# *Urine diverting dry toilets as appropriate adaptation to flood prone areas in cities of developing countries*

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# Urine diverting dry toilets as appropriate adaptation to flood prone areas in cities of developing countries

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*Living in flood prone areas is a serious challenge for citizen in developing countries, especially in Cameroon. MAFADY Project has been working through identifying best low cost sanitation technologies so as to propose a technology suited to flooded areas of Wouri estuary in Douala. From a defined set of social, financial and technical criteria, analysis of existing sanitation technologies developed in flooded ecosystems was made, and it was found that elevated Urine diverting dry toilets were the one suitable for flood pone areas. A plastic Drum twin pit Urine Diverting Dry Toilet (DUDDT) model was designed and constructed. This paper presents: socio-economic and environmental context of the Wouri estuary, the selected criteria and design parameters, the DUDDT, and finally discuss the construction costs. From analysis, this toilet seems to feet flood prone areas, specifically in urban wetlands of developing countries.*

## Introduction

Economic growth in cities of developing countries result in development of informal settlements on hills and marshes, as well as coastal areas. As a consequence, uncontrolled production of liquid and solid wastes poses huge urban and environmental problems. The Cameroon Sanitation Strategy stress the need for the development of autonomous sanitation as a major trend of the sanitation chain improvement. Unfortunately, in the absence of significant government intervention in the construction works, investment in the sector is essentially at the expense of households (Ngnikam *et al.,* 2010).

Several authors have proposed technical low cost solutions for poor households (NWP, 2008). However, sometimes these systems are not consistent with local realities. In fact, the choice of adequate sanitation solution tailored to local context is complex; as sewerage is relevant of many policy areas and dependent of multiple criteria (PSEAU, 2010). Thus, the *Mastering Sanitation in an urban ecosystem in the coastal zone of Douala and the neighbourhoods of Yaoundé project* abbreviated "MAFADY" has set as goal to determine: actions to take in the areas of sanitation wastewater and excreta, practices of various stakeholders, which can improve hygiene and human health in coastal areas, and informal settlements of large humid tropical cities in Cameroon. During the project some toilet models were developed accordingly. This paper presents the proposed technology, in a context of low income households facing slums changing climate and wetland conditions.

## Presentation of the features of Wouri estuary in Douala

The MAFADY project was developed in the districts of Douala 4 and Yaoundé 6, but our focus will be on the Douala 4 district which is in North West of the Wouri River Mouth, within the gulf of Guinea (Fig.1). This coastal town is characterised by large population and economic dynamism, as well as high rainfall and tidal variation which make it prone to recurrent floods.

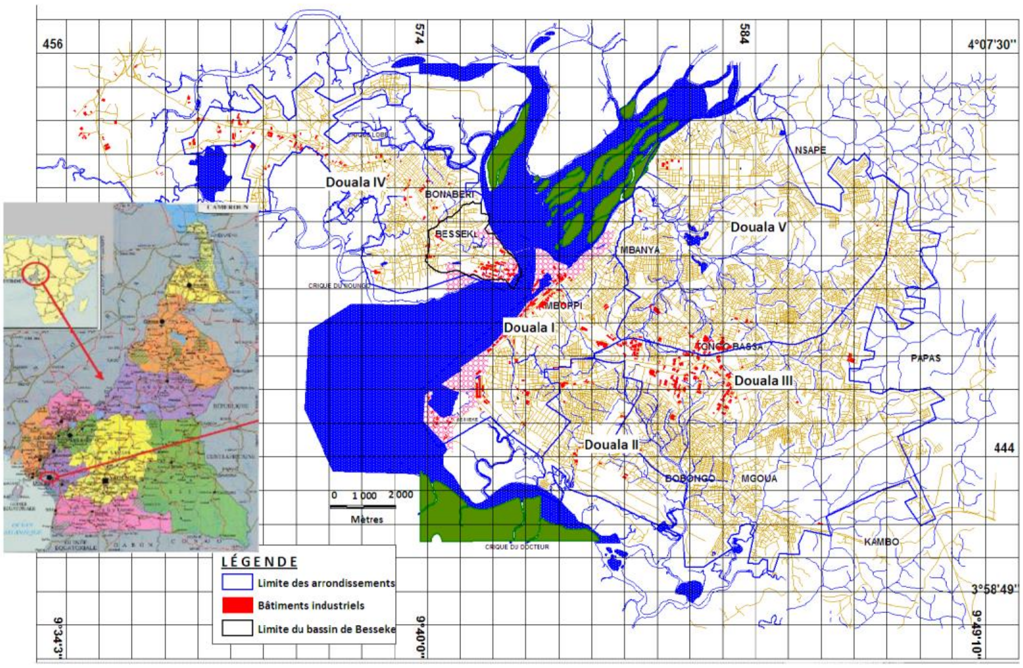


**Figure 1. Localisation of Douala 4 in the mouth of the Wouri estuary in Cameroon**

## Socio-economic and environmental conditions

Douala 4th District, has 356 000 inhabitants, in settlements which are 80% informal. SOGREAH (2006) found that in Douala, individual sanitation is the most common feature with various technologies: traditional latrines (60%), septic tanks (25%) and open defecation (15%). The project area covers three residential strata: informal flood-prone, non-floodable informal and structured dry neighbourhoods. Flood prone areas which were of particular interest were in Besseke basin: Besseke 1, Nkomba and Mambanda. In these areas, people regularly clean drains to reduce the effects of flooding. But this is not significant on the long run, because flood is quite permanent and the area is owned by the Industrial zone development Authority (MAGZI) which can clear them off at any time.

The MAFADY project neighbourhoods are characterized by a high rate of tenants (over 40%) living on small plots (100 and 200 m$^2$) disposed as in slums habitat. Analysis of some socio-economic and environmental constraints of the receiving milieu shows that accessibility and contamination of the water table issues seem to be acute. In the other hand, people are alike to rebuild or share their sanitation systems, because of weak financial power and restricted land space for sanitation facility (less than 6 m$^2$).

The low-income households (over 70% of them, living with less than $173.84/month) living in that area have a low standard sanitation dominated by latrines with shallow pits (1.38 m), sometimes in contact with surface water or water table; from which people fetch water for domestic use. As such, in this context, the appropriate sanitation technology should be preferably dry, occupying less than 06 m$^2$ and of low cost. But this should also prevent contamination of surrounding water sources.

## Geomorphic and hydrological characteristics of Douala 4

Douala 4 is part of the Wouri estuary (1 200 km$^2$) where is located the Douala sea port, one of the biggest of Central Africa in terms of float and financial exchanges (fig. 1). The relief here is flat with mostly sedimentary base and three other groups of soils: ferrallitic, loamy and hydromorphic. The climate is humid, with 230 rainy days per year for a mean annual rainfall of 3 773 mm. Mean monthly temperature arise to 25.2 °C for 1 384.4 mm of annual potential evapotranspiration. The air is quite permanently wet (99% in rainy season and 80% in dry season) and tidal variation is frequent. According to climate forecasts for Cameroon, there would be rise of rainfall and storms (up to 15%), as well as upwelling of the water level in coastal areas to up to 0.56 meters (Mc. Sweeney *et al.*, 2008). So, floods here arise from two major phenomena based on saturation of the capillary zone: capillary water rise and permanent water standing due to low infiltration rate compared to rainfall intensity or volume.

## Methodology

### Evaluation of existing technologies and selection of the required type

For the selection of appropriate sanitation technology, Cameroon Sanitation Strategy, both with NWP (2008), highlights the importance to: 1) Meet the demand, 2) Build on existing practices, experience and infrastructure, 3) Consider socio-cultural sensitivities as far as the ability and willingness to pay of beneficiaries. They also recommend to consider: a) population density; b) level of socio-economic development; c) sensitivity of the receiving environment to pollution; d) Consultation and active participation of all stakeholders and e) Ease of use, maintain and repair of the facility**.**

The process that led to the proposal of MAFADY latrine included the analysis of various existing technologies according to financial and technical criteria in line with the above guides as well as those proposed by DGAEUE (2008). Findings were shared through stakeholder's consultations (monitoring group, open audiences). As we need to exchange with a large and diverse audience, some key criteria were targeted to ease the selection. Financial criteria included: **cost of the sanitation facility**, **ability to pay** and **will to pay for the facility**, when technical criteria included: **space required for the facility**, **durability of the material used**, **flood safety**, **water dependency**, **storage**, **treatment** and **disposal**. Indeed, this process allowed the identification of sustainable sanitation technologies taking into account constraints identified in the context of flood prone areas. The value given to each technology where relative to the climatic, socio-economic and environmental context.

### Evaluation of the plastic Drum Urine Diverting Dry Toilet (DUDDT)

Based on previous analysis, a Urine Diverting Dry Toilet (UDDT) model was designed to feat existing constraints. The design was inspired by experiences undertaken in the city by NGOs (ERA-Cameroon, GTZ) and urban development program (PDUE), as well as experiences from Asian and African countries. The constraints of its construction were then assessed while building some modules. The evaluation focussed on labour, transportation cost, total toilet cost, space required and duration of construction.

## Results and discussion

### Evaluation of existing flood prone sanitation technologies in developing countries

In many tropical contexts many of the latrine models developed for flood areas present constraints of cost, durability or functionality, as they have to adapt to the socio-environmental conditions. From the analysis of MAFADY report (2013), most of the technologies suit for flood prone slums are dry toilets with narrow footprint space. But those who have appropriate material (cement blocks) are of high cost. The humid environment of Douala does not promote the sustainability of wood or metal materials and the water vapour in the mouth of Douala is salty. The best option here seem to be the BARD UDDT (Uddin, 2013). But as Cameroonian law forbid deposit of excreta waste anywhere and in the absence of appropriate collection service yet, the vaults had to be changed. More-over, the cost of Urine Diverting technologies developed in Cameroon are still too high (1 043.03 to $1 564.54) compared to ability to pay of households ($34.77); 2 to 3% of the total cost. This is even less than the 15% of the total cost required in some projects promoting UDDT. So financing the technology will remain a key issue.

### Plastic drum urine diverting toilet constraints and description

#### *Specific technical constraints of the DUDDT*

From stakeholder consultation, it was found as DGAEUE (2008) in Burkina Faso and PRATICA (2008) in Madagascar that: ECOSAN models and double pits are best suited for urban and rural areas. In addition, dry latrines are adequate regardless of the type of anal cleansing; they are easy to maintain, respect several principles that ensure their proper functioning and are flood resilient. Uddin (2013) justifies this resilience by three main reasons: 1) UDDTs are constructed using elevated structures generally at the same height than house doors; 2) UDDTs produce little or no odour and 3) UDDTs faeces chamber is water tight.

From analysis, some specific technical constraints arise: seal of the pit in order to protect the web; separate urine from faeces; adapt the seat to ease squatting; choose durable materials available on the market, ease the handling and assembling, raise the sit above the highest upwelling level (50 cm); reduce as much as possible the construction cost and respect minimum dimension of cubicles (1.1 x 0.7 x 2 m).

***Description of the drum urine diverting dry toilet***

Based on previous experiences and given specific constraints, the Plastic Drum Urine Diverting Dry Toilet (DUDDT) was designed. It is made of twin cubicle placed on top of plastic drums who serve as pit. Walls are made of cement blocks to feat humid salty air conditions. The space required for the latrine is 6.3 $m^2$ (2.4 X 2.6 m) and the drum volume (250 litres), which provides one year use for each drum, considering a family of six (06) members. The pit is ventilated by one vent pipe of 100 mm for each drum. Protection walls are provided for the drums and allow a nice looking of the toilet (Photograph 1).


**Photograph 1. MAFADY Drum Urine Diverting Dry toilet**
**(from left to right: empty pit, drum pit 2 and the cubicles)**

The DUDDT is provided with a concrete urine diverting seat for the adjustability to the rest of the functional parts of the toilet and the ability of local technicians. It was designed according to the AQUA project model, but that model was too large and too heavy. Then, we need to design a lighter and smaller size seat. Table 1 shows the size and weight of the two models. The major characteristics of that seat are: squatting hole (13 cm diameter); pedestal length (36 cm); pedestal width (12 cm) thickness (4.7 cm); horizontal angle of micturition (35°); seat's length (63 cm); seat's width (47.5) and mass (32.4 Kg).

**Table 1. Size and weight of the seat developed through AQUA and MAFADY projects**

| | **Seat** | | | | | **Squatting hole** | | **Pedestal** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Width (cm)** | **Length (cm)** | **Thick. (cm)** | **Area (m2)** | **Mass (Kg)** | **Hole Diam. (cm)** | **Ring Thick. (cm)** | **Dist. border (cm)** | **Length (cm)** | **Width (cm)** |
| **AQUA** | 64 | 77 | 8 | 0,5 | 90,7 | 14 | 3 | 18,5 | 33 | 16 |
| **MAFADY** | 47,5 | 63 | 4,7 | 0,3 | 32,3 | 12,5 | 2 | 4 | 36 | 12 |

From the table 1, the proposed seat provides reduction of 2/3 of the mass and 1/3 of the Area. Pedestal has been increased in length to ease urinating and squatting both for men and women. The seat which is of UD type is connected to a 30 litres gallon for the re-use of urine after safe and appropriate treatment.

**Photograph 2. Seat of the plastic drum UDDT developed in the MAFADY Project**

### Evaluation of the construction of the plastic drum urine diverting dry toilet

This model were built in the Douala 4 neighbourhoods to determine real duration and costs of its construction. Thus, for a standard team of 02 masons and 01 skilled manoeuvre, the time to build the DUDDT should be 14 dry days' work. Following cost analysis on Table 2, there is an overall increase in the cost of the plastic drum toilet by 48% compared to initial target. This seems to be related to increase of costs of materials, especially aggregates, but also labour. Detailed analysis showed that quantitatively, the binder (cement) seems to be overused, which actually increase expenses on aggregates. The overuse of material was due to the low mastery of technicians, who do not have sufficient training to fully achieve the realization of prescriptions. Despite this, the holding area has been reduced by 12%, an interesting result, as the space for toilets in the area is narrow (4 to 6 $m^2$).

**Table 2. Cost of the plastic drum UDDT in Douala**

| | Initial | Final | Increase (%) |
|---|---|---|---|
| Labour cost ($) | 104.30 | 173.84 | 67 |
| Transportation cost ($) | 17.38 | 43.46 | 150 |
| Material and aggregates cost ($) | 504.13 | 704.04 | 40 |
| Total Cost ($) | 625.82 | 921.34 | 48 |
| Holding Area of the toilet ($m^2$) | 6.3 | 5.6 | - 12 |

In the other hand, labour cost which was targeted to be 17% is now at 18.9%. This is due to competitive job available in that zone. Transportation cost (4.7%) is slightly lower than percentages recorded in UDDT technologies built in Kampala, which were 5 to 7% (U-ACT (2013). Here, the reason might be the accessibility to construction sites. Besides, the cost of transporting small quantities of materials is high (average 10.43 to $17.38/trip). The cost of the DUDDT is higher than various types UDDT (226 to $460.67) built in most West African countries (Niger, Burkina Faso, Mali, Benin), but within the normal range according to PRATICA (2008), PSEAU (2010) and U-ACT (2013), where the cost of this type of latrine is between 717.95 and $1 077.79. So, grouping purchasing and construction sites would help achieve substantial reductions in the unit cost of building materials. Also, training technicians would help to reduce expenses on aggregate and binder.

## Conclusion

This paper discussed the appropriateness of urine diverting dry toilet technology as adaptation measure to flood prone zones, especially slums. Based on analysis of technical and financial criteria considering geomorphic, hydrological, climatic, socio-economic and environmental conditions, existing technologies in Africa and Asia were compared. Elevated plastic drum urine diverting dry toilet (DUDDT) were found suitable for flood prone areas, especially in slums where accessibility, limited space and financial means is a key issue. The reasons being its flood resilience, reduced footprint and environmental security.

Building a DUDDT requires 14 dry working days. The total cost of a 6 $m^2$ DUDDT is $922, with 19 % of the total cost dedicated to labour and 5% to transportation. The ability to pay of households (3.8 % of DUDDT cost) indicate a serious need to subsidise such a technology (material and finance). But beneficiaries can contribute through man power so as to reduce labour cost.

This also call for consideration of managerial measures to reduce as much as possible labour and transportation cost, as well as the use of construction materials. It is then advisable to provide: appropriate training, up scaling of the technology and financing mechanisms to reduce environmental and health risks to households living in flood prone zones in developing countries, in a sustainable way.

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