Wat. Sci. Tech. Vol. 22, No. 3/4, pp. 283–290, 1990.
Printed in Great Britain.

0273-1223/90 $0·00 + ·50

URBAN DRAINAGE STRATEGIES FOR SMALL COMMUNITIES IN DEVELOPING COUNTRIES

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ABSTRACT

In this paper, the interactions of small waste water treatment plants within an urban drainage system are pointed out. Especially in developing countries, the characteristics of catchment areas differ very much from the ones in industrialized countries. Consequently, the plants have to be adapted to the local conditions of drainage, climate and location. Finally, an urban drainage strategy will give an idea how to sanitize drainage systems.

KEYWORDS

Urban drainage strategies; small communities; developing countries; catchment characteristics; drainage standard; sanitation;

INTRODUCTION

Urban drainage systems have to fulfil both the safe removal of storm water and waste water. Most of the drainage and treatment techniques have been developed in highly industrialized countries. Unfortunately, in small communities in developing countries, only a few of these techniques are applicable. Since the majority of the people in the world are living in small communities, these few techniques are no longer only of regional or national but of worldwide interest. In this paper, the following topics are discussed:

* Tasks of urban drainage systems
* Drainage systems for small communities
* Small waste water treatment plants
* Urban drainage strategy

TASKS OF URBAN DRAINAGE SYSTEMS

The standard of the urban drainage system is a main factor of the living standard. An insufficient drainage standard directly influences basic needs of the human being:

* Plenty of clean drinking water
* Plenty of unpolluted food
* Health and hygiene
* Housing

In case of uncontrolled drainage of storm water and sewerage, the public health will be endangered by polluted drinking water and food. Further, the housing might be damaged by floodings or landslides.

Specifications of the tasks to be performed by the urban drainage system:

1. The drainage system has to prevent the spreading of potential infectious diseases.
   Infections may be transmitted by direct contact or contact through animals (insects, rats etc.) or by polluted drinking water or food. As a protection people used to treat their drinking water and food by simple filtering or washing.
   Since the population density is growing more and more, the risk of uncontrolled discharge of sewage has become acute. Moreover, the kind of pollution of the sewage has changed rapidly during the last twenty years. As the industrialization is progressing, the sewage is more and more polluted by synthetic (chemical) material, even in the countryside. This means that nowadays beside the hygienic and biological pollution chemical pollution also endangers the people. This danger is comparatively high, because the people are not used to take care of it. Further, there doesn't always exist a protection from these chemicals.

2. The prevention of flooding in the urban areas.
   A low hydraulic capacity of the drainage system causes flooding. During flooding faeces might flush, the traffic might be obstructed and the risk of landslides increases in steep catchment areas.
   Paving the surface without improving the drainage system decreases the hydraulic capacity. Whenever the housing or traffic density increases - which happens very often in developing countries - the paved surface grows and the drainage system has to be adapted to the new conditions.

3. The drainage and treatment system should protect the receiving waters, soil and groundwater from the pollution caused by the sewerage.
   Increasing population density and industrialization cause an increasing environmental pollution. This means the drinking water and food will be polluted, step by step, and this (mainly chemical) pollution will cause a lot of diseases among the people.

To fulfil these tasks in small communities in developing countries a lot of work should be done in the near future. Otherwise, the low living standard will deteriorate. This may become a real political problem worldwide.

Beside these tasks, there are some special requirements on the urban drainage systems in the small communities.

* The costs and energy consumption, during the installation and operation, have to be very low.
* The used techniques have to be simple in construction, handling and control and furthermore easy in maintenance.
* The construction materials should be available in nearby markets and also the construction work should mainly be supported by the community itself.

DRAINAGE SYSTEMS

Three different drainage systems can be built in small communities in developing countries.
To distinguish them, the sewage has to be specified as follows:

* Storm water (SW) - The rain water minus surface losses.
* Faeces (F) - The faeces itself including all the pertaining sewage.
* Grey water (GW) - All the other sewage, for example washing water etc.

The different drainage system types are:

• Combined sewerage system (CSS).
Storm water (SW), faeces (F) and grey water (GW) are discharged into the combined sewer. During the dry weather periods, the whole sewage is treated in a small treatment plant. During the rainfall periods, the storm water is partly separated by overflows to the receiving waters, while a limited runoff of the combined sewage is treated (Fig. 1).
Pro - partly treating of the storm water; only one pipe; no wrong connections.
Contra - sludge deposits and smell emissions during dry periods; big diameter of sewer pipe; no easy planning and installing of well working overflows.

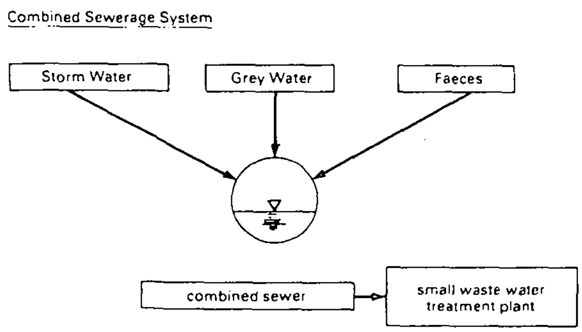

Fig. 1. Combined sewerage system

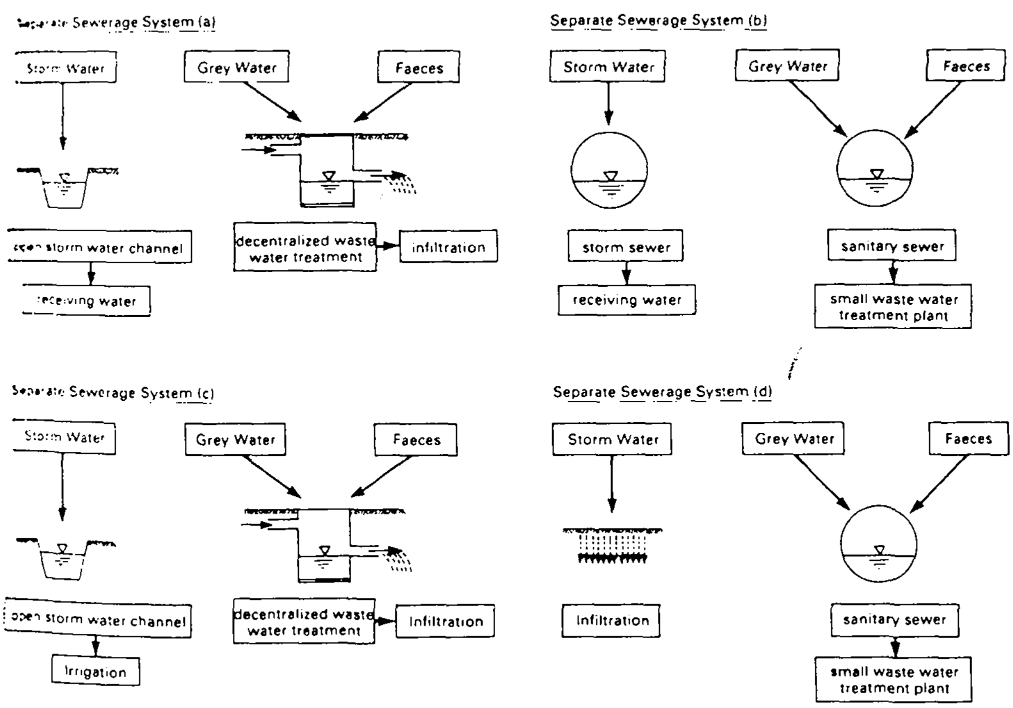

Fig. 2 a-d. Separate sewerage systems

• Separate sewerage system (SSS/a-d).
The storm water (SW) is discharged into the storm sewer and further either into the receiving waters or used for infiltration or irrigation. The faeces (F) and grey water (GW) are discharged into the sanitary sewer

and treated within a small treatment plant. The treatment can be performed centralized or decentralized (Fig. 2 a-d).
Pro - no flushed faeces; simple and cheap construction of the storm sewers.
Contra - two drainage pipes; wrong connections possible.

* Qualified separate sewerage system (QSSS/a,b).
  The faeces (F) are collected separately,whereas storm water (SW) and grey water (GW) are discharged into the storm sewer and may be treated in special ponds (Fig. 3 a,b).
  Pro - as SSS and: recycle of the organic matters → energy production and hygienic dunging.
  Contra - no chemical and no industry allowed.

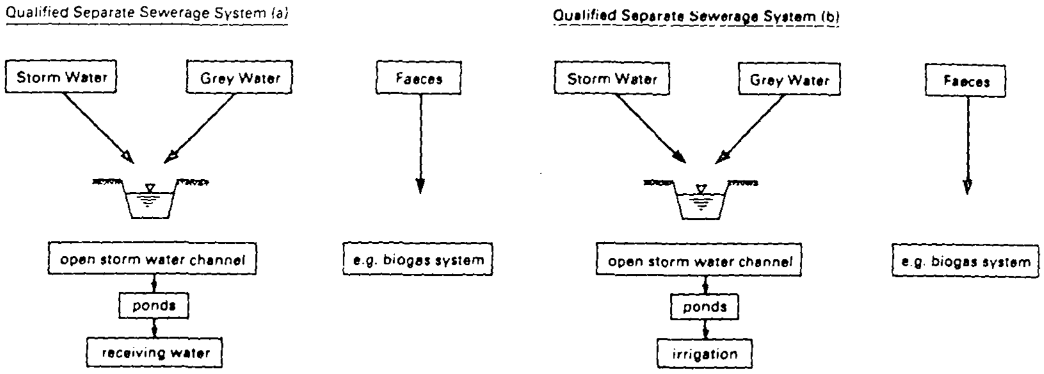

Fig. 3 a,b. Qualified separate sewerage systems

Each of these drainage systems has pros and cons which depend on the characteristics of the catchment area and the location (climate conditions, geographical situation etc.) of the urban drainage system.
One of the main characteristics is the precipitation, since the dimension of a sewer pipe is mainly influenced by the rainfall characteristics. The locations shall be distinguished through the number of independent storm events and the rainfall intensity:

* great number of independent storm events ($n \geq 200/a$)
* medium number of independent storm events ($20/a \leq n \leq 200/a$)
* small number of independent storm events ($n \leq 20/a$)

* high rainfall intensities: $r \geq 150$ l/s·ha.
* low rainfall intensities: $r \leq 150$ l/s·ha.
  with a frequency of $f = 1/a$ and within a duration of $T = 15$ min.

Another characteristic is the degree of urbanization. Three cases shall be distinguished:

* village
* decentralized community within a small town with rural structures
* small community at the outskirts of a city.

These three different kinds of catchment areas are mainly characterized through the population density, farming density, drinking water consumption, energy consumption, road conditions, number of technicians or engineers who are looking after the urban drainage and the density of local industry. A coarse quantification of these characteristics is shown in Table 1.

Further, the use of the receiving waters, soil and ground water, the slope and the need of irrigation water are characteristics to decide about the optimal drainage system of a catchment area.

TABLE 1 Characteristics of Different Catchment Areas

location	popul. density	farming density	d.water consum.	energy consum.	road cond.	technician /engineer	local ind.
village	low	high	decentral	bad, decentral	unpaved	max. 1 techn.	no
small town	medium	medium	partly central	bad, decentral	partly paved	few techn. max 1 eng.	low density
outskirts of a city	high	low	central	good, central	paved	few techn. few eng.	high density

In Table 2, the optimal drainage system of 15 catchment areas with different locations or characteristics are pointed out. The pros and cons of the drainage systems are:

Combined sewerage system (CSS).
The CSS can only be used in locations without any significant dry season. Otherwise, a lot of problems with sludge deposits and smell emissions will occur. During heavy storm events ($r \geq 150$ l/s·ha) a comparatively high pollution load will overflow at the overflows to the receiving waters. Consequently, CSSs should be used in locations with low rainfall intensities ($r \leq 150$ l/s·ha) and many storm events ($n \geq 200/a$). In this case, compared with the SSS a high ratio of storm water will be treated.
Since CSSs need more difficult planning and dimensioning work, only in small towns or outskirts of cities should these systems be installed.

Separate Sewerage System (SSS a-d).
In many villages or small towns in developing countries, there is a chronic lack of money for any installation within the drainage system. Open storm water channels are cheap and easy in construction (SSS a+c). Furthermore , in rural areas with a significant dry season, the storm water can be stored and used for irrigation (SSS c). The treatment of grey water and faeces can be done decentralized (SSS a+c). This treatment is cheap but its efficiency is low. The mechanically treated water is infiltrated to the ground water and may pollute it.

TABLE 2 Optimal Drainage System of 15 Catchment Areas

		village	small town	outskirts of a city
$n \geq 200$	$r \geq 150$ l/s·ha	QSSS a	SSS a	SSS b
	$r \leq 150$ l/s·ha	QSSS a	CSS	CSS
$20 < n < 200$	$r \geq 150$ l/s·ha	QSSS b	SSS c	SSS b
	$r \leq 150$ l/s·ha	QSSS b	SSS c	SSS b/d
$n < 20$, $r \geq 150$ l/s·ha		SSS a	SSS a	SSS b

In cities (high ratio of imperviousness), pipes should be preferred to transport the sewage (SSS b+d). Since these communities are comparatively big (more than 500 inhabitants) and the ratio of industrial waste water is high, a centralized waste water treatment is an efficient way to treat the sewage.

Qualified Separate Sewerage System (QSSS a,b).
In villages, the most appropriate drainage system is the QSSS. The faeces and other organic matters are collected separately - for instance into a biogas system - and used for dunging the fields and sometimes for energy production. These decentralized drainage systems fit to the often decentralized structure of a village.
The storm and grey waters are discharged into open storm water channels to ponds which can be used for fish-hatching and further to the receiving waters.

SMALL WASTE WATER TREATMENT PLANTS

The optimal technique of waste water treatment depends on the inflow rate and pollution concentration of the sewerage. Consequently, for each drainage system, there exists one or more suitable treatment plants. In Table 3, for the above-mentioned drainage systems these treatment plants are pointed out.

TABLE 3 Drainage Systems and Treatment Plant

Drainage system		Treatment plant
CSS		System of lagoons, sewerage treatment by vegetation
SSS	a,c	Septic tank, multicompartment septic tank
	b,d	Trickling filter, contact aerator, activated sludge tank
QSSS	a,b	Faeces: biogas system, latrine/septic tank, multicompartment septic tank Storm and grey water: fish-ponds

CSS - In CSSs a part of the storm water must be treated in the treatment plant. This causes a high variation in the quantity and quality of the treatment plant inflow. Consequently, the buffering capacity of the treatment plant has to be very high. Lagoons with or without special vegetation (like reeds) are suitable to treat variable inflows. A system of lagoons (e.g. 1 sedimentation, 3 degradation and 1 clarification lagoon) provides an efficient treatment. Depending on the pollution load, temperature, and depth of the lagoons, aeration may be necessary. Especially in warm countries, fish-hatching in the clarification lagoon is possible throughout the year. This may constitute a source of food in poor communities. Moreover, the fish density is a good indicator of the water quality.
In case of high chemical pollution, the lagoons are not very efficient. A decentralized special treatment of the industrial waste water should be installed.

SSS a,c - In villages and small towns, mainly in dry regions a decentralized waste water treatment is common and suitable. In these communities, a sanitary sewer would be very expensive because the population density is low or medium. A septic tank or a multicompartment septic tank provides a decentralized waste water treatment. The main

advantages of this system are:
- the inhabitants are responsible for the system; this favours safe operating.
- in case of an accident (toxic pollution) only a small area will be polluted.
- the collected sludge can be used for dunging on their own fields.

The main disadvantages are the low treatment efficiency and the possible pollution of the ground water. To reduce the risk of pollution, one should install a multicompartment septic tank with a connection to the storm sewer via a filtration ditch.

SSS b,d - In the outskirts of cities, the population density and drinking water consumption is high. This causes a relatively continuous treatment plant inflow with small daily and weekly variations. A trickling filter, contact aerator or activated sludge tank should be built, depending on the inflow amount and pollution concentration. A qualified operating staff for these more technical systems is necessary. The efficiency of the central treatment is comparatively high.
In any case a special treatment of industrial waste water within the catchment area is necessary, because the dilution capacity within the sewer system is still very low.

QSSS a,b - The faeces can be collected within a latrine/septic tank or a multicompartment septic tank and reused for dunging. Another solution is the biogas system, in which the faeces and other organic matter (from farming activities) are degraded within the anaerobic zone into biogas. For biogas systems in villages there are significant advantages compared to the SSS a,c:
* hygienic dunging (no proliferation of infectious germs)
* independent and source of energy in a sufficient quantity.

URBAN DRAINAGE STRATEGY

An urban drainage strategy should be worked out to improve the drainage system of a small community in a developing country. The strategy can be subdivided into four steps.

1. Investigations about the drainage and treatment standard in the catchment area by using the available data if possible.

   * The surface drainage can be evaluated by

     Removal of faeces:
     a - 1 toilet per 10 and more homes
     b - 1 toilet per 2 - 10 homes
     c - 1 toilet per home

     Surface pollution:
     a - no waste disposal, many animals on the streets
     b - controlled waste disposal, many animals on the streets
     c - controlled waste disposal, no animals on the streets

     Drainage condition:
     a - uncontrolled drainage
     b - partly controlled drainage (main roads)
     c - controlled drainage
   * The drainage system can be evaluated by its hydraulic capacity in Table 4.
   * The treatment system can be evaluated by the ratio of waste water treatment in Table 5.

2. Forecast about the change of the following catchment characteristics for the next 10-20 years.
   * population density
   * density of local industry
   * density of traffic etc.

TABLE 4 Hydraulic Capacity

Ratio of flooding % of subcatchments	1	2 - 5	5 - 10	≥ 10
	times per year			
≤ 5	A	A	B	B
5 - 20	A	B	C	C
20 - 50	B	C	D	D
≥ 50	B	C	D	D

A ≙ very good hydraulic capacity
B ≙ good hydraulic capacity
C ≙ medium hydraulic capacity
D ≙ bad hydraulic capacity
E ≙ very bad hydraulic capacity (no drainage system)

TABLE 5 Ratio of Waste Water Treatment

$\mu = \frac{ALW}{Q_S}$	no	mechanical	mechanical/ biological
	waste water treatment		
≤ 10	E	D	C
10 - 50	E	C	B
50 - 100	D	C	B
≥ 100	D	C	A

μ ≙ quotient of average low water in the river (ALW) to dry weather flow (Q_S)

A ≙ very good waste water treatment
B ≙ good waste water treatment
C ≙ medium waste water treatment
D ≙ bad waste water treatment
E ≙ very bad waste water treatment

3. Improvement of the existing drainage and treatment standard.
   Following aspects have to be accounted for
   * The sanitation concepts should be elaborated in cooperation with the inhabitants, who know better about the present state of the drainage system and its weak points. At the same time an education campaign about pollution recycling and toxicity of the different kinds of pollution (hygienic, biological, chemical) is necessary.
   * Don't build a complete new system.
   * Prevent recycling of pollution
   * Order of the sanitation priorities:
     Surface drainage » hydraulic capacity » waste water treatment
   * Sanitation objectives in details:
     Removal of faeces: 1 toilet per 2 - 10 homes or 1 toilet per home
     Surface pollution: controlled waste disposal
     Surface drainage condition: controlled drainage
     Hydraulic capacity : A or B
     Waste water treatmment: A, B or C