

Analysing Environmental Risks and Perceptions of Risks to Assess Health and Well-being in Poor Areas of Abidjan

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Abstract—This study analyzed environmental health risks and people's perceptions of risks related to waste management in poor settlements of Abidjan, to develop integrated solutions for health and well-being improvement. The trans-disciplinary approach used relied on remote sensing, a geographic information system (GIS), qualitative and quantitative methods such as interviews and a household survey (n=1800). Mitigating strategies were then developed using an integrated participatory stakeholder workshop. Waste management deficiencies resulting in lack of drainage and uncontrolled solid and liquid waste disposal in the poor settlements lead to severe environmental health risks. Health problems were caused by direct handling of waste, as well as through broader exposure of the population. People in poor settlements had little awareness of health risks related to waste management in their community and a general lack of knowledge pertaining to sanitation systems. This unfortunate combination was the key determinant affecting the health and vulnerability. For example, an increased prevalence of malaria (47.1%) and diarrhoea (19.2%) was observed in the rainy season when compared to the dry season (32.3% and 14.3%). Concerted and adapted solutions that suited all the stakeholders concerned were developed in a participatory workshop to allow for improvement of health and well-being.

Keywords—Abidjan, environmental health risks, informal settlements, vulnerability, waste management.

I. INTRODUCTION

NUMEROUS studies indicate a direct link between environmental health risks and limited access to clean water, sanitation facilities and services on the one hand, and poor hygiene practices on the other. Water-borne pathogens alone infect around 250 million people per year, resulting in 10–20 million deaths [1]. This leads to negative health

impacts, environmental degradation and related economic impacts on the affected population [2,3]. Access to qualitatively good drinking water, adequate sanitation facilities and services and satisfactory hygiene practices significantly contribute to reducing the rate of morbidity and mortality among populations [4-6]. The World Health Organization has summarized the results of studies worldwide in the following way [7]:

Unfortunately, despite numerous national and international efforts to promote measures, so far there has been regrettably little progress, particularly in Africa [7]: (i) 88% of diarrheal diseases are attributed to unsafe water supply, inadequate sanitation and hygiene, mostly in developing countries, (ii) 1.3 million People die of malaria each year, 90% of which are children under five, (iii) 396 million episodes of malaria are recorded every year; Africa, south of the Sahara, is affected most by this disease burden.

Effective waste management remains a major challenge for many countries; particularly in underprivileged urban settings [8]. The urban poor generally bear the most heavy burden of environmental problems affecting urban centres [9], [10].

Like other African cities, Abidjan also faces deteriorating environmental conditions. These are caused on the one hand by rapid urban population growth, with which the provision of urban infrastructure and services cannot keep up. The situation, especially dramatic in poor informal settlements, has been exacerbated in recent years by the effects of the socio-political crisis from 2002 onwards [11]. In these poor settlements, the residents are increasingly subjected to threats of deficient sanitation.

The present study analysed environmental risk factors and people's perceptions of risks related to waste management in six informal settlements of Yopougon, a large district of Abidjan, in order to foster participatory development of measures to mitigate current problems and improve the health and well-being of residents. As the role of sanitary engineering must be in harmony with the population's interests and needs, therefore, it was important to identify citizens' perceptions regarding water supply and waste management in order to support the formulation of strategies that would lead to providing the service in a way that was appropriate to each reality and the needs of the community.

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However, it had become widely accepted that perceptions of all stakeholders were important and that successful risk-management policies needed consensus. To this end, the study used a trans-disciplinary approach involving cartographical, sociological and epidemiological studies, as well as a stakeholder workshop. Using an integrated approach the study had the ambition to avoid isolated and dispersed actions or measures, but required consistent and concerted action over a wide range of policies and measures. These measures needed to address diverse needs and conditions and to be the result of the interaction of institutions and a large number of stakeholders.

II. MATERIALS AND METHODS

A. Study area

The study area is situated in Yopougon, a large area of the city of Abidjan, the economic capital of Côte d'Ivoire. The targeted informal settlements are located around open drainage channels in which untreated liquid and solid waste flows to a lagoon downstream (Fig.1). The six settlements (Doukouré, Yaoséhi, Gbinta, Mamie Fatai, Yamoussoukro, and Niangon Continu) selected for the extensive study conducted in October and December 2004, comprised a total of about 13,000 inhabitants situated in a high-risk area around the Uniwax Canal. This canal is used to drain rainwater as well as domestic and industrial sewage; it is also the location of indiscriminate dumping of solid waste. Soil erosion, landslides and flooding occur often, particularly during the rainy season. The whole area is characterized by lack of a regulated and adequate solid and liquid waste disposal strategy and system.

B. Remote sensing investigation and geographical survey

Quick Bird images taken in January, 24th 2004 were acquired for the study. They consisted of four multispectral bands and a fine spatial resolution (2.5 m on the ground) for easy detection and extraction of urban objects [12, 13]. The images were first subjected to geometric correction performed in the field by GPS at 12 reference points and 6 control points. They were subsequently processed (image fusion) using the "pansharpened" method [14] to enhance identification of the different urban objects in the underprivileged settlements and to facilitate their manual extraction. The investigation aimed at providing an updated overview of the built environment in these informal settlements. This cartographic information, validated by GPS ground-trashing, provided the data needed for a subsequent improved health and vulnerability assessment of the poor settlements.

Using these new residential maps of the informal settlements, geographic mapping of three types of variables was conducted: i) access to drinking water sources, ii) sewage discharge and iii) uncontrolled waste dumping sites. The researchers visited all six informal neighbourhoods to collect information on these three aspects and transferred the information on previously developed data sheets. ArcView

version 3.2 for Windows was used as software to map and analyze these data.

C. Household survey

The study comprised a total of 1800 households, which consisted of 300 households in each of the six underprivileged settlements of Yopougon based on a simple random sample in each settlement. This approach is free from classification errors and required minimum prior knowledge of the specific population demographics and was easy to use in practice [15]. Within households female heads of households were selected whenever possible, as women in Abidjan, as in most African cities, are responsible for general household tasks such as providing drinking water, as well as managing liquid and solid waste at household level. Other household members were selected randomly within the group, aged between 20 and 60 years. A semi-structured questionnaire used to collect information was divided into three parts. Part A focused on household identification and basic information. Part B dealt with perceptions, water, sanitation as well as diseases contracted by the household in the two weeks preceding the survey. Part C investigated the characteristics of the household members in each poor settlement.

A pilot survey was first conducted to test the applicability and functionality of all methods and procedures. The main study was conducted between October and November 2003 (rainy season) followed by another in January 2004 (dry season) focusing only on the aspect of diseases. For quality control, the questionnaires were checked for completeness by the survey supervisors before entering the data. Data was entered twice, first using the Epi-Info 2002 software prior to transferring the data to Excel spreadsheets for correction and control. Finally, the data was imported into SPSS.11 for Windows for statistical analysis of all criteria. Some results from household surveys were combined with geographical information from the GIS database, thus allowing development of specific maps highlighting the health and vulnerability of the population in these underprivileged settlements.

D. Semi-structured interviews with key informants

Selected resource persons, particularly representatives of the local population, the central and municipal governments, organizations and NGOs were rallied and interviewed on the research topic. The information gathered focused on real life situations in these settlements, particularly on the perceptions, behaviour and knowledge of the population and various stakeholders with regard to socio-sanitary conditions and overall population diversity in these informal areas.

MAXQDA, a software program for qualitative analysis was used to register and process the interviews. The awareness and knowledge data collected was classified according to a coded structure based on the main topics of the study for the different interviews. The answers considered relevant were subsequently isolated and subjected to a factor analysis using the statistical functions of XLSTAT, version 2006 for

Windows.

E. Integrated participatory workshops

A workshop based on a socio-anthropological approach aimed at identifying adequate solutions for solid and liquid waste management in poor settlements, using integrated participatory methods. Since sustainable solutions involve all stakeholders, an integrated participatory workshop was organized for all stakeholders' concerned (public institutions, private persons, researchers, NGOs, the local population). The workshop was conducted using the Rapid Appraisal Method [16]. The findings of the workshop were then combined the results of the environmental risk factors and perceptions studies were compiled into one database. This aggregated information enabled the elaboration of a systemic model for sustainable waste management and establish potential mitigation pathways to reduce the vulnerability and health status in these underprivileged settlements. Data from the workshop were further structured using the MindManager option of the MindMapping software (version 2006).

III. RESULTS

A. Updated digital land use units for the informal settlements

The high spatial resolution of the *Quick Bird* images and the results of the field surveys enabled identification of the housing units, the types of land use and a fine description of the household types. The analyses show that current land use planning in the poor settlements does not match the currently accepted town planning standards. Furthermore, due to the narrow streets and disparate land use in the disadvantaged settlements of Yopougon, door-to-door primary waste collection and construction of sewers are not feasible. The spatial structure of the settlements is characterized by irregularly shaped housing units built from recycled material and arranged in a dense and unstable architectural setting, with a high population density and lack of well conceived and regulated roads and paths. The updated mapping of the informal settlements, which until now was missing in the official numerical files of Yopougon, has become the basis for further investigations as well as for planning at municipality level.

B. Environmental risks factors in the informal settlements

People's predominant waste management practices in these informal settlements resulted in significant pollution, contamination risk and possible subsequent transmission of diseases. Household waste (solid and liquid) collected in these underprivileged settlements was generally disposed of directly in the sewage/drainage channel, along roads or onto nearby land. A high percentage (50%) of households used the rainwater drainage channel for disposing of their solid waste, which corresponded to a daily disposal of over 12 tons or 42% of the daily waste quantity generated in the six settlements under study. The streets and open land areas were also used as

waste dumps for another 37% of the waste produced in the 6 settlements and only 3% of this waste was collected and transported to the municipal landfill. The highest percentages of people using the rainwater drainage channel for disposing of solid waste were observed in Gbinta (82.1%), Yaosehi (72.2%) and Niangon Continu (66%).

The situation was similar for people's liquid waste management practices, as indicated in Table 1. Toilet sewage and "greywater" from showers was discharged mainly into pits, whereas other wastewater, also defined as "greywater" (from laundry and kitchen) was predominately discharged into the streets. Such greywater practices lead to a relatively high exposure of people to health hazards, in particular in the settlements of Gbinta, Yaoséhi and Niangon Continu. The households in these settlements also used the proximity of the rainwater drainage channel to discharge shower greywater (25%, 21% and 14%, respectively) as well as toilet (excreta) sewage (28%, 19% and 18%). This is in contrast to the settlements of Doukouré and Yamoussoukro, which have little contact with the channel and therefore do not use it for wastewater discharge. The closeness of the channel thus favours and determines the greywater and excreta discharge behaviour of the households (Table I).

TABLE I
 DOMESTIC WASTEWATER DISPOSAL PRACTICES IN THE INFORMAL SETTLEMENTS (FREQUENCY EXPRESSED IN %)

Type of waste	Location of waste discharge	Dk	Ys	Gb	Nc	Mf	Yk	Average
Shower grey-water	Street	5.8	4.4	2.9	3.7	2	3.7	3.8
	Pit	91.1	73.3	68.4	79.4	86.6	93.6	82.1
	Channel	1.7	21	24.9	13.7	9.1	1	11.9
	Courtyard	1.4	1.3	3.8	3.2	2.3	1.7	2.3
Toilet sewage	Pit	95.9	80.9	72.2	81.4	86.5	97.6	85.8
	Channel	4.1	19.1	27.8	18.6	13.5	2.4	14.3
Kitchen grey-water	Street	70.2	51.3	27	56.2	61.4	56.3	53.7
	Pit	15.3	12	36.5	13.1	15.4	34.1	21.1
	Channel	9.3	33	35.8	17.7	19	5.3	20.0
	Courtyard	5.2	3.7	0.7	13	4.2	4.3	5.2
Laundry grey-water	Street	71.1	51.1	27.2	55.4	59.6	50.2	52.4
	Pit	15.9	11.7	36	15.5	16.3	38.3	22.3
	Channel	7.9	34.2	35.4	17.5	19.2	7.1	20.2
	Courtyard	5.1	3	1.4	12	4.9	4.4	5.1

Dk= Doukouré, Ys= Yaosehi, Gb= Gbinta, Nc= Niangon Continu, Mf= Mami faitai, Yk= Yamoussoukro

Moreover, the study revealed that the majority of the households share common showers (61.2%) and/or inadequate latrines (58.5%). The most important environmental risk factor relates to the practice of kitchen and laundry greywater discharge. 76% of households indicated that they discharged greywater either in the channel, streets or courtyard, thereby increasing exposure to contamination. The average daily greywater (laundry and kitchen) discharged by the populations in the (heavily used) streets of the settlements amounts to 365 m³. The average amount of laundry and kitchen greywater

discharged daily into channels in the underprivileged settlements totals 123 m³. Use of the streets in the poor settlements as laundry and kitchen waste discharge exceeds by far the average discharge of 53%. Such solid and liquid waste management practices, particularly the mixing of different greywaters with toilet sewage, increase environmental health risks in the informal settlements.

C. Stakeholders' perceptions of risks related to waste management

The institutional stakeholders regarded informal settlements as illegal housing communities on unauthorized building areas. This view significantly influenced the availability and provision of solid and liquid waste management facilities and services. These settlements were consequently not provided with basic municipal services and/or were excluded from municipal sanitation and planning programs. As these underprivileged settlements were therefore not included in the Urban Master Plan, this easily explained the prevailing situation of lacking basic sanitary infrastructure. The interviews also revealed a lack of collaboration among the different institutional organizations that had a stake and responsibility for intervening to ensure the health and well-being of the community. The factor analysis highlighted the perceptions, knowledge and awareness of the population in the informal settlements regarding solid and liquid waste management (Fig. 1).

As reflected in this Fig.1, the findings regarding knowledge and awareness showed two significantly diverging views. The first, the F1 axis with 43.18% of total information, revealed that households (F1<0) regarded sewage (43%) and rainwater drainage channels (10%) as insufficient for waste and rainwater disposal in their settlements. These households felt concerned (36%) about erosion and were dissatisfied (44%) with the current household waste disposal systems. These types of views were contrary to those of households (F1>0) that were hardly aware of the existence of sewage (44%) and rainwater drainage channels (63%) in their neighbourhood, and therefore were unable to comment on the appropriateness of this aspect of sanitary infrastructure. Furthermore, these households considered payment for household waste disposal as unwarranted (45%).

As regards the second diverging view on the F2 axis, with 31.19% of the information, the households (F2>0) showing a poor knowledge of the sewage aspects (59%), rainwater drainage channels (40%), and erosion (48%) stated that they did not feel concerned by the situation (41%). These households differed from those (F2<0) well informed about the risks of erosion and familiar with the role of water drainage channels (20%). These households were also willing to contribute (32%) towards improving sanitation in their community. The analysis thus revealed that most of the people from the underprivileged settlements had a poor awareness of waste and environmental management aspects in their community as well as a lack of knowledge pertaining to the role of infrastructure and sanitation systems.

D. Health status of the population in the informal settlements

The combination of existing environmental health risks and people's poor awareness and lack of knowledge regarding waste management increases the risk of disease in the informal settlements. The present study revealed that this situation had increased the risk mainly of malaria, diarrhoea and skin diseases as mainly reported by the populations. Solid waste was accumulated in the streets, where potholes provided opportunities for potential mosquito breeding sites. The household interviews showed that among households revisited two weeks after the main survey, the prevalence of disease was reported to be 48%. During the rainy season, malaria was the main reported disease (47%), while reported diarrhoea and other diseases amounted to 19% and 38.8% respectively (Table II).

TABLE II
REPORTED ILLNESS EPISODES THROUGH HOUSEHOLD SURVEY IN THE INFORMAL SETTLEMENTS

Impacts	Survey results		Frequency (%) = level of reported prevalence	
	Dry season	Rainy season	Dry season	Rainy season
Whole population				
Reported illnesses	536	860	34.6	48.1
• Malaria cases	252	406	32.3	47.1
• Diarrheal cases	78	166	14.3	19.2
• Other diseases	209	316	28.4	38.8
Children (all illness episodes)				
Children (0-5 years)			52.1	53.6
> 5 years			53.4	54.2

The surveys repeated during the dry season revealed a prevalence of malaria (33%), diarrhoea (14%) and other diseases (28%). The number of cases of the first two reported diseases (malaria and diarrhea) was unequally distributed. In certain settlements, the reported prevalence of malaria exceeded 50%, as in the settlements of Yamoussokro (57%) and Yaoséhi (50.3%), which would therefore be considered more vulnerable. The settlement of Niangon Continu has exhibited the lowest prevalence (36%), as shown in Fig. 2.

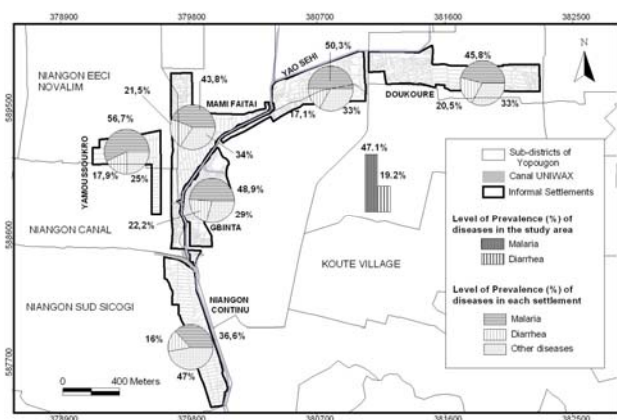
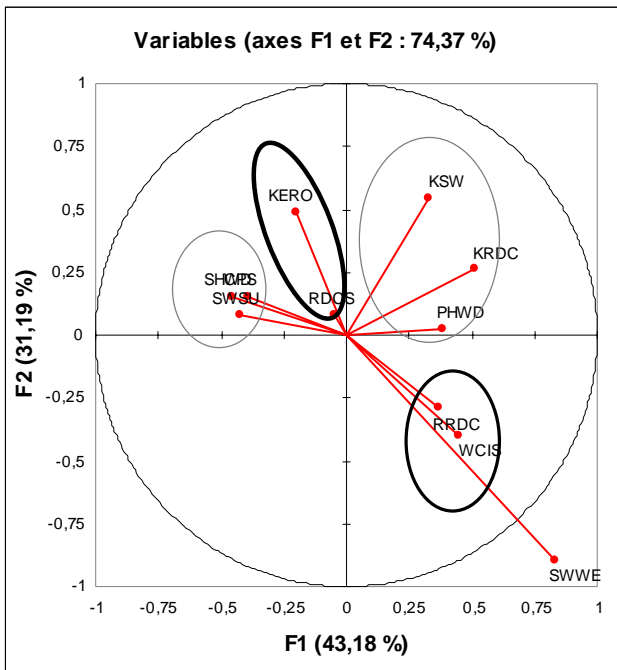


Fig. 2 Spatial distribution of the level of reported prevalence of malaria and diarrhoea in the informal settlements

Impairment of the quality of people's lives in the informal settlements could be linked to the contamination risk factors as a result of perceptions, behaviour and risk practices of the population in these areas. The data presented here provided the basis for discussing and establishing solutions and strategies to mitigate the problems due to deficient solid and liquid waste management.



ABBREVIATIONS	MEANING
SWWE	Be satisfied for wastewater evacuation
KSW	Knowledge of sewage channels
SWSU	Swages are sufficient for wastewater evacuation
KRDC	Knowledge of rainwater drainage channels
RDOS	Rainwater drainage channels are sufficient
RRDC	Knowing of the role of rainwater drainage channels
SHWD	Be satisfied of household waste disposal
PHWD	Agree with payment for Household waste disposal
WCIS	Willing to contribute towards improving sanitation
KERO	Knowledge of Erosion aspects
CPS	Be concerned by the problem of sanitation

Fig.2 Factor map (F1and F2) illustrating the perceptions and knowledge of the populations in the informal

E. Finding consensual mitigation solutions through a participatory workshop s

The participatory workshop resulted in a concerted definition of sustainable and consensual solutions for solid and liquid waste management in the underprivileged settlements of Abidjan. An action plan was set up defining the role and level of intervention of each stakeholder. During the participatory workshop, the beneficiary populations were involved in identifying and agreeing upon interventions. The percentage of their involvement was above the average, totalling 60%, followed by the municipal authorities with 53%. The weakest management role was attributed to the central government (25%). The information collected at various levels and compiled in an integrated analysis allowed the development of a systemic decision-making model for risk mitigation. The model linked each problem to one or more solutions and identified each stakeholder and the necessary level of intervention. This decision-making tool, designed for the local authorities in charge of urban management in Yopougon, is easily reproducible in similar environments and is currently being further validated.

IV. DISCUSSION AND CONCLUSION

The research followed a multi and trans-disciplinary approach, including cartography, sociology, epidemiology and participatory workshops. Multi-source information from QUICKBIRD satellite images on the one hand, exogenous data and socio-environmental interviews and surveys on the other hand, were combined to analyse the waste management situation and health risk factors in the informal settlements. Integrating both objective and subjective aspects of waste management in this poor area increased the relevance of the study and was highlighted by Boiral [17]. Moreover, the use of satellite images with high resolution made it possible to specify and map environmental factors in a simplified Geographic Information System (GIS).

Since waste management in the underprivileged settlements is very often subjected to perceptions and behaviours that are not conducive to appropriate and safe waste management, these studied areas were exposed to greater sanitation health risks. Lack of willingness of institutional stakeholders - mainly at municipality level - to include these settlements in their sanitation programs, unclear and interfering

responsibilities, and poor collaboration among institutional stakeholders were the main determinants for the deficiencies observed. Given the lack of commitment of the local authorities to more effective waste management, solutions must be sought which require participatory partnership agreements [18]. The study revealed how institutional stakeholders might be potential barriers to achieving sanitation facilities and services which benefit the poor [19].

Ignorance of the existence and function of basic sanitation infrastructures and the conviction that the channel in Yopougon could serve as a solid waste disposal site, were further proof of the lack of public awareness and active involvement in waste management. Similar situations have been described for waste management in Accra, Ghana, and in Dar-es-Salam, Tanzania [20-22].

The behaviour and risk practices of the residents in the informal settlements with regard to waste management reflected their knowledge and awareness. As a consequence, household waste (liquid and solid) in these settlements was most commonly disposed of in rainwater channels, on the curbsides or on nearby open land. The streets were also used for wastewater (mostly greywater) discharge (365 m³/day). This situation was a risk factor for the transmission of various diseases, particularly aggravated in the rainy season, when soil saturation hinders infiltration, thereby increasing the number of sites with standing water that could serve as mosquito breeding sites and sources of contaminated water. This explained the higher reported disease prevalence rates during the rainy periods. In comparison, studies conducted in poor settlements in Bangladesh have revealed that the mortality rate caused by a lack of adequate domestic sewage disposal systems was higher than in rural areas particularly during the rainy season [23].

The most problematic waste disposal practices were observed at household level, with stored in bins or open storage. The majority of households dumped this refuse directly into the rainwater drainage channel and, to a lesser extent, occasionally on streets and open land in the settlements. The large quantity of waste disposed of in the different risk areas, and the large amount of biodegradable organic matter (66.43%) contained in household waste in Abidjan [24] increased the risk of pollution and contamination in this area. Solid waste with a high organic matter content is indeed a favourable environment for the development of germs and insects, and for transporting helminth eggs [25]. In addition decomposing organic matter attracts predators, which in turn could increase contamination. Consequently, household waste has to be efficiently managed to reduce environmental and health risks incurred by the residents [19].

The rainwater drainage channel in the underprivileged settlements acted as a transit area for sewage, greywater and household solid waste. However, even though quantities decreased during certain periods of the year, the constant presence of these elements posed a potential contamination risk. According to Gulis et al. [26], most informal settlements of Nairobi, Kenya, generally discharge their liquid and solid

waste in the drainage channels. In these marginalised areas, the infection rates remain very high, with regular risks of epidemics – a situation similar to the one observed in the investigated area regularly struck by increases of communicable diseases during the rainy seasons that exceed what is commonly known for Côte d'Ivoire [27]. The reported disease rates found in this study was higher and occasionally almost double the rates obtained by certain studies previously conducted in the informal settlements of Yopougon [28]. The underprivileged settlements was thus the most vulnerable; as the results of the present study have shown, this was most likely linked to the inadequate sanitation practices, thus confirming findings in other recent studies in comparable settings [29, 30]

Though the burden of disease resulting from inadequate water quality, sanitation practices and hygiene is high, there is unfortunately still quite a limited understanding of how to integrate environmental control strategies. The health benefits of providing safe water depend on sanitation and hygiene conditions and thus interventions could not be assessed as a single entity [31-36]. On the basis of this idea, strategies for mitigating the water, waste management and health problems in these poor areas were developed during a participatory workshop integrating the three components – water, sanitation and hygiene. But development of sustainable solutions presupposes that the beneficiary populations is motivated and have a genuine willingness to implement the proposed sanitation system in their neighbourhoods. A system based on the need of the populations is only sustainable if the needs correspond to the demand and willingness of these populations to help implement the improvements. Strong involvement of the population in the implementation of solutions identified in the concerted participatory workshop, was a basis for guaranteeing sustainable management of a systemic approach needed in this case as it looked at the whole structure of systems that input upon an issue. The beneficiaries are generally not invited to participate in the design and planning phases of any waste collection and disposal system and thus their motivation remains difficult to ensure [20]. The present study contributed to finding concerted solutions to mitigate the risks of diseases in the underprivileged settlements, as possible solutions were developed by the residents themselves and discussed in an active participation of the beneficiaries. The perceptions and behaviours of the population involved were shown to be a key factor influencing the success of interventions [37]. Consequently, we remain confident that if implemented, the solutions will lead to a significant and sustainable improvement of the health of people in the area, since they include the concepts of integrated water, sanitation and hygiene health education [38, 39].

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REFERENCES

- [1] B. Dzwayiro, Z. Hoko, D. Love & E. Guzha, Assessment of the impacts of pit latrines on groundwater quality in rural areas: A case study from Marondera district, Zimbabwe. *Physics and Chemistry of the Earth, Parts A/B/C* 31(15-16) (2006), pp.779-788.
- [2] K.-M. Kapepula, G. Colson, K. Sabri, P. Thonart, A Multiple Criteria Analysis for Household Solid Waste Management in the Urban Community of Dakar. *Waste Management* 27 (2007), pp.1690-1705.
- [3] C. M. N. Souza, C. M. De Freitas, L. R. S. Moraes, Discourses on Sanitation-Health-Environment Relationship in the Legislation: An Analysis of Concepts and Lines of Direction, *Eng. Sanit. Ambient.* 12 (4) (2007), pp. 371-379.
- [4] M. Kosek, C. Bern, R. L. Guerrant, The Global Burden of Diarrhoeal Disease, as Estimated from Studies Published between 1992 and 2000. *Bull. of the WHO* 81 (2003), pp.197-204.
- [5] T. Clasen, J. Brown, O. Suntuira, S. Collin, Safe Household Water Treatment and Storage Using Ceramic Drip Filters: A Randomised Controlled Trial in Bolivia. *Wat. Sci. & Tech.* 50 (2004), pp. 111-115.
- [6] D. Cutler and G. Miller, The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States. *Demography* 42 (2005), pp.1-22.
- [7] WHO. Water, Sanitation and Hygiene Links to Health Facts and Figures – updated November 2004. *Water Sanitation and Health (WSH)* (2004), Vol. 2005.
- [8] A. O. Afon, and A. Okewole, Estimating the Quantity of Solid Waste Generation in Oyo, Nigeria. *Waste Management and Research* 25 (2007), pp.371-379.
- [9] J.-E. Hardoy, D. Mitli, D. Satterthwaite, Environmental Problems in an Urbanizing World - Finding Solutions for Cities in Africa, Asia and Latin America. Earthscan publications LTD: London 15 (2001)
- [10] K. Boadi, M. Kuitunen, K. Raheem, K. Hanninen, Urbanisation without Development: Environmental and Health Implications in African Cities. *Environment, Development and Sustainability* 7 (2005), pp. 465-500.
- [11] F. Akindès, Cote d'Ivoire: Socio-political crisis, "Ivoirite" and the course of history, in: *African Sociological Review* 7(2) (2003), pp. 11-28.
- [12] K. E. Sawaya, L. G. Olmanson, N. J. Heinert, Extending Satellite Remote Sensing to Local Scales: Land and Water Resource Monitoring Using High-Resolution Imagery. *Remote Sensing of Environment* 88 (2003), pp.144-156.
- [13] D. Stow, A. Lopez, C. Lippitt, S. Hinton, J. Weeks, Object-Based Classification of Residential Land Use within Accra, Ghana Based on Quickbird Satellite Data. *International Journal of Remote Sensing* 28 (2007), pp. 5167-5173.
- [14] R. Haydn, G. W. Dalke, J. Henkel, J. E. Bare, In *Int. Symp. Remote Sensing of Arid and Semi-arid Lands*, Cairo, Egypt (1982), pp. 599-616.
- [15] R. McNamee, Efficiency of Two-Phase Designs for Prevalence Estimation. *International Journal of Epidemiology* 32 (2003), pp. 1072-1078.
- [16] F. S. Makoni, J. Ndamba, P. A.Mbati, G. Manase, Impact of Waste Disposal on Health of a Poor Urban Community in Zimbabwe. *East African Medical Journal* 81 (2004), pp.422-426.
- [17] O. Boiral, Tacit Knowledge and Environmental Management Long Range Planning 35 (2002), pp.291-317.
- [18] H. Francos; and M. Bituro. Innovative Way for Solid Waste Management in Dar-es-Salaam: Toward Stakeholder Partnerships. *Habitat International* 23 (1999), pp.351- 361.
- [19] F. Richard, A. Weitz, Public-Private Community Partnerships in Infrastructure for the Poor. *Journal of International Development* 15 (2003), pp.1083 - 1098.
- [20] F. N.Addo-Yobo, A. Mensor, Households: Passive Users or Active Managers? The Case of Solid Waste Management in Accra, Ghana. *International Development Planning Review* 35 (2003), pp.373-390.
- [21] S. M. Kassim, M. Ali, Solid Waste Collection by the Private Sector: Households' Perspective – Findings from a Study in Dar-es-Salaam City, Tanzania. *Habitat International* 30 (2006), pp. 769-780.
- [22] I. K. Osumanu, Environmental Concerns of Poor Households in Low-Income Cities: The Case of the Tamale Metropolis, Ghana. *GeoJournal* 68 (2007), pp.343-355.
- [23] A. M. Wright, Ed. *Toward a Strategic Sanitation Approach: Improving the Sustainability of Urban Sanitation in Developing Countries.* International Bank for Reconstruction and Development/The World Bank: 1818 H Street NW Washington, DC 20433, 1997. 41p.
- [24] Y. Sané, La Gestion des Déchets à Abidjan: Un Problème Récurrent et Apparemment sans Solution. *A J E AM* 4 (2002), pp.13-22.
- [25] J. Stern, D. Southgate, J. Strasma, Improving Garbage Collection in Latin America's Slums: Some Lessons from Machala, Ecuador. *Resources, Conservation and Recycling* 20 (1997), pp. 219-224.
- [26] G. Gulis.; J. A. A. Mulumba, O.Juma, B. Kakosova, Health Status of People of Slums in Nairobi, Kenya. *Environmental Research* 96 (2004), pp 219-227.
- [27] PNLN "Programme Nationale de Lutte contre le Paludisme. Rapports Annuel d'Activité 2001, 2002, 2003," Institut National d'Hygiène Publique (INHP) (2003) 43p.
- [28] N. S. Dagnan, A. B. Kone, I.Tjembe, K. D. Ekra, V. J.Benié, M. Ndoutabe, J. Tagliante-Saracino, Étude de la Prévalence du Paludisme dans la Commune de Yopougon, Abidjan, Côte D'ivoire. *Médecine d'Afrique Noire* 49 (2002), pp.507- 510.
- [29] S. R. Doe, M. S. Khan, The Boundaries and Limits of Community Management: Lessons from the Water Sector in Ghana. *Community Development Journal* 39 (2004), pp.360-371.
- [30] K. O. Boadi, M. Kuitunen, Environment, Wealth, Inequality and the Burden of Disease in the Accra Metropolitan Area, Ghana. *International Journal of Environmental Health Research* 15 (2005), pp.193-206.
- [31] E. Sinanovic.; S.Mbatsha.; S.Gundry, J. Wright, C. Rehnberg, Water and Sanitation Policies for Improving Health in South Africa: Overcoming the Institutional Legacy of Apartheid. *Water Policy* 7 (2005), pp.627-642.
- [32] J. N. S. Eisenberg, J. C. Scott, T. Porco, Integrating Disease Control Strategies: Balancing Water Sanitation and Hygiene Interventions to Reduce Diarrhoeal Disease Burden. *American Journal of Public Health* 97 (2007), pp. 846-852.
- [33] L. Fewtrell, J. J. M. Colford, Water, Sanitation and Hygiene in Developing Countries: Interventions and Diarrhoea – A Review. *Water Science and Technology* 52 (2005), pp.133-142.
- [34] S. O'Hara, T. Hannan, M. Genina, Assessing Access to Safe Water and Monitoring Progress on Mdg 7 Target 10 (Access to Safe Water and Basic Sanitation): Lessons from Kazakhstan. *Water Policy* 10 (2008), pp.1-24.
- [35] M. A. Montgomery, M. Elimelech, Water and Sanitation in Developing Countries: Including Health in the Equation – Millions Suffer from Preventable Illnesses and Die Every Year. *Environ. Sc & Tech* 41 (2007), pp.17-24.
- [36] J.N.S. Eisenberg, J.C. Scott, T. Porco, Integrating disease control strategies: Balancing water sanitation and hygiene interventions to reduce diarrheal disease burden *American Journal of Public Health* 97 (5) (2007), pp.846-852
- [37] M. Ezzati, J. Utzinger, S. Cairncross, A. J. Cohen, B. H. Singer, Environmental Risks in the Developing World: Exposure Indicators for Evaluating Interventions, Programmes, and Policies. *Journal of Epidemiology and Community Health* 59 (2005), pp.15-22.
- [38] A. M. Metwally, A. Saad, N. A. Ibrahim, H. M. Emam, L. A. El-Etreby, Monitoring Progress of the Role of Integration of Environmental Health Education with Water and Sanitation Services in Changing Community Behaviours. *International Journal of Environmental Health Research* 17 (2007), pp 61-74.
- [39] V. E. Manga, O. T. Forton, A. D. Read, Waste Management in Cameroon: A New Policy Perspective? *Resources, Conservation and Recycling* 52 (2008), pp.592-600.