EFFICIENT MANAGEMENT OF WASTEWATER

Lesson A 2

HYGIENE AND RISK MANAGEMENT

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Overview and Summary

Hygiene is the science of preventing and protecting the health of people through control of the environment i.e. our physical surroundings: air, water; and land, biological ecosystems: animals and plants, and social structures. Environment influences the health of human beings. Normally, humans can react physically, socially and mentally on changed environmental influences, in order to adapt oneself and herewith avoiding damages. But, there are also many environmental influences, which can overcome human’s adaptation and defence capacity and cause diseases. There are two types of diseases: infectious and non-infectious. An infectious disease is one which can be transmitted from one person to another or, sometimes, to or from animals. All infectious diseases are usually caused by pathogenic organisms. Pathogens that are solely responsible for the transmission of diseases are mostly bacteria, viruses, protozoa and helminths and a disease is transmitted by the passing of these organisms from one person’s body to another. The health problems related to environmental pollution are considered to be the result of contamination of water, food, and air with toxic chemicals. The resulting diseases are non-infectious.

Human excreta are the principal vehicle for transmission and spread of a wide range of infectious diseases. Therefore, wastewater has to be treated before discharging it to the environment in order to prevent and control the spread of diseases. The conventional approach of wastewater treatment has contributed to ensuring public health in industrial countries. However, due to the lack of financing for expensive conventional centralised sanitation system most of the wastewater is discharged without any treatment mostly in developing countries. This contributes largely about 1.2 billion people without access to clean drinking water. Almost 80 % of diseases throughout the world are water-related. Water-borne diseases account for more than 4 million infant and child deaths per year in developing countries. In ecological sanitation, human excreta is separated and treated at or near the source which avoids spreading of pathogens in the environment. The separated human excreta, which are easily biodegradable, can be treated biologically. When the organic matters decompose, due to self heating capacity heat is produced. This self produced heat will create self-hygienization of the organic matter. The mostly applied methods for the sanitisation of separated faecal waste are composting and dehydration.

In practice, complete elimination of pathogens may not be possible in any kind of sanitation. Therefore, secondary barrier such as personal, food and domestic hygiene must be included to destroy the pathogens completely. Hygiene awareness and proper education are the crucial points for faecal waste management. Additionally, guidelines and recommendations for the handling and reuse of wastewater can work as a tool to minimise risks.

1. General hygiene

1.1 Definition

Health is defined in the WHO (World Health Organization) constitution of 1948 as: a state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity.

Hygiene is the science of preventing and protecting the health of people through control of the environment.

Environment is our surroundings described as physical surroundings (air, water and land), biological surroundings (animals and plants), and social surroundings.

1.2 Areas of hygiene

The Hygiene comprises the following areas:

- **Environmental hygiene:** it deals with the methods of defence from harmfulness (heat, cold, weather, rays, poison or pathogens) that originate from land, air and water.
- **Social hygiene:** it avoids damages of the social environment of the human being. In practice social and environmental hygiene are inseparable.
- **Individual hygiene:** it comprises of body cleaning and its clothing. Always keep your hands clean: after using the toilet, before cooking, before meals and after contact with raw or uncooked food wash your hands with **soap** or **detergent**
  Besides body cleaning, as mentioned above, there is clothing. The cloth should have good qualities. Enough rest, sleep, sport etc. belong to individual hygiene too.

- **Food hygiene:** it protects us not only from insufficient, unsuitable, rotten or poisoned food, but also changes our deficient dietary habit. Kitchen hygiene also belongs to food hygiene.
- **Occupational and domestic hygiene:** working and residing place should be hygienic.

1.3 Environmental influences and their impact on human health

Normally, humans can react physically, socially and mentally on changed environmental influences, in order to adapt themselves and thus avoiding damages. But, there are also many environmental influences, which can overcome human's adaptation and defence capacity and cause diseases.

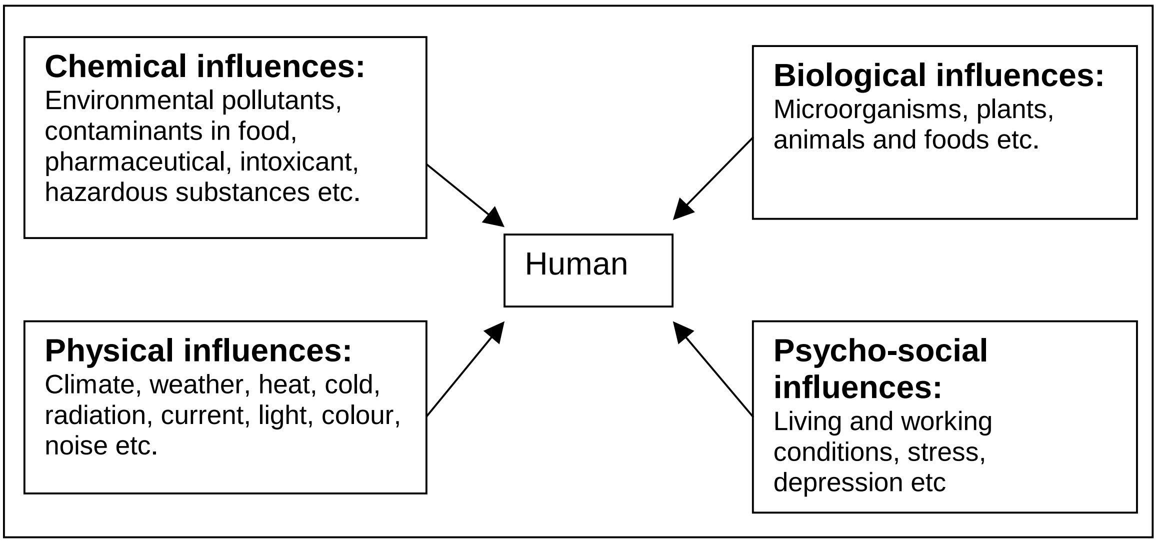

Figure 1: Environmental influences on human

1.4 Infectious and non-infectious diseases

1.4.1 Infectious diseases

An infectious disease is one, which can be transmitted from one person to another or, sometimes, to or from animals. All infectious diseases are usually caused by microbes. Most microbes are essential components of our environment and do not cause diseases. Those that cause diseases are called pathogenic organisms (pathogens). Pathogens that are solely responsible for the transmission of diseases are mostly bacteria, viruses, protozoa and helminths and a disease is transmitted by transfer of these organisms from one person's body to another.

1.4.1.1 Water-related infections

Water related infections are transmitted by water through following routes:

Water-borne: When the pathogen is ingested by a person drinking water, this is called water-borne transmission. One important control strategy is providing good quality of drinking water.

Water-washed: Water-washed route is related to the quantity of water. Good personal and domestic hygiene requires the availability and use of water for bathing, clothes washing and utensil washing.

Water-based: A water based disease is one, whose pathogens spend part of their lifecycle in the water, usually in a snail or other aquatic animals. The water-based diseases are all caused by parasitic worms. Pathogens usually enter the water from faeces and urine of infected persons.

Water related insect vector: in this transmission mechanism insects, which breed in water or bite near water, spread diseases.

Table 1 shows types of water-related transmission route for infections, causes and the control strategies..

Table 1: Water-related infection: transmission and control strategy (Carincross and Feachem, 1993)

Transmission Route	***Diseases***	***Control***
Water borne	Cholera Typhoid Dysenteries Diarrhoeas Infectious hepatitis	Improve drinking water quality. Prevent use of other contaminated sources.
Water washed	Skin and eye infections Louse borne typhus	Increase quantity and use of water. Improve personal hygiene by increasing accessibility and availability of water.
Water based	Schistosomiasis (penetrating skin) Guinea worm (ingested)	Decrease contact with contaminated water in the environment. Control appropriate aquatic animals. Reduce excreta contamination of surface water.
Water related insect vector	Yellow fever River blindness Malaria Sleeping sickness	Eliminate breeding sites by improving Drainage. Keep people away from the breeding or biting sites. Use mosquito netting.

1.4.1.2 Classification of water-related infections

Each water-related infection can be assigned to one of the following categories:

Faecal-oral, water-washed, water-based and insect-vectored. Table 2 classifies major water-related infections and assigns them to their category in addition to linking them to the infectious agent that causes the disease.

Table 2: Classification of water-related infection (Carincross and Feachem,1993)

Category	***Infection***	**Pathogenic agent**
Fecal-oral	Diarrheas and dysentaries	
(water-born or water-washed)	*Amoebic dysentary*	Protozoon
	Campylobacter enteritis	Bacterium
	Cholera	Bacterium
	E. coli diarrhea	Bacterium
	Giardiasis	Protozoon
	Rotavirus diarrhea	Virus
	Salmonellosis	Bacterium
	Shigellosis	Bacterium
	Yersinosis	Bacterium
	Enteric Fevers	
	Typhoid	Bacterium
	Paratyphoid	Bacterium
	Poliomyelitis	Virus
	Hepatitis A	Virus
	Leptospirosis	Spirochete
Water-washed:	Infectious skin diseases	Miscellaneous
a) skin and eye infections	Infectious eye diseases	Miscellaneous
b) other	Louse-borne typhus	Rickettsia
Infectious skin diseases	Louse-borne relapsing fever	Spirochete
Water-based:		
a) penetrating skin	Schistosomiasis	Helminth
b) ingested	Guinea worm	Helminth
	Clonorchiasis	Helminth
	Others	Helminth
Water-related		
insect vector		
a) biting near water	Sleeping sickness	Protozoon
b) breeding in water	Filariasis	Helminth
	Malaria	Protozoon
	River blindness	Helminth
	Mosquito-borne	
	Yellow fever	Virus
	Dengue	Virus
	Others	Virus

1.4.1.3 Excreta-related infections

Diseases which are faecal-orally transmitted usually enter the environment by the excretion of faeces from infected persons.

Table 3: Classification of excreta-related infections

Category	**Infection**	**Patho-genic agent**	**Dominant transmission mechanisms**	**Major control measures (engineering measures in italics)**
Faecal-oral (non-bacterial) Non-latent, low infectious dose	Poliomyelitis Hepatitis A Rotavirus diarrhoea Amoebic dysentery Giardiasis Balantidiasis Enterobiasis Hymenolepiasis	V V V P P P H H	Person to person contact Domestic contamination	*Domestic water supply* *Improved housing* *Provision of toilets* Health education
Faecal-oral (bacterial) Non-latent, medium or high infectious dose, moderately persistent and able to multiply	Diarrhoeas and dysenteries *Campylobacter enteritis* *Cholera* *E. col i diarrhoea* *Salmonellosis* *Shigellosis* *Yersiniosis* Enteric fevers *Typhoid* *Paratyphoid*	 B B B B B B B B	Person to person contact Domestic contamination Water contamination Crop contamination	*Domestic water supply* *Improved housing* *Provision of toilets* *Excreta treatment prior to re-use or discharge* Health education
Soil-transmitted helminths Latent and persistent with no intermediate host	Ascariasis Trichuriasis Hookworm Strongyloidiasis	H H H H	Yard contamination Ground contamination in communal defacation area Crop contamination	*Provision of toilets with clean floors* *Excreta treatment prior to land application*
Beef and pork tapeworms Latent and persistent with cow or pig intermediate host	Taeniasis	H	Yard contamination Field contamination Fodder contamination	*Provision of toilets* *Excreta treatment prior to land application* Cooking and meat inspection
Water-based helminths Latent and persistent with aquatic intermediate host(s)	Schistosomiasis Clonorchiasis Diphyllobothriasis Fasciolopsiasis Paragonimiasis	H H H H H	Water contamination	*Provision of toilets* *Excreta treatment prior to discharge* *Control of animals harbouring infection* Cooking
Excreta-related insect vectors	Filariasis (transmitted by *Culex pipiens* mosquitoes) Infections in Categories I-V.especially I and II, which may be transmitted by flies and cockroaches	H M	Insects breed in various faecally contaminated sites	*Identification and elimination of potential breeding sites* Use of mosquito netting

B: Bacterium V: Virus H: Helminth P: Protozoon M: Miscellaneous

Those of the excreta related disease, which are also water-related, can be controlled by improvements in water supply and hygiene. But these and the other excreta-related diseases can also be affected by improvements in excreta management. If we classify these excreta-related diseases by their routes of transmission in and through the environment, it becomes clearer that intervention measure might be most effective in controlling or preventing the disease. Table 3 shows the classification of excreta-related infections

1.4.1.4 Transmission routes of pathogens

The routes of infection with the pathogens found in faeces are illustrated in figure 2. The arrows indicate the routes of pathogen transmissions, whereas the crossing bars represent barriers to prevent the spread of pathogens. The physical barriers can be applied to intercept the routes of transmission. An effective primary barrier can prevent pathogens spreading. However, secondary barrier like personal hygiene and food hygiene must be sufficiently implemented to prevent spreading diseases. Before the pathogens gain access to the environment, there are many primary prevention facilities, which can effectively block their pathway.

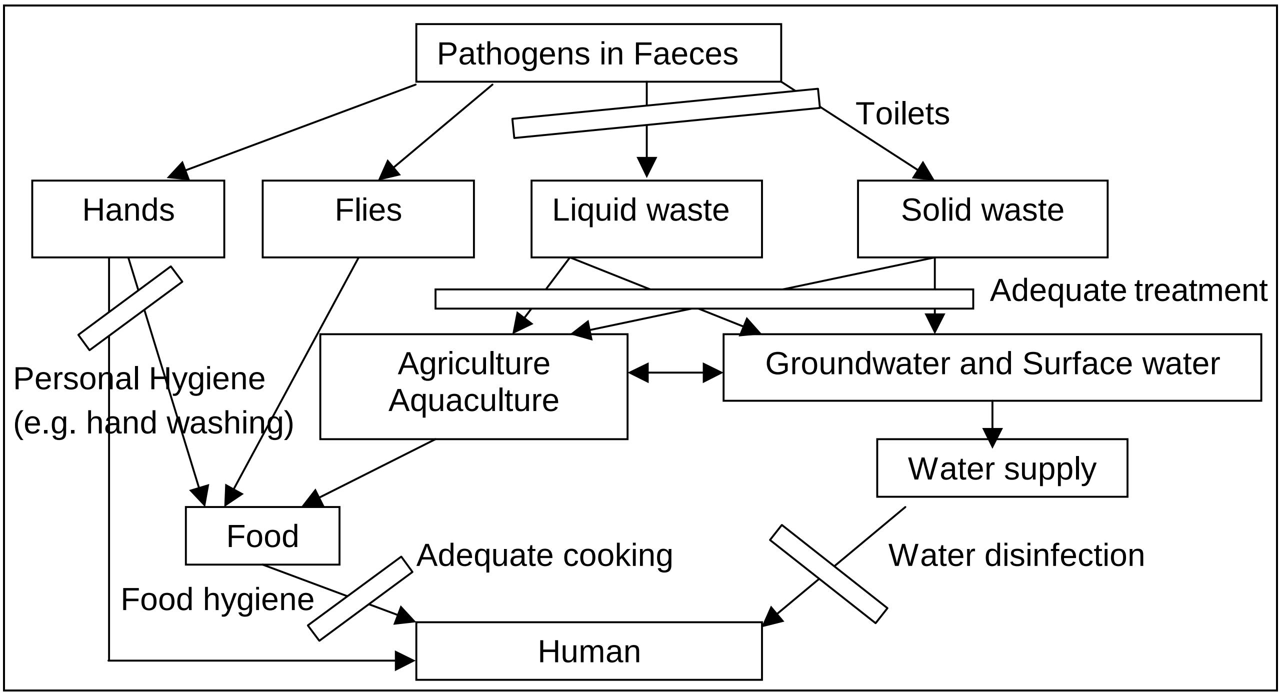

Figure 2: Routes of Pathogens transmission from faeces to human (Adopted from Franceys et al., 1992 and modified)

1.4.1.5 Survivability rate of pathogens in environment

Survival of the pathogens in the environment is of great concern in the management of faecal waste. Within the environment and treatment methods, they have varying survivability rate (see table 4). Survivability rate of pathogens is controlled by many factors such as:

- competition for food (limited food sources limit microbial numbers);
- predator-prey relationships (some organisms consume others as food sources);
- antagonism (some organisms produce toxic substances which inhibit other organisms);
- environmental conditions (Oxygen concentration, nutrient levels, temperature, moisture, pH).

In order to eliminate pathogens, faecal containing waste must be treated in a controlled environment, where the above mentioned factors act effectively. This can be done in many ways. However, low-tech and low-cost are the deciding factors.

Table 4: Survival time (d) of pathogens in day by different disposal/treatment conditions (adapted from Esrey et al., 1998)

Condition	Bacteria	Viruses	Protozoa*	Helminths**
Soil	400	175	10	many months
Crops	50	60	not known	not known
Night soil, faeces, sludge 20-30 ^{O}C	90	100	30	many months
Composting Anaerobic at ambient temperatures	60	60	30	many months
Thermophilic composting 50-60 ^{o}C maintained for several days	7	7	7	7
Waste stabilisation ponds Retention time > 20 days	20	20	20	20
* excluding Cryptosporidium parvum ** mainly Ascaris; other parasitic eggs tend to die quicker				

1.4.2 Non-infectious Diseases

The health problems related to environmental pollution are considered to be the result of contamination of water, food, and air with toxic chemicals. The resulting diseases are non-infectious. Some non-infectious illnesses associated with toxic chemical pollution have a relatively sudden and sever onset, and the acute or immediate health effects can be readily traced to a specific contaminant. Heavy metals are particularly notorious in this regards. Other non-infectious diseases may take years to develop and can involve chronic or long-lasting health problems. Generally, various synthetic organic substances cause this type of problem, even in extremely small concentrations. Some organics are considered to be carcinogenic, having the potential to cause cancer in humans.

2. Wastewater management and associated hygienic risk

2.1 Conventional sanitation

Due to disease risks caused by faecal wastewater, in large European cities sewers were constructed to drain the wastewater away from the people's surroundings to the nearby water courses, and ultimately into the sea. Later it was found that discharging raw wastewater had deteriorated aquatic environment of the receiving water body, and at the same time it caused diseases to the people, who received their drinking water from the same river downstream. Because of drinking water contamination, epidemics of cholera had periodically caused heavy losses of life in large European cities. The outbreak of cholera in 1892 for instance, took place all over in Hamburg, where drinking water supply was extracted from the river Elbe. To protect these rivers from the pollution as well as the public health from water borne diseases, the wastewater was since then treated at the end of the sewer before discharging it into the river. This tradition has been widely established as a standard way of managing wastewater world wide. However, most of the wastewater is discharged without any treatment mostly in developing countries.

Centralised wastewater management systems have been built and operated for more than hundred years. In the mean time, because of advanced technological development, the wastewater management has reached a high standard in many industrialised countries. However, in developing countries the present situation is still similar to that of the currently industrialised countries in the 19th century in many respects. About 95 % of wastewater in developing countries is still discharged without any treatment into the aquatic environment . This contributes largely about 1.2 billion people without access to clean drinking water. Almost 80 % of diseases throughout the world are water-related. Water-borne diseases account for more than 4 million infant and child deaths per year in developing countries.

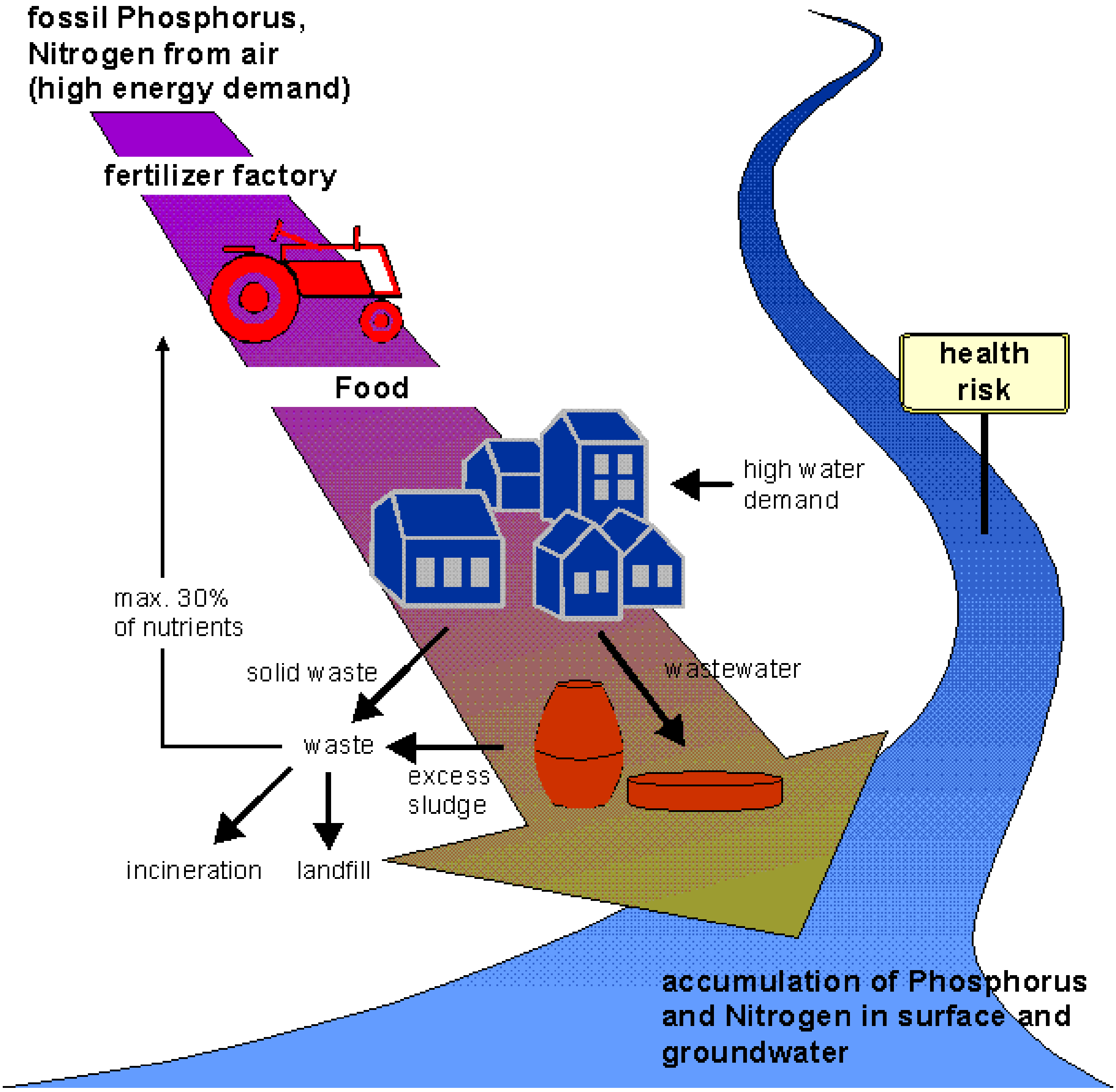

Figure 3: Conventional Sanitation System (source Otterwasser GmbH)

In conventional sanitation systems, a huge amount of fresh water is used as a transport medium and a sink to dispose of wastes (see figure 3). In this process a small amount of human faeces is diluted with a huge amount of water. Therefore, it is hardly possible to prevent contaminants from emitting into surface and ground water bodies. As a result a huge amount of fresh water is contaminated and deemed unfit for other purposes. Moreover, due to the pollution and hygienic problems in receiving waters, surface water can no longer be used as a source for drinking water supply. Huge investments have to be made to improve the surface water quality in order to use it as drinking water.

Conventional sanitation systems show clear deficiencies in recovery of nutrients and organic matter, which are valuable fertiliser and soil conditioner respectively. Even the best affordable treatment plants discharge those to the aquatic environment, where they are lost for ever and cause severe problems. Those nutrients, which are captured in sludge, are often contaminated with heavy metals such as Cadmium (Cd) and organic compounds such as PCB (polychlorinated Biphenyl), which pose potential toxic risks to plants, animals and humans. Therefore, large amounts of sewage sludge are disposed of in landfills or incinerated. Only a smaller part is applied to agricultural land.

Also decentralised sanitation systems, such as pit toilets, septic tanks, etc. cause pollution i.e. nutrients and pathogens seeping from these systems contaminate the groundwater and nearby surface water - they cannot destroy pathogens. Basically septic tanks are designed only to collect household wastewater, settle out the solids and anaerobically digest them to some extent, and then leach the effluent into the ground, not to destroy pathogens contained in wastewater. Therefore, septic tank systems can be highly pathogenic, allowing the transmission of disease causing bacteria, viruses, protozoa and intestinal parasites through the system. It is reported that there are 22 million septic system sites in the USA issuing contaminants such as bacteria, viruses, nitrate, phosphate, chloride, and organic compounds into the environment. Another problem is home chemicals with hazardous constituents, which are discharged to toilets and contribute to severe groundwater contamination in sanitation using septic tanks. According to the EPA, states of the USA reported septic tanks as a source of groundwater contamination more than any other source, with 46 states citing septic systems as sources of groundwater pollution (see figure 4), and nine of them to be the primary source of groundwater contamination in their state. It has to be noted that occasionally problems with broken septic tanks occur leading to infiltration of nearly untreated wastewater.

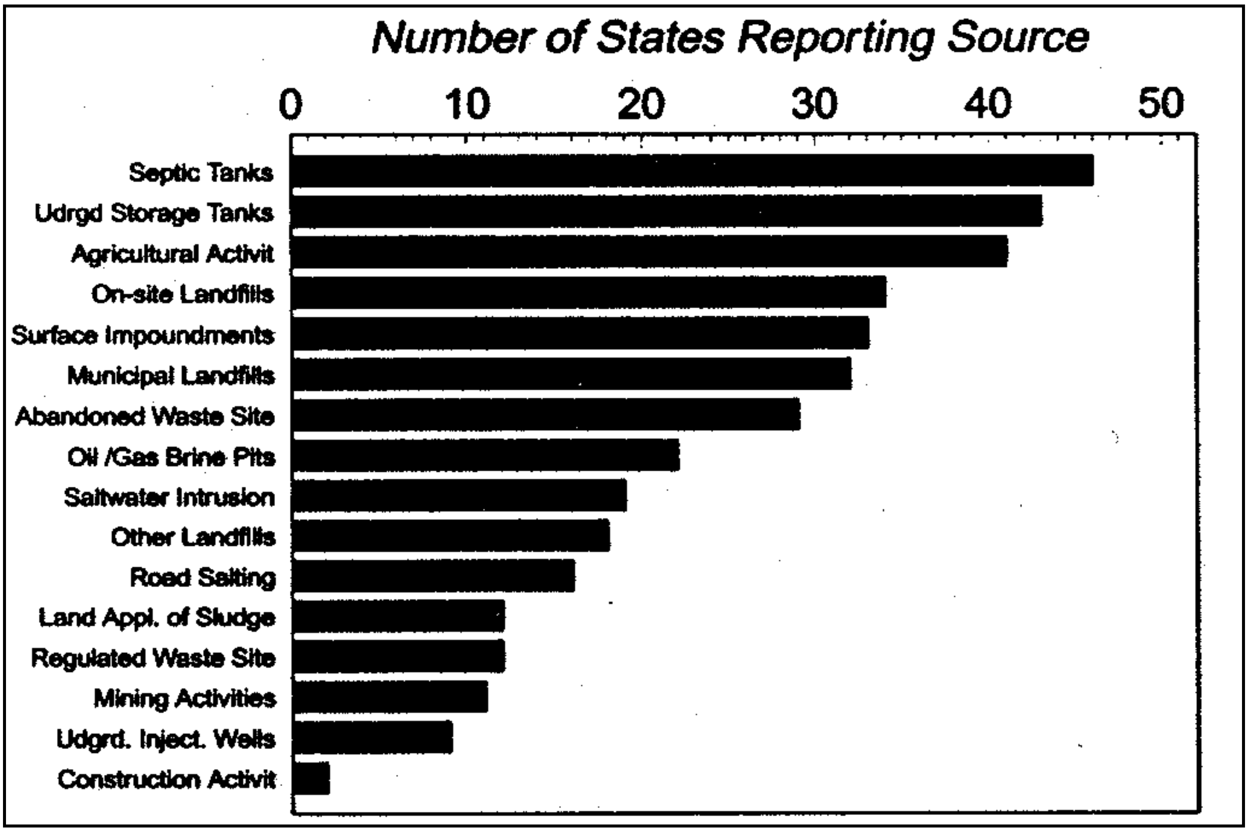

Figure 4: Reported sources of groundwater contamination in the United States (Jenkins, 1994)

2.2 Ecological sanitation

Human faeces contain most of the pathogens with a potential of causing diseases. Therefore, source control of faeces from household wastewater prevents these disease-causing pathogens gaining access to water bodies where they survive longer than on land and pose a long-term threat to human health. The most beneficial is when it is kept separated at source which avoids dilution of faeces. The separated solid fractions, which are easily biodegradable, can be treated biologically. When organic matter is decomposed oxidatively, heat is produced due to self heating capacity. This self produced heat will create self-hygienization of the matter.

The mostly applied methods for the sanitation of separated faecal waste are composting and dehydration. Treatment methods based on dehydration can reduce pathogens effectively, because there is a rapid pathogen destruction at moisture content below 25 %. Composting of a sufficient amount of fresh and easily degradable organic materials can produce heat, which raises the temperature of the materials. At the temperature of 60 °C and above, most of the pathogens are destroyed. Low temperature composting takes long time to kill the pathogens. The rate of reduction of pathogens is significantly dependant on time and temperature. The higher the temperature of the materials, the shorter the time for destroying the pathogens and vice versa. The factors such as a high pH, competition for food, antibiotic action and the toxic by-products of decomposing organism play a significant role in eliminating or reducing pathogen.

Feachem et al. (1983) stated that three months retention time will kill all of the pathogens in a low-temperature composting toilet except for worm eggs (Table 5).

Table 5: Pathogens survival by composting (Feachem et al., 1983)

Pathogens	**Composting Toilet (3 months retention time)**	**Thermophilic Composting**
Enteric Viruses	Probably eliminated	Killed rapidly at 60°C
Salmonellae	A few may survive	Killed in 20 hrs. at 60°C
Shigellae	Probably eliminated	Killed in 1 hr. at 55°C
E.coli	Probably eliminated	Killed rapidly above 60°C
Cholera vibrio	Probably eliminated	Killed rapidly above 55°C
Leptospires	Eliminated	Killed in 10 min. at 55°C
Estamoeba histolytica cysts	Eliminated	Killed in 5 min. at 50°C
Hoohworm eggs	May survive	Killed in 5 hrs. at 50°C
Roundworm(Ascaris)eggs	Survive well	Killed in 2 hrs. at 55°C
Schistosome eggs	Eliminated	Killed in 1 hr. at 50°C
Taenia eggs	May survive	Killed in 10 min. at 59°C

There is a synergistic correlation between time and temperature (see figure 5). The hatched areas refers to safety zone, where due to the combination of time and temperature all pathogens will be killed. Also the factors such as competition for food, predator-prey relationships and antagonism help to reduce or eliminate pathogens.

Desiccation by drying and adding high-alkaline additives is the best way to kill pathogens. Addition of ash helps in raising pH and decreasing moisture of faecal material. Both of them shorten the surviving time of pathogens. There are also other additives such as saw dusk, dry soil etc. Plant ash is the most effective additive to eliminate pathogens.

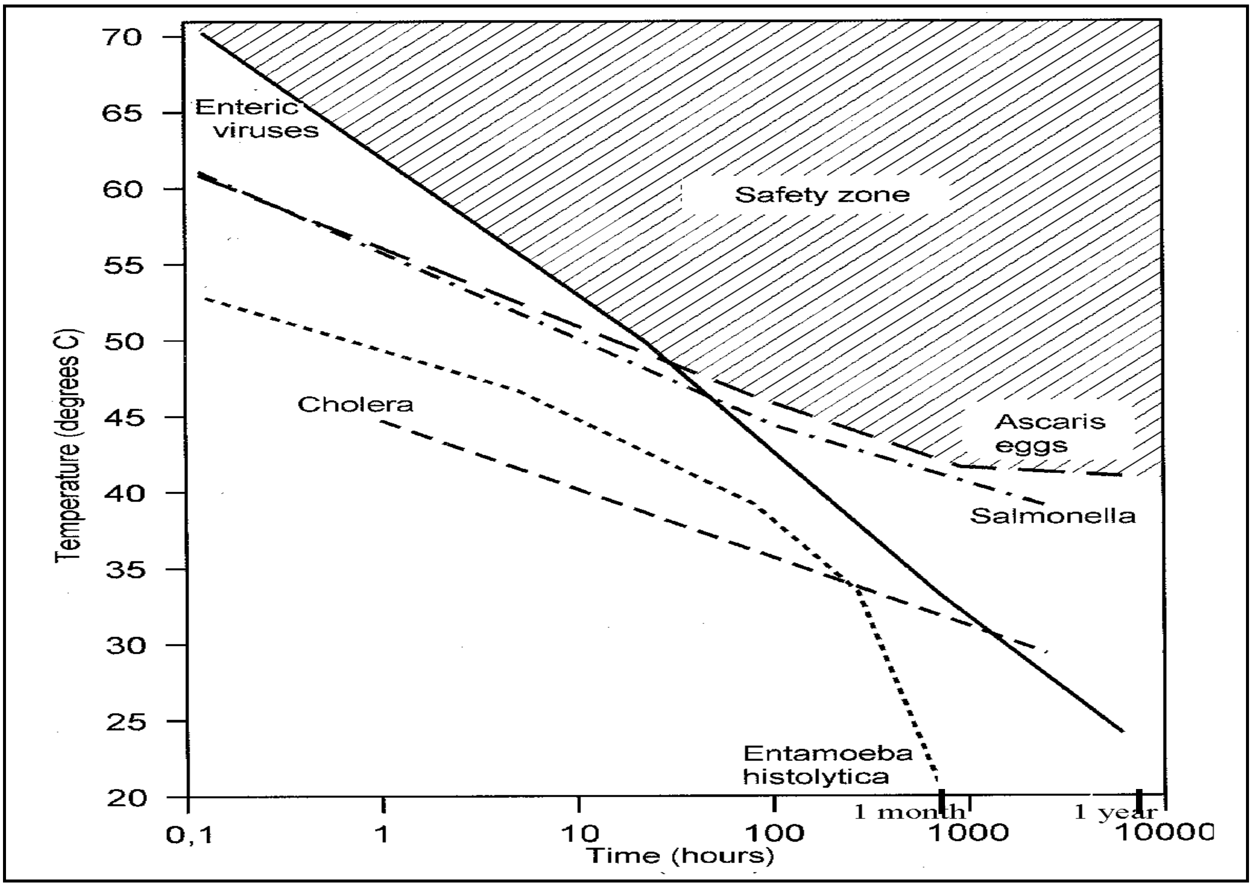

Figure 5: Combination of time and temperature of pathogens elimination. Hatch area represents complete pathogens elimination due to the combined effect of time and temperature (Feachem et al., 1983)

In summary, the die-off rate of the pathogens depends on the environmental condition of the place where they reside. The following factors are lethal to most of the pathogens:

- high pH (> 9)
- Low moisture contain (< 25%)
- High temperature (> 55 ^{O}C) over more than 10 hours
- Long retention time (> 6 months)
- Ammonia and high salt content
- Limited nutrients (competition for food)
- predator-prey relationships
- antagonism

High pH can be obtained by adding alkaline material such as ash or lime (but lime is not preferable) that reduces the moisture additionally. Moisture can be lowered by drying. Solar dryer can be used for this purposes, also high temperatures can be achieved at least part of the year in hot climate regions. High ammonia and salt can be obtained from urine. Long retention time, ammonia and high salt content, limited nutrients availability, predator-prey relationships and antagonism can be obtained in multi-chamber batch composting process.

The hygiene risk associated with urine is quite small compared to that with faeces. The fate of the pathogens entering into urine collection tank due to faecal contamination in urine diversion toilets is of vital importance for the hygiene risks related to the handling and reuse of the urine. For urine mainly temperature and the elevated pH (~9) in combination with ammonia has been concluded to affect the inactivation of micro-organisms. Bacteria like *Salmonella* (i.e. Gram-negative bacteria) were inactivated rapidly, whereas viruses were hardly reduced at all at low temperatures (4-5℃), (see table 6).

Table 6: Inactivation of microorganisms in urine, given as T90-values (time for 90% reduction) in days (Höglund,2001)

	Gram-negative Bacteria	Gram-positive Bacteria	*C.*parvum	Rhesus rotavirus	S.typhimurium phage 28B
4℃	1	30	29	172[a]	1 466[a]
20℃	1	5	5	35	71

a Survival experiments performed at 5℃.

In practice, complete elimination of pathogens may not be possible in any kind of sanitation. Therefore, secondary barrier such as personal, food and domestic hygiene must be included to destroy the pathogens completely. Therefore, hygiene awareness and proper education are the crucial points for on-site faecal waste management.

2.3 Sustainable Sanitation

If the above mentioned ecological sanitation can fulfil furthermore as well social en ecological m requirements it is called "sustainable sanitation". Such a sanitation is also form the hygienic point of view desirable, due to the fact, that it includes also other aspects, which save health in order to a risk management. Some further aspects of sustainable sanitation are (see also figure 6):

- Closing and separating the cycles of water and nutrients; avoidance of hygienic problems due to the separation of faeces from the water cycle
- Reclamation of nutrients (phosphorus and nitrogen) for agricultural use and hence saving of resources and energy (for the production of artificial fertilizer)

- Considerable savings of freshwater through the use of water saving toilet systems (vacuum, separating or dry toilets)
- Energy production (biogas) instead of energy consumption (for carbon degradation in sewage plants)
- Savings of construction, operation and maintenance costs compared to the conventional central sewerage systems
- Sophisticated modular system, which can be adapted perfectly to local social, economical and environmental conditions
- Easier operation and maintenance compared to centralized technology; local job creation

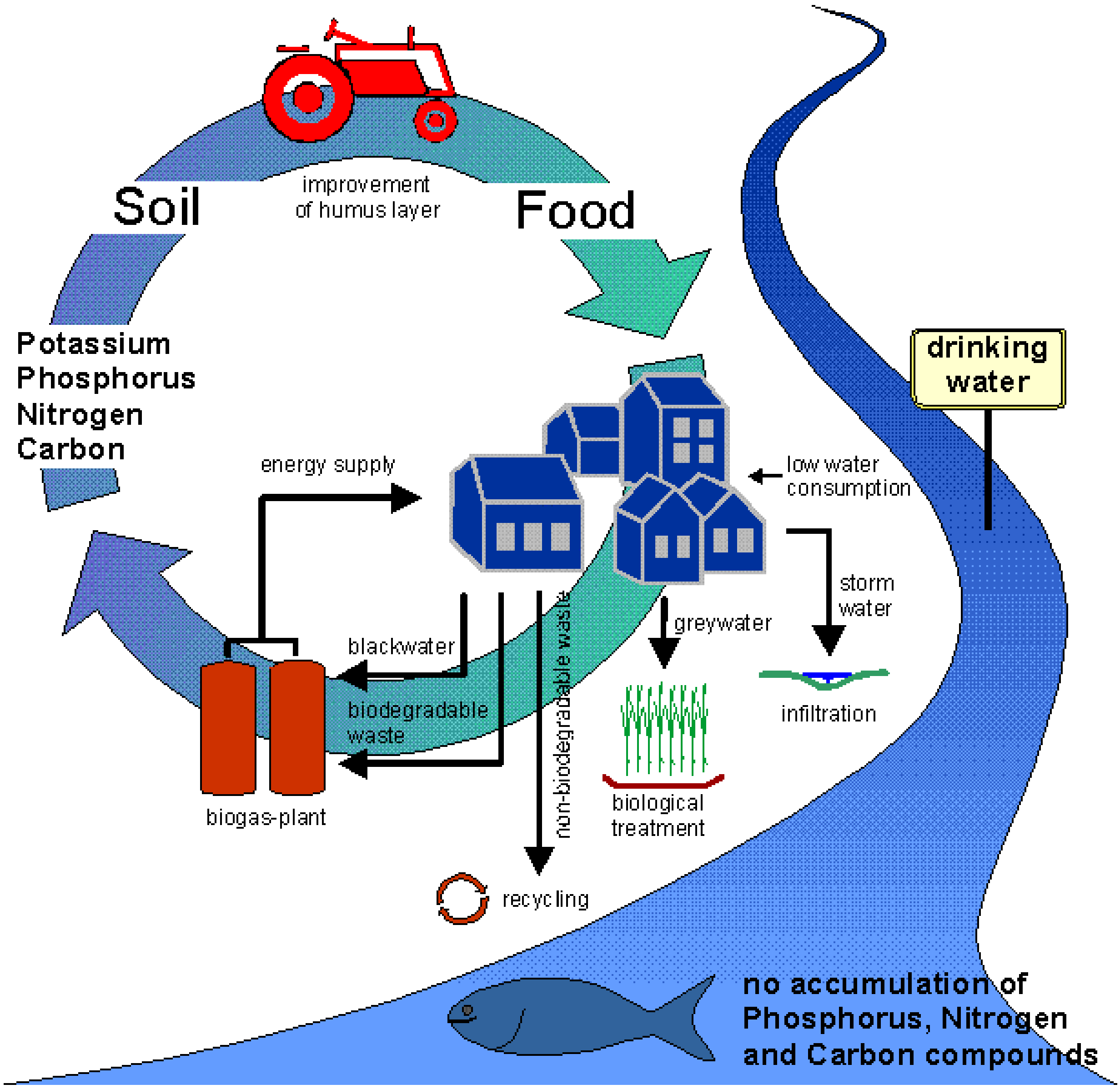

Figure 6: Sustainable Sanitation System (source Otterwasser GmbH)

3 Risk management through guidelines

Guidelines and recommendations for the handling and reuse of wastewater can work as a tool to minimise risks. Currently, it is recommended that the sanitised faecal matter is covered after application and not used as fertiliser to vegetables, fruits or root crops that are consumed raw, excluding fruit trees. At household level, urine can be used directly, but in a large-scale system it should be stored for a month at 20℃ prior to apply in agriculture. For vegetables, fruits or root crops that are consumed raw, a withholding period of one moth should be additionally applied i.e. one month should pass between fertilisation and harvest (see for details in Schönning and Stenström, 2004). Definite guidelines in ecological sanitation for safe handling and reuse of urine and faeces are required to minimise health risk. There are already existing guidelines for reuse of wastewater and faecal sludge in agriculture. The World Health Organisation (WHO) has developed guidelines for wastewater reuse in agriculture. Faecal coliforms and intestinal nematode eggs are used as pathogen indicators. For restricted irrigation, WHO recommends the treated wastewater should contain no more than one human intestinal nematode egg per litre. For unrestricted irrigation, WHO recommends the same helminth egg value, and additionally no more than 1000 faecal coliform bacteria per 100 ml of treated wastewater. Similar principles were applied to the derivation of guidelines for the use of excreta in agriculture. It is essential that the treated sludge contains no more than one helminth egg per kilogram and no more than 1000 faecal coliforms per 100 g. In USA, EPA guidelines for bio-solids are classified as class “A” (pathogens below detectable level) or class “B” (pathogens detectable, but do not pose a threat to public health). In Germany bio-waste Ordinance (Ordinance on the Utilisation of Bio-wastes on Land used for Agricultural, Silvicultural and Horticultural Purposes) requires that endproduct must be free of Salmonellae. Council of the European Communities Directive No. 86/278/EEC has not included guidelines for microbial hygienic risk for reuse of sludge, but only for heavy metals concentrations in soil, in sludge and maximum annual quantities of heavy metals that can be introduced into the soil. However, in ecological sanitation heavy metals are not a big concern, since human excreta contain approximately the same amount of heavy metals as food. Therefore, there is no risk of heavy metal accumulation in soil due to these fertilisers. The issue of pharmaceutical residue in excreta has to be addressed here, indeed.

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