Urban stormwater management in developing countries

La gestion des eaux pluviales urbaines dans les pays en développement

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RÉSUMÉ

La question des eaux pluviales est une problématique pointée de manière récurrente par les décideurs locaux des pays en développement. Cet enjeu se manifeste de manière très concrète à travers les épisodes pluvieux qui inondent les quartiers situés dans les points bas des villes. Les impacts de tels épisodes pluvieux sont nombreux : sanitaires, matériels, économiques et environnementaux, etc.

La gestion des eaux pluviale (GEP) est un système fort complexe, qui va être soumis à de nombreux facteurs conditionnant son efficacité que l'on peut regrouper en 4 groupes : facteurs naturels, facteurs liés aux activités humaines, facteurs liés aux modalités de gestion de l'espace urbain et facteurs liés à l'insuffisance ou aux lacunes des capacités de gestion des eaux pluviales.

Des approches innovantes ont été mises en œuvre, pour agir sur ces facteurs. Elles restent cependant insuffisamment connues et diffusées. Les principes clés que l'on peut retenir sont de bien distinguer l'échelle géographique de la problématique GEP de l'échelle d'intervention, d'envisager la GEP avec toutes les interactions liées aux autres services urbains, et enfin de programmer le secteur selon un gradient d'évolutivité et de complémentarité des approche classiques et des approches s'appuyant sur les techniques alternatives ou compensatoires.

ABSTRACT

The issue of stormwater is one frequently raised by local decision-makers in developing countries. This issue becomes particularly problematic when there is heavy rainfall that floods the settlements situated in the lowest parts of towns. The effects of such rainfall are manifold: sanitation, material, economic and environmental impacts, etc.

Stormwater management is a highly complex system that will be exposed to a number of factors, each affecting its effectiveness. These factors fall into 4 groups: natural factors, human activity related factors, factors related to the management of urban space and factors associated with insufficient or lack of stormwater management capacities.

Several innovative approaches have been implemented to address these factors. However, these are not yet sufficiently well-known or disseminated. The key principles to be borne in mind include: clearly distinguishing between the geographic scale of the stormwater management issue and the scale of intervention; taking all interactions with other urban services into account in stormwater management planning; and, lastly, organising the sector using an upgradeable and complementary approach to utilising both traditional solutions and those that draw on alternative or compensatory techniques.

KEYWORDS

Challenges, Developing countries, Impacts, Urbanisation, Urban stormwater management

1 INTRODUCTION

This document contains an analysis of issues, existing practices and areas for research related to **urban stormwater management in developing countries**. As frequently highlighted by their elected officials, this is a topic that is becoming increasingly important for towns in developing countries. Whilst the extent of the issue becomes particularly apparent when there is heavy rainfall that floods the settlements situated in the lowest parts of towns, it at the same time encompasses a large number of urban development issues.

The present document is based on both a synthesis of a literature analysis and interviews with subject matter experts. This work was monitored by a scientific committee of experts in development and urban issues.

DEFINITION

Urban stormwater management, as understood in this document, refers to all the measures undertaken to improve the way in which the flow and volumes of water generated by rainfall and surface runoff in urban areas are controlled and managed.

2 STORMWATER MANAGEMENT IN DEVELOPED COUNTRIES

A quick review of stormwater practices in developed countries provides a context in which to discuss stormwater management in developed countries.

2.1 Step one: channel and store for evacuation or flow management

In the middle of the 19th century, when the first urban sewer systems were being constructed, stormwater was essentially seen as a nuisance to be evacuated from the city as quickly as possible. The hygienist movement thus put sanitation equipment in place with a view to ensuring **public health**.

In the middle of the 20th century, as a result of urban growth coupled with developments in agricultural practices, the perception of urban stormwater changed and instead began to be seen as a threat liable to cause flash flooding. Technicians therefore developed a **hydraulic approach** that involved optimising the use of evacuation systems and further equipping these with large retention ponds to control peak discharge.

2.2 Step two: treat the discharge and regulate flow

During the 1980s, driven by growing environmental concerns, focus turned to the pollutants contained not only in runoff but also in combined sewer overflows. In addition, it was becoming increasingly clear that traditional sewer systems were often no longer able to regulate all the stormwater. New, so-called alternative or compensatory techniques were thus introduced to supplement the hydraulic approach with a **regulatory and environmental approach.**

2.3 Step three: reuse the stormwater

At the end of the 20th century, work undertaken to optimise these techniques, coupled with fears over the impact of climate change on the future availability of water resources, soon led to further expansion of this environmental approach; first, through urban planning to **reintegrate stormwater into urban water cycles**; then by recognising urban stormwater as a **resource**, as is increasingly the case today.

3 ISSUES DRIVING STORMWATER MANAGEMENT IN DEVELOPING COUNTRIES?

The increasing urbanisation of the world's population is constantly creating new challenges for stormwater management. Although rain is vital for both human beings and their environment (to replenish rivers, water points and groundwater, grow vegetation, etc.), rainfall events generate flows and volumes of water that can be difficult to control and that accumulate in the lowest parts of towns, flooding residential areas and creating pools of stagnant water.

The impacts of such rainfall can be broken down into four types: sanitation, material, economic and environmental.

3.1 Safeguarding public health

Flooding and the pools of stagnant water created by heavy rainfall events pose major public health risks for the population: epidemics caused by stagnant and contaminated drinking water (bacteria, parasites), injury and death (drowning), discomfort (mud).

3.1.1 Stormwater-related diseases

Diseases are transmitted through:

- direct contact with the water used for drinking, cooking, cleaning and personal hygiene which has been contaminated by parasites (flooding can disperse the ascaris, trichuris trichiura, hookworm eggs and facilitate their development) and chemical or organic pollutants;
- vectors of disease, such as mosquitoes (yellow fever, dengue fever, filariasis, malaria), rats (transmit leptospirosis through their urine) and snails (schistosomiasis) that thrive in these conditions.

3.1.2 Accidents and injury

Heavy rainfall events can lead to numerous accidents and injuries, caused by people being swept away by the current, landslides and subsidence and by traffic accidents.

3.2 Protecting the land and urban infrastructure

Flash flooding and the stagnant water that can follow periods of heavy rainfall cause considerable deterioration and even the destruction of urban areas. In this context, the main stormwater management issues are as follows:

- Maintaining the stability of developed and developable land to minimise the risk of landslides caused by a combination of **erosion** and flooding.
- Preventing the **degradation** or **destruction** of housing, public buildings and equipment and those providing basic services (water supply, sanitation, energy, etc.) and roads (to enable the mobility of people and goods).

3.3 Safeguarding economic development

Public commercial facilities (markets, bus stations, etc.) and private industrial, economic and commercial equipment, as well as the roads and tracks that enable the movement of people and goods, all support the economic activity of urban centres. By protecting these different types of infrastructure, stormwater management aims to safeguard economic development.

3.4 Protecting the environment

Stormwater collects pollutants (as it comes into contact with wastewater and solid waste and flows down roads) and is most often discharged into the environment without treatment, contaminating the waterways.

4 FACTORS INFLUENCING STORMWATER MANAGEMENT IN DEVELOPING COUNTRIES?

In developing countries, urban stormwater management is generally inadequate or non-existent.

Where they exist, stormwater collection systems serve only the most central or wealthiest areas. Due to a chronic lack of care and maintenance, they are in extremely poor condition. In outlying neighbourhoods, water runs along natural ravines, but these are not able to evacuate all surface runoff during heavy rain. This water collects pollutants (wastewater, trash, sediment) and constitutes a significant public health, economic and environmental risk.

Stormwater management is a highly complex process, the effectiveness of which is influenced by a number of different factors. The principal factors are listed below.

4.1 'Natural' factors

4.1.1 Rainfall patterns (frequency and intensity of rainfall)

In countries in the Sahel, tropical or equatorial zones, precipitation is 3 to 4 times more intense than rainfall in temperate areas, thus rendering urban stormwater evacuation all the more difficult and costly. Enormous drainage systems are required (sometimes twice as large as those in countries with a temperate climate) and these can reduce the effectiveness of storage or alternative infiltration solutions, which have more limited capacities.

4.1.2 Characteristics of the catchment area

Prior to developing any form of response to stormwater issues, it is vital that a study is carried out to identify the exact characteristics of the catchment or mini-catchment area (relief, size, land use plan, etc.).

4.1.3 Soil type

The type of soil will directly affect the infiltration capacity. Lateritic soils, in particular, are highly impermeable.

4.1.4 Presence of a watercourse

Water level fluctuations in watercourses have a direct impact on the flood risk.

4.1.5 Climate change[1]

Specialists estimate that the current climate change process will lead to an increase in extreme weather events, such as drought or severe storms, in certain zones: the increased intensity of rainfall in these areas will therefore increase the flood risk.

4.2 Human activity-related factors

4.2.1 Extension and densification of urban areas

Although, overall, urban growth rates have fallen over the last 20 years, in most developing countries they remain very high, both in capital and secondary cities. Thus, the urban landscape is constantly expanding and becoming denser, extending into areas with no stormwater drainage system and leaving the authorities struggling to cope.

4.2.2 Impermeability

Increasing urbanisation (housing developments, road construction, etc.) leads to increased soil sealing; thus, water is no longer absorbed by the soil but runs off along the surface, increasing the quantities of water to be treated and preventing groundwater recharge. It is estimated that a city with relatively low housing density is able to absorb up to 35% of its surface runoff, whereas a city with high housing density can absorb only 10%.

4.2.3 Degradation of plant cover

The degradation of plant cover both upstream of and within cities increases the surface runoff within

[1] Likely caused by human activities, this factor could also be included in 4.2

the entire urban catchment. Within the city itself, during heavy rains, this degradation of plant cover increases both the speed and volume of runoff in urban areas, causing **soil erosion**, **landslides** and **mudslides**, as well as **clogging the networks** with solid particles (sediment, urban waste, etc.).

***Brazzaville (Congo), erosion with disastrous effects**.*
Due to their sandy and easily eroded banks, the Urban Development Plan of 1980 forbids any building on the hills overlooking the north-west of Brazzaville. However, subsequent land pressure led to this constraint being partially lifted. This prompted work on numerous uncontrolled activities, notably the careless clearing of sloped areas and earthworks, leading to often catastrophic erosion during the rainy season. As a result of this erosion, huge ravines appear, engulfing tens and hundreds of houses and cutting off access roads. This erosion also produces thousands of tons of sandy sediment, which is deposited in the central reaches of the collectors where the gradient is lower, filling sections of the road crossings; this leaves roads underwater whenever there is heavy rain and causes insufferable flooding for residents. This phenomenon is further compounded by the lack of any collection and storage system for solid waste, which is systematically dumped into the beds of waterways and, carried by floodwater, accumulates causing obstructions. In addition to obstructing the flow of water, this waste spreads pollution so also poses a risk to public health.

Source: Etude du Schéma Directeur de Drainage des Eaux Pluviales de Brazzaville, 2009

4.3 Factors linked to the management of urban space

4.3.1 Lack of planning and poor land management

Poor planning results in urban development that fails to follow norms and recommendations**:** **numerous neighbourhoods spring up haphazardly in flood zones** (low-lying land) without any respect for urban development plans.

There is, therefore, no proper land management of those areas where construction is not allowed. These areas (marshes, low-lying land, erodible areas), particularly when they are near town, attract low-income populations due to the convenience of their location (close to work, shops and services). However, these areas in turn become over-populated and problematic, exposing the population to the risk of flooding and landslides.

4.3.2 Overlap between stormwater, wastewater, solid waste and drinking water

Lack of management and the poor state of infrastructure mean the different public services encroach on each other, often with harmful effects.

Wastewater discharged into the stormwater drainage system

In the dry season, **the intrusion of stagnant wastewater into the stormwater drainage system** creates major smell and hygiene issues.

During the wet season, **stormwater is mixed with this same wastewater**, and with solid waste, seriously contaminating flooded areas and the environment.

Solid waste dumped in the stormwater drainage system

The lack of an effective solid waste collection system **causes the stormwater drainage system to become blocked**.

Stormwater contamination of drinking water

Stormwater, loaded with pollutants, **contaminates underground water resources** (wells and boreholes).

4.4 Factors directly linked to stormwater management

4.4.1 Lack of knowledge and information

Although clearly identified as a major issue in times of flooding, the agencies responsible often lack the knowledge and tools required to deal with stormwater management.

In many African countries, rainfall data is frequently lacking, obsolete or inaccessible. Furthermore, the quality of any data that is available is compromised by a lack of reliable measuring equipment or data collection tools.

Developing countries often make use of the approaches implemented in developed countries during the 20th century: their aim is to evacuate the water from the city as quickly as possible, rather than endeavour to store and reuse it. Alternative and additional measures (storage /infiltration/delayed surface runoff) remain relatively unknown and rarely used in developing countries.

4.4.2 Lack of coordination between sector stakeholders

The large number of actors involved in stormwater management (ministries of urban planning, the environment, municipalities, operators in charge of sanitation, etc.) renders management and coordination of the sector difficult.

There is currently no specific stormwater management sector within the public authorities: stormwater management is rarely dealt with by a dedicated department, but responsibility for its design, planning and financing is instead usually dispersed among the different development, road or sanitation departments. As there is no clear legal and institutional segmentation, stormwater management does not strictly constitute a sector.

4.4.3 Stormwater management decentralisation policies still in their infancy

As part of a decentralisation process, the management responsibility for different services is progressively transferred to local authorities. However, responsibilities for stormwater management lack clarity and the allocation of financial responsibilities between the state and local authorities is not properly defined.

4.4.4 The myth of the master plan or poor alignment of planning to local capacities

Stormwater management master plans have been developed for a number of cities. However, the majority of these have been poorly (or never) implemented. The main reason for this being that the investment capacities of local and national governments rendered the cost of technical recommendations prohibitive.

4.4.5 Failure to take the populations' expectations into account

Although stormwater management is considered a priority by the populations of the majority of African towns and cities, this issue is not always prioritised by the public authorities.

4.4.6 Limited local capacities for financing investment

Most technical solutions developed to address stormwater management issues require costly civil engineering infrastructure. The investment costs involved commonly exceed local authorities' investment capacities. The low investment capacity of these local authorities is unlikely to change significantly over the next few years.

4.4.7 Limited capacities for financing operation

Operating even the simplest form of stormwater drainage system (cleaning out the drainage channels before the rainy season) is extremely labour-intensive. As such, it is also a costly activity and one that local authorities struggle to finance.

4.4.8 Failure to comply with best construction practice

Failure to comply with equipment design and construction standards increases both the risk of flooding downstream (poor evacuation) and flood damage.

5 INNOVATIVE ACTIVITIES IMPLEMENTED IN DEVELOPING COUNTRIES

The most common solution for dealing with the problems caused by stormwater in developing countries is to construct drainage channels or evacuation systems; however, this does not enable the full extent of stormwater management needs to be addressed. Nevertheless, some activities have been identified that are having an influence on a number of factors, although these remain highly disparate and localised.

5.1 Activities influencing the natural factors

5.1.1 Controlling runoff upstream from the city

Controlling runoff upstream of cities can not only considerably reduce the volumes of water to be evacuated, but also invigorate the local economy by encouraging agriculture, aquaculture and reforestation.

Stormwater management by controlling runoff, Dogondoutchi in Niger
In the city of Dogondoutchi, problems of stagnant water have been considerably alleviated by the retention and infiltration systems that have been installed upstream from the city, namely filter dykes and half-moon terraces (hillside retention). In addition to the significant reduction in runoff within the city, these techniques have enabled land to be reclaimed for farming and the reforestation of desert areas and have also led to a reduction in silt build-up in a pond used for aquaculture and irrigation.

Source: Maîtrise des eaux de ruissellement à Dogondoutchi, RAIL Niger 2009

5.1.2 Reducing erosion

Certain techniques, such as introducing shallower gradients (e.g. Bogota, Colombia) or constructing reinforced concrete pier walls to stabilize slopes (e.g. Santo Domingo, Dominican Republic), can help reduce erosion.

5.2 Activities for improving the management of urban space

5.2.1 Promoting collaboration between different local authority departments

Some African local authorities have a 'Runoff Control' unit (e.g. Dogondoutchi in Niger), mainly composed of staff from the environmental and the land use and rural engineering departments. This type of collaboration helps develop the required linkages between these different specialists to harmonise stormwater management related activities.

5.2.2 Developing multi-service approaches

Certain stormwater management initiatives are not restricted solely to the development and maintenance of drainage systems. Such initiatives combine stormwater activities with activities linked to other basic services, notably household waste and water supply.

5.2.3 Integrated management of urban water

One commonly recommended approach is that of Integrated Urban Water Resources Management. This essentially involves applying Integrated Water Resources Management (IWRM) principles to the urban context**:** sustainable development, economic efficiency and social equity. This method enables all urban water related issues to be addressed, in all their forms, in an integrated manner at catchment level.

Although recognized as an effective way of managing urban water without harming either the environment or human health, this approach involves a long and complex methodology. It is more of a general recommendation framework and thus is often difficult to implement in developing countries.

5.3 Activities for improving stormwater management

5.3.1 Improving care and maintenance services

Drainage service improvement programs tend to focus on design and construction yet afford little importance to improving care and maintenance. However, these activities are vital as insufficient care and maintenance of the drainage system can result in loss of capacity or even deterioration.

5.3.2 Using alternative techniques

There are a number of advantages to using alternative techniques for stormwater management. Depending on the technique used, it is notably possible to utilise the water as a resource or to retain then infiltrate stormwater to compensate for the inefficiencies of the evacuation system. Ultimately, these techniques help to reduce not only flood events and the creation of stagnant ponds but also the volume of contaminated water discharged into the environment.

Although there is a relatively wide choice of techniques available (see the Annex for more details), in developing countries, very few of these solutions are actually used. Even when these techniques are implemented, they tend to serve little purpose as they are rarely properly maintained.

E.g.1: porous pavement (As the main cost is for local labour, this technology can be easily implemented in developing countries).

E.g.2: streets and roads used as a drainage system

E.g.3: retention ponds

Although there are retention ponds either upstream from cities or incorporated into the stormwater evacuation system in many cities in developing countries, these are too few in number. They can regulate the flow of runoff and stimulate the local economy (irrigation, fish farming).

E.g.4: reforestation and hillside retention

5.3.3 Computer modelling

Commonly used in developed countries, computer modelling is an effective tool for designing, sizing and improving stormwater drainage systems. Developing countries are now gradually starting to use computer modelling, particularly for more complex scenarios.

5.3.4 Involving different stakeholders

A stormwater management strategy that involved the different stakeholder groups and ensured their expectations and needs were taken into account has been piloted in Nepal.

Stakeholder groups and their interests and priorities in urban drainage planning

Stakeholder group	Interests and priorities
Public and community leaders	Largest community of residents and service users/beneficiaries
Slum dwellers	Low-income communities who often inhabit areas which are at risk from flooding
Land developers	Construction of new developments for new housing or industry
Farmers	Peri-urban community with agricultural interests
Environmentalists	Protection of quality of water resources and conservation of natural habitat
Local politicians	Priority issues responding to local constituents' demands
Councillors and civil servants	Trade-off between cost-benefits in relation to municipal expenditure
Architects and land planners	Planning and design of urban space
Private sector, business community	Protection of industrial and commercial interests

Source: Bhattarai and Neupane, 2001.

5.4 User-targeted activities

5.4.1 Flood risk prevention and reduction strategies

As an urban drainage system often reaches the limit of its hydraulic capacities during a particularly heavy rain event, in addition to improving the drainage system's hydraulic capacities, certain cities also adopt non-structural measures, which are namely those that require no physical intervention. These measures can be divided into 3 types:

- Activities aimed at preventing flooding;
- Risk reduction measures aimed at reducing the extent and duration of floods;
- Flood damage reduction measures: in the event of flooding, this involves helping those affected recover from and repair the damage caused by the flood.

Risk prevention plans

Dynamic flood warning system: an integrated approach to disaster mitigation in Bangladesh

An integrated flood management plan has been adopted in the district of Sundarganj (Thana) in the north-east of Bangladesh that includes the following elements:
- Identification of flood risk areas;
- A real-time flood warning system (using a hydrodynamic model and GIS);
- Identification of accessible routes to evacuate people during a flood emergency.

Source: Aziz et al (2002)

Re-housing families living in high risk zones

In particularly high risk areas (where there is a risk of landslides and flooding, especially), certain

municipalities decide to re-house the most vulnerable families.

*In **Bogota, Colombia**, the municipality undertook an initiative to protect 6,000 highly vulnerable families living in high risk zones. The initial stage consisted of identifying and mapping these zones to develop a risk reduction strategy that focused on redeveloping the land. Where structural work was not viable (reducing slopes, reinforcing houses), families were re-housed. In order to ensure the sustainability of this relocation and prevent new families from moving into these high risk zones, the legal land development market needed to be more competitive than the illegal market. To this end, the housing system was restructured to provide access to housing for the most socially vulnerable families earning below the minimum wage. Key to the success of this operation was the role played by the municipality in developing a suitable policy, an official plan and procedures.*

Source: The Together Foundation and UNCHS

Setting up warning systems

Due to the recurrent nature of floods, the populations of some flood risk areas have developed response strategies, creating a warning system to alert residents to evacuate their homes and thus avoid danger.

*In **Indore (Madhya Pradesh, India),** residents have acted on their own initiative to develop a flood prediction system based on the duration and intensity of rain. When there is a flood warning, families are prepared to evacuate quickly. Infrastructure projects to improve stormwater management disrupt their ability to predict flood events and so are not always well-tolerated.*

Source: Stephens et al, 1996

Voluntary individual protection

Users act on their own initiative to develop their own means of protecting themselves from heavy rainfall and thus dealing with the deficiencies of the stormwater evacuation services. These initiatives can include:

Improving the land or house:

- Constructing houses on stilts, raising the building's foundations;
- Sealing doors, raising electrical equipment;
- Using more resistant materials;
- Building roofs with detachable metal sheets (held in place with stones rather than nails, so easy to remove if there is a risk of the roof being washed away by a flood).

Neighbourhood protection:

- Constructing protective walls (around the house or the neighbourhood);
- Deliberately blocking the drainage channels to protect against flooding.

These initiatives, when not coordinated between the different neighbourhoods, considerably increase the flood risk further downstream.

5.4.2 Involving the most vulnerable users in the management and development of the service

Dialogue between users and the local public authorities is an essential part of the service improvement process. It is particularly important to include the poorest communities in such discussions, as these are the people most affected by poor stormwater management and who are too often insufficiently consulted or completely ignored.

5.4.3 Involving residents in infrastructure construction and management

It is vital that residents and all those with a vested interest in improved stormwater drainage are involved in stormwater management decision-making and planning.

5.5 Conclusion

Substantial work is still required in developing countries to develop knowledge and practices and to test different approaches to stormwater management. Although complete answers remain to be found,

we have identified a number of potential options for addressing this issue . The majority of solutions presented seek to expand on the practices seen in the field. In order to deal with stormwater management issues, it is appropriate to use complementary types of approaches: clearly distinguishing between the geographic scale of the stormwater management issue and the scale of intervention, and taking into account interactions with other urban services, and organising the sector using an upgradeable and complementary approach utilising both traditional solutions and those that draw on alternative or compensatory techniques.

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