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Pervious Materials for the Flood Mitigation Process in Kuala Lumpur: A Review

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Abstract
By locating and examining existing literature on this topic's past research, this study aims to assess the importance of perviousness in reducing flash floods in Kuala Lumpur. The terms perviousness, pervious materials, pervious surface, and flash floods were used in the literature research and identification. The majority of articles are found on environmental and water management websites. Pervious surfaces come in two basic designs. Permeable pavement is the initial design including permeable interlocking concrete pavers and concrete grid pavers. A buffer garden is the second option. However, due to space constraints in urban locations, the permeable pavement has become the preferred method of reducing stormwater runoff. Using permeable pavement has a lot of benefits, but there are some drawbacks to consider. This constraint can be alleviated if all proper methods are used during installation and maintenance. Because the most significant constraint is a lack of competence in permeable pavement technology, technical research on how to manage the right approach to this technology should be produced, covering all important areas from management, planning, site selection, and pervious paving maintenance. This program should include participation from all levels of decision-makers and stakeholders, as well as civil society.
Keywords: Perviousness, Permeable Pavement, Buffer Garden, Pervious Surfaces, Flash Flood

Introduction
The quantity and quality of runoff water entering lakes and streams is significantly impacted by landscape urbanization (Hussain et al., 2015, Davis, 2005; Wang and others, 2001; Williamson, 1993). The replacement of natural land covers (grasslands and woods) with impermeable surfaces such as parking lots and streets resulted in a loss of water, while the soil and plants continued to play a role. Increased runoff from impermeable surfaces causes substantial flooding, severe stream erosion, decreased groundwater recharge, and fish habitat deterioration. These impermeable surfaces can convey many toxins accumulating in metropolitan areas, such as fertilizers, silt, pathogens, pesticides, and chloride (Selbig, 2018, Safee et al., 2015).

To avoid flooding, stormwater runoff must be directed appropriately and effectively in the urban environment. As a result, while evaluating BMP (best management practises) solutions for a specific region, both water quantity and water quality issues are considered. In metropolitan areas, efficient collection and channeling of stormwater runoff is essential to avoid localized flooding and provide adequate drainage to properties (Selbig, 2018). Greater impermeable surfaces in metropolitan areas can result in higher storm runoff volumes and velocity due to increased imperviousness and limited spaces for runoff infiltration. Because they promote rainwater penetration and filtration while also providing structural capacity, permeable pavements are a better BMP than impermeable pavements (U.S. Army Corps of Engineers 2013). Stormwater runoff volumes and pollution loads carried by stormwater are both reduced or eliminated via infiltration and filtration.

Pervious Surfaces

Porous or permeable surfaces are both examples of pervious surfaces. Porous surfacing allows water to permeate the entire surface, whereas permeable surfacing is comprised of a substance that is resistant to water but allows infiltration through the pattern of gaps caused by holes on the surface.

Pervious surfaces are suitable for pedestrian and vehicular use because rainwater can pass through the surface and into the underlying layers of the material. Before it seeps into the ground, the water can be temporarily stored, re-used, or discharged to a waterway or other drainage system. Water quality can be improved by adopting surfaces with an aggregate sub-base. (susdrain.org).

Permeable Pavement

A permeable pavement is made out of open-pore pavers, concrete, or asphalt and contains an underlying stone reservoir. Rain and surface runoff are collected and stored in a reservoir before gently seeping into the soil underneath it or draining through drain tiles (Selbig, 2018). In permeable pavements, the permeable surface material is put beneath an aggregate reservoir layer. Permeable pavers contain open cells filled with gravel or grass that allow water to infiltrate their surfaces, be held in the rock base, and then absorb into the earth beneath them. Stormwater will gather in paving systems with hardscape surfaces (concrete, asphalt, or compacted gravel), causing it to pool or run off. Permeable pavers, on the other hand, have a porous surface that mimics and recreates how the ground reacts to rainwater naturally. The pace at which water drains into the surface is determined by the sort of permeable pavement system that has been installed. Stormwater storage and treatment are common goals for permeable pavement systems. Infiltration into the subsurface soils is also a possibility. The design of the system is heavily influenced by the pavement and its surroundings. Success also involves the creation and application of appropriate design elements.

It is expected that permeable pavements will last 15 to 20 years if properly sited, carefully designed and installed and routinely maintained. If the capacity of the soil drainage system and the height of the water table are not sufficiently assessed, and paved sections are not protected from construction-related sediment losses, sudden blockage and collapse can occur. The appropriate operation of permeable pavements may also be a concern in regions where large volumes of road salt are utilised and large truckloads are a problem.

Types of Permeable Pavement
Permeable pavement systems and other stormwater management technologies are used to control the quality and quantity of stormwater runoff (ASCE, 2015). Permeable pavements are porous surfaces that allow rainwater to enter through cracks in the pavement's surface and into an underlying stone reservoir, where it is temporarily stored or penetrated (Virginia Department of Environmental Quality, 2011). In a typical cross-section of a permeable pavement system, Figure 1 depicts a permeable pavement surface layer on top of open-graded aggregate base/subbase reservoir layers. The thickness of this reservoir layer is determined by structural and hydrologic design analyses (Virginia Department of Environmental Quality, 2011).

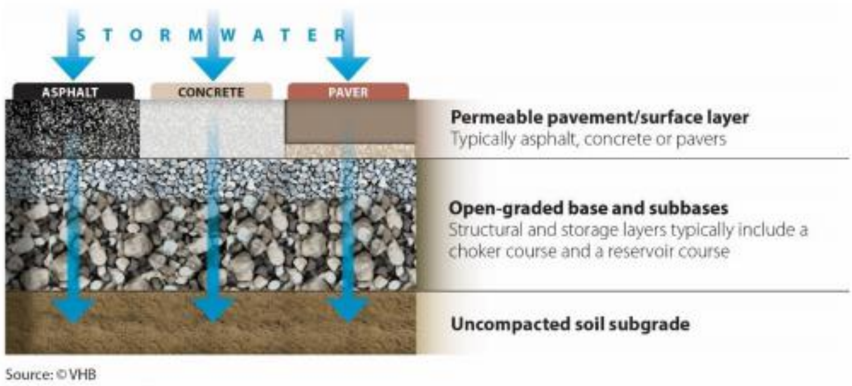


Figure 1: Generic permeable pavement cross-section
Source: National Academic of Sciences

Porous Asphalt
Asphalt pavements are made up of a variety of aggregate materials, as well as a binder to hold them all together, and are meant to allow just a little quantity of liquid to pass through. One or more layers of porous asphalt pavement are laid down beneath a choke stone layer (or treated base layer) and aggregate base/subbase reservoir in porous asphalt pavement (Figure 2). This design keeps moisture out of the underlying layers, preventing damage to the overall pavement structure. Porous or permeable pavement, on the other hand, allows water to flow quickly through the surface to a sub-layer, allowing for general or directed drainage. Porous asphalt pavements are becoming more well-known and accepted in the industry as viable alternatives in regions where drainage is a problem (Lombardo, 2020).

Lombardo (2020) also state that this indicates that they are frequently utilised for applications such as parking lots and other light-duty tasks. As part of attempts to alleviate flooding concerns, reduce hardscape, and increase sustainability, full-depth porous asphalt pavements are increasingly being used on roadways. For a successful porous asphalt pavement, the National Asphalt Pavement Association (NAPA) recommends that an underlying, open-graded stone bed be used as a waterway. Water gently infiltrates into the soil as it sinks through the porous asphalt and into the stone bed. The layer thickness is influenced by the structural load, stormwater needs, and frost depth requirements (ASCE, 2015). There are fewer fines in porous asphalt than in traditional hot-mix or warm-mix asphalt (aggregate passing the No. 4 sieve), resulting in an open-graded mixture that allows water to enter through the void space.

Additives and higher-grade binders are frequently utilised to improve longevity and lessen the risk of asphalt draining. Traditional asphalt pavement has a similar appearance to porous asphalt, although the texture is frequently coarser. In porous asphalt, surface void space typically ranges from 18% to 25% (normal HMA has about 5% air gaps), and surface permeability ranges from 170 to 500 in./h (ASCE, 2015).

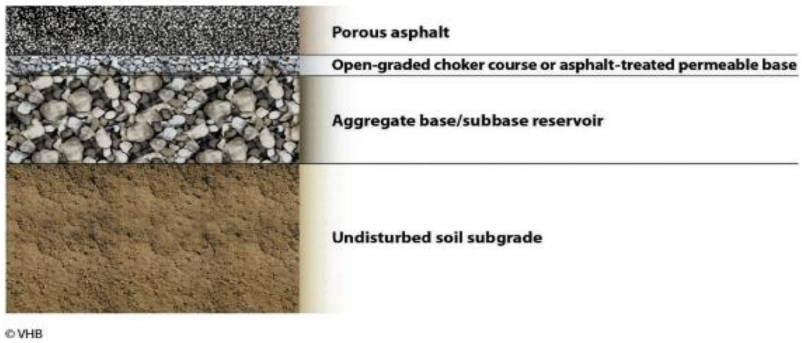


Figure 2: Typical porous asphalt system cross-section
Source: National Academic of Sciences

Pervious Concrete
Pervious concrete is a strong, durable pavement consisting of open-graded aggregate bound together using a hydraulic cementitious binding process (e.g., Portland cement). Frequently, pervious concrete is laid on top of a choke-stone layer (or treated base layer) and an aggregate base/subbase reservoir (Figure 3). Pervious concrete is a high-porosity concrete created from a combination of cement, water, coarse aggregate, and a small proportion of fine aggregate (sand). Pervious concrete generates a porous medium that allows rainwater and other sources of water to pass through and reach the underlying soil. This decreases site runoff while replenishing groundwater levels. Pervious concrete is commonly used in sidewalks, parking lots, and greenhouses and has applications in sustainable construction.
The US Environmental Protection Agency (EPA) has designated pervious concrete as a Best Management Practice for Stormwater because it reduces pollution. Because of their size and the cost of complying with stormwater rules, stormwater drainage systems are becoming more challenging to construct. Pervious concrete for paved areas minimize runoff, reducing the demand for stormwater retention ponds and storm sewer capacity requirements.

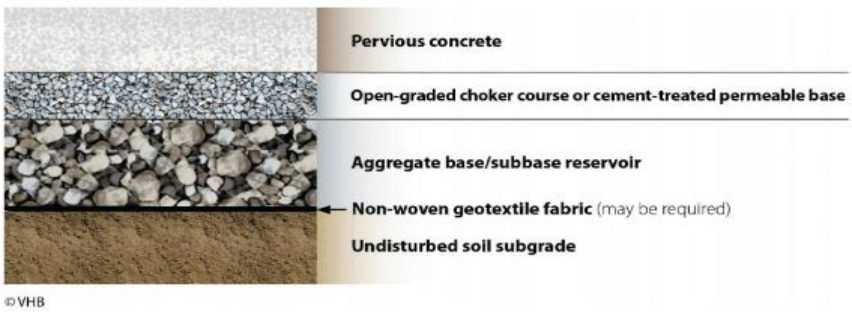


Figure 3: Typical pervious concrete pavement system section.
Source: National Academic of Sciences

The void zone in pervious concrete pavement is typically 15% to 25% linked with a surface permeability of 300 to 2,000 in./h (ASCE, 2015). The entire thickness of the permeable pavement system is determined by hydrologic design, vehicle loading, and frost depth issues. A minimum thickness of 12 inches is usual in freeze-thaw climates (ASCE, 2015). Stormwater is naturally filtered by pervious concrete, which reduces the number of contaminants that enter streams and other bodies of water. This concrete acts as a rainwater retention basin, allowing groundwater levels in the area to remain stable. Another advantage of pervious concrete is that it reduces the impact of construction on neighbouring trees by allowing both water and air to enter the root systems.

PICP (Permeable Interlocking Concrete Pavement)

As environmentally friendly and labor-intensive paving technology, permeable interlocking concrete pavement (PICP) is widely used in various nations to solve specific paving issues (Muraleedharan & Kumar, 2000). Constructed from solid concrete paving pieces joined together to form patterns, PICP creates openings in the pavement surface. Water can freely enter the surface because the seams are filled with porous pebbles. With the permeable surface, the flow rate can be up to 1,000 in./hr (2,540 cm/hr) (Borst, 2010).

Prefabricated concrete units, when laid out in a pattern, generate permeable voids and joints in the PICP (ASCE, 2015). The joints allow stormwater to flow into a crushed stone aggregate bedding layer and a base/subbase reservoir that support the pavers (Figure 4). Permeability of cross-section joints in PICP is 400 to 600 inches per hour, accounting for 5 to 15% of the paver's surface area (ASCE, 2015). It is typical for PICP to have an additional small-sized aggregate bedding layer beneath the pavement and on top of the choke stone layer to ensure a smooth surface for the pavers/grids (ASCE, 2015). Water is stored in the base and subbase, which then infiltrates into the soil subgrade. Water that does not infiltrate within a design period of 48 to 72 hours is removed using perforated underdrains in the base or subbase. There are many different types of materials that can be put to the subgrade in order to achieve certain structural and hydrologic design goals such as geotextiles, geogrids, or geomembranes. Separation geotextiles are utilized on the edges of the base/subbase to keep particles from neighbouring soils out (Smith, 2015).

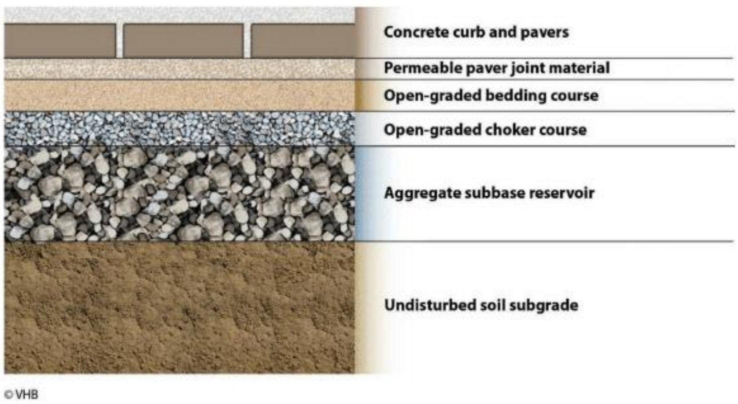


Figure 4: Typical PICP cross-section.
Source: National Academic of Sciences

Walkways, driveways, parking lots, alleys, low-speed roadways, and road shoulders are all places where PICP is deployed. PICP is designed for places where vehicle speeds do not exceed 35 mph (50 kph). Smith (2019) also stated that PICP is often employed in locations with fewer than one million 80 kN lifetime equivalent single axle loads (ESALs; or Caltrans Traffic Index < 9). These applications use unstable open-graded aggregates. Higher ESALs can be achieved by using pervious concrete or porous asphalt, or by using open-graded bases supported with cement or asphalt. PICP is also a space saver. Pedestrian and vehicular pavements are combined with detention rather than consuming land as separate areas. The spared land can be used for green space or homes and buildings.

Others (such as grid pavement systems)

Permeable pavement material selection and overall pavement system design will be guided by the site's objectives as well as the pavement's anticipated use (ASCE, 2015). The most common approach is total infiltration, which involves channelling water through the base/subbase reservoir and into the soil subgrade. A full-infiltration system, which does not require underdrains, is widely used in areas with high permeability soils (ASCE, 2015). Partial infiltration systems use drainage pipes to transfer excess water from the base/subbase to the subgrade soil and to a sewer or stream. When the soil has low permeability and strength or when groundwater recharge into the soil is contaminated, no-infiltration technologies are necessary (Smith, 2019).

The open grid pavement system is made up of conventional concrete blocks with a considerable amount of open or penetrable surface area. When compared to the standard pavement (clay or concrete asphalt), the open area allows water to permeate the paving and help it runoff into stormwater systems. Open grid blocks have a persistent open region on the surface and are structurally stable, durable, and load-bearing. Grass blocks, for example, help to promote the development of grass and other vegetation. If the open grid is filled with small stones, the water will flow more freely through the device.

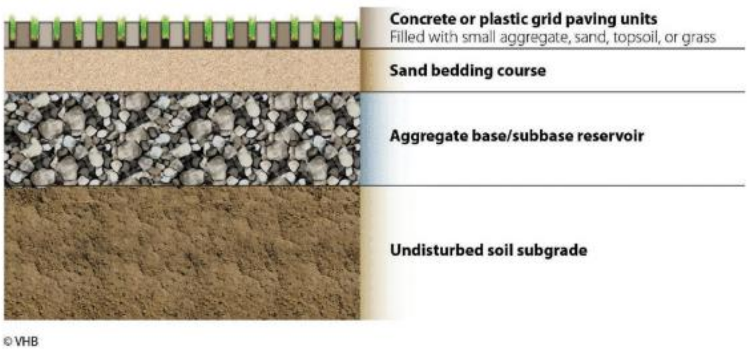


Figure 5: Typical grid paving unit cross-section.
Source: National Academic of Sciences

Advantages and Disadvantages of permeable pavement

Below is a summary of several common advantages and disadvantages associated with permeable pavement in the following table.

Table 1

Advantages and Disadvantages of permeable pavement

Advantages	Disadvantages
- Management of storm runoff (possibly reducing the size of storm sewers and reducing the risk of flooding). - Filtration of runoff, reducing contamination in waterways. - Recharging groundwater supply. - Cool down the temperature of urban runoff, reducing stress and impact on the stream or lake environment. - Reduced heat island effect. - Help re-establish a more natural hydrologic balance and reduce runoff volume by trapping and slowly releasing precipitation into the ground. - Save Money and effort in reducing the regional BMP's requirement.	- Limited use in conjunction with heavy vehicle loads. - Lack of design and construction experience (e.g., failure of pavement). - A potential lack of experience with maintenance can lead to poor performance (e.g., clogging of the surface). - Possible groundwater contamination from fluid spills. - Potential higher initial construction cost.

Source: Selbig, 2018; National Academies of Sciences, Engineering and Medicine 2017

Buffer Garden

A perennial garden that serves as a buffer between a residence and a waterway is referred to as a buffer garden. To put it another way, it's a planted area whose sole purpose is to lessen pollution and enhance the surrounding environment . It is essential to reduce the amount of nutrients and contaminants that stormwater runoff carries into storm drains. Vegetation slows the flow of runoff, allowing it to sink into the ground before it reaches storm drains. Protecting our local waterways by utilizing vegetation to absorb runoff goes a very long way (rulingrobotfalcons.com). Besides providing food and cover for local wildlife, the roots of the native plants used in the buffer garden also help to retain soil and collect rainwater for use in irrigation. Conventional lawns and gardens, on the other hand, employ chemical fertilizers and water, resulting in contamination of the air and water.

Types of Buffer Garden

Buffer garden can be any landscaped area with plants, shrubs and/or mulch groundcover. The plant is usually planted or growing naturally either in the yard/lawn or along the waterfront. Two types of buffer gardens will be highlighted in this paper; rain garden and bioswale.

Rain Garden

A rain garden is a recessed area where rainfall from a roof, driveway, or street is collected and allowed to seep into the earth. Rain gardens, which are typically planted with grasses and flowering perennials, are a cost-effective and visually pleasing solution to reduce runoff from your property. Rain gardens can provide food and refuge for butterflies, songbirds, and other animals in addition to filtering pollutants from runoff (EPA, 2017). A rain garden is a garden that is typically formed on a natural slope and contains native plants, perennials, and flowers. It's made to hold and sponge up rainwater flow for a short period of time. Rain gardens can reduce the amount of pollutants in storm water runoff by as much as 80 %, including chemical and nutritional pollutants as well as sediment. Water can penetrate deeper into the ground in a rain garden, up to 30 percent deeper, than in a traditional grass.

Rain gardens are not the same as water gardens. It is also not a wetland or pond. A rain garden, on the other hand, is mostly dry. It usually only holds water during and after a rainy event. Mosquitoes cannot breed in rain gardens because they drain after 12 to 48 hours. To add to their aesthetic value, rain gardens also serve practical purposes. By creating a rain garden, you may safeguard local rivers, lakes, fish, and drinking water supplies while preserving the natural water cycle.

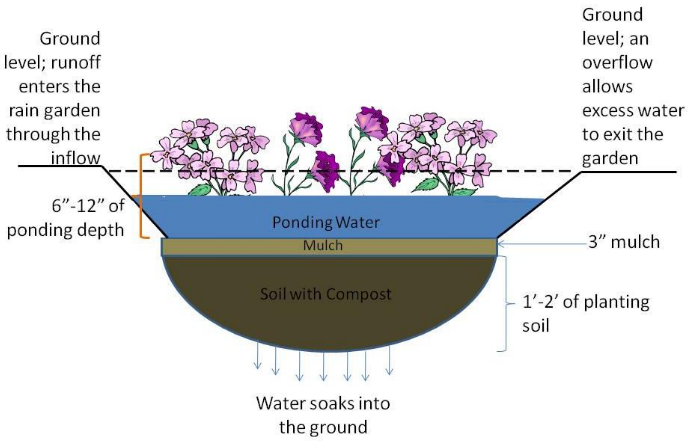


Figure 6: Typical rain garden cross-section.
Source: arlingtonva.us

Bioswale

Bioswales can be utilised as an alternative to traditional storm sewers for transporting rainwater runoff. During heavy rains, they can absorb excess water, while at other times they can channel it to a storm drain or nearby body of water. Bioswales enhance water quality by filtering out debris from large storm flows and absorbing water from the initial wave of stormwater runoff (National Resources Conservation Service, 2005). Bioswales are shallow, vegetated depressions in the landscape that collect, filter, and infiltrate stormwater runoff. They are typically sized to treat the "first flush," or the first and frequently most polluted volume of water that results from a storm occurrence. To reduce the rate of runoff, filter the water, and replenish the groundwater table, bioswales are the most efficient green infrastructure facility. They feature flexible site criteria, allowing for integration with medians, cul-de-sacs, bulb outs, and other public space or traffic calming methods (NACTO).

Unlike rain gardens, bioswales transport water from one location to another and often feature a drain at one end to remove non-infiltrating water. As water infiltrates the soil, soil bacteria break down pollutants, and plants absorb some of the water and utilise available nutrients for development. The remaining water percolates into the earth, replenishing the groundwater table (HGIC, 2015). A bioswale will only act as an above-ground drainage system once every twenty-five years, on average. Thus, bioswale systems are always required to have access to surface water. The drainage system's secondary function is to redirect water from less porous soil to more permeable ones.

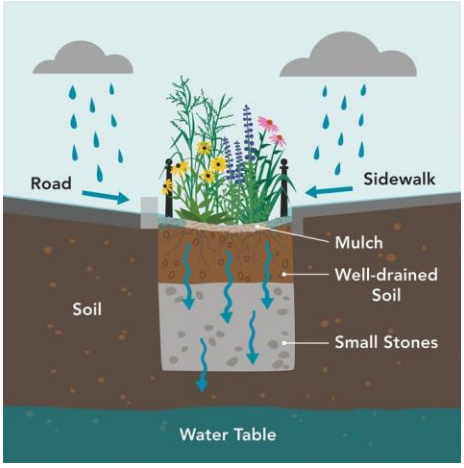
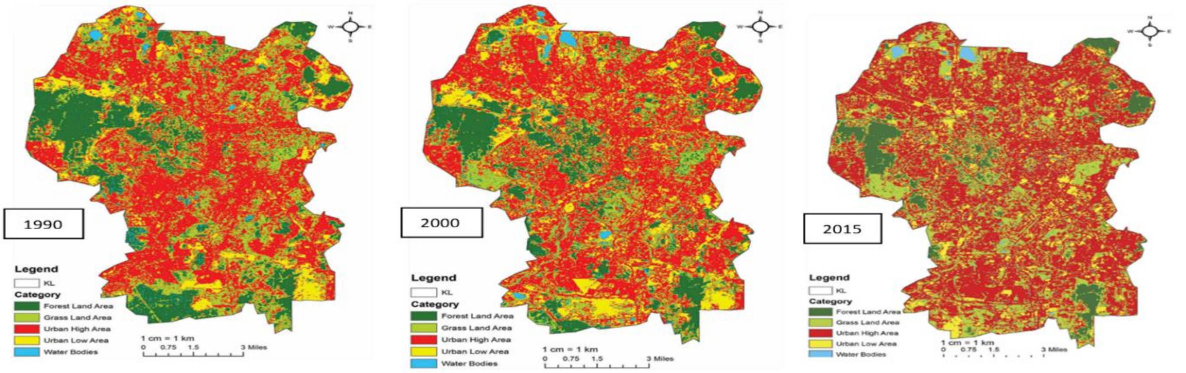


Figure 7: Typical bioswales cross-section.
Source: Pinterest

Advantages and Disadvantages of buffer garden

Table 2

Advantages and disadvantages of buffer garden



Advantages	Disadvantages
- Improved water quality by filtering out nutrients from rainwater runoff before it reaches stormwater sewers and waterways. - A unique landscaping feature that's relatively low maintenance. - Tendency to be a pest- and disease-free relative to conventional landscapes. - Habitat for birds and butterflies. - Prevent rainwater runoff from entering the stormwater sewer system. - Protecting communities from drainage problems and flooding. - Increasing groundwater flow. - Creating natural wildlife habitats. - Improving the way a landscape functions with effective green infrastructure.	- If it is not built correctly, it can accumulate standing water and increase erosion. - Requires landscaping and management - Susceptible to clogging if surrounding landscape is not managed

Figure 8: Distribution of land use and land cover of Kuala Lumpur in 1990, 2000, and 2015.
Source: Selbig, 2018; National Academies of Sciences, Engineering and Medicine 2017

Stormwater Management in Kuala Lumpur

Flash floods are a typical occurrence in Kuala Lumpur, and they are caused by a variety of sources. Rapid urbanisation has resulted in a significant increase in migration, as well as changes in Kuala Lumpur's land use and land cover (LULC) and the evolution of natural components such as lithology, terrain, excessive rainfall, and a natural drainage (river) system. Kuala Lumpur's flash floods are linked to the city's rapid development, as shown in figure 8 below. The changes shown in figure 8 are the reduction of green areas and the substitution of natural surfaces with concrete with a limited water absorption rate. The existing drainage systems that could not support the large volumes of surface runoff and overdevelopment in the city have also contributed to flash floods (New Straits Times 2020).

Source: Hua & Ping (2018)

The city's municipality covers an area of 243 km^2 and referring to figure 8 above, there used to be more green spaces on the west and southern edge of Kuala Lumpur. However, it has developed into urban areas, and the amenities are much denser towards the city center.

Flood Mitigation in Kuala Lumpur

Stormwater Management and Road Tunnel (SMART) and Sungai Klang River of Life are the two projects that have succeeded in alleviating Kuala Lumpur'sflooding woes. SMART started operational from July 2007, the target area is the heart of Kuala Lumpur city, around Masjid Jamek, Jalan Tun Perak, Dataran Merdeka, Kampung Baru, Jalan Munshi Abdullah, Old Court Complex, Jalan Melaka, and Jalan Tunku Abdul Rahman (Samsuri et al., 2018). Data has shown that the SMART successfully diverted 280m^3 of floodwater from the upper river into the Berembang Klang village holding pond more than 70 times (until 27 April 2009), having a capacity of 600,000m^3 (Abdullah, 2004). SMART has managed to save the Kuala Lumpur City Centre from the flood and avoid the loss of damage and destruction of public property as it often happens when flash floods hit Kuala Lumpur City Centre (state.water.gov.my). The efforts to mitigate floods in Kuala Lumpur is continuing as flooding still occurs. Nevertheless, SMART is not a total solution because its primary use in solving flash floods is mainly through forecasting, which can be improved through radar technology and modelling assimilation and decision support systems (Samsuri et al., 2018).

River of Life project has been accomplished along Sungai Klang, which comprise main components; river cleaning, river master-planning and, river beautification. This project covers the convergence of three city rivers (with a total area of 781ha and 63ha of water bodies) is a goal to bring the community to the river through a 100 percent modification into a liveable waterfront, rejuvenating the city's river and reconnecting it to the surrounding urban fabric (AECOM, 2017). This project contributes to the conservation of flood plain area as a recreational area that plays a water-absorbent place.

Apart from these two project, all local governments, as well as the public and commercial sectors, must adhere to a new Urban Stormwater Management Manual (MSMA) published by DID in 2000. Best practises for stormwater control techniques such as runoff quantity and quality controls were incorporated into the MSMA. MSMA's major goal is to manage stormwater rather than drain it as quickly as possible, resulting in a more environmentally friendly strategy known as control the source. Detention/retention, infiltration, and purifying processes are all used in this method. Current issues such as flash floods, river pollution, soil erosion, hill development, and other issues are also addressed in this manual. This document has been assessed by several departments, non-government organizations and international experts. This manual describes a novel technology that is based on the control at source method. However, the approach is not widely applied for old development. There are a lot of circumstances in placing the technology, for example, limitation of the space, the cost of construction and maintenance.

How permeable pavement can be applied in Kuala Lumpur

Land development and urbanization in which soil has been surrounded by impervious materials lead to poor rainwater percolation through the ground. This resulted in a significant source of water pollution as contaminants are carried from urban communities into natural water sources such as streams and rivers. Permeable pavement is an intelligent solution capable of solving these issues through the implementation of a single system. It is hypothesized that the widespread application of permeable pavement in urban environments for rainwater collection could provide a singular system capable of collecting large amounts of rainwater, surpassing conventional rooftop rainwater harvesting efforts (Beecham, 2018). Permeable pavement may also reduce urban runoff at the source by infiltration of stormwater through permeable surfaces and filtration of water, which inexorably ends up in streams, lakes and rivers, preserving the water quality of natural sources (Wang, 2010). The permeable pavement applications are generally made of three principal materials; permeable interlocking concrete pavement, pervious concrete and porous asphalt (Selbig and Buer, 2018). These various materials each have their own set of benefits and drawbacks. Their successful application is very dependent on environmental factors such as traffic intensity, the volume of rainfall, presence or absence of polluting particulate, the volume of suspended solids such as leaves, pebbles and sediment in the target area, availability of maintenance as well as aesthetic considerations (Daniel & Jeriel, 2021). There is no multipurpose material for these permeable pavements. Consequently, a combination of different materials customized to other environmental conditions is necessary for practical application.

Permeable interlocking concrete pavement is basically impermeable concrete units arrayed in such a way as to create open, permeable voids between the units. This technique produces a surface capable of bearing moderate traffic. Permeable interlocking concrete pavement is ideal for pedestrian walkways with regular maintenance due to the surfaces' vulnerability to clogging.

Pervious concrete consists of cement, water and exclusively large aggregate. The large aggregate size increases the porosity of the concrete by opening minuscule channels allowing infiltration of water. Typically capable of bearing heavy traffic, the quality of permeable concrete relies on frequent inspection and installer skill due to the very low tolerances set on the ratio of water to cement required in fabricating and maintaining a resilient and robust surface. Pervious concrete is ideal for areas with heavy traffic and particulate pollutants due to the smaller void spaces' ability to filter out particulate matter.

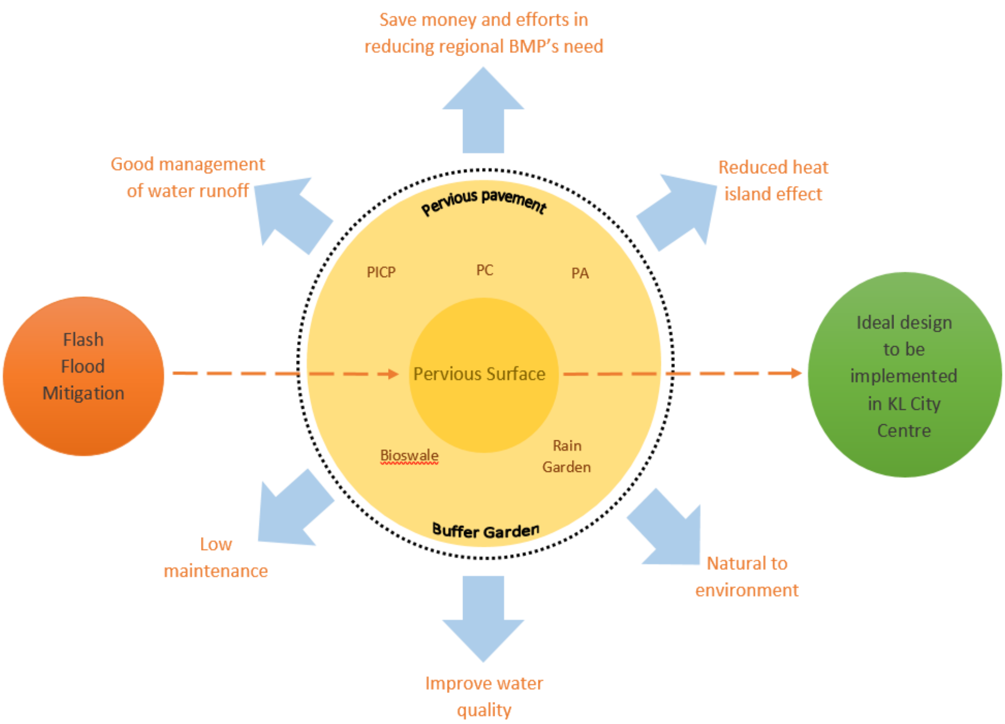
Porous asphalt is similar to conventional asphalt, involving the same application methods, with the omission of finer aggregate from the asphalt mixture, creating void spaces allowing the permeation of water. Subsurface reservoirs are usually built underneath porous asphalt surfaces to allow gradual infiltration of water into the ground due to the high porosity of porous asphalt. They are commonly used for parking lots (mosques, shopping malls, employees, event areas) and other light-duty applications. For example, due to its high porosity, porous asphalt is ideal for areas that experience large volumes of surface runoff, and a lack of regular maintenance as the large void spaces in porous asphalt do not accumulate small particles.

Void spaces within the material to allow infiltration of water inevitably results in diminished strength. This limits the use of permeable pavement to areas with low-volume and low-speed traffic, such as pedestrian pathways and residential streets. As Daniel & Jeriel (2021) stated, a possible solution to this issue is a semi-permeable paving technique that fabricates a surface with a permeable top layer with an impenetrable base. This allows water to infiltrate the upper layers of the surface and drain away to the side into a storm drain or a fully permeable pavement. This preserves the overall strength of the material, rendering it suitable for use in high-intensity traffic routes. An example of such paving is open-graded friction courses (OFGC) which utilize porous asphalt.

The latest affected areas by the flash flood were Jalan Kuching near Taman Wahyu and Bulatan Batu Caves, Jalan Cheras near Cheras Sentral and the Billion roundabout, both directions of Jalan Maharajalela near the MRT station and Jalan Raja Chulan headed towards Muzium Telekom. These events occurred on April 2021 (New Straits Times 2021). We can utilize the pervious materials near the areas stated in Table 3 below to avoid such incidents.

Table 3
Estimation of areas that pervious materials can utilize

	Types of pervious material	Estimated area to be utilized
Jalan Kuching	PICS	400m long of a pedestrian walkway
	PC	Eko Sky building's road
	PA	Eko Sky parking lots
Jalan Cheras	PICS	300m long of a pedestrian walkway
	PC	Eko Cheras Mall's road
	P.A.	Petrol pump parking lots at Jalan Mutiara
Jalan Maharajalela	PICS	600m long of a pedestrian walkway
	P.C.	No suitable places to be utili
	P.A.	Rapid K.L. Monorail's parking lots
	PICS	600m long of a pedestrian walkway



Jalan Raja Chulan	P.C.	No suitable places to be utili
	P.A.	Starcom Malaysia's parking lots

Figure 9: A Conceptual Framework of permeable surfaces and the benefits of the pervious materials.

Conclusion

Although buffer garden has few to none disadvantages and is more natural to the environment, these garden cannot be considered an ideal design for the urban area due to lack of available soil. The rain garden requires an area with good drainage and not under any trees. It should be strategically located to intercept water runoff. A rain garden is not recommended to plant over a septic system, close to foundations or the seasonal high water table within 24 inches of the soil surface. Bioswales are not suggested in low-infiltration areas because standing water, localised floods, and other concerns might cause problems in the street and sidewalk in an urban setting. Therefore, permeable pavement is the ideal design for an urban area with low availability of soil. Permeable pavements offer several environmental, operational, and economic benefits. However, there are also limitations associated with their use. The most critical limit is the lack of expertise in permeable pavement technology. We should provide a technical study to manage the proper method of this application. The study will cover all relevant aspects from management, planning, site selection until maintenance of the pervious paving. Besides, the technique can be applied to all levels of decision-makers, stakeholders and civil society.

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