RAIN WATER HARVESTING (RWH): A SUSTAINABLE SOLUTION TO PUBLIC WATER SUPPLY CHALLENGES IN NIGERIAN URBAN CITIES.

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Abstract

Rainwater harvesting is the accumulation and storage of rainwater for domestic re-use and other purposes rather than allowing it to run off. This practice dates back to early years and is still being practiced today in rural areas on a small scale. A report by the United Nations Department of Economic and Social Affairs states that Nigeria’s Population will overtake that of United States and become the third most populous country in the World. This will happen without commensurate amenities and employment to sustain it. With the population growth forecast, the demand for clean water as a major social amenity will become even more critical by 2050. The responsibility to provide clean water has rested solely on the government with supports through few private sector intervention programs. If Nigeria must however achieve equal access to portable water according to one of the Sustainable Development Goals, it will require more deliberate sustainable approaches by the government, private sector and individual property owners and future would-be home owners. This paper aims at revisiting the concept of rain water harvesting as a sustainable solution to public water supply challenges in major Urban Cities. The objectives of the study shall be to identify design solutions to rain water collection at residential and community level, to study few existing cases, to evaluate the success of the technology and to identify governments’ role in the successful implementation of rain water harvesting. The study adopts review and case study approach. Two identified cases will be studied for effectiveness, user perception and adaptability at communal level. The paper developed usable design solutions and workable community approaches to rain water harvesting usage. It also identified the visible role of government in its successful implementation at communal level.

KEY WORDS: Public Water Supply, Rain Water, Sustainable Development Goals (SDG), Sustainability.

1.0 INTRODUCTION

The concern about water shortage is a target for studies all over the world as the demand on potable water for use is daily on the increase. Kummu et al, 2016 demonstrated that while water consumption increased fourfold in the 20th century, the population suffering from water scarcity rose from 0.24 billion (14% of the world population) in the 1900s to 3.8 billion (58%) in the 2000s. Vörösmarty et al, 2010 pointed that almost 80% of the world population as at today is exposed to high levels of threat to water safety. Globally, at least 2 billion people use a drinking water source contaminated with faeces (WHO factsheet on water, 2018). Contaminated water can transmit diseases such as diarrhoea, cholera, dysentery, typhoid, and polio. Contaminated drinking water is estimated to cause 502 000 diarrhoea deaths each year.

A report released by the World Bank on Monday, August 28, 2017, said Nigeria provided clean water to fewer than 10 per cent of its city dwellers in 2015, down from 29 per cent in 25 years earlier, 1990 (Punch Online Article, 2017). One of the troubling paradoxes in life in Nigeria is that social infrastructure such as potable water supply, adequate electricity,
availability of health care facilities, good road networks, and so on cannot match the pace of the country’s population growth. Nigeria has become one of the fastest growing and the most populated country in Africa and currently lies 7th in the world ranking. As at 2018, Nigerian Population lies at 197 million, 7 million more than what was obtainable in 2017 (World Population Live Report and forecast, 2018). With the increasing daily population of Nigeria as noted in population forecast and statistics, it is of great essence that we return back to basics in order to effectively and sustainably tackle the expected critical water supply challenges that will occur due to greater demand on the limited water supply sources currently available.

Rainwater Harvesting (RWH) as a source of water supply for domestic consumption has been practiced throughout the world for many years (Mayo and Mashauri, 1991). However, although rainwater is recognized as an alternative source of water supply, it has been used on a relatively small scale in Nigeria, mostly in rural areas where its practice has been limited to the use of small containers for storage. RWH is not only relevant in the rural context but also in the urban settings where water supply from the municipal government system falls critically below the daily demand of the user (Gowing et al, 2012). Exploring its potential use and adapting same right from the building design stage of urban city structures (residential, commercial, offices etc) have however been neglected by allied building professionals and researchers in the construction industry as an alternative source of water supply for portable and non-portable use. With Nigeria falling in the tropical region characterized with approximately 8 months Rainy Seasons out of the 12 calendar months in a year (between April to November), a lot of cost savings on water stand to be gained during the rain peak periods. Incessant cases of Flooding during rainy peak periods resulting from excess rain water run-off will also be drastically reduced when RWH is explored on a wider scope for communal domestic non-portable use, agriculture and livestock farming. Excess Rain Water Run-offs can also be channeled to nearby rivers and oceans for survival of the aquatic body.

2.0 CONCEPT OF RAIN WATER HARVESTING

Rainwater harvesting is a basic practice of catching rain that was implemented largely for agricultural use in ancient civilizations (Boers and Asher 1981). There are various technologies and practices associated with rainwater harvesting for agricultural use including utilizing channels, dams, diversion systems and many more (Boers and Asher 1981).

For this study, Rainwater harvesting is defined not as the method of collecting surface runoff for agriculture, but as a method for collecting rainwater from rooftops through a gutter or downspout system into a cistern or holding tank for future use (Caitlin and Tamim, 2008).

Many anticipate that freshwater resources will become widely unavailable in coming decades (Furumai 2008). The exponential increase in population and subsequent urbanization of countries around the world has caused a major strain on waterways including complete loss of rivers and natural watersheds in order to provide more space for structures and infrastructural development (Furumai 2008). In addition to the loss of watersheds due to development, the increase in urbanization dramatically affects the amount of runoff created by impervious surfaces. This increase in impervious surfaces
causes decrease in natural groundwater recharge resulting in less available groundwater to meet increased water demand (Caitlin and Tamim, 2008). Rainwater harvesting is an excellent tool which, with proper use, could dramatically reduce the continual strain on watersheds. Rainwater harvesting is not only useful in rural areas but it can provide numerous benefits for urban ecosystems by managing storm water runoff. It can also provide communities with another option for storm water management in places such as the Chesapeake Bay watershed where there are laws enacting the proper maintenance of storm water runoff (Cabell Brand Center 2007).

Harvesting rainwater makes sense for a variety of economic and environmental reasons which include:

i) Rainwater is a cost efficient alternative to public water, especially for exterior water uses such as landscape irrigation that requires minimal filtration.

ii) Rainwater is also a more energy efficient decentralized water source than groundwater pumping especially when it is to be used for non-portable use where extra treatment process is not required. The collection process of rainwater capture is completely energy free since the environment and gravity harness the rain (Caitlin and Tamim, 2008).

iii) Rainwater is often the only viable water source in arid regions or on islands where other water sources may be high in salt, limited in availability, or very expensive (Conservation Technology Rainwater Handbook, 2012).

iv) Rainwater is low in minerals, so it is ideal for laundry, dishwashing, hair washing, and car washing. Since it contains no chlorine, rainwater is also ideal for filling garden ponds and irrigating sensitive plants (Gondwe, 1983).

v) Rainwater is not regulated by municipal water restrictions. During periods of drought, rainwater can protect investments in landscaping, garden ponds, and swimming pools.

vi) Rainwater can cause leaky basements, eroded foundations, overflowing sewers, soil erosion, water pollution and flooding. Collecting rainwater can eliminate these problems while eliminating the need for expensive storm water controls (Conservation Technology Rainwater Handbook, 2012).

Rainwater can supplement limited ground water resources. With reduced extraction rates, low-yield ground water wells and springs can last indefinitely. Rainwater can also supplement surface water resources threatened by rapidly growing municipal water use. Rainwater collection could significantly reduce water extraction rates from rivers during critical summer months, ensuring adequate water remains to support native ecosystems (Conservation Technology Rainwater Handbook, 2012).

Rainwater harvesting systems are very flexible and alterable based on specific site needs. The main components for each system include a catchment area (rooftop), a gutter or downspout system, a cistern or holding tank, and a pump to redistribute the water (Rainwater Management Solutions Inc 2007).
Potable uses for rainwater include: drinking water; cooking; bathing, and washing dishes. Non-potable uses for rainwater include household cleaning; irrigation; toilet flushing; pond/landscape use; fountains; vehicle washing (Cabell Brand Center 2007)

2.1 Rainwater Demand

The potential per capita consumption of rainwater depends on the size of the collection surface, the volume of the rainwater storage tanks, the amount and annual distribution of precipitation, the size of the family and the efficiency with which the precipitation is collected (Mayo and Mashauri, 1991). The underground rain water tank is mostly made of reinforced concrete with additional treatment to battle water leakages. Glass or Fiber Reinforced Plastic (GRP, FRP) surface or elevated mounted tanks can also be employed where there is enough ground space on the site to accommodate such. The dimensions of the tank can vary depending on the daily demand of the end user. See fig 1 for tank storage capacity calculation guide.

2.2 Rainwater Quality

Harvested rainwater quality can be affected by several factors. The major factors that affect water quality are site location and climate, as well as the nature of the catchment system (Langdon 2007). Location impacts the water quality of the rain, for example if the area is prone to acid rain or if there is a high amount of pollution in local watershed. The harvested rainwater quality is also affected by rooftop material. For residential and commercial rainwater capture, roofing material can become a serious source of nonpoint source pollution (Chang 2004). The water quality is also affected by air pollution and potential contamination of rooftop water by plants or animals (Langdon 2007).

The chemical and physical quality of rainwater is generally acceptable but on a few occasions bacteriological quality may be unacceptable, especially when undesirable collection, storage and use of rainwater is practiced (Mayo and Mashauri, 1991). Rainwater quality is influenced by several factors as the rainwater passes through the catchment surface, storage tanks, pumping and plumbing system and finally to the consumers (Gumbo, 1985). The quality of the rainwater may be influenced by the quality of precipitation, most notably the acidity of the rain, deposition on the catchment surfaces (which may increase turbidity and color and introduce bacterial agents) and other contaminants which may be introduced into the system by man himself through the use of contaminated containers for
the collection of rainwater (Malcolm, 2015). When all these are adequately taken care of, rainwater is generally considered as bacteriologically safer than municipal water (Gumbo, 1985).

Materials used for construction such as cement and lime in cases of concrete tanks may impair the taste of water (Mayo and Mashauri, 1991), it is therefore advisable that the finished internal surface be tiled.

2.3 Rainwater Treatment

Rainwater from a properly designed rainwater pre-filtration and storage system can be used without further treatment for non-portable uses such as landscape irrigation, garden ponds and watering, flushing, cold water flushing etc. When rainwater is however also to be deployed for portable use, supplemental filtration is essential and disinfection is recommended. Potable uses include drinking water and dishwashing. In order to use rainwater for potable uses, a water treatment unit is usually required (Caitlin and Tamim, 2008). Rainwater may contain pollution, animal excrement and other particles which are harmful to humans, plants and animals. Therefore collected rainwater needs to be treated before it is safe to use for business. A process of treatment and sterilization is necessary to make rainwater compliant with regulations and safe to use in homes and for businesses (Cleanawater.com Online Article, 2016).

There are two primary steps to rainwater treatment: filtration and sterilization using chlorine or UV light.

Filtration involves the removal of sediments, small particulate matter that might have settled at the bottom of the tank. There are many filtration devices available and micro-organism and particle removal varies with the filter type. Water filters should not be necessary to maintain microbial, chemical or physical quality of rainwater if catchments and tanks are well maintained[m]. It is however safer to have a filtration system as the first option in your water treatment process.

![Figure 2: Rainwater Treatment. (Source: Cleanawater.com Online Article, 2016)](image)

The second stage of treatment is sterilization which may either be chlorine sterilized or through Ultra Violet (UV) Light.
Adding chlorine to water is a simple and effective way to sterilize filtered rainwater. It is a common form of disinfection that is effective against harmful bacteria, viruses and Giardia, but has limited effect against Cryptosporidium. Chlorine treatment is an ideal solution for rainwater that needs to be stored for future use (Cleanawater.com Online Article, 2015). Rainwater is compliant with the treatment regulations at all times, as a sampling pump will automatically regulate the appropriate chlorine concentration (Cleanawater.com Online Article, 2015).

Ultraviolet (UV) light is an alternative method of sterilization which works by disrupting and damaging pathogens’ cells. It is effective against most bacteria, viruses and protozoa.

UV light sterilization requires rainwater to be virtually free of any large sediment. If the rainwater has not been filtered, shadowing can occur, whereby sediment blocks the UV light rays, reducing the effectiveness of sterilization (Cleanawater.com Online Article, 2015). Rainwater supplies therefore need to be first filtered to ensure effective UV treatment. Advantages of UV systems are that it requires relatively low maintenance, do not require the addition of chemicals and can include warning alarms to indicate equipment faults. Specialist UV chambers for treating rainwater are designed to provide a dosage of UV light at a given flow rate. UV systems will require a power supply. Water that has been disinfected using UV is best used straight away, not stored in tanks. Chlorine treated water can however be stored in tanks for future use.

2.4 Rainwater Collection and Storage

In order to utilize resources and sustain the intensely water driven agriculture practices, various technologies have been implemented to harness rainwater. The techniques currently employed include infiltration pits, tied ridges, and the use of channels as methods of collecting surface runoff (Kudakwashe 2004). Varying from agricultural use, most residential and commercial practices utilize a rooftop, a gutter and downspout system, a collection tank or cistern, and a water distribution pump for harvesting rainwater. In both cases, the amount of harvestable rain is based on the surface area of collection, the ridges...
and pits of agricultural practices and the rooftop, as well as the average rainfall in the area (Caitlin and Tamim, 2008). To ensure that water void of dust and pollutants are collected from the catchment surface, it is important that the first few rains is allowed to flow out to external drains. (See fig 6 below). Roof wash or first flush system is therefore incorporated in the RWH system to keep dust and other pollutants like bird droppings and leaves that have settled on the roof from reaching the cistern (Malcolm, 2015). The collection process of rainwater capture is completely energy free since the environment and gravity harness the rain. This makes Rainwater Harvesting a more energy efficient means than the pumping of groundwater (Caitlin and Tamim, 2008). The distribution process however, requires energy usually through a pump. Also, if rainwater harvested for potable use, energy is required throughout the filtration process.

The tank size is determined by the rooftop area, the average rainfall and water use at the site (Caitlin and Tamim, 2008). The storage tank size will determine how much water can be collected and stored at a particular time for reuse. The storage tank can be mounted on the ground surface, elevated or underground. From the tank, the water is pumped to treatment unit to be treated for potable use and non-potable use.
2.5 General Design Requirements of Rainwater Harvesting Systems.

Rainwater harvesting systems consist of 7 major components namely: (1) catchment area, (2) roof wash (first flush/filter) system, (3) prestorage filtration system. (4) Rainwater conveyance (e.g. gutter, pipe) (5) cistern or tank for storage (6) water delivery, and (7) water treatment (disinfection/filtration) system (Malcolm, 2015).

All these 7 components must be planned and designed for at the detailed drawing stage of any structure that will effectively harness the potentials of RWH for both portable and non-portable use. The mechanical and electrical engineers must be informed ahead to make necessary services provision to accommodate the RWH systems. It is better and more economical when all these are allowed for right from the design stage. It may pose an initial additional cost to the overall cost of construction, but the overall cost savings on water and the benefits to the environment over the long period of use of the building cannot be compared to the initial cost of adapting the system. Existing buildings can however also adapt the system.

2.6 Application Areas of Rainwater Harvesting Technology

Rainwater can be used for both potable and non-potable uses. Potable use include drinking and washing plates while non-portable use include irrigation and watering plants, washing cars, filling swimming pools and ponds, flushing toilets, washing clothes, showering and bathing etc. (See fig 7 below). Its various uses can be applied in residential homes, offices, shopping malls, schools, university campus, hostels and even business ventures such as restaurants, car wash etc. to safe business running costs. On a communal scale, rain water dams can be constructed for irrigation and agriculture purposes, to service open relaxation parks and gardens and also serve small communities and villages that are suffering from acute water shortage and are forced to fetch contaminated water from nearby streams.

Figure 7: Non-Potable Use of Rainwater. (Source: Conservation Technology Rainwater Handbook, 2012)
3.0 RESEARCH METHOD

A systemic literature review of Rainwater Harvesting technology (RWH) as successfully implemented in few selected countries was done. Two identified cases were reviewed for effectiveness, user perception and adaptability at communal level. A review of government roles and interventions in the successful implementation of RWH system in few selected countries such as United States, Tanzania, Brazil, Mexico etc. were studied with a view to give direction and adapt same in the Nigerian Urban Context where applicable. Therefore, various books, journals, magazines, study groups, online publications and write-ups have been reviewed. Backup Data were also collected through interview of persons and observation.

3.1 Rain Water Harvesting In Tanzania

Rain Water Harvesting is a technology already been put to use in Tanzania for wide variety of purposes ranging from domestic water supply in buildings to water supply for use in farming and livestock. In the Semi-Arid areas of Tanzania where agriculture and the livelihoods that depend upon it are greatly affected by the unreliable and highly variable rainfall regime, Rain water harvesting has been harnessed as the best prospect for sustainable intensification for the vast majority of dry land farmers (Gowing et al, 2012). In places where surface water is not available, rainwater storage in impoundments has been practiced mainly for livestock and to a lesser extent for domestic use (Mayo and Mashauri, 1991).

In Situ Rain Water Harvesting, Micro and Macro Catchment Rain water harvesting are examples of other practicable techniques used in Tanzania as it relates to RWH for farming and livestock purposes.

Rainwater harvesting for domestic consumption was regarded as one of the vital options for water supply after a long and chronic experience of water shortages at the University of Dar es Salaam main campus due to the location of the main campus which is about 100m above sea level, and its topography and shortages of water supply to the city (Mayo and Mashauri, 1991). The University Campus was the worst hit as it relates to water shortages in the whole city (Mayo and Mashauri, 1991).

In a bid to tackle this challenge, Rain Water cistern systems was therefore introduced in the University of Dar-es Salaam main campus and since been used in other urban areas and cases example of which are notable at the African Medical and Research Foundation (AMREF) offices in Dar-es Salaam and the Sungura textile mills. The Sungura textile mills, for example, have a 2000 m³ storage tank which is used to store rainwater and municipal water supply for use during shortages (Mayo and Mashauri, 1991).

Case Study of 16 Units of two storey Swiss sponsored housing units for Da res Salam University Staffs

Rainwater cistern system was adopted in 16 Swiss sponsored housing units for University staff in order to supplement the municipal water supply which had become very intermittent.
The two storey Swiss sponsored housing units were provided with a basement tank which has two compartments with a total capacity of 80 m³ and a roof tank of capacity 400 liters. Rainwater is collected on the galvanized iron sheet roofs and stored in the basement reinforced concrete tanks through a network of gutters and downpipes. The daily water requirements are pumped through a roughing filter by a hand pump located on the ground floor to the roof tank which then provides water by gravity (Mayo and Mashauri, 1991). (See Fig 8 below)

Figure 8: Rainwater Cistern System in Swiss sponsored housing units for Dares Salam University Staffs. (Source: Mayo and Mashauri, 1991)

3.2 Rain Water Harvesting in Lekki, Lagos, Nigeria

Complete Renovation of an office space located in Lekki Phase 1, Off Admiralty Way, Lagos, Nigeria was embarked upon in 2017 with the author been directly involved in the renovation project as the consultant. The initial brief received from the client did not capture the possibility of a rainwater harvesting system as part of the agenda to be achieved after renovation is completed. The office had largely depended on the purchase of water from tankers which is stored in an existing underground concrete tank and after treatment is pumped to an elevated GRP Tank mounted on a concrete slab portion of the roof which is then distributed by gravity to various internal office spaces where required for both portable and non-portable use. This has been the office usual practice for over 15 years since the office was in operation. Government Public Water Supply was practically non-existent and pumping of ground water through borehole was not an option often employed in the Lekki axis of Lagos due to the shallow water table, high salinity, reddish/brownish water coloration and high risk of contamination from the dirty lagoon in the axis (Oladapo 2014). However, while carrying out a survey of the existing building with a view to document the as-built drawing and also determine the leak areas on the concrete slab portion of the roof noticeable on the first floor internal slab soffits resulting in the damage of ceilings and wall paints, the thought of a rain water harvesting system came up in mind as an alternative water supply system that can be presented to the client for approval.
A survey carried out on the office staffs to get their view and consent to adapt the rain water harvesting system in their office shows that 13 of the 15 staffs agreed it will be cost effective if implemented. However, less than 35% of the staffs were previously aware of the potential of rain water harvesting system as alternative water sources both for portable and non-portable use. The larger percentage were not aware and had out of ignorance cited risk of contracting infections and diseases as high if the system is implemented even for non-portable use as washing. Little did they know that even the purchased water from tankers goes through a treatment process without which the risk of contracting diseases is also possible as the water quality from the tankers can as well not be guaranteed. 2 out of the 15 staffs noted they were aware of RWH’s potential for portable use while 5 of the 15 staffs noted they were aware of its possibility only for non-portable use. A brief advocacy lecture was conducted for all staffs enlightening them of the merits and cost savings the office stands to gain while also putting them through the treatment process the water goes through and also other measures that will be put in place to ensure clean water gets out of the taps. 8 out of the staffs were in support of the idea before the advocacy lecture was conducted while the other 7 felt it will be a waste of time and resources. After the advocacy lecture and enlightenment was conducted, all the 15 staffs agreed to the idea (See Table 1 below).

Table 1: Survey Result carried out for RWH awareness and Acceptance on Staff

In this case, the initial cost of setting up RWH system is very minimal as the bulk of the equipment required such as the underground water tank; treatment plant and the overhead tank to store the treated water already existed. Few lengths of 6” pipes, elbow, wire gauze and vent caps were plumbing materials required to re-direct the rain water into the underground tank from the existing down pipe previously throwing the water unto the site drain.
The concrete roof slab portion of the roof as seen in fig 9 above was retained as the main catchment surface from the long span aluminum roof. The existing screed and bituminous felt were however carefully hacked off and new ones laid to fix the leakage that have occurred for long through the concrete slab. Fulbora was installed with a wire mesh embedded to prevent the passage of stone particles and leaves that may find their way into the down pipe conveying water into the underground water tank.

The downpipe as seen in fig 10 was retained but with a T elbow installed at the base to have a 2 way branch channel. The first elbow channel to serve as the flush out channel to pass out the first few rains at the beginning of each rainy season while the second channel takes the water into the underground tank. When the first few rains have been flushed out and the catchment surface clean enough, the flush out channel will be blocked to activate the second channel that releases the rain water into the underground tank.

After 2 months of continuous successful usage, the accountant was the first to send a mail of the considerable savings of about 25,000 naira monthly savings made noting that they normally buy a tanker of water at the rate of about 12,500 naira of which 2 of the tankers is normally delivered monthly in most times of the year. The environmental benefit of it reducing the amount of rainwater run off to the external drain that will contribute to excessive flooding is also achieved.

4.0 Rainwater harvesting at Communal level and Government Role

Taking Lagos City for example, the cumulative effect of having a Rainwater Harvesting (RWH) System installed in all buildings in each Urban Suburbs will have immense environmental benefits. Flooding is one of the significant environmental disasters during rainy periods in most urban cities of the country. Flood events and impacts in recent times have arguably been unprecedented and affected the lives of hundreds of millions of people across the world (Ajibade et al. 2013, 2014; Adelekan, 2013). During this period, floods have caused harm to millions of people physically, emotionally, and economically (Nkwunonwo et
A typical example is the July 2011 flooding event, which affected approximately 5 thousand people and resulted in about 25 deaths. The direct economic losses resulting from the event totalled about 50 billion Nigerian naira (i.e. USD 250 million). Public utilities including road networks, bridges, and schools were destroyed. In addition, houses collapsed, private homes were submerged, and several cars were swept away by flood water (IFRC, 2011; Oladunjoye, 2011). Apart from critical years such as the July 2011 event, there have been several cases of environmental havoccs caused by flooding almost every year.

Flood cases will be drastically reduced if every homes, offices, shopping malls, hotels, schools etc. can install RWH system in their buildings as their will be significant reduction in the amount of rain water offs at a particular period of heavy rain down pour in time.

A significant amount of the rain water run-off will also be reduced if rain water dams can be installed in specific areas of communities and villages with different channel of pipes emanating from different purpose-built gutters to channel the rain water into the dam. The rain water dams will be purpose built to serve landscape irrigation purpose, agriculture, livestock farming and may even be an alternative water source for nearby villages that may be faced with acute water shortage challenges.

All these will however not be possible without the Government playing an active role in its successful implementation. Relevant Government Ministries, agencies, departments and parastatals must come together with a view to map out workable strategies towards its successful implementation. For example, the Federal Ministry of Works, Housing and Urban Developments and its equivalent ministries at every 36 states of the Federation can make it mandatory that every new building permit approval submissions must be accompanied with a workable RWH system report and same clearly designed for in the detail drawing submission for approval. This will significantly help ensure that all building professionals and future property owners are RWH system compliant in their property development endeavors. All existing property owners can be mandated under a new code to embark on adapting a RWH technology in their buildings with a specific fine attached if not implemented at a particular due date.

Another agency can be responsible with a new code to regulate and control the use of the system to ensure that the quality of the installations and the harvested rain water are not compromised.

**Review of Government Roles and Intervention Initiatives in few selected developed countries**

In developed countries, many states, countries, and cities have different restrictions and mandates constraining the implementation of indoor RWH systems.

In Virginia, a code has just been enacted stating that the indoor use of rainwater must be not only filtered and designed according to the Virginia Rainwater Manual, it must also be sampled and tested for approval by the Virginia Department of Health (Division of Engineering and Building 2008). The states of Texas, California, and Hawaii allow rainwater water catchment. The City of Portland, Oregon allows rainwater catchment and San Juan
County, Washington allows it for new construction. Bermuda and the US Virgin Islands require the use of cisterns in all new construction (Malcolm, 2015).

Texas, one of the leading states of rainwater capture, published a Rainwater Harvesting Manual in 2005 (TWBD 2005). Leading the country in state mandates, this manual provides valuable information for legislators, citizens, and company owners to better comprehend various aspects of Rainwater Harvesting (RWH) system. These aspects include everything from basic knowledge about the components for the most common systems, to the state and federal drinking water regulations. Now widely used, the Manual provides guidance for rainwater harvesting system design. In addition to the valuable the manual provides readers with information adequate for estimating and reducing indoor water usage.

In the United States, rainwater harvesting systems can count towards the LEED, Leadership in Energy and Environmental Design, certification (United States Green Building Council 2008). While the LEED certification offers no immediate tax incentives, this certification often increases the property value of the site and is becoming more popular in cities such as Austin, Texas and Seattle, Washington which now requires some level of LEED certification on all new public buildings (Department of Planning and Development, Seattle 2000).

Several counties in New Mexico also have specific regulations for rainwater harvesting such as the Santa Fe County mandate for all new residential and commercial buildings over 2,500 sq. ft. to have a rainwater system in place (Santa Fe, New Mexico www.santafecounty.org).

Considering the Brazilian government scenario, the rainwater harvesting is encouraged in several cities by legislation, either because it is a sustainable strategy or because it is a policy of access to water in arid cities (Enedir et al, 2017).

In Brazil, the "National Water Resources Plan" is the instrument that regulates and guides investments and actions related to water management in the country (Carvalho, 2010). In this plan, the government water management programmes are detailed with a target up to 2020. Related to rainwater, the document only mentions the "One Million Cisterns" programme, which is a federal government investment launched in 2001 to provide access to water for families in the Brazilian semi-arid region by encouraging the construction of cisterns (Enedir et al, 2017).

On July 8 of 1999, the Brazilian Association for Catchment, Management and Utilization of Rainwater was founded. The objective of this association is to promote actions aimed at the rational and efficient use of rainwater in Brazil. Since its foundation, it has promoted symposiums and brought together researchers and professionals of the field to discuss the theme. It also has provided books and educational material, spreading information and concepts about the theme (Enedir et al, 2017).

Also in the national scope, on May 28th of 2015, a bill was proposed in the Federal Congress House that intends to make mandatory the implantation of rainwater use in buildings larger than 200 m² (Federal Law Project # 1750 of 2015). However, this legislation depends on the approval by political leaders to come into force (Enedir et al, 2017).

A review of these Government intervention initiatives in few selected developed countries have been documented to give a guide to Nigerian Government as to how the intervention programmes can be approached to ensure that Rain Water Harvesting System (RWHS) is...
made part of our way of life to ensure sustainable provision of water to its increasing populace.

5.0 CONCLUSION.

The survey carried out as shown in Table 1 under section 3.2 shows that mass awareness and advocacy has to be conducted to change the mindset of majority of the Nigerian populace on the concept of Rainwater Harvesting system and its implementation. Its potential for enormous cost savings during rainy seasons have to be emphasized while also explaining that the initial cost to get the system running is negligible when compared to the long term benefits. Its imminent environmental benefits should also be highlighted during the advocacy. The various components and design requirement of RWH system from the catchment area through to the pre-filtration, treatment and final circulation for end use should be explained.

For a successful implementation of the RWH System, Government has a major role to play as already documented in section 4.0. It is therefore recommended that proactive steps be taken by the related government ministries, agencies and parastatals in ensuring a successful implementation of the system across major urban cities of the country.

If Nigeria must be able to meet the part of the Sustainable Development Goal which emphasized “equal access to potable water for all” with the seemingly increasing daily population growth rate in mind, the successful implementation of RWH System will be a crucial technology to be explored and harnessed as is already been done in other developed countries of the world.

Further research is required to fully ascertain the end user perception of RWH system vs Groundwater abstraction through borehole installation as it relates to cost and energy efficiency in different locations and regions in Nigerian cities. In addition, further researches are also required on the potentials of RWH system in combating flooding in Nigerian cities.

Similarly, in a more applied setting, energy efficiencies of large scale rainwater harvesting systems should be analyzed to help determine the future of rainwater harvesting as a valuable technology for providing water, a crucial resource that is becoming more depleted with the ever increasing population and water demand.
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