Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2013.822148

52 (2014) 6050–6057
September

Taylor & Francis
Taylor & Francis Group

Wastewater management in informal settlements: a case study from Algiers

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Received 11 October 2012; Accepted 27 May 2013

ABSTRACT

Algiers has faced flashing urban growth during last three decades. The settlements associated with al-Harrash River became a center of discussion since water scarcity, surface and groundwater contamination and flooding threatened its habitat. The expansion of settlements are causing heavy toll on public hygiene and sanitation, which virtually leads into a diffusing urban insalubrity. We hypothesize that water related pathologies seem insurmountable and wastewater system is inefficient to cater adequate public health, personnel security and wellbeing of the city dweller. The Trois Caves informal settlement within the municipality of Al-Harrash from Algiers was selected to test this hypothesis. The study adapts a wastewater management's multicriteria analysis with respect to the urban water cycle management strategy. The cumulative sum of their performance indices has been formulated after three mean values designating efficiency, profitability and sustainability closely associated to the sustainable development strategy. The scores obtained revealed that only the collecting operation presents a comparative efficiency.

Keywords: Algiers; Informal settlement; Multicriteria analysis; Wastewater management

1. Introduction

Algiers has faced with flashing urban growth due to informal settlement proliferation within the surrounding urban areas. This practice has generated precarious, poor and insalubrious urban dwellers who are considered as a source of many social ills. This situation is causing heavy toll on public hygiene, which virtually leads into a diffused and aggravated urban insalubrities. We hypothesize that water related pathologies seem insurmountable and wastewater system is inefficient to cater adequate public health personnel security and wellbeing of the city dweller. The Trois Caves informal settlement within the municipality of Al-Harrash from Algiers was selected to test this as a probative case study.

During the past three decades, increasing frequency of natural hazards due to climatic events was observed in many urban areas including the city of Algiers. The study area is located within the western plain of Algiers in a coastal wetland crossed by al-Harrash River. It has been threatened by many water

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related hazards such as scarcity, flooding, and surface and groundwater contamination.[1] One could observe a high level of pollution causing heavy toll on public hygiene where it virtually leads into a diffusing urban insalubrity with regard to commodities and quality of life. This situation is similar to problems faced in rural areas rather than the problems faced by urban density or land use patterns.

If immediate actions are not taken, one could anticipate dangerous levels of increase in the surface and groundwater contamination. Since the western plain is still the main water source for the city, water scarcity can cause severe aquatic and environmental degradation, which subsequently infests the community with water related diseases. Therefore, one needs to take actions to prevent high population density, remedy dilapidated buildings, minimize polluting rivers and exploit inadequate land use in such poor districts before the problem gets aggravated.

At present, the question is whether the sewage network is structurally insufficient, or mismanaged by the current system or both? To answer this question, we adapt a wastewater management's multicriteria analysis and asses its performance to identify gaps related to water urban cycle management strategy (WUCMS). The WUCMS is based on five successive operating steps viz: collecting, draining, cleansing, transferring to the natural environment and/or reusing. The cumulative sums are formulated for each objective after three mean values designating efficiency, profitability and sustainability [1].

2. Case study

Al-Harrash coastal municipality is situated in southern half of the capital Algiers, close to the mouth of Al-Harrash River. The municipality is about twenty kilometers from the downtown. General latitude and the longitude are 36°43′16.46′′ N and 3°8′14.68′′ E respectively. Historically, the plain had been the rural hinterland providing vegetables and water for irrigation and drinking before transforming into a modern urban land [2].

It was selected due to its pertinence on the current sociotechnical environment. Since Algeria was classified amongst water stress countries,[2] the current national strategy aims at regularizing the precarious habitats and hydraulic systems, planning of the river bank, implementing the great urban transport projects and preserving water and environment program.

Recent studies revealed critical vulnerability issues facing with natural risks and more specifically water related risks. Considering such situations, the Al-Harrash coastal municipality paved a strong platform for the present study [3] (Fig. 1).

The municipality faced with several aggravating issues such as proliferation of precarious habitats and insufficient wastewater discharge system, which could threat public health, security and wellbeing. Today it counts around 51,000 inhabitants living in 942 ha. and 98% of them are connected to the sewage network [4]. In addition, about 9% are decrepit, whilst 9.6% are agglomerated within numerous dense precarious districts located in the downtown or along the riverbanks.

Compared with meridional zone, the central northern area of the municipality has more population and allotted with regular sewage network, whereas the Southern zone appears to have unplanned connections. Except for the industrial zone, which was created before the Algerian independency (in 1962), the urban development of the southern zone was accelerated after 1980s sociopolitical upheaval. The Trois Caves located on the riverbanks between Al-Harrash and Smar Rivers was divided by the local authority in 1987, in order to station refugee influx coming as victims of terrorism from the surrounding cities. The development process of twenty four precarious settlements provides evidence of inadequate governance practice [5]. Even at present, additional population influx as initiated by such an auto-construction is waiting for proper facilities and an extension of the water network (Fig. 2).

[1]Bureau d'Hygiène Communale (Public Hygiene Local Office), 2011.

[2]The plain has been urbanized at the beginning of the XIXth century. The French colonizing villages could be settled thanks to a large marshland draining operation. Since then, al-Harrash municipality, that was named Maison Carrée, has been regularly exposed to flood hazards threatening inhabitants, buildings and economic activities. Later, many factories and workshops have been built close by banks initiating the river's pollution that is still going on today. Such a degraded urban environment has attracted and still does informal settlements that have never really beneficiated of urban commodities. In fact, within some districts, the wastewater threat seriously menaces the public health and the environment salubrity (Aroua and Berezowska-Azzag [2]).

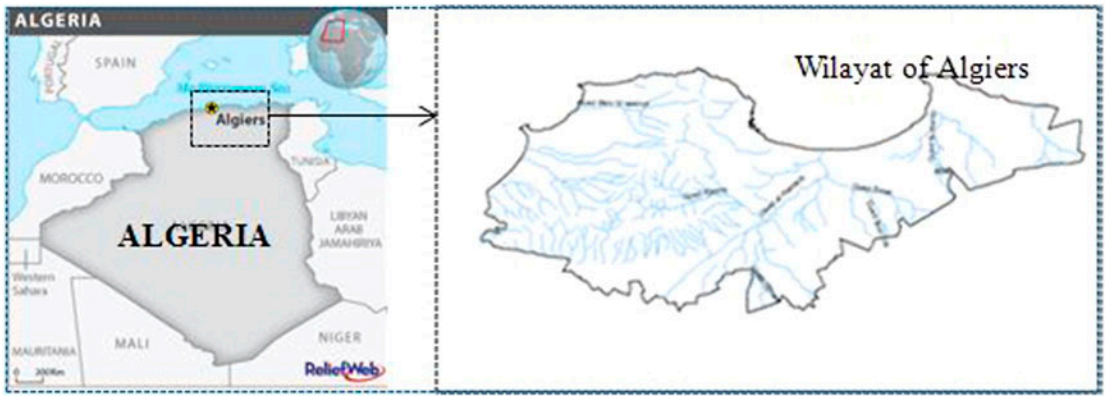

Fig. 1. Al-Harrash municipality in the western costal wetland of Algiers (modified after [6]).

The area has a Mediterranean moderate climate with two main unequal seasons viz: rainy and wet seasons from September to May (9 months), while dry and hot seasons from June to August (3 months), (Al-Harrash Municipality, 2011). The first rain showers generally fall between September and November while the last usually falls in April-May. The cumulative daily rainfall increases in September, and then diminishes slowly between January and June.

Referring to the rainstorms causing floods (>30 mm/24 h), only four months from June to September do not present any risk due to river or sewage network overflow. However, exceptions could have been observed during some summer storms in August. Thus, even if the rainfall events are short and not frequent, they still could be intense during eight months between October and May. This scenario pretends that the expected flash flooding could cause notable human and material damages, especially along with the river banks.

Al-Harrash River divides the plains into two sub-plains: the western marsh (0–50 masl) and the eastern hills (50–250 masl). The municipality is mainly located on the right (left?) bank. With regard to its flat topography and the presence of alluvial soils, the study area is enclosed within a flooded perimeter. Even the Water Departmental Office has reserved a belt for 30 m, some houses are violated this restriction and extended over the banks within the river ramps.

The «Trois caves» lot is located by southwestern segment of the municipality and occupy 75 ha. Northern and eastern segments are delimited by the al-Harrash River and its tributary, the Adda River. The southern and western segments are encircled by the departmental road n°115 and the southern highway. It is composed of five registered plots with 9,156 inhabitants (in 1998).[3] It is expected that the population will be doubled by 2010. Even though the lot is enclosed by a large Hospital and the police headquarters new construction plots are generated from regular and illegal division. An investigation conducted about ten years ago revealed urgent requirements to improve the public lighting system and infrastructure. This is to provide secure conditions to houses and open spaces as well as to improve water supply and sanitation services respectively.

Other than some minor improvements in the public works, living conditions are quite similar as in the past. The reason is that the subsidized departmental budget has used to renovate the city market with building more than fifty shops in the "Trois Caves" district. Subsequently the local budget was consecrated to restore the municipal road network. Recent local development programs (in 2011) mainly involved with road and wastewater sectors. Obviously, the hygiene and sanitary issues constitute an urgent local priority. In addition, the sewage network inspection reveals an overall defective state due to the low

[3]Average of temperature = 10.5°C/ winter; 24.2°C/ summer. Average annual rainfall = 672 mm/year.

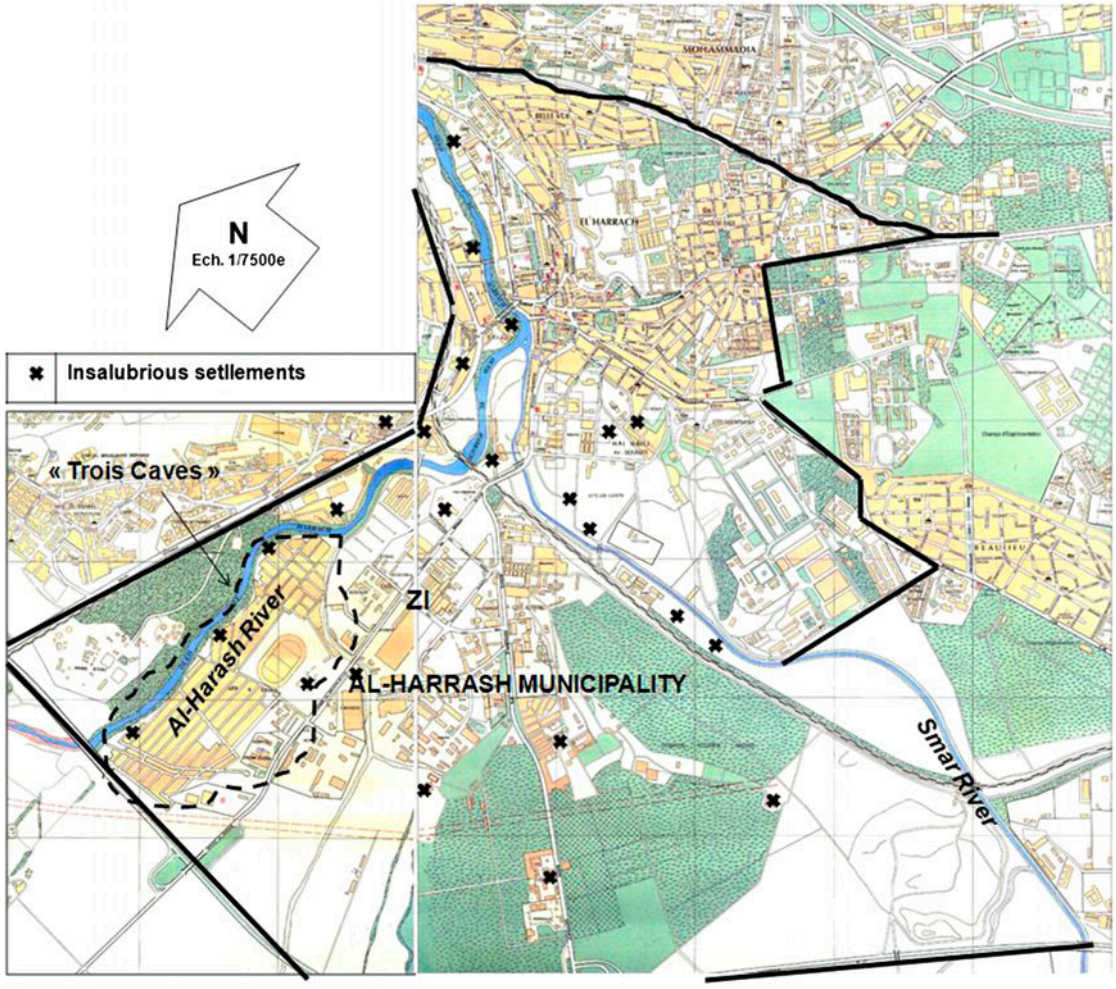

Fig. 2. Localization of insalubrious quarters in Al-Harrash Municipality (after Al-Harrash Municipality urban development office, 2011).

performance of the main treatment station located in the bordering municipality of Baraki.[4,5]

Since its commission, the station has frequently being out of order for different reasons, several such reasons are silting up, malfunctioning equipment and malevolence actions, which led to partial treatment of urban wastewater. In the worst-case scenario, the wastewater directly discharged into the Al-Harrash River, there again will increase harmful chemicals and organic products to a dangerous level.

In addition to wastewater from Blida in upstream, the river receives both domestic and industrial wastewaters from fifty other municipalities occupying 2 million inhabitants. The volume then discharged gives rise to the low sweetening capacity. After the Water Resources National Agency directive was introduced, the wastewater must be treated before any use. In the European standards, any use of wastewater is forbidden if the toxicity surpasses the maximum threshold level, presenting a serious menace for the public health and the environmental balance [6].

Besides, wastewater generated by the municipalities located beyond the station and below its ground level require additional pumping. However, when

[4]Quartier les Trois caves. Commune d'el-Harrach. Opération de restructuration. Phase 01, Ministère de l'habitat, Direction de l'aménagement du territoire, de l'urbanisme, de la prévention et de la résorption de l'habitat précaire de la wilaya d'Alger. *Actualisation du schéma directeur d'assainissement de la Wilaya d'Alger, Phase A1—Etat des lieux—Recueil de données, Rapport de synthèse*, Société des Eaux et de l'Assainissement d'Alger, Août 2008, 136p.

[5]The station initially provided a capacity of 900 000 eg/inhab.

Table 1
Wastewater treatment steps

Management step	Description
Collecting	Private arrangement; without any administrative or technical control
Draining	Drain directly to the river Or: Across illegal connections to the public network
Sweetening	If drained; partly treated in the regional station
Transferring back to the river	Directly from the station or draining through pipes
Reusing	Currently not being adopted

these pumps are out of order, wastewater directly discharge into the river. Such situations create a nauseous condition, which calls upon immediate actions to safeguard this famous river. As summarized in Table 1, one could realize that different processes were inadequately developed within the Trois Caves insalubrious settlement.

Therefore, the municipality has to break conventional sanitation models and introduce sustainable structural or ad hoc measures considering wastewater as a resource than a risk. Meeting such strategy needs organized actions, which categorized into sector, location, cost and timing. Especially, for developing countries, where human and material means are limited, actions should be prioritized to ensure timely realization of main goals. We are aware of what to implement under current situation. Therefore, we should well manage how to get the optimum output through best-adapted practices. The wastewater management multicriteria analysis can be effectively and efficiently used for such management.

3. Multicriteria analysis

The purpose of wastewater management multicriteria analysis is to classify five successive process performance indices and subsequently orientating the strategy towards different development plan and term horizons. Referring to the Integrated Water Cycle Management concept (IWCM),[6] we have defined the wastewater management system over following five steps: *collecting, draining, purifying, transferring back* and *reusing*. Indeed, similar water technologies combining engineering practices and policy decisions are already in use in several developed countries such as France, Belgium and USA. They also contributed significantly to deal with scarcity [7]. Moreover, principles lined up with the water resources, sustainable strategy and the ecohydrology favored global water cycle as a framework concept. In addition, the catchment could be considered as an analytic tool in spatial scale and in the long run as a timing horizon [8–10]. The integrated water cycle management also considered the whole water users, including natural environment, within the urban ecosystem (http://www.Aqueduc.info).

The multicriteria analysis can be used to identify different sources and kind of wastewater related threats facing the area. Subsequently the criteria can be used to assess the local management system as per the notations defined (Table 2). The score is given to assess the performance of the wastewater system through its strategic, regulative and operating tools. With the best-case scenario, the presence of improving measures guarantees the resilience objective so that the system obtains 5 points. On the contrary, with the worst-case scenario, the existing law cannot be applied, so that the system obtains only 1 point.

The multicriteria analysis is based on the following values and scores as shown on Table 3.

The performance of each tool is evaluated according to the sum of the five steps' corresponding scores (Table 4).

4. Results and discussion

Referring to integrated wastewater management system, one can observe that the chain is defective, at the cleaning step. The relative performance level must be complied with the real situation as observed *in situ* in order to understand how some steps could be (or not) compromised by the social behaviors, inadequate planning strategy and/or development programs. Within vulnerable areas, inhabitants tend to connect their private sewage pipes to the public network without considering its bearing capacity. The only governmental actions conducted were pinpointing such problems and taking ad hoc measures such as extending or enlarging the pipe network. Table 4 assesses the impact of such ad hoc measures except the first and second steps where legal and planning tools achieve high scores. It also indicates that the wastewater system is quite inadequate; however, the collection seems comparatively efficient due to the public network restoration. On the other hand, the purifying process needs to be improved with sustainable tech-

[6]IWCM concept has been widely diffused by the *International Conference* on *Water* and the *Environment* in *Dublin*, Ireland, on January 26-31, 1992.

Table 2
Notation scale

Score	Performance criteria	Causes and/or consequences
5	Measures exist and improve the local resilience	Resilience objectives are met
4	Sustainable measures exist but insufficient or not applied	Mismanagement + Lack of material or human means
3	Efficient measures exist but only attenuate the effects	Only technical means are available
2	Efficient measures exist but insufficient or not applied	Lack of material or human means
1	Sustainable strategy exists but not applied	Neither regular nor operational tools exist

Table 3
Performance score based on multicriteria analysis

Performance criteria and horizon	Objective	Performance score interval
Short term efficiency	Attenuating the effects	$5 < P \leqslant 11$
Medium term sustainability	Mitigating the causes	$11 < P \leqslant 18$
Long term resiliency	Taking advantage from the wastewater	$18 < P \leqslant 25$

nologies. The transferring and reusing steps display low-level scores, as they do not result from a rational strategy (Fig. 3).

Based on the information provided by the local water office, neither the municipality nor the lot area study seems to be able to face an extreme rainfall event. In spite of a renewed sewage network, the added volumes discharging from informal settlements, could not cope up with the situation. As a result, the public hygiene service could not apprehend an epidemic may quickly propagate within such an insalubrious environment. Considering specific nature of these challenges, the situation calls upon flexible adaptation measures sustained by an appropriate development strategy and governance.

In this respect, the sewage network efficiency should decrease due to the high number of habitations connected. In addition, the unitary collecting system has only 40 cm diameter pipes where domestic wastewater discharges meeting with industrials rejections, storm waters and solid organic wastes (Al-Harrash Municipality, 2011).

Along the river, collection pipes intercept with the rainwater through storm outfall. In the case of a high frequency rain event, the excess volume will directly discharge into the natural environment. At present, the Trois Caves lot and the Industrial Zone do not have any transferring collector so that the wastewater discharges directly into the river aggravating pollution, overflow and flood risks. On the other hand, during drought periods, the concentrated contaminants and the wastewater discharge could cause unbearable living conditions.

Besides, Al-Harrash River receives wastewaters from seven bordering municipalities.[7] In these zones, conveying systems may be in a critical state and partially silted up. Meanwhile, for the Water Subdivision Office, the Trois Caves lot remains a worrying problem due to flood prone risks. As a result, Public Health and Urbanism officers discussed and concentrated on matters related to insalubrity and precariousness in Al-Harrash municipality and called upon an urgent departmental support.

5. Conclusion

With regard to the resilience objectives, we conclude with the following outcome:

(1) Though the decision making process has been referred in official texts and manuals, the wastewater management system remains quite inefficient.
(2) This especially concerns the steps 3 and 4 below, whereas the reusing program seems to be out of order.
(3) Identified gaps seem to be related to the deficiency or non-application of strategic and operational existing tools.
(4) The performance related indices only designate a short term security.

Such an efficient overall strategy would result in notable ecological, environmental and urban benefits due to restoring the river system, improving the pub-

[7]Kouba, Bach Djerrah et Magharia, Mohammadia, Hussein Dey, Bourouba, Gué de Constantine.

Table 4
Performance score and indices in the case study

Strategic tools		The wastewater disharging system in five steps					Tool's performance score (TPS)/25)	Tool's performance index (TPI)
		Colleting	Draining	Sweetening	Transferring back to the river	Reusing		
		S1	S2	S3	S4	S5		
Legal tools	T1	4	4	2	4	1	15	*0.60*
Planing tools	T2	4	4	4	2	1	16	*0.64*
Management process	T3	3	2	2	2	1	10	*0.40*
Techical means	T4	3	2	3	2	1	11	*0.44*
Step's performance score (SPS/25)		14	12	11	10	04		
Step's performance index (SPI)		*0.56*	*0.48*	*0.44*	*0.40*	*0.16*		

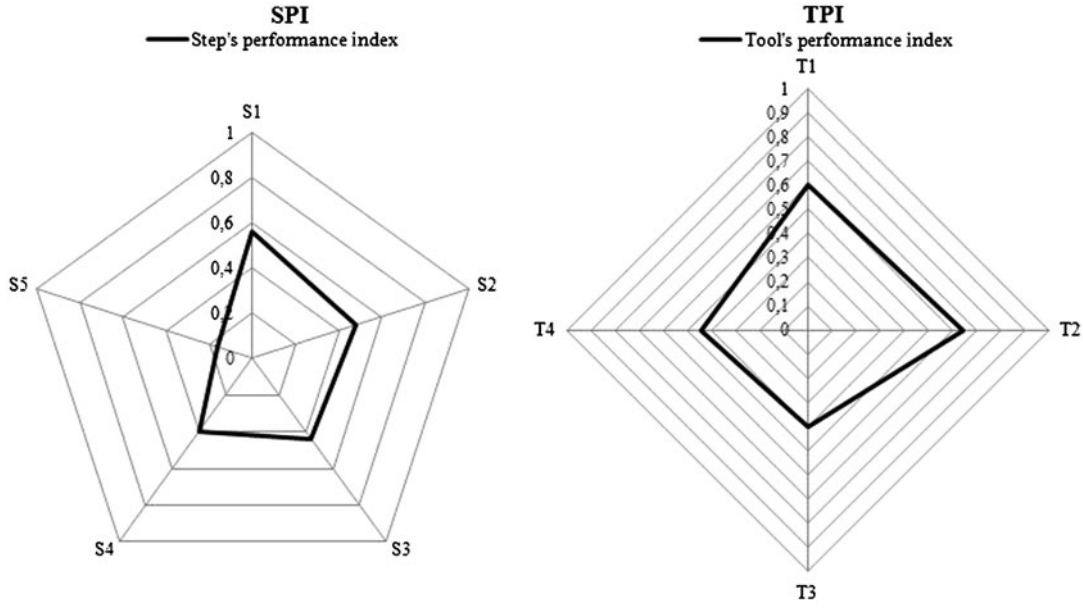

Fig. 3. Radars of performance score and index in the case study.

lic hygiene and reducing water related risks [11,12]. After diagnosis based on local wastewater management, we are arguing over, several deficiencies that cannot be acceptable within the urban area with respect to the public health, security and environmental standards. Even if some of these measures are efficient and profitable in the short term, they cannot give a guaranty to the population or to the environment security by the long run.

Al-Harrash municipality seems more vulnerable to face with water related risks and specifically to the surface and groundwater contamination. Even the problem in hand become familiar, it is only considered as a distant threat till today, though it is managed by the technical office rather than the city planning department or within a local development strategy. From the above discussions, following conclusions can be drawn.

- From the wastewater strategy point of view, there is a dire need for improving the management process with low impact technologies.[8,9]
- From the urban planning strategy point of view, water sensitive urban design may be effectively used for public hygiene and water circulation.[10,11]

Water related risks threatening the Al-Harrash municipality in Algiers could affect wider regional catchment. In addition, the municipality is facing several challenges over its administrative boundaries. The municipality needs to look after regional measures resulting from a common adaptive strategy between up and down stream areas in order to reduce or eliminate internal and external causes of the danger. Current urban projects should explore readily available local opportunities.

References

[1] C. s/d Maksimovic, J.-A. Tejada-Guibert, P.-A. Roche, Nouvelles frontières de la gestion urbaine de l'eau, Impasse ou espoir? [Frontiers in urban water management. Deadlock or hope]. UNESCO-PHI, Presses de l'école nationale des Ponts et Chaussées) 2001, 443p.
[2] N. Aroua, E. Berezowska-Azzag, Peuplement de la Plaine orientale d'Alger, urbanisation ou vulnérabilisation ? [The populating of Algiers western plain. Urban development or vulnerability increasing?] IIIè Colloque International du Groupe d'Histoire des Zones Humides, Zones humides et villes d'hier et d'aujourd'hui: des premières cités aux fronts d'eau contemporains. Faculté des Lettres, Langues, Arts et Sciences Humaines Université de Valenciennes et du Hainaut-Cambrésis. Campus Mont Houy-Bâtiment Matisse.
[3] N. Aroua, E. Berezowska-Azzag, Urban vulnerability and resiliency variabilities over water related risks in Algiers. A case study from Al-Harrash municipality. 5th International Conference on Flood Management (ICFM5) September 27–29, 2011, Japan. Available from: http://www.ifi-home.info/icfm-icharm/icfm5.html (Accessed from 05.11.11).
[4] Al-Harrash municipality, Monograpie 2009 (Monography 2009).
[5] Al-Harrash municipality, Urban planning office, 2011.
[6] Water resources national agency, www.anrh.dz.
[7] N. Aroua, Facteurs de vulnerabilite et capacite de resilience du milieu urbain face aux risques hydro climatiques dans la commune algeroise d'el Harrach, Thesis, Polytechnic School of Architecture and Urbanism, Algiers, 2012, 327p.
[8] Aldana Valverde, Understanding the hydrological cycle: Key to sustainable development, WMO Bull. 57(3) (2008) 170–172.
[9] A. Chanan, P. Woods, Introducing total water cycle management in Sydney: A Kogarah Council initiative, IN International Conference on Integrated Concepts on Water Recycling, Wollongong, Australia, February 14–17, 2005.
[10] M. Felkenmark, J. Rockstrom, Balancing Water for Humans and Nature. The New Approach in Echohydrology, Earthscan, London, 2004, 247p.
[11] H. Langenbach, W. Holste, J. Eckart, Theses for the Future of Water Sensitive Urban Design (WSUD), First SWITCH Scientific Meeting, University of Birmingham, Birmingham, 2006.
[12] T. Gardner, H. Gibson, G. Carlin, A. Vieritz, Water Sensitive Design to Reduce the Ecological Footprint of Urban Development, Queensland Department of Natural Resources, Birsbane, 2000.

[8]*Low-Impact Development Hydrologic Analysis*, Prince George's County, Maryland, Dept of environmental resources, Programs and Planning division, July 1999, 45p.
[9]Algerian Water Resources Ministry, www.mre.dz
[10]*The Water Urban Sensitive Design* (WSUD) is the principle created out of necessity to answering the increasing water demand and the lancinating drought systematically followed by an important rainfall and flooding events. The main objective of WSUD consists in protecting the global cycle and quality of water, favoring the reusing of storm waters, reducing the flooding and contamination risk, minimizing the sanitation infrastructure cost.
[11]Direction de l'Hydraulique de la Wilaya d'Alger (Water Departmental Office), Subdivision d'al-Harrash (Water Local Office), 2011.