 20 households with 140 populations is considered for the execution of a pilot ecosan project. The concept of this hypothetical project is to provide adequate sanitation, generate energy and extract the nutrient from excrements. The close loop is shown in figure 64.

A biogas plant of 6 m³ with urine diverting toilets in each household is proposed. The urine is collected in a polythene tank and later used in the field as fertilizer after a storage period of six months. Further, the slurry from this biogas plant is composted with the help of carbon-rich additive (leaves, grass) at least for six months, then used as compost in the field. It is assumed that after six months harmful pathogens are killed during composting.

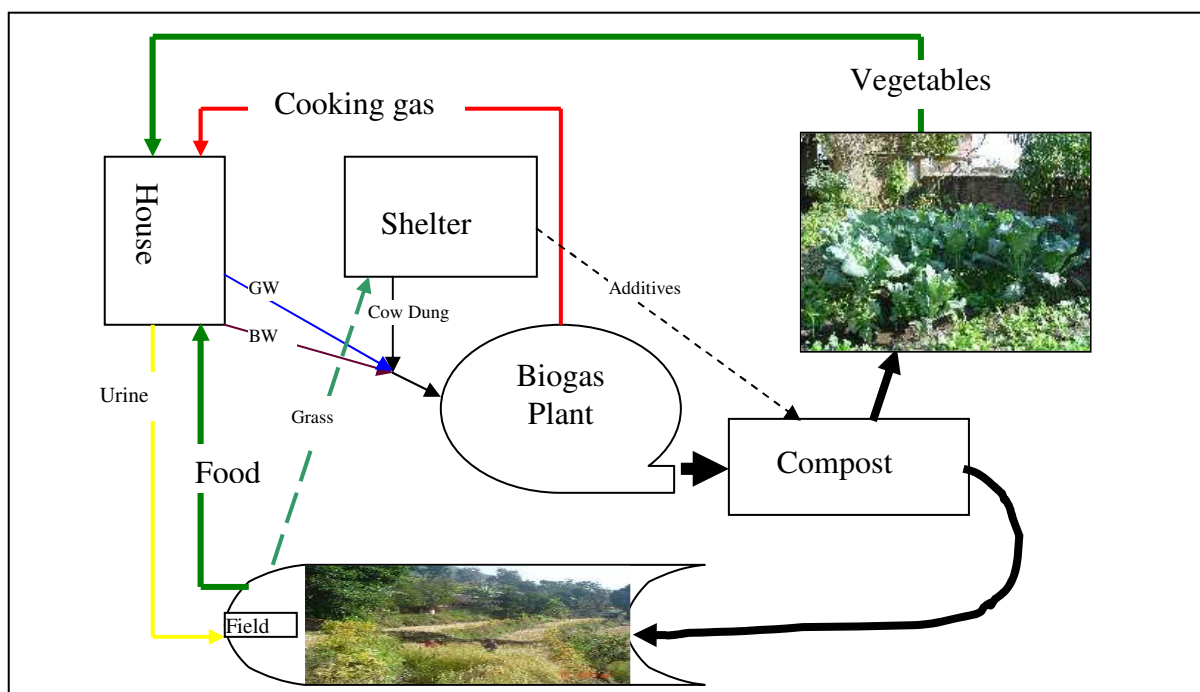


Figure 64 Proposed Nutrient Flow Cycle Of Village in Closed loop**5.7.2.1 Construction Cost**

20 Biogas with urine diverting toilet @ 24000	= NRs.480000
40 Sludge composting chamber @ 2000	= NRs 80000
40 no 500 l polythene tank @ NRs3/lit	= NRs.60000
Total	= NRs.620000
Training and motivation @ 10%	= NRs 62000
Grand Total	= NRs 682000
	= 7413 Euro.

It is assumed that required stone, and unskilled labours are contributed by the villagers which will be about NRs.(8000*20) = NRs 160000 ~ 1740 Euro.

5.7.2.2 Energy extraction

Input	Dung from Two Buffelo	= 24kg
	Excreta	= 3 kg
	Kitchen waste	= 2 kg
	Total	= 29 kg.
Output	Gas production	= 3*70+26*36 Litre
		=1146l/day
		~ 5 stove hour per day

Let us here now consider only excrements as input

Total extracted gas per year	= 3*20*70*365
	=1533 m ³ per year
	=1.533*24.28 GJ; (1000 m ³ = 24.24GJ)
	=37.22 GJ per year; (1GJ=10 ⁹ WS= 10 ⁶ kws= 277.78 kwh)
	=10338 kwh per year

Taking NRs8per unit cost of energy total value of energy = NRs.82704 per year

5.7.2.3 NPK extraction

It is estimated that each person produces around 5 kilo of NPK per year

$$= 20 \times 6 \times 5$$

$$= 600 \text{ kg @ NRs40 per kg}$$

$$= \text{NRs}24000$$

Total out put in terms of cash = NRs.106704

Taking 20 years life span of project and 10% rate of interest

$$\text{Net Present Value of income} = \text{NRs.}106704 \times 8.784$$

$$= \text{NRs.}937287$$

$$= 10188 \text{ Euro}$$

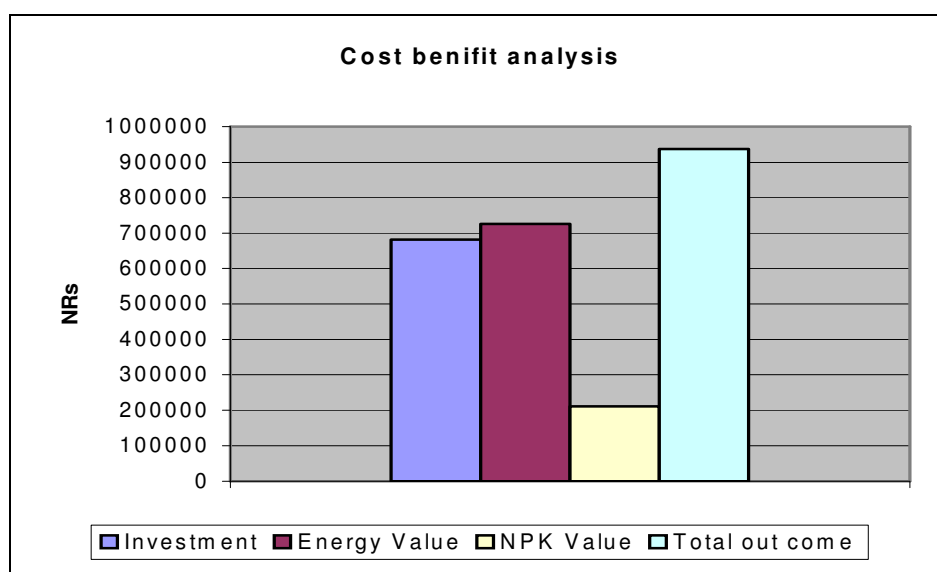


Figure 65 Cost Benefit Of Proposed System

From the above analysis it could be concluded that in the village scenario ecosan combined with biogas would certainly result in better sanitation as well as energy generation.

5.8 Further ecosan development possibilities

There are many possibilities for the further developments as the country still lack in proper sanitation. A combined development of sanitation and agriculture can be foreseen

in the country as the country has agricultural based economy in other words ecosan can provide better health as well as fertiliser for increasing crop yield.

In the areas where cooking fuel, electricity and water are still far away, Integration of sanitation with bio gas as well as rain water harvesting are two major potential areas where ecosan can prove its suitability.

5.8.1 Integration with bio gas

The main cause of polluted water and environment is due to unmanaged human excreta and household waste. Household expenses in health care, productive time losses due to illness, social costs of individual's psychological stress and social disharmony due to communicable disease (sometimes epidemic), normally, the hidden micro-economic costs to an individual or a household in Nepal, can be saved if small-scale interventions are made in bio-gas plant with attached toilet and kitchen waste and waste water.

A survey carried out by Bio-gas Support Programme (BSP, 1998) showed that about 30% of bio-gas users feel that the cases of intestinal diseases and diarrhoea have been prevented after installation of bio-gas plant combined with toilets.

5.8.2 Integration with rain water harvesting

Rainwater harvesting is not new in Nepal. From the time in memorial in the north western part of Nepal people have been collecting rain water for domestic purposes. It uses simple technology, which can be maintained, at the household level. No new organisational structures are needed for operations and maintenance. Settlements in ridges and crests make problem to the people to have access to water. Rainwater harvesting is a viable technological option that has been practised for centuries in these areas.

Form different studies Rain Water Harvesting has been found very useful in rural settlements as well as in urban. Rainwater is a key aspect of integrated water resources management as it enhances groundwater recharge, balances water resources demands, and favours ecological sustainability.

6 CONCLUSION & RECOMMENDATION

6.1 Conclusion

Efficient and equitable water resources management and provision of safe water supply and sanitation are essential for poverty reduction, ecosystem protection and its sustainable growth. We all know about the importance of water in our daily lives. Clean water is essential for human health and survival. Safe drinking water and adequate sanitation and hygienic practices are preconditions for overall reductions in malnutrition and mortality, especially among children.

We need a paradigm shift from current flush and forget or pit and store type of management to sanitise and reuse type of excreta management approach. To ensure these objectives and to protect the world's precious water resource we need to work towards Integrated and holistic approach which promotes the co-ordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

There is no doubt ecosan is a positive and sustainable concept in wastewater management and food security. There is no any option rather than ecological sanitation to protect the environment. The ecosan concept is based on the win-win approach. It provides required sanitation, conserve environment, and increase production. . All should adopt this sanitation system however the time and method may differ from place to place. With regard to future water scenarios, rising water prices and the increasing food demand, closed-loop approaches will prevail. In future ecosan will not just representing an “alternative” to sanitation but will be accepted as an valuable instrument.

The importance of ecological sanitation does not only maintain the sanitation but also close the loop between agriculture which ultimately enrich the fertility of soil and maintain balance between input and output from soil. This results the food production without adding any expensive chemical fertiliser on it. The separation of urine and faeces from the total wastewater results in a relief from nutrient discharge into the waterways, and a recover fertiliser for agricultural product, which is beneficial to increase food production and reduce the economic burden of chemical fertiliser.

Ecosan is our future; there is no any option rather than ecosan every one must go for this concept however the time and process may differ from place to place. A general conclusion from ecosan experiences is difficult, because each project is adjusted right for the specific condition. In these areas the concept is still in the stage of implementing pilot projects, and it will mainly depend on the willingness of the authorities and the financial budget to carry out alternative solutions to conventional treatment. All in the entire concept proved its positive approaches in rural areas in the design of dry or pour-flush sanitary latrines. In densely populated areas, with high connection degree of flushing toilets, the separate treatment of urine and faeces reach its limits.

It is felt that ecological sanitation approaches need to assuage people's health fears. Knowledge of pathogen destruction using different toilet designs under a variety of field conditions is necessary to ensure that communities and households can rely on producing and receiving a sanitised product.

Probably the most important gap to fill is how to destroy pathogens at the point of excretion. If faeces are to be transported to another location (e.g., to compost piles), then more information and knowledge is needed for practitioners to know how to minimise exposure. If pathogens are not adequately destroyed in the chamber or are spread during faecal harvesting and transfer to a secondary processing site, then traditional interventions focused on installing barriers to prevent transmission (e. g . , hand washing , improved food hygiene and water purification) need to be employed.

There are a variety of technologies available, which can be adapted to specific conditions in developing as well industrial countries. Still there is big lack in appropriate and economical technology in this sector

6.2 Recommendations

There is no option rather than ecosan however due to lack of sufficient research, definite guidelines, in this area makes difficult to promote ecosan all over the world. The thinking of ecosan is just sprouting in the applied field. There are a lot to do. Here I would like to make recommendations of two types: recommendations on research and recommendation for action. These recommendations are equally applicable to develop as well as in developing countries however these may not be sufficient for each and every case, they may vary from place to place.

6.2.1 Recommendations for Research

Technical:

- Further epidemiological studies must be undertaken regarding the potential for heavy metals to accumulate and contaminate food products that are produced when nutrients and water recovered from waste water resources are shifted up the food chain in agriculture.

Technology Development

- Research efforts should be made on destruction of pathogens from faeces as well as from black water and optimization of nutrients in case of compost and double vault urine diverting toilet.
- Research efforts should be made on developing small scale anaerobic treatment technologies such as bio gas.
- Environmental impacts of any proposed system must be considered.
- Research efforts should be made on storage of urine as well as its applying technique.

Economic

- Emphasis should be placed on developing demonstration projects that will validate low technological innovations that are powered or driven by natural processes. These pilot projects should include cost benefit analysis
- Emphasis should be done on involving public sectors in the projects.

Socio cultural

- Research should be directed towards the development of methods to mobilize local community groups in self-help sanitation schemes centered on key technologies.
- Research should be directed on socio cultural aspects of using human excreta for food production.

6.2.2 Recommendations for Action

Strategic

- Emphasis should be paid on disseminating ecosan messages through institute such as school and universities

- Efforts should be made on involving all the stakeholders and go for house hold centered approach. Especially the involvement of religious and cultural leaders and reach persons are important. If the ecosan technology are cost effective to serve the un-serve poor, these will only be an interim alternatives, which could be discarded after people become rich, hence awaring and involving reach people are important in ecosan concept
- Efforts should be made on involving women and children
- Efforts should be made to change people attitude and behavior rather than dumping new technologies.
- Emphasis should be given in advocacy in political forums
- In the areas with scare water resource people should be encouraged to harvest rainwater in order to meet their domestic demand, however emphasis should be made to combine it with better sanitation (ecosan)

Technical

- Emphasis should be given on empowering people through training and workshop and demonstrations
- Emphasis should be made in integrated water resource management such as rainwater harvesting
- Emphasis should be made on generating economic resource such as integrating bio gas in sanitation projects.

ANNEX

Annex: 1 Time line for Wastewater Treatment

3500-2500 BC	Mesopotamian empire storm-water drainage system in Babylon clay pipes led to cesspools
1700 BC	Four separate drainage system in King Minos palace. In Knossos, Crete terracotta pipes drained to stone sewers
c. 800 BC	Cloaca Maxima central sewer system built in Rome
c. 100 AD	Sewer Network in Rome connected to houses
c. 400 AD	Brick sewer in London
c. 1100	Cistercian monasteries in Scotland locate next to water courses and flush latrines via sewer to watercourse
1189	Regulations in London on placement of cesspool
1370	First covered sewer in Paris dumps sewer into the river Seine near the Louvre
1531	Commission on sewer in London
1596	Sir John Harington builds two water closets for Queen Elizabeth I. Called the 'Necessary', this is the first water closet flushed by a valve system
1740	First recorded mention of chemical treatment of sewage. Lime used in Paris
1776	Magistrate John Shortbridge requires Glasgow tenants to drain the water from kitchens via lead pipes, and excreta should be taken to maidens.
1790	First sewer build in Glasgow
1793	First water closet in Glasgow 200 years after its invention Edwin Chandwick publishes the landmark reports on the sanitary condition of the labouring population of Great Britain. Health of Towns Association formed
1844	Commission on Health of Towns adopted Chadwick's proposals.
1846	First British patent on chemical treatment is granted to W. Higgs for the use of lime.
1848	Public Health Act in the UK masterminded by Edwin Chadwick. Set up local Boards of health and gave them right to construct sewers.
1849	Metropolitan Commission of sewers of London.
1848-1854	Dr John Snow proves link between cholera outbreak and water supply polluted by sewage
1853	First comprehensive sewerage system completed in Hamburg, Germany. System designed by William Lindley serves as model for European cities and US.
1850-1910	Many patents applied for the UK and US for chemical treatment of sewage. 417 patents granted in the UK between 1856 and 1876.
1860	Overflowing cesspool (precursor of septic tank) designed in France by L.H.Mouras.
1862-1865	More soldiers die from typhoid and cholera than combat in US Civil war
1866	Medical officer of the Privy council (advisors to Queen Victoria)

	reported that death rates are dropped considerably where the Chadwick report recommendations were followed.
1868-1870	Frankland's tests on filtration of sewerage through soil and gravel (extension of land treatment). Nitrification achieved.
1870-1890	Many tests in UK and US on filtration of sewage through various media.
1887	Dibdin suggests basis for biological treatment by organisms and describes modern primary and secondary treatment.
1890	First true biological filter at Lawrence Experimental Station, Massachusetts State Board of Health, US.
1890-1990	Many tests and designs in the UK follow up American work on biological filters.
1895	Cameron and Cummins (Exeter) patent septic tank.
1898	1 st Royal Commission on Sewage Disposal in UK.
1906	Imhoff tank designed in Germany.
1912	8 th Royal Commission on Sewage Disposal defines the 20mgBOD/litre, 30mg SS/litre 'Royal Commission Standard.'
1913	First laboratory experiments on activated sludge by Fowler, Ardern and Lockett at University of Manchester, UK.
1916	First full scale activated sludge plant at Worcester. Large scale Tests in US. First full scale Activated Sludge plant in US at Houston, Texas.
1922	Activated Sludge Plant built at Soelleroed, Denmark.
1924	Pilot Activated Sludge Plant in Germany at Essen
1926	Full- scale AS plant at Rellinghausen, Germany.
1927	Kessener brush aeration, Apeldoorn, the Netherlands.
1936	Denitrification used in Sheffield.
1964	Development of basis for consistent nitrification by Downing Painter and Knowles, WPRL, Stevenage, UK.
1972	Biological phosphorus removal describes by Barnard in South Africa.
1970s	Development of dynamic process computer models by WRc and IAWPRC.
1990s	Membrane biological reactors developed in Japan

Source: Cooper, P.F. "Historical Aspects of Wastewater Treatment" Decentralised Sanitation and Reuse, IWA Publication.

Annex: 2 Typical Wastewater Treatment Costs (Small Treatment Plant)

Treatment Technology	Capital cost (\$/person)	Annual O&M cost (\$/m ³)
Activated Sludge	660	0.7
Biological Filter	500	0.6
Horizontal- Flow Reed- bed	500	0.4
Vertical Flow Reed- bed	400	0.5
Aerated Lagoon	400	0.6
Facultative Lagoon	230	0.4

Source -Mara, Eurling, Cogman, Simkins and Schembri 1998

Annex: 3 Food grain Production, Requirement and Balance by Ecological Belt, 1994/95

Particulars	Mountain	Hill	Teria	Nepal
Number of districts	16	39	20	75
Food deficit districts (1991/92)	14	27	0	41
Food deficit districts (1994/95)	16	33	6	55
Mid-year population (million)	1.5	8.9	10.0	20.4
Total cereal prod ('000 mt)a	194	1638	2264	4097
Requirement ('000 mt)a	322	2021	1935	4279
Cereal Balance ('000 mt)a	-127	-383	329	-181

Source: AMDD (1995)

a- SINA/MoAC, 1999/2000

Annex: 4 Potential Gas Production from Different Feed Stocks

S. No.	Type of feed stock	Gas yield per kg. (Cu.m)	Normal feed availability per animal per day kg (wet weight)	Gas yield per day (Cu.m)
1	Cow dung	0.036	10.0	0.36
2	Buffalo dung	0.036	15.0	0.54
3	Camel dung	0.056	6.0	0.336
4	Horse dung	0.045	10.0	0.45
5	Sheep dug	0.042	1.0	0.042
6	Pig (Approx. 50 kg)	0.08	2.25	0.18
7	Chicken (Approx 2 kg)	0.062	0.18	0.011
8	Human excreta	0.07	0.40	0.028

Source: <http://www.techno-preneur.net/timeis/technology/STMarchApril02/biogas.html>

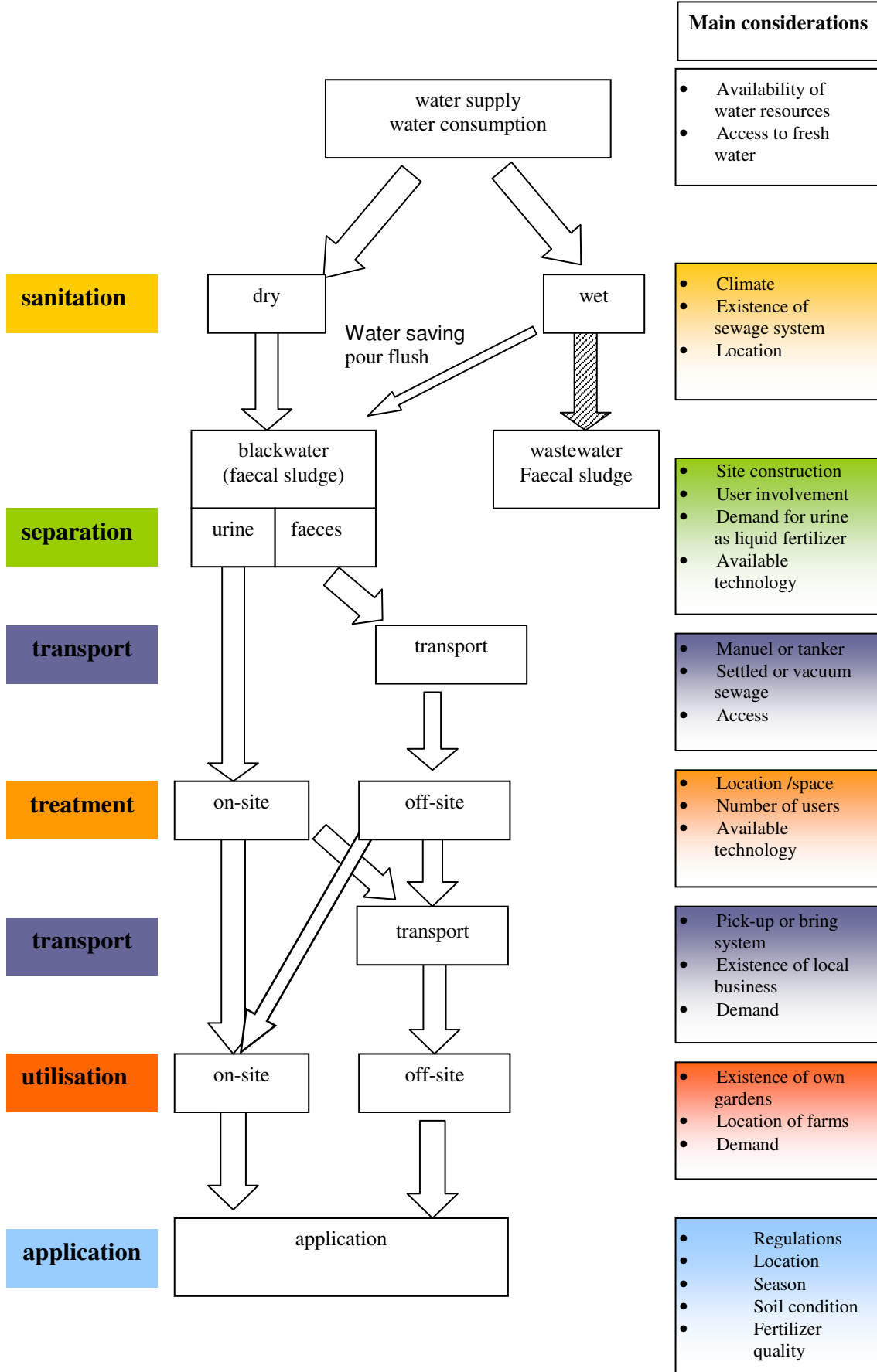
Annex: 5 Availability of Nutrients in Biogas Slurry and Farm Yard Manure (F.Y.M.)

S. No.	Type of Manure	Time of decomposition	Loss in quantity during process	Available		
				N	P	K
1	Biogas slurry	1-2 months	7-10%	1.175%	1.10%	1.0%
2	Farm yard manure (composted under cover)	3-4 months	20-25%	0.9%	0.75%	0.75%
3	Farm yard manure composting	4-6 months	45%	0.75%	0.60%	0.60%

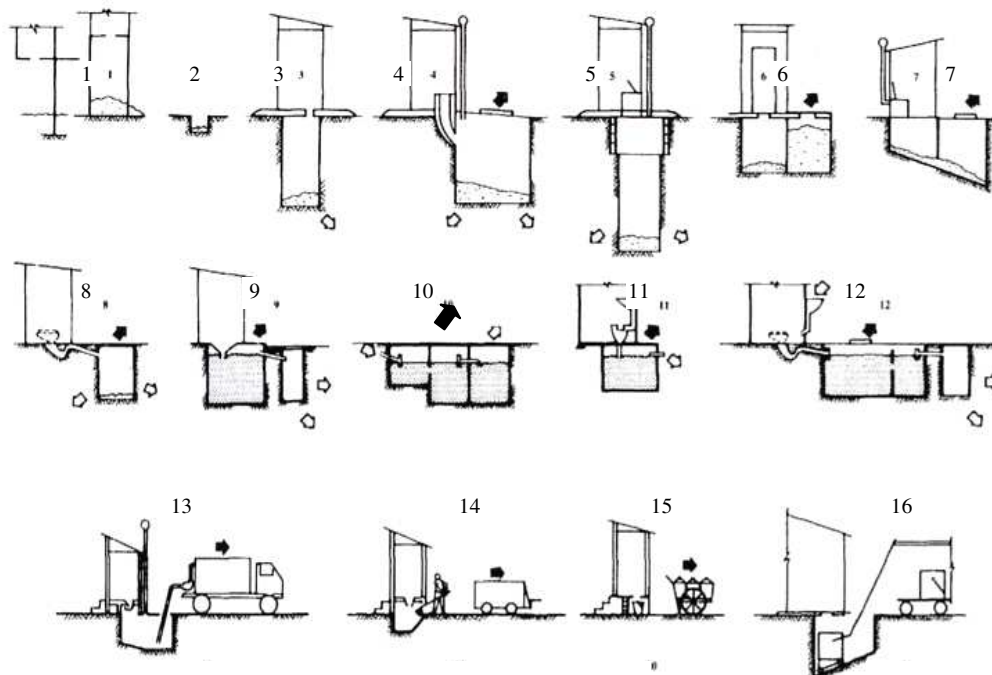
Source: <http://www.techno-preneur.net/timeis/technology/STMarchApril02/biogas.html>

Annex: 6 Expressions related to urine and faeces

Brownwater	faeces
Blackwater	faeces and urine - undiluted
Household wastewater	faeces, urine and greywater
Excrements	faeces and urine = blackwater
Humanure	word-combination of 'human' and 'manure' = blackwater
Human waste	all wastes produced by a human = excrements, in some cases also including household wastes
Night-soil	faeces and urine collected in buckets and pits depending on sanitary equipment: <ul style="list-style-type: none"> • from dry system - this is the most common system = blackwater • from wet system (flushing) = blackwater diluted • separate collection of urine and faeces - e.g. in China = brownwater
Faecal sludge	two categories: <ul style="list-style-type: none"> • high strength: from public toilets, pits, septic tanks, buckets = night-soil • low strength: from sewage can only considered as faecal sludge if sewage is only for household wastewater
Sewage sludge	two categories: <ul style="list-style-type: none"> • settled sludge from sewage • sludge from wastewater treatment plants if including industrial wastewater, sewage sludge contains higher amounts of heavy metals
Manure	animal excrements, commonly used for excrements of farm animals, rather liquid composition Often used in agriculture



Annex: 8 Generalised design of latrines (Kalbermatten et al., 1983)



⇒ movement of liquid ➡ movement of solids

Annex: 9 Properties of different latrines based on Annex 8

Type of latrine	dry	water saving	wet	Separation of urine and faeces ?	Reuse of solids possible ?	Remark
On-site						
1. Overhung Latrine	+			no	no	Drop & store
2. Trench latrine	+			no	no	Drop & store
3. Pit latrine	+			yes	no	Drop & store
4. Earth closet	+			yes	yes	Soil, dry faeces
5. Ventilated improved pit latrine	+			yes	no	Drop & store
6. Batch composting latrine	+			demanded	yes	Compost
7. Continous composting latrine	+			demanded	yes	Compost
8. Pour flush + soakaway		+		~	~	Faecal sludge
9. Pour flush + aqua privy		+		~	~	Faecal sludge
10. Pour flush latrine septic tank		+		~	~	Faecal sludge
11. Sullage or cisterne flush + aqua privy		+	+	no	~	Faecal sludge
12. Sullage or cisterne flush + septic tank		+	+	no	~	Faecal sludge
- Biogas latrine		+	+	~	~	Sludge
off-site						
13. Vault + vacuum tank		+	+	~	~	Only suitable if treatment and not a disposal is connected
14. Vault + manual removal, truck	+	+	+	~	~	
15. Bucket latrine	+			yes	~	
16. Mechanical bucket latrine	+			yes	~	

~ conditional, only suitable if reuse and not disposal is connected

	treatment		Location		water		substrate			Technology		Cost	Experience***	
	On-site	Off-site	rural	Urban	dry	Wet	urine	faeces	Black water	Design skills	Main-tenance		approved	new
Storage	++	+	++	+ Low-medium	+*	+	++			low		Low	++	
Drying toilet/latrine	++		++	0-+	++			++	0-+	Low-medium	Low-medium	Low	++	
Composting toilets /latrine	++		++	0-+ Low - medium density	++			++	0-+	Low-medium	Low-medium	Low-medium	++	
Container	++	+	++	+ Low - medium density	+**			++	+	Low-medium	Medium	Medium	+	
Compost pile	+	++	++	0- + Low - medium density, outskirts	+**			+	+	Low-high	Medium - high	Medium - high	+	
Biogas	++	+	++	+ Low - medium density	+**			+	+	Medium-high	high	high	+	+
Dry-fermentation	+	++	+	+ Low - medium density	+**			+	+	High	Medium-high	High		++
3 compartement septic tank	++		++	0-+ Low - medium density		+		+	++	Low-medium	Low	Low-medium	++	

Annex: 10

Suitability of treatment technologies

++ very suitable/applicable + suitable/applicable 0 less suitable

* in combination with dry sanitary equipment

** process demands for a specific water content. This can be achieved by material moisture or by adding of water

** experiences with the treatment of urine and faeces, and not with organic wastes

Methods	Retention time	Process temperature*	Destruction of pathogens	Remarks	Additives	Climate
Storage	> 6 months	> 20°C	++		Acid to stabilize ammonium	Not demanded
Drying toilet/latrine	>1 year	ambient	0- +	Besides process criteria ensured by addition of valuable amounts additives Re-activation may occur	Lime, soil, ashes, saw dust	Arid, semi-arid not humid areas
Composting latrine	> 1 year	Ambient	+	Besides process criteria ensured by addition of valuable amounts additives	Lime, soil, ashes, saw dust	Arid , semi-aride
Composting toilet	> 6-12 months	> 18°C low temperature heating	+++	See composting latrine	Lime, soil, ashes, saw dust	Not demanded Special design for humid and cold areas (heating)
Container	> 1 year	ambient	+	-	Organic waste	Not demanded
Compost pile	> 3-6 months	30-35°C mesophil 50-55°C termophil inside pile <70°C	+++	Steady conditions in the pile must be guaranteed	Organic waste	Not demanded , but Semi-arid preferable Probably heating of pile necessary
Biogas	30 days 40 days 55 days	> 20 (Mesophil) 15-20 °C <15 °C	0-+	A higher grade of pathogen destruction can be achieved / depends on post-treatment (e.g composting)and pre-hygenisation	Organic waste	Not demanded, but arid preferable Special design for cold areas (heating)
Dry-fermentation	40-55 days	30-35°C mesophil	0- +	See biogas	Innoculatnt Organic waste	Semi-arid preferable Probably heating necessary
3 compartement septic tank	50 days	ambient	+++	See biogas	-	Not demanded, arid and semi arid preferable

0 low /not guaranteed + partially destructed ++ good/guaranteed

* related to retention time, if temperature is lower, longer retention time is demanded

Annex: 12 Recommendations for Action of Lueback Symposium

In April 2003, at the 2nd International Symposium on Ecological Sanitation in Lübeck, Germany, 350 experts from 60 countries formulated 10 Recommendations for Action, as priorities for the further promotion of ecosan and for bringing ecosan to scale.

1. Promote ecosan-systems as preferred solutions in rural and peri-urban areas

A variety of ecosan solutions, ranging from low to high-tech, exist for rural and low density urban areas. These should now be implemented on a large scale, in accordance with local physical, cultural and socio-economic conditions.

Technologies based on ecosan principles should be vigorously promoted for all new construction of buildings and for the refurbishment of older structures wherever feasible. Additionally, existing on-site sanitation facilities that pose a significant health risk should be upgraded in accordance with ecosan principles.

2. Accelerate large scale applications of ecosan principles in urban areas

Urban areas with their rapidly growing populations are in greatest need of sustainable sanitation. Although initial experiences with ecosan systems are available from urban areas, further research and development is urgently required. Further ecosan pilot-projects should be carried out in order to develop a variety of technological, organisational and economically viable solutions for densely populated urban areas and to obtain results concerning the costs and performances of different systems in both industrialised and developing nations. The conversion of existing conventional systems towards ecosan should, wherever possible, be immediately started, adopting if necessary a step-wise approach.

3. Promote agricultural use

Ecosan systems are not complete until the fertiliser products are reused. The promotion of agricultural reuse must therefore be a key element of every ecosan project. Reuse options for ecosan fertilisers need urgent field testing at medium and large scale, and appropriate pre-treatment, distribution, marketing strategies and guidelines for safe handling and use for different local conditions must be developed. Particular care has to be taken to ensure that the pathogen cycle is broken.

4. Raise awareness and create demand

To be willing to make a change, politicians, local and regional authorities and the public need to know that the current system can cause many problems and that the application of ecosan principles can solve several of them. Advocacy and lobbying is therefore essential. There is also an urgent need to showcase ecosan systems at a municipal or large neighbourhood level in order to convince decision makers ("seeing is believing").

5. Ensure participation of all stakeholders in the planning, design, implementation and monitoring processes

Planning with a household or neighbourhood-centred approach should be adopted as it places the user at the core of the planning process. The Household Centred Environmental Sanitation Approach (HCES, as developed by the WSSCC) responds to the knowledge, needs and demands of the users. This approach attempts to avoid the problems resulting from either "top-down" or "bottom-up" approaches, by employing both within an integrated framework. Gender issues must be given particular consideration in all processes.

6. Provide for decisions on an informed basis

People should be involved in assessing a range of ecosan options addressing their needs, thus placing, as far as possible, the decision for the type of system they wish to use directly in their hands. In ecosan projects, all stakeholders must be informed intensively about the closed-loop ecosan philosophy, the use of the sanitary facilities, and the safe treatment and application of the recycles with respect to hygiene and the environment. Study and documentation of the health risks posed by the different sanitary concepts, and the necessary means to overcome these, is required.

7. Promote education and training for ecosan

Ecosan is multidisciplinary and should be integrated in the teaching curricula of universities, schools and vocational training centres. The engineers, architects, farmers, developers, constructors, consultants, municipal planners, economists and authorities concerned should know about the concept, the wide range of existing technical and organisational ecosan solutions and

the hygienically safe treatment and reuse of the recyclates. Ecosan principles should be integrated into capacity building and continuous learning programmes for all the actors involved. The documentation and results of pilot-projects must be transformed into e.g. technical, socio-economic, and reuse guidelines reflecting the interdependencies of water supply, sanitation, waste management, health, hygiene, environment, agriculture and energy supply.

8. Adapt the regulatory framework where appropriate

Ecosan technologies should be codified into the local, national and international systems of technical standards and norms in order to provide reference for Best Practice and Best Available Technology. The regulatory framework should be verified or adjusted with the aim of authorising and promoting a closed loop with new innovative technologies and management concepts.

9. Finance ecosan

Appropriate financing instruments need to be developed, putting particular emphasis on the possibility to finance the users investment for on-site and neighbourhood systems, recognising that ecosan systems have a different cost structure from conventional sanitation systems. Innovative financing alternatives including start-up funds, community based finance programmes and cost recovery mechanisms may be required. The possibilities for private sector participation are large and should be stimulated, thus opening opportunities particularly for small and medium-sized enterprises and job creation. Additional financing should also be provided to secure research activities.

10. Apply ecosan principles to international and national Action Plans and Guidelines

Ecosan strategies should be implemented in national and international action plans including the Implementation Plans for the MDGs (Millennium Developments Goals), PRSPs (Poverty Reduction Strategy Papers) and the National Plans of Action within the UNEP GPA (Global Programme of Action for the Protection of the Marine Environment from Land-based Activities). The indicator system for safe and sustainable sanitation provision should be revised to reflect the real risks and dangers to the environment and public health posed by all forms of sanitation.

Annex: 13 Kathmandu Declaration “First National Conference on Ecological Sanitation” (Draft)

First National Conference on Ecological Sanitation

Nov. 3-4, 2003.

1. Identification of the stakeholders from relevant networking body within the nucleus of national sanitation steering committee, which will have a contact person, as a responsible person promoting (Ecological Sanitation (ECOSAN) approach in Nepal.
2. Discovering emerging traditional ECOSAN technologies for documentation and delivering to the expatriate for improvising the indigenous methods which are socially acceptable and economically viable.
3. Socio-cultural impact analysis of the application of ECOSAN technologies for effective implementation of the technique.
4. Dissemination through comparison of the ECOSAN and Conventional approaches to the grass root level.
5. Health impact assessment studies of ECOSAN and Conventional approaches and dissemination of the preventive and precautionary measures.
6. Incorporating ECOSAN concepts at the academic institutions in the curriculum and helping them in establishing centre of ECOSAN studies.
7. As a follow up of the First National Conference, second National Conference to be hosted by the agencies on the recommendation of national sanitation steering committee after a thorough analysis of the stakeholders in every two years from now.
8. Efforts are needed to develop strategies for the application of ECOSAN in the urban context.

Annex: 14 Companies involve in Producing utensils Required for ecosan concept

Company	Product	Web site
Roediger Vakuum und Haustechnik	Separation toilet, Vacuum toilet Vacuum sewage	http://www.roevac.de/
BB Innovation &Co	Separation toilet	http://www.dubletten.nu/
Wost Man ecology	Separation toilet Vacuum toilet	http://www.wost-man-ecology.se/english.html
Aquatron	Seperator Composting toilets	http://www.aquatron.se
Waterless Co	Water less urinal	http://www.waterless.com/
Construction Resources	Water less urinal	http://www.constructionresources.com
Vakutech	Vacuum toilet	http://www.vakutech.de
EVAC	Vacuum sewage	http://www.evacgroup.com
Airvac	Vacuum toilets Vacuum sewage	http://www.airvac.com/
Enviro options	Dehydration toilet	http://www.eob.alvsbyn.net/presentationEOB.htm http://www.eloo.co.za/
ESAC, CITA	Drying toilet	http://www.laneta.apc.org/bs/
Biolet	Composting toilet	http://www.biolet.com
Seperett	Composting toilet	http://www.seperett.com
Ecotech	Composting toilets Separation toilets	http://www.ecological-engineering.com/ecotech.html

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