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Study about Water Sensitive Urban Design Mechanisms; with an Emphasis on Technologies for the Sustainable Management of Stormwater

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Abstract

Unsustainable growth of cities and creation a set of contiguous impervious surfaces have result on disorder of natural cycle of water in urban environments. This situation causes flooding and problems due it, pollution of groundwater resources and degrade the quality of the urban landscape by increase the speed, volume and frequency period of runoffs. conventional methods about the stormwater management have failed to demonstrate their effectiveness in this field. Thus, in recent years a new topic are created in the field of urban design that known as "water sensitive urban design". Water Sensitive Urban Design (short: WSUD) is the interdisciplinary cooperation of water management, infrastructer engineering, urban design, and landscape designing. WSUD develops integrative strategies for ecological, economical, social, and cultural sustainability.
The purpose of Water Sensitive Urban Design is to combine the demands of sustainable stormwater management with the demands of urban designing, and thus bringing the urban water cycle closer to a natural one. This approach attempts to increase urban sustainability indicators, improve the quality of urban landscape and urban space amenities by offer operational mechanisms in relation to urban design and it attempts not only to close the urban water cycle in its natural cycle and achieve technical goals, but gain optimal utilization of runoff and change the vision of the issue from a threat to a valuable opportunity.The following is a description of some essential methods for sustainable stormwater management. These methods are grouped according to their primary function: water reuse, treatment, detention and infiltration, conveyance, and evapotranspiration. Here is the techniques of water sensitive urban design about stormwater management and link them to urban design concepts, till through that some methods to be introduced that they are more efficient than conventional stormwater management methods about performance, helping to complete the natural cycle of water, environmental sustainability of cities and urban design aspects.

Keywords: water sensitive urban design, stormwater, Retention and infiltration, space amenity, urban landscape

1. Introduction

In recent decades, urban growth, especially in developing societies like the metropolises of our has not been along with growth, particularly in the field of sustainability and environmental sustainability. Cities are made and formed without the side impacts of this type of construction be considered. Some of these side impacts are separation of water cycle chain and its secondary results. These results become apparent when the rate of water infiltration is reached to minimum level, the evaporation is reduced, the flooding flow on site surface and the amount and condensation of impurities due to industrial, commercial and residential sites are increase because the demage to this cycle. This is in addition to the loss of significant volumes of water that have high utilization capability. Some another results of this process is reducing the amount of stored underground aquifers which in

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recent years has been downward. However, the conventional measures to manage runoff have focused on two themes, collected and drained and don't have attention to the retention, increase permeability, treatment and re-use. these measures have no attempt to remove pollutants and have shown their inefficiency in rainy days and floods periods. Therefore, in order to resolve the present problems should be to follow the mechanisms that are efficient and have harmony with the environment in a city context and are responsive to concerns above.

Conventional methods to manage runoff with purely technical nature can not respond to environmental concerns, impacts of the crisis, maximum utilization of the stormwaters and fulfill the urban design requirements. These methods with an emphasis on two major sectors (collect and discharge) virtually no attention to the complete water cycle in urban areas and can not answer to the concerns in this field. In addition to, The conventional methods are unable to manage runoff volume and speed due to urban flooding and make maximum use of it. So, the objective of this study are the introduction of environmentally compatible solutions through water sensitive urban design approach, utilization of their potentials to create urban space and urban amenity, increased the efficiency of surface waters and answers to issues related to the water cycle chain in urban environments.

In this study the main hypothesis is that in comparing between two methods of surface water (runoff) management; the conventional method that pay attention to the issue with a technical and engineering approach and mainly focuses on two aspects of collecting and discharging and water sensitive urban design approach that is the integration of methods and mechanisms of engineering, environmental and urban design, the second approach is a more appropriate way to respond to the concerns. This means that this approach will help to complete the urban water cycle, increase the efficiency of their use by increasing the permeability of underground aquifers supply and at the same time effective guidance of the runoffs and finally these mechanisms lead to create urban amenity.

2. Water cycle situation in cities

The type of waters in the cities include:

- wastewater and greywater managed by urban sanitation systems.
- drinking water for daily use (drinking, cooking).
- stormwater that needs to be drained from hard surfaces (roofs, streets, etc.) to prevent flooding and keep streets and buildings dry and safe.
- Water by natural directly resources.
- and artificial water bodies and features in open spaces contributing to the amenity of cities (improving micro climate, reducing dust and air pollutants, and providing recreation).

Aside from the unique experiences such as floods and droughts, Where the role and importance of water is discovered, there is no general awareness of the functions of water. Conventional methods of water management to help cities to promote the importance of water resources faced with serious challenges [1]. The natural water cycle of evaporation, condensation, precipitation, infiltration, and it can not complete its cycle properly and is often impaired in urban environment due to unsustainable urban construction. Urban waters contain pollutions that can not infiltrate into the ground properly because of the impervious surfaces. it is collected quickly and discharge into the public drainage system and not leave any chance to evaporate.

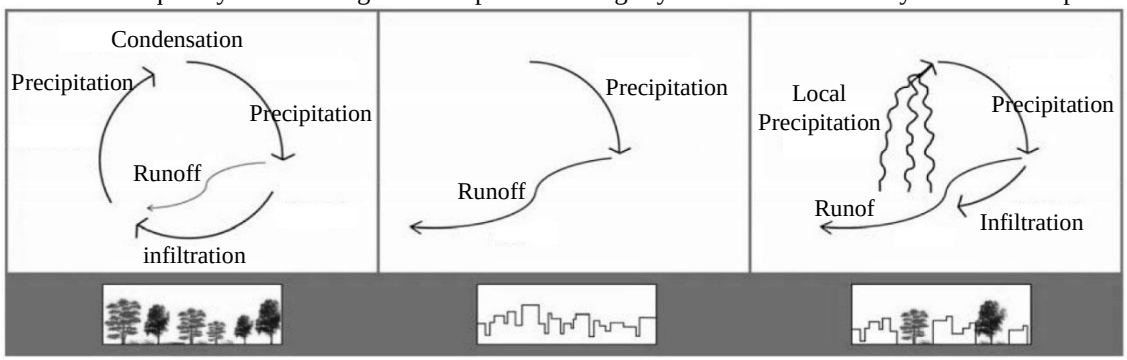

Fig.1. Water cycle in natural systems (left) - the water cycle in an urban area without sustainable management of stormwater (mid) - the water cycle in an urban area of sustainable management f stormwater (right) [1].

The water cycle is vital for the protection of city ecosystems. Effectively management of this process in urban environments requires a coordinated and effective interventions to reconnect this chain. Unsustainable management of runoffs in the cities cause to flooding and provide damages and numerous

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problems in rainy days on the streets surfaces, open spaces, public spaces and even private spaces in some case, in addition to the disruption of the natural water cycle system.

3. Problems in the conventional stormwater management

In natural systems, water from rainfall absorbed into the ground and filtrate by plants and soil. This mechanisms keep the measure of ground water to the acceptable and stable level and reduce the risk of flood. Soil and vegetation act as a sponge to collect and store water that it can control the flow of surface waters. Type of vegetation, soil, topography and land use all of them affects natural water cycle by changes in the frequency, volume and periods of the flows [2].

Conventional stormwater management systems typically have focused runoffs management through the collection and rapid discharge of runoff in rivers and sewage networks and in addition to the lack of supply aquifers and putting it into the natural cycle way, caused floods and lack of control and lack of proper use of water resources in the during of heavy rainfall. Impervious surfaces in urban area as a effective factor, plays a negative role.

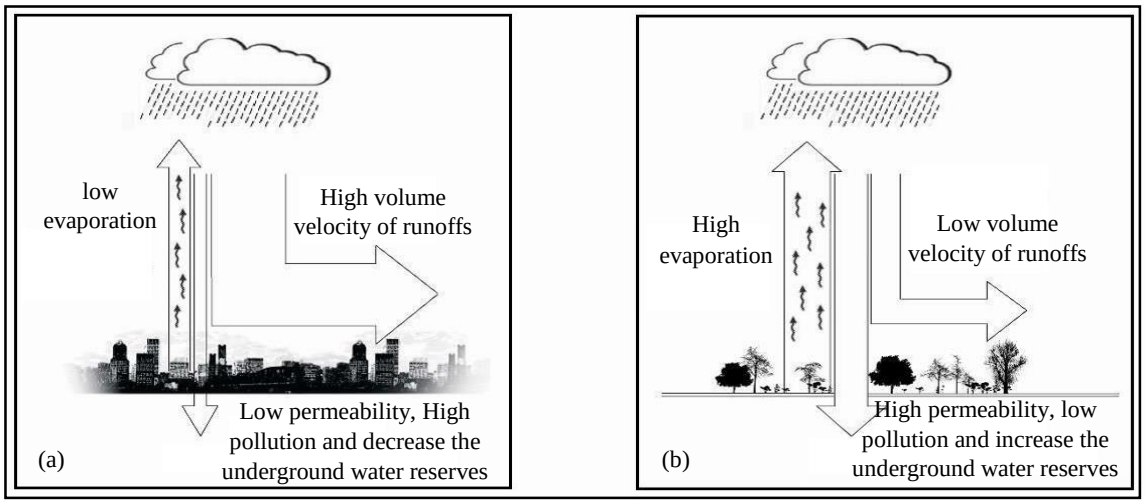

Fig.2. Compare speed, infiltration and evaporation of water in the natural environment (a) and urban areas (b) [1].

4. The introduction of water-sensitive urban design approach

Water Sensitive Urban Design (WSUD) is an approach to land use planning, urban planning and design, infrastructure engineering and environmental engineering that integrated urban water cycle including runoff management, groundwater, wastwater and water supply and storage management. This approach uses from urban design principles to water cycle management and reduce damage to the environment in the cities and by adopting an interdisciplinary collaboration, defines integrated strategies for environmental, economic and social sustainability [3].

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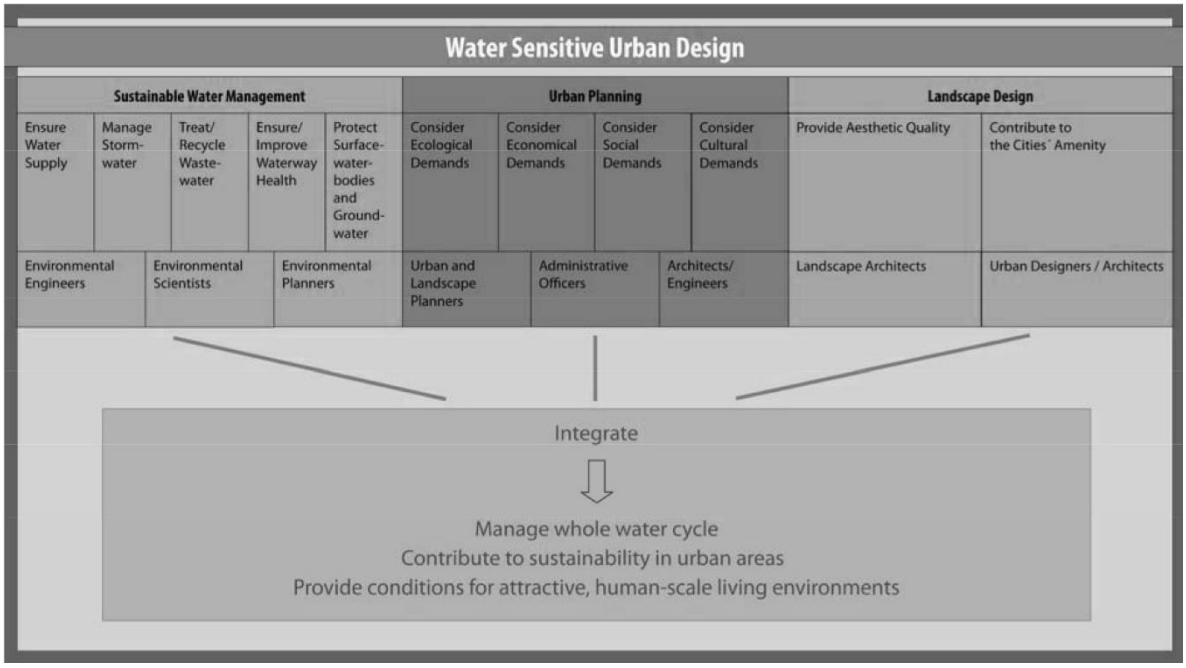

Fig.3. Water sensitive urban design components in terms of structure and nature interdisciplinary cooperation [1].

5. sensitive urban design purposes

The water sensitive urban design purposes is that combine the demands of sustainable management of surface water to the demands of planning and urban design and through that provide a water cycle that is closer to the natural cycle for cities. In fact, WSUD considers all kind of urban water such as (potable water, water for daily use, runoff from rain and storm, Health of Directions channels of water, wastewater, redesign of the water cycle, etc.), but focus on the management of surface water and runoff in the cities [1]. In a general description can be said that the 5 main objectives of water sensitive urban design include:

5.1. Functional aspects

- protection of environmental, economic and social values
- integrated services
- multiple use

5.2. Increasing the quality of the water resources

- reduce pollutants
- maintain the appearance quality
- management of crisis impacts

5.3. Water resources supply aspects

- reduce the demand for water
- replace drinking water
- water recycling

5.4. The quality of runoff

- reduce peak flows
- reduce the frequency
- reduce the volume

5.5. Aesthetics and ecology

- protection of natural drainage systems
- creation of urban spaces amennity and new perspectives
- integration of the built environment and existing landscapes [4].

6. Sustainable management of runoff background

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Issues related to the management of urban water cycle, urban water resources supply and runoff management spread from the mid-90s in developed societies and in the past decade in the field of different policies and programs are implemented in several countries and in this way the concept of sustainable management of surface water has been introduced in these countries. Germany is the first countries that has done a lot of research on sustainable management of stormwaters. In united states, cities such as Portland and Philadelphia have developed local policies and financial programs to support the procedures and technologies of sustainable management of stormwaters [5]. In the UK, legislation and action plans for sustainable management of surface water are passed and implemented [6]. In many cities of the US and Australia, municipalities infirm citizens about the benefits of sustainable management of surface water by use of information technologies and websites. However, we can mention from Australia as a pioneer country that introduced WSUD approach for first time. This country are implemented some action plans about WSUD Since the beginning of this century in cities like Melbourne , Sydney,etc.

7. Water sensitive urban design in comparison with other similar concepts

Water sensitive urban design (WSUD) may be sometimes may confuse with the term "ecologically sustainable development" (ESD) or "water cycle management" (WCM). Although these three terms are closely related but they are different concepts. ESD is anenvironmental component of sustainable development that protect and preserve the environment's processes. Water sensitive urban design as a functional concept of this issue in urban areas placed under the ESD.

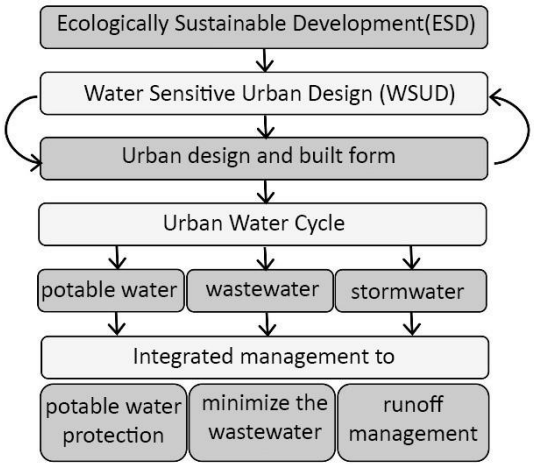

Fig.4. Relationship between ESD, WSUD and water cycle [2].

Water sensitive urban design is considered for integrate and protect from different aspects of urban water cycle. this article has paid to method and precedures of stormwater management and its relation to urban design from 3 fields of WSUD (potable water, wastewater and stormwater).

8. The purposes of sustainable management of runoffs in WSUD

Generally, the purpose of sustainable management of runoff includes:

8-1- protection of natural water systems in urban development.

8-2- Protection of water quality by filtration and retention methods.

8-3- reduce the flow of runoff and the intensity of the peak flow, such as retention and preservation measures in place and minimize the impervious surfaces.

8-4- reduction of drainage infrastructure and the costs associated with it, as well as improving the sustainability and urban spaces amenity.

8-5- Integrated management runoffs flowing through urban landscapes by combining multiple paths that help to increase visual quality and urban spaces amenity.

9. Implementation mechanisms of water sensitive urban design in the management of surface waters

There are several metods and technical solutions to facilitate the management of surface waters. These procedures have been developed as a response to the special needs stormwater management and site conditions , each with unique features, advantages and disadvantages of self. Choose an appropriate metods in this field is very important for the success of any system but there is not a metod as “best practice” necessarily. In fact, the ideal metod is one that is achieved from a combination of several methods according to the conditions and related requirements to the environment [7]. For WSUD an issue that is very important

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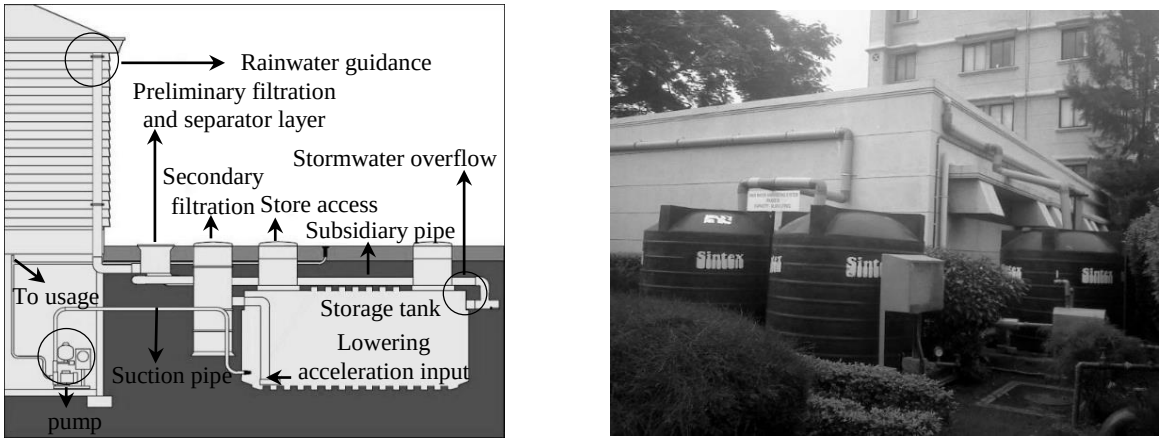
is appropriate integration of practices and type of landuse. For example, a border of sidewalk is an ideal place for open channels, But if established in the vicinity of a busy street, waste and debris left in it by disturbance in water flow can cause a lot of problems in the traffic and car parks.
In this article the most important surface water management procedures have been described. In addition, there are some other methods and techniques too, but The proposed procedure in this study are according to urban design concepts, architecture, landscape and urban planning.

9-1- Step 1: the use of rainwater

Collecting and storing rainwater has many advantages that save energy, resources and costs over time.
Rainwater harvesting
This practice encourages the collection, treatment and reuse of rainwater for daily and emergency use. Rain water can be used more safely than any other current sources of waterin term of health and treatment. Rainwater harvesting tanks can be established underground (underground tanks) or on it (barrels of storage). Underground collecting storage tanks are larger devices that are applied for bathrooms, toilets , etc if treatment. While the ground storage tanks are smaller devices that can used from their stored water to for less consumption such as garden irrigation and and yard washing. Design standards in terms of materials, dimensions, capacity and discharge should be considered. Methods to collect and harvest rainwater can be used for residential complexes, private buildings, commercial buildings, schools and used them to adapt themselves to the situation. The system can be combined with the design of a building or can be included in their landscape design.



(a) (b)

Fig.5. (a) Rainwater harvesting underground system; (b) Rainwater harvesting tank

9-2- Step 2: treatment

The use of bioretentions, biotopes and snd or gravel filters are from methods to stormwater treatment
9-2-1- bioretention

Bioretentions are Bioretention areas are shallow landscaped depressions, which typically drain from below and rely on engineered soils and enhanced vegetation and filtration to remove pollution and reduce downstream runoff. These systems manage and treat runoff from frequent rainfall events [8]. The system consists of vegetated buffer strips, sandy bed, water retention basins and arable soil that can manage runoff due to frequent rainfalls. The ponds are in a variety of sizes and shapes and include different kinds of vegetation. Bioretentions can landscaped and adopted with different urban spaces. During the dry period, these spaces can be used for recreation and leisure puposes and redesign. Land slope and existent spaces should be considered for implementation of these systems. Bioretentions are appropriate for relatively flat or gentle slope areas.

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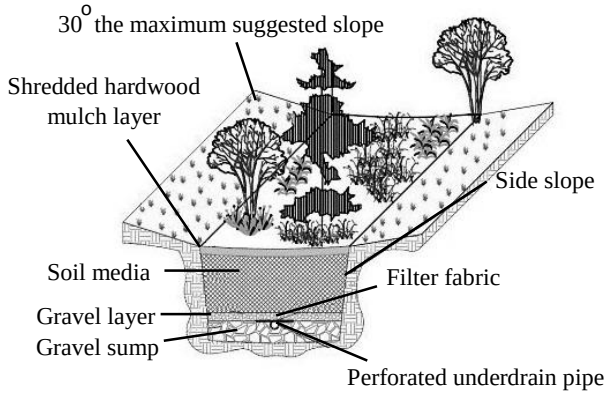


(a)

(b)

Fig.6.(a) components of bioretentions; (b) bioretention

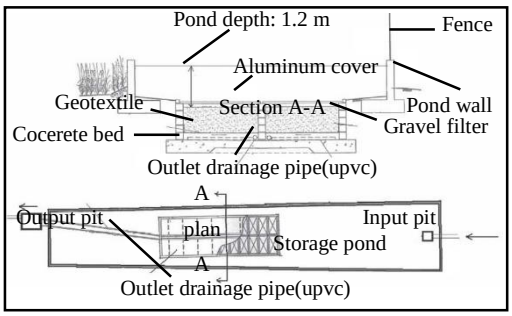
9-2-2- biotopes

A biotope as it pertains to sustainable stormwater management is a landscape of plants and sometimes animals deliberately assembled for ecological stability. Biotopes can be used to improve water quality through natural oxygenation [1]. However, biotopes are used to improve water quality but nevertheless can considered to provide space amenities and aesthetic aspects. As a feature of the environmental element of the urban landscape biotopes can be used as public spaces for people and the space for walking. In addition to, the wind stream flowing from biotopes causes refreshing urban atmosphere and the process that formed within it can make urban biodiversity.

Fig.7. biotop

9-2-3- sand or gravel filters

Filter systems are above ground or below ground chambers that are designed to treat surface water runoff, typically with gravel or sand as the primary filter medium. Surface filters can be used as the edges of adjacent green spaces, channels or buildings and integrate in the design of buildings, urban landscapes and design of different part of cities.



(a)

(b)

Fig.8.(a) Components of gravel filters; (b)Gravel filters

9-3- Step3: Retention and infiltration

Retention of rainwater is done for reduce the risks of flooding, reduce the flow of surface water, reduce of surface waste water pressure and restore the natural hydrology. Typically the water harvesting systems

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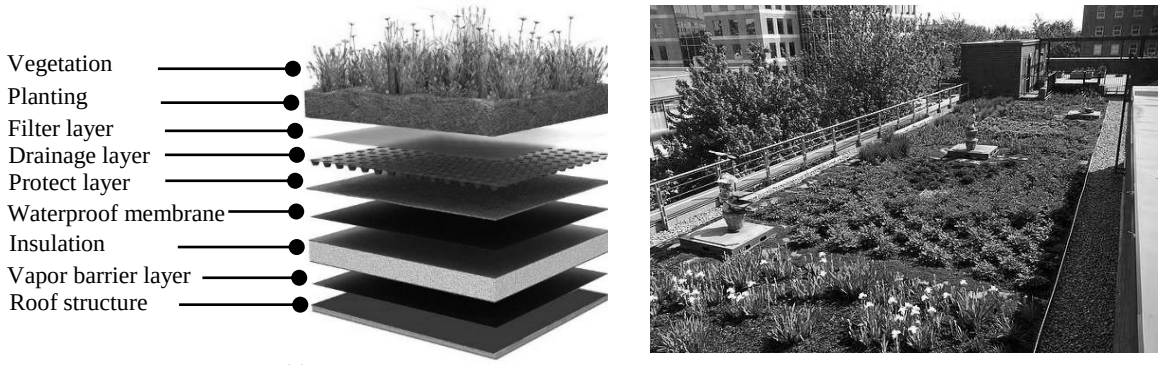
restore water temporary and infiltrate it into the ground gradually or transfer to other places where are permeable [1].

9-3-1- rooftop retention

Retention of rainwater on the roof includes from a multilayer composed structure generally. These systems are designed in accordance with the performance and size of roofs. Green roofs are extensive or intensive.Extensive green roofs are lighter and included resistant and durable plants. Whil, intensive green roofs are heavierand include thinker plants and have a thick media layer to protect negetations that include deep roots. Green roofs can affect the performance of individual buildings and landscapes and appearance and also affect the whole city. For urban designers a green roof is not only an affected element for the buildings, but also is an opportunity for the relationship between the structures and the urban landscape.

Green roofs improve the visual quality of the buildings beyond the hard surfaces and can be considered as available gardens. In urban scale the green roofs are replaced the lost green habitats and restore urban ecology and urban biodiversity. In addition to, they are connected with the physical health of people directly. Because green roofs can increase evaporation and perspiration and be affective on urban heat islands restrain. There are also some psychological benefits that bringing a green space near the building occupants is one of them.



(a) (b)

Fig.9.(a) Components of rooftop retention; (b)rooftop retention

9-3-2- Permeable paving

Permeable paving includes asphalt, concrete or some other types of paving matrials for sildwaks or streets that discharge stormwaters from the inside specially from sand beds or porous middle layers. Permeable paveing systems retain water in underside layers and then they are infiltrated, evaporated and drained. Permeable pavements generally are included smart asphalts from “pervios/open-graded” type, concrete from “no fines concrete type”, modular concrete blocks and supple modular pavements. Permeable pavement can be designed for vehicles, pedestrians, on streets and sidewalks and public parking where the ground is considered as a commodity.New technologies also provide a variety of pavement design and when applied correctly can increase the amenities and aesthetic aspects of urban spaces. They are also can help to traffic speed reduction and calming. It should be considered that avoided from these pavement into areas where have high rate of traffic.

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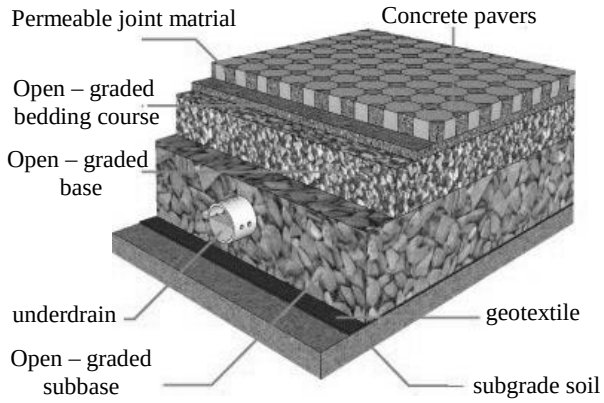


(a)

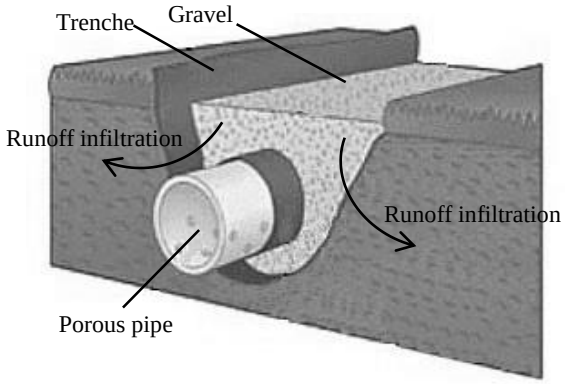
(b)

Fig.10. (a) Components of permeable pavement; permeable pavement

9-3-3- Infiltration trenches

Infiltration trenches, are long and narrow trenches that are fill by coarse sand and rock fragments inside it. These trenches retain runoffs in basins and aquifer temporary, before infiltrate into the soil around [8]. In fact, these systems are suitable beds to direct outlet runoffs from area such as car parks and urban highways. Some of infiltration trenches drain and direct runoffs through the pipes that are installed into it. This system consists of a high technical specification in terms of classification and stratification in order to retain, filtering and infiltration. The design standards in this field depend on rainfall intensity, local soil conditions and available spaces.

Infiltration trenches can be formed in different parts including public and private green spaces, streets adjacent plants, parks, sidewalks and road median strips. These systems can used in conjuction with traffic control and calming facilities as well as neighborhoods beautifications. When these trenches integrate into streets and sidewalks,community health and public perception from environment can be effectively improved. Infiltration areas can also integrated and landscaped into residential areas, officials, large or small public parks and gardens.



(a)

(b)

Fig.11. (a) Components of infiltration trenches; (b) Infiltration

9-3-4- Swales

Swales are linear shallow vegetated waterways and create for prevent of erosion and water infiltration facilitate into the ground [9]. These waterways store stormwater or transfer them. Swales can be designed based on impermeability and in this case only to be used to transfer runoffs to downstream and also can be designed based on permeability for infiltrate runoffs during the transmission. Sediments removal, reducing the volume of runoffs and delays in time of runoffs peak volume by its speed flow reduction are from swale functions.

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Swales can be integrated in open spaces such as streets and public parks. They are often designed on the sidewalks margin, roads and parking lots and if designed carefully, their delicate and gentle slope can create beautiful landscape that can be used for recreation space even in dry periods. These spaces can be used for different groups of users(such as children, elders, etc).

Fig.12. swales

9-3-5- Geocellular systems

Geocellular or modular systems are prefabricated structures installed underground to store and slowly infiltrate stormwater. Systems come in a variety of sizes and can service large quantities of stormwater [1]. Geocellular systems are useful in high-density urban areas where space is a commodity because they are invisible on the street surface.

Fig.13. Geocellular systems

9-3-6- detention ponds

Detention ponds are surface storage basins that attenuate and hold stormwater runoff. While water is held in the pond, particulates settle. Water is then slowly infiltrated or drained into additional conveyance systems or surface water [8]. They have been made in both dry and wet form and two large and small scales for rainwater retention. While, as long as these ponds are dry, they can be used for recreational purposes and new entertainment spaces. As well as, they are can landscaped and be used to park designing and integrated with them.

Fig.14. Detention ponds

9-4- Step 4: Conveyance

9-4-1- open canals

Open channels can convey surface waters from impervious surface such as streets and roofs. They can change experience and perception of urban spaces significantly. Open channels can stimulate pedestrian's emotions and provide appropriate space to encourage children to play. In addition to,open channels can change interactions of rainwater and urban spaces through connection with ponds, pools and etc.

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If in these channel designing in urban context, the coordination with dominate wind direction be considered, Production and Transfer of cool air flow through the channels and amenity of the surrounding spaces in summer will increased.

Fig.15. Open channel

Results

According to the hypophesis, this study shows comprehensiveness and efficiency of water sensitive urban design methods in order to sustainable management of surface runoffs in various aspects. Certainly, today, runoff management discussion is not responsive only through a series of conventional engineering methods and can not meet all the targets in stormwater management. New methods have multiple benefits in the field of technical, environmental, creating urban spacesand increase of efficiency. The most important advantage is efforts to close the urban water cycle to its natural cycle through connection the precipitation, infiltration, evaporation and condensation chain.

The nature and main features of the mechanisms proposed in this study is the " combination " of it. This means optimal utilization of an approach in the field of urban design. Because in WSUD, at the same time that paid to direction of surface runoffs somehow managed by series technical measures, it is proceed to create urban space amenity and improve urban landscapes and public place quality and with these two practices, we proceed to harvesting and reuse of runoffs nd increase the efficiency. Synchronous, by using of water sensitive urban design methods, in addition to feeding the aquifers through soil permeability, treatment of runoffs and pollutant removal will be possible.

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