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CHAPTER 4

POTABLE WATER DISTRIBUTION SCHEME USING AUTONOMOUS WATER TANKERS FOR LIFE SUSTAINABILITY IN DEVELOPING NATIONS

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Introduction

Water is an indispensable natural resource required for the sustenance of all living creatures (plant, animals, and human beings). The essentiality of water spans from domestic use (such as washing, drinking, cooking, and bathing) to industrial use by manufacturing industries. In food production, the role of water cannot be over emphasized; this resource is the back-bone of agriculture otherwise, the entire world will die of starvation. However, domestic water use accounts for 5% of water consumption. As the demand for water increasing unavoidably daily, the world is at a risk of experiencing a terrible water draught with developing nations at the receiving end. According to IWMI study(Seckler et. al.1998)**,** it was estimated that nearly 1.4 billion people (amounting to a quarter of the world's population, or a third of the population in developing countries) live in regions that will experience severe water draught within the first quarter of the next century. Thus, there is the need for a scheme to defy the water scarcity monster before it devours the universe.

The main sources of water are ground water and surface water. Ground water is a portion of atmospheric precipitation, mostly rainfall which has(Yamin, 2014) infiltrated into the earth to form underground deposits called acquifers. Ground water sources include bored wells, jetted wells, dug wells and drilled wells. Surface water sources are a mixture of rainfall, run-off and ground water. They include rivers, ponds, lakes and streams.

Every year, several people die of water diseases owing to poor water supply and sanitation in developing nations of the world. Water diseases are categorized into waterborne diseases; water-washed diseases; water-based diseases; and water-related diseases. Waterborne diseases (diarrheal and enteric diseases) are contracted by drinking unsafe water polluted by human or animal waste that contains pathogenic bacteria or viruses. Water-washed diseases (for example scabies) are caused by improper personal hygiene or contact with infested water. Water-based diseases are caused by parasites whose intermediate organisms reside in dirty water. Water-related diseases (for example, malaria and yellow fever) are caused by insect vectors and the most common insect vector in developing nations is mosquito. The mortality rate of diarrheal diseases (such as cholera, typhoid, etc.) ranges from 2,200,000 to 5,000,000 yearly(WHO, 2000). About 73% of diarrheal and enteric diseases are traceable to ingestion of unsafe water (UNICEF, 2020).

In view of the above, this paper reviews the causes and consequences of water scarcity, with a view of exploring the feasibility of drinkable water distribution scheme using autonomous water tankers. The paper is divided into three parts: description of water scarcity in developing nations with emphasis on Africa and Asia; causes of water scarcity in developing nations; and safe drinking water distribution using autonomous water tankers.

Water Scarcity in Developing Nations

Water scarcity is defined as a situation where human activities and natural occurrences encroach into the supply or quality of water to a level when the available water will not be able to meet the demand by all sectors.In 2015, The United Nations (UN) proposed 17 sustainable development goals (SDGs) which promote economic, environmental, and social advancements to achieve a better and more sustainable future for all. Goal 6 emphasizes the significance for potable water for human sustainability. However, scarcity of potable water is still an issue as over 97% of the water on Earth is salt water, while only 2.5% is fresh. Of this freshwater, two-thirds is snow and ice, and one-third is ground water. Therefore, only 0.0083% of Earth's water is available. The UN declared that more than 2 billion people are living with the risk of abridged access to freshwater resources, and at least one in four people is likely to be affected by chronic or recurring shortages of freshwater by 2050. Over 1.7 billion people are currently living in river

basins where the quantity of water usage is greater than the quantity of water supply (UnitedNations, 2015).Water is an economic resource required for human sustenance and survival. Water Scarcity has become a global menace and it is aggravating as a result of urbanization as well as increasing population.This is because of the rising demand of water for industrial, agricultural and domestic use(WHO, 2009). Scarcity of water affects all social and economic sectors and it is a threat to the sustainability of the natural resource base. UN FAO states that by 2025, 1.9 billion people will be living in countries with absolute water scarcity and two-third of the world population could be under stress condition (UN2020).

Assessment of water scarcity in a geographical region can be based on demand, supply, use and development focusing mainly on human and the ecosystem. From demand viewpoint, improvement on the volume of water production per unit of water is germane to alleviate water scarcity (FAO, 2007).

Water is an indispensable resource required for socio-economic development as well as maintenance of a healthy ecosystem. The geometric increment in human population has mount a great pressure on fresh water due to increasing demand for agricultural, industrial and domestic use. Thus, the world is tending towards a terrible water crisis in the near future. Although, several measures are being put in place to alleviate water scarcity over the last three decades, about 900 million people continue to lack access to safe water(World, 2012). Water scarcity leads to degradation in water quality and pollution with the poor populace at the receiving end. Many poor people are forced to drink unsafe water as well as being made to face the challenges of poor sanitation because of poor water quality. The quality of water used for domestic or industrial purposes has a great impact on health. Poor quality water can cause disease outbreak and even result in endemic in the society. Furthermore, scarcity of water adversely affects the level of food production as this depends mainly on water.

The effect of water scarcity on food production is exemplified by the current debate over grain production in China without having to import cereals from other nation. In a survey carried out by Lester Brown (Brown et. al. 1998), it was clearly stated that China will have to import as much as 210-370 million tons of grains yearly to feed her population by 2025, owing to impending water shortage in the northern region of China. This claim was buttressed by MEDEA

study sponsored by National Security Agency of the United States. MEDEA study estimated that by 2025, China's demand for cereal import will be 175 million tons which is close to Brown's lower estimate. In Nigeria, according to multi-indicator cluster survey of 1999 by the Federal office of statistics, about 120 million of the country's population has no access to potable water. That means only 52% urban dwellers and 39% rural dwellers have access to potable water.

In geographical areas suffering from water scarcity, women and children are left to search for water for domestic use of the family; such search can require them trekking several kilometers in developing nations like Nigeria. Over one billion people dwell in arid regions with tendency of facing absolute water scarcity by the year 2025 while about 348 million more people will face severe economic water scarcity by 2025(Seckler et. al. 1998). Water scarcity can be humanly influenced through affluence, expectations, and customary behaviours; or naturally influenced by climate change, flood, etc. Water scarcity can be viewed from two dimensions; namely,absolute water scarcity; and economic water scarcity.

Absolute water scarcity: This is a situation in which a nation does have enough water resources to meet the per capita need of her fast-growing population. Thus, such country will depend on other countries to meet her water need; the country may even give-in to importation of water resources from neighbouring countries with abundant water resources.

Economic water scarcity: This is a situation in which a nation has enough water resources to meet the per capita need of her populace. However, such country has to reinforce her water scheme or even develop new water management strategies in order to prevent being faced with water scarcity challenges in the future.

In the water scarcity study carried out by the International Water Management Institute (IWMI) between the year 1990 and the year 2025, 118 nations were examined and categorized based on the available water resources and the water demand by the populace. The study result was analysed, and a projection was made on the nature and degree of their water scarcity by the year 2025. According to IWMI survey, by the year 2025, Nigeria, South Africa, Ghana, Cameroun and other sub-Saharan African nations are likely to struggle hard with financial and other resources to achieve the rapid pace of water development.

Furthermore, countries in Latin America, North Africa and East Asia also need to improve on water development. However, sub-Saharan African nations, they have more resources to achieve the objective. Finally, countries in North America and Europe have minimal requirement for additional water development. China and India were considered separately. According to the IWMI survey, at the national level, China does not have a major water problem; while North China is arid, South China has surplus water resources. India is at risk of facing water scarcity later, due to depleted ground water and shrinking glaciers that sustain their key rivers.

Causes of Water Scarcity

The world is blessed with abundant water resources; however, it is untapped. In most developing nations, the available water resources have not been successfully harnessed for life sustainability. Hence, water, though an abundant resource, has been relatively scarce in several developing nations. Water scarcity is the result of an imbalance between water supply and demand. Water scarcity has been a great threat to life sustainability in most developing nations of the world. In developing nations of the world, for example Nigeria women and children have to go in search of water to meet the domestic needs of the family. The duo may go several kilometres before they are able to find water which is likely not be potable.

Fig. 1: Child fetching water from a local stream

Scarcity of water differs in regions of the world; some of the causes of inadequacies in the quantity of water available for use are examined in this section. The causes of water scarcity can be broadly categorized into two namely: natural causes and man-made causes.

Natural Causes of Water Scarcity

The natural occurrences of water scarcity include the following:

Impact of climate change or disruption

Climate plays a significant role in determining the quantity and quality of water available in a region. Climate change contributes to environmental health risks associated with water. For instance, changes in precipitation patterns are likely to increase flooding, and as a result mobilize more pathogens and contaminants. It is estimated that by 2030, the risk of diarrhoea will be up to 10% higher in some countries due to climate change. Furthermore, climate change can also infect coastal surface and groundwater resources due to sea level rise which leads to saltwater intrusion into rivers, deltas, and aquifers; increase water temperatures, leading to more algal and bacterial blooms that further contaminate water supplies. In addition, climate change can increase extreme precipitation and flooding, which will increase erosion rates andwash soil-based pollutants and toxins into waterways.

Africa

The climate of Africa is subjective to the equator, the two tropics and its major deserts (Sahara and Kalahari). The distribution of rainfall in Africa is exceptionally imbalanced both spatially and temporally which has major implications on livelihoods and human sustenance on the continent. Furthermore, most African nations are deficient in human, economic and institutional capabilities to efficiently develop and manage their water resources sustainability. According to WWDR4, sub-Saharan Africa uses barely 5% of her annual renewable freshwater. However, sub-Saharan Africa has the lowest access to improved water supplies both in Urban and Rural contexts in the world. The low accessibility to potable water in sub-Saharan Africa is traceable to inadequate investment in the development of Africa's potential water resources.

Nigeria, a country in sub-Saharan Africa has annual rainfall that varies from over 4,000mm in the South-East to below 250mm in the extreme North-East and is subject to significant temporal variation. The surface water resources potential of the country is estimated at 267.3 billion cubic meters while the groundwater potential is 51.9 billion cubic meters (FRN, 2009). There is a wide margin between the volume of rainfall in the South-East and North-East region of Nigeria owing to the nature of the climate.

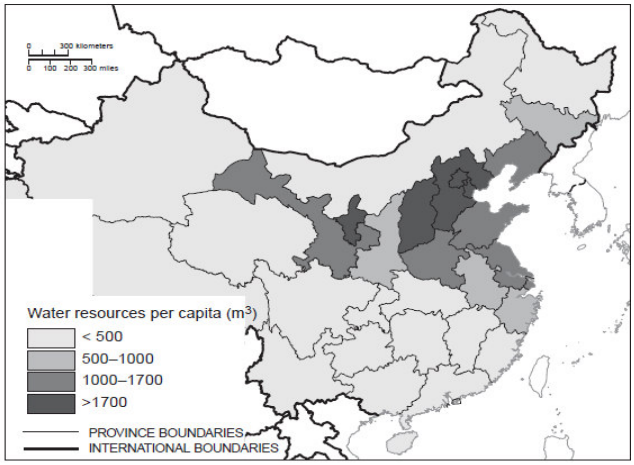
Egypt is also involved in water crisis as a result of climate. In a detailed climatic prediction carried out on Egypt by UNEP, it was inferred that the Nile region and Egypt in particular will experience further warming thus increasing irrigation needs(Elshamy et. al. 2009)(UNEP,

2014).Furthermore, rise in sea-level will mount more pressure on agriculture and water resources in the boundaries of Nile which is the home of over 35 million people and providing 63% of Egypt's agricultural production(Bank, 2014). Owing to intensive irrigation, Nile's environmental flows are already very limited, contributing to salinization and making the delta more vulnerable to seawater intrusion with detrimental effects on agricultural productivity and local water resources.

Tanzania though blessed with adequate surface water and ground water resources is also at the receiving end of the effect of climate on water available for consumption. More than half of the country receives below 800mmof rainfall per annum thus making the country relatively dry. The semi-arid central and northern parts Tanzania as well as south of Lake Victoria receive below 700mm rainfall yearly thus making them arid. On the other hand, southern, western and northern highlands of Tanzania receive over 1000mm rainfall per year thus making them flood prone(URT, 2006).

Asia

In Asia, water availability, allocation and quality are major issues. Asia-Pacific contains 60% of the world's population but has 36% of the world's water resources (APWF, 2009).In China, the amount of rainfall per annum in South China is 2000mm/pa while in North China, the rainfall is 200-400mm/pa. Thus, South China has more water volume than North China thereby China falls below water threshold level of 1000cubic meter/pa, which places the nation at the risk of water scarcity.



Source: The World Bank (2007a).

Fig. 2: Spatial Distribution of Annual per Capita Water Resources – China (World Bank. 2007)

In Mongolia, according to the European Commission Humanitarian Aid department (ECHO), increasingly austere climatic conditions that are making rural life difficult for humans and livestock alike have led to a massive rural exodus towards the cities, in particular the capital which is totally incapable of responding to the basic needs of the new population." Despite the facade of modernity in Ulaanbaatar, aid workers claim that those who have lost everything from natural disasters live in a dramatic state of poverty, lacking food, water, shelter, non-food items, heating, healthcare and education.

Going by the existing climate change scenario in the world, by the year 2030, almost half of the world's population will be living in areas of high water stress, with between 75 million and 250 million people dwelling in Africa. In addition, water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people.

Impact of Natural Disaster on Water Scarcity

Life-threatening weather conditions are also reflected in the increased frequency and intensity of natural disasters such as flood, tornados, and cyclonic storm surges, etc. Natural disasters have negative impacts on water cycle. Regions that have experienced natural disasters or prone to occurrence of natural disaster are at risk of experiencing imbalance in water cycle. In 2010, over

200 million people were victims of natural disasters, including floods, with important upshots for waterborne and water-related disease transmission. When flooding occurs, in areas of major human development, it is catastrophic. The aftermath of floods includes poor hygiene, increased vulnerability to disease outbreak especially amidst the displaced people. Furthermore, potable water is contaminated by pollutants from overflowing sanitation facilities such as gutters and shallow latrines this result in increased risk of waterborne diseases such as typhoid fever, cholera and hepatitis A (WHO n.d.). In cases of flood outbreaks, the poor are more vulnerable and most affected of the populace (Yamin, 2014).

Africa

Africa is not left out of the impact natural disasters on water cycle. Flood is the most common natural disaster in sub-Sahara Africa. Nigeria, a West African nation has been threatened with flood with riverine areas and densely populated regions close to the creeks at greatest risk. According to the World Health Organization the 2012 flood that occurred in Nigeria in the year 2012 was categorized as the worst flood to have hit the country in the past 50 years. One of the flood prone cities in Nigeria is Lagos; Lagos is the smallest city in Nigeria but the most densely populated with a population of over 10million people. The total land area of Lagos is 3,577.28square km, of which 22% is made up of lagoons and creeks(Oshodi, 2013). As a result of the location of Lagos, it has a humid tropical climate with two distinct wet and dry seasons(Adelekan, 2010). The rainy season spans from the month of April to October. During the long rainy season, most parts of Lagos are liable to flooding this is because houses are built on flood plains, the drainage of storm water is inadequate, existing drainage systems are poorly maintained, expansions of impermeable surfaces is uncontrolled leading to increased run-offs and weak institutional capacity(Adelekan, 2016). Lagos State ranks 15th in the world in terms of population exposed to coastal flooding(Sojobi et. al. 2016). The consequences of flood in Lagos include displacement of people from their homes and businesses, contamination of potable water resulting in disease outbreak. The high frequency of diarrheal outbreak was credited to contaminated potable water from destroyed sanitary infrastructure and sewage systems, as documented by(Sessou, 2012). Flooding has become a yearly recurrent issue in Lagos, Nigeria. Some of the commonly affected areas are Marina, Lekki, Dopemu, Iyana-Ipaja, Egbeda, Ikeja

and Ajah (Agada, 2020).The impacts of floods in Nigeria are similar to what is experienced in other countries of the world such as Mali, Senegal, Burkina Faso and Niger (OCHA, 2016).

Asia

The geographical location of Bangladesh, India places her in the permanent stage of disaster. Bangladesh is the largest delta in the world; thus, the nation faces natural disasters such as flood, cyclonic storm surges, tornado and river erosion perpetually. The havoc wreaked by cyclonic storm in Bangladesh greatly destabilized Southern and Central Bangladesh in which about 4000 people were killed leaving over 30000 seriously injured(Setu et. al. 2014). The aftermath of continuous natural disasters in Bangladesh is severe imbalance in the water cycle of the region.

Fig. 3: Flood in Dhaka, Bangladesh (IRIN)

Flood in Lagos Nigeria (Cable News, June 2020)

Fig. 4: Flood in Lagos Nigeria

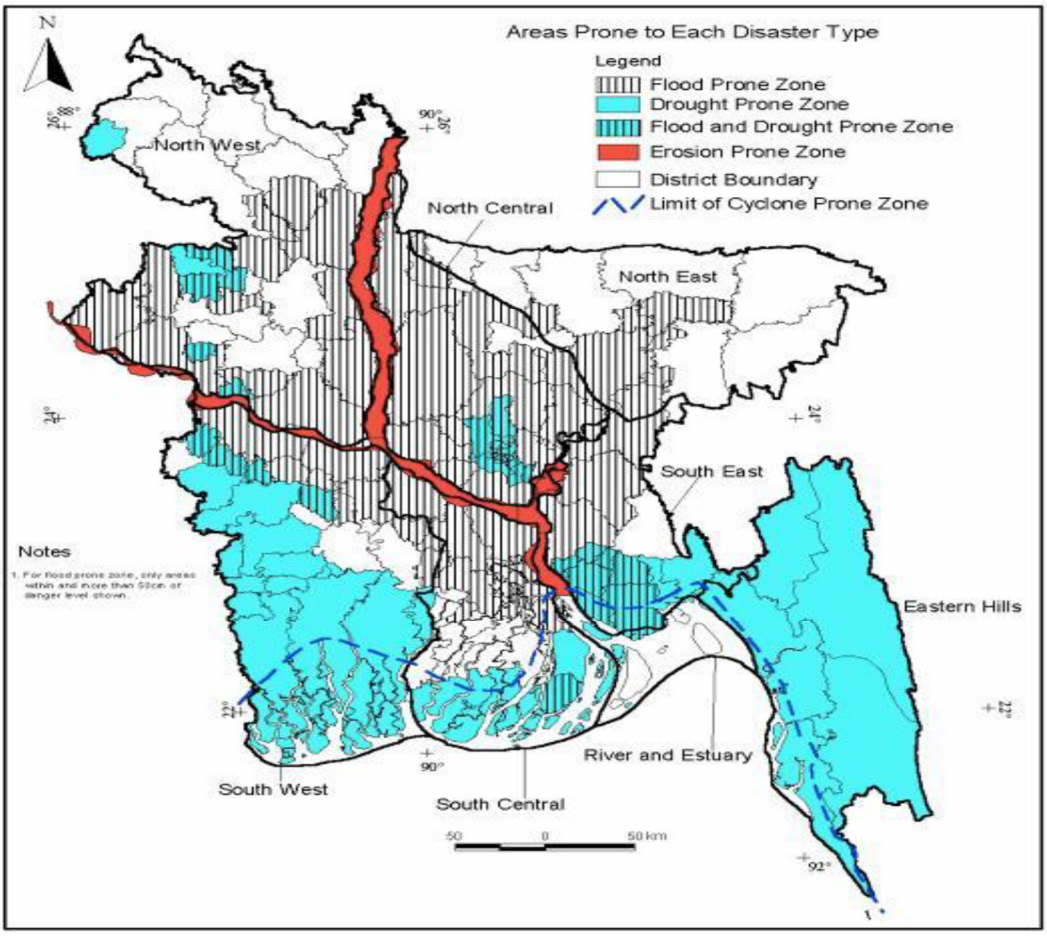


Fig. 5: Natural disaster areas in Bangladesh (IRIN)

Man-made Causes of Water Scarcity

The surface water and groundwater table are receding in many parts of the world due to human influences. The following are some of the man-made causes of water scarcity in developing nations of the world.

Effect of population on water scarcity

Human population is rising geometrically in the world; sequel to the rapid population growth there has been more pressure on water resources. Population rise affects per capita withdrawals of water. The rise in population is traceable to two main sources viz: increased birth rate and migration. Cities and towns have become the primary human living space. Since 2007, more than half of the world's population has been living in urban areas and the figure is estimated to exceed

70% by 2050 (UN, 2018). The global population is predicted to reach between 9.4 and10.2 billion people by 2050 (UNDESA, 2017). Population growth and changes in consumption patterns, including new nutritional preferences necessitate the production of more food. Thus, there is need for agricultural expansion and intensification which have impacts on water quality.

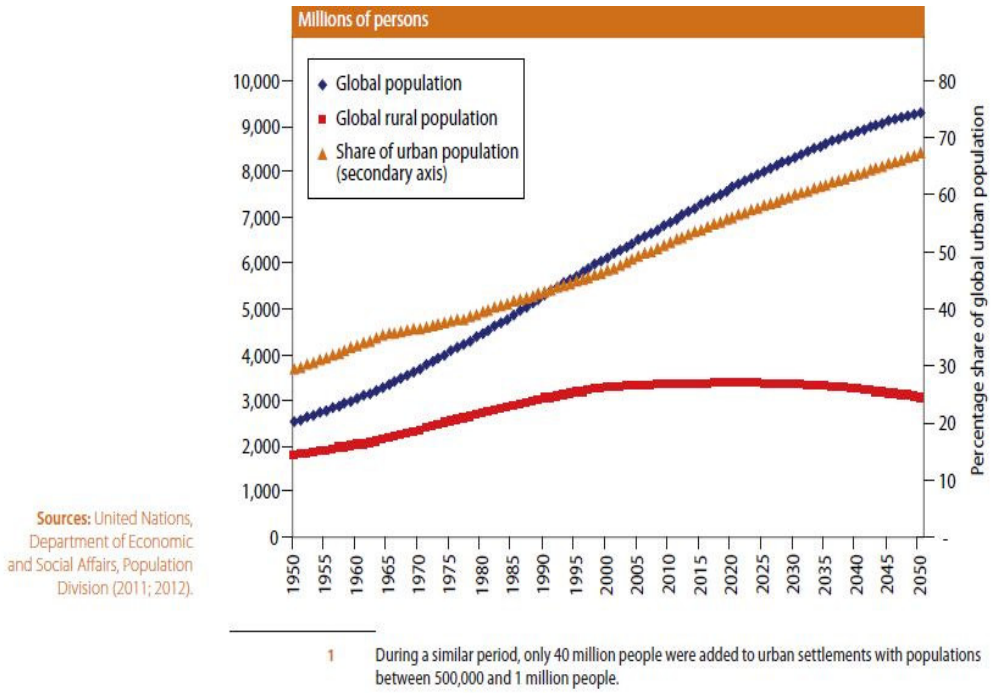


Fig. 6: Population trends and projections, 1950-2050(United Nations)

In developing nations of the world, rapid population growth has not been accompanied by an increase in the delivery of essential urban services with water supply on top of the list.

Africa

In Africa, the population of the people living in urban centers is below 50% of the entire population unlike nations which are well developed. The population growth in Africa has not been accompanied by an increase in water delivery. Development in some African countries such as Burkina Faso, Burundi, Ethiopia and Malawi could be as low as 20 per cent, the urban population represents over 60 per cent of the total population in South Africa. Moreover, urban populations in underdeveloped nations are highly concentrated in a very small number of cities,

which also contrasts with the urbanization pattern in developed regions. For example, 75%, 60% and 47% of the urban populations in Sierra Leone, Kenya, and Guinea are concentrated in Freetown, Nairobi and Conakry, respectively (Grubler et. al. 2013).

In Nigeria, the eighth most populous nation of the world with a population of over 150 million people, less than 30% of the population has access to potable water. It is estimated that only about 50% of the urban and 20% of the semi-urban populations have access to potable water. Overall effective urban water supply coverage may be as low as 30% of the total population due to poor maintenance and unreliability of supplies. Rural coverage is estimated at 35%(FGN, 2000).

In Egypt, rapid population growth increases water stress by increasing water requirements for domestic intake and increased irrigation water use to meet higher food demands (Dakkak, 2017). Egypt has one of the highest population growth rates in the Middle East. Furthermore, rising population figures are contributing to the escalation of water use for domestic crop production, which accounts for nearly 86% of water withdrawals (ci:grapes, 2020). Water demand is also expected to increase as a result of ambitious projects to expand agriculture, industrial activities and urban centres into the Egyptian desert(Bedawy, 2014).

Asia

In Asia, less than 50% of the population dwell in urban areas owing to high level of poverty, thus water resources are being stressed mostly in areas where the people are concentrated. In India for example, due to geometric rise in population, nearly 80% of the country's available water largely from groundwater is channelled into agriculture so as to meet up with the food demand of the people. At current rates, World Bank estimates that India water supply is irregular and reports that groundwater depletion, environmental degradation and climate change will increase water scarcity in India. Furthermore, if dramatic changes are not made, by 2025 three out of five aquifers in India will be critically low and by 2050 India will have exhausted her available water supplies by 2050(WHO, 2013). Delhi is in continuous water disaster, especially during the dry season. With a population of over 15 million, Delhi encounters a water shortage of 750 million litres per day. According to the World Bank, of the 27 Asian cities with populations topping one million, Chennai and Delhi are rated as the poorest performing metropolitan cities in terms of hours of water availability per day, while Mumbai is ranked as second worst and Kolkata fourth.

Fig. 7: Water scarcity in India

Table 1

Regional figures for share of urban population, 1975, 2000, 2012, 2025, 2050

Percentage					
Country/region	*1975*	*2000*	*2012*	*2025*	*2050*
World	37.7	46.7	52.6	58.0	67.2
More developed regions	68.7	74.1	78.0	81.1	85.9
Less developed regions	27.0	40.1	47.1	53.6	64.1
Africa	25.6	35.6	39.9	45.3	57.7
Asia	25.0	37.4	45.7	53.1	64.4
Europe	65.2	70.8	73.1	76.1	82.2
Latin America and the Caribbean	60.7	75.5	79.4	82.5	86.6
North America	73.8	79.1	82.5	85.0	88.6
Australia and New Zealand	85.4	86.9	88.9	90.3	92.4
Oceania	71.9	70.4	70.7	71.1	73.0
Least developed countries	14.7	24.3	28.9	35.2	49.8
Small island developing States	45.8	55.5	59.5	62.4	67.3
Landlocked developing States	22.2	26.1	28.3	32.6	45.6

Source: United Nations, Department of Economic and Social Affairs, Population Division (2012).

Effects of pollution on water scarcity

Human activities such as poor waste management among others have greatly affected the quality of water available for use. Water pollution is a global menace in developed and developing nations of the world. Water pollution is traceable to three main causes – human waste, industrial wastes and agricultural wastes. In addition, oil spillage also affects the quality of water in coastal areas. Globally, 80% of municipal wastewater is discharged into water bodies untreated, and industry is responsible for dumping millions of tonnes of heavy metals, solvents, toxic sludge and other wastes into water bodies each year (UNWWDR, 2017). Agriculture, which consumes about 70% of water worldwide, plays a foremost role in water pollution. Farms discharge large quantities of agrochemicals, organic matter, drug residues, sediments and saline drainage into water bodies (FAO &IWMI, 2017). The resultant water pollution poses demonstrated risks to aquatic ecosystems, human health and productive activities (UNEP, 2016).All these pile in degrading the quality of water available for human consumption. Several health issues emanate from ingestion of polluted drinking water as well as inability to get clean water for daily hygiene especially in low-income countries and emerging economies of the world.

Africa

Africa's water quality has been under a great threat sequel to pollution. The causes of water pollution in Africa are mainly industrial wastes, agricultural wastes and human excreta especially in sub-Saharan Africa. Open defecation is a leading cause of morbidity and mortality in sub-Saharan Africa(UNICEF, 2016). For example, in Nigeria, poor disposal of human excreta has been a bottle-neck in promoting waterborne and water-related diseases. One of the major problems affecting millions of Nigerians is lack of access to potable water supply and adequate means of human waste disposal, refuse disposal and drainage facilities. This is aggravated by inadequate awareness of proper hygiene and sanitary behaviours that result in water and sanitation related diseases (Ngwuluka et. al. 2011). Nigeria is still lagging behind the global transformation agenda to universal access to potable water: 66 million Nigerians are deprived of basic drinking water service while 47million people are practicing open defecation which exposes the populace to risks of water related diseases(UNICEF, 2020).

Fig. 8: Open defecation practice in Nigeria (WHO & UNICEF JMP, 2017)

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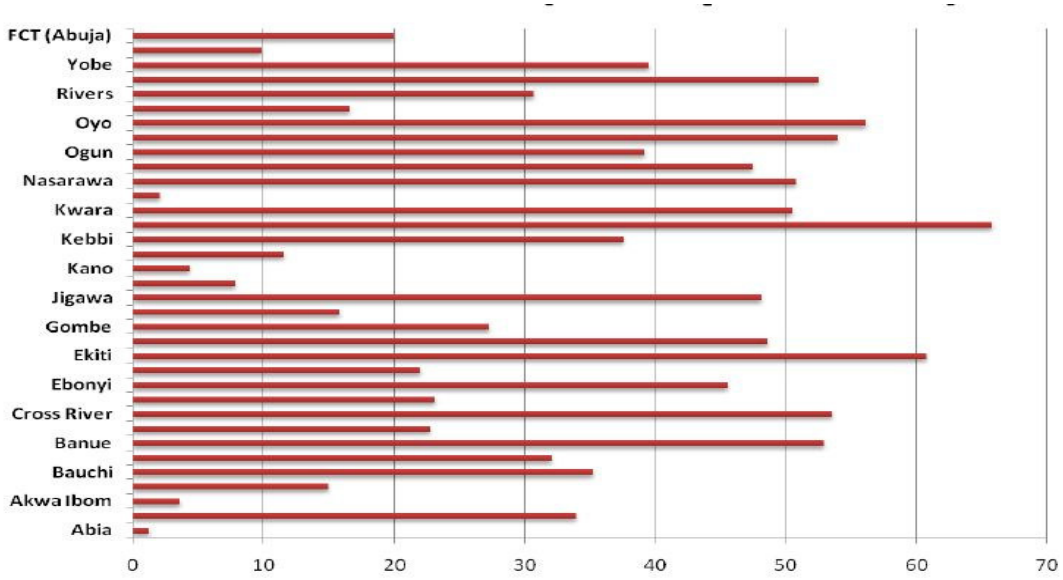

Fig. 9: Open defecation in Nigeria (% Population) (WASH, 2019)

The World Health Organization had claimed that 37% of death would be averted in Angola yearly, if environmental factors like drinking water and sanitation were improved. Open defecation practice is well pronounced in Angola. The lack of toilets poses severe public health and security problems, especially for women and young girls. In the settlements, several communities share a single toilet. Deficiency of water prevents children and adults from using the available latrines, and people defecate at night in open areas, in the streets and rubbish dumps. In a joint survey carried out by UNICEF and Angola government, it was discovered that the entire communities in Luanda have proper means of human waste disposal. In Sao Pedro da Barra, it is the practice of the residents to defecate into plastic bags and throw them into the sea. In addition, there is virtually no means of sewage disposal in Luanda, the untreated sewage flows into the sea; this results in the degradation of water quality (UNICEF, 2007).

Fig. 10: Water pollution in Luanda, Angola (UNICEF, 2007)

Furthermore, poor sewage disposal is one of the avenues through which water is being polluted in Africa. Lagos Nigeria has been rated one of the dirtiest cities in the world. The city is deficient in effective refuse-collection service and has no central system for sewage and industrial

effluents. According to the World Bank, about 6000 tons of waste is generated in Lagos per day and only 3000 tons are taken to the three official dump-sites by government-appointed refuse collectors and informal collectors. Lagos health and environment officials acknowledge that most of the sewage collected by private operators as well as industrial effluents is expelled in the lagoons and creeks. Untreated sewage pollutes the lagoon and destroys marine and aquatic life, thus, reducing the quality of water. Similarly, degradation of water quality in Nigeria is also pronounced in Rivers, Kano, and Kaduna States because most of the country's industries are located there, and the major pollutants are effluents from the industries.

In Egypt, as a result of inadequate water facilities and slack regulations, agricultural runoffs containing pesticides, industrial effluents and organic sewage are being dumped in the Nile River making the water progressively unhealthy for human ingestion (Dakkak, 2017; Bedawy, 2014). Also, in Tanzania, industrial and municipal wastes are progressively degrading the quality of water resources.

Asia

In Asia, aquaculture has grown more than 20-folds than in the 1980s (FAO, 2016b), thus, the pressure on water has tremendously increased as well as water pollution through agriculture. For example, in China, agriculture is the major source of surface water pollution and almost exclusively for ground water pollution through nitrogen deposits from fertilizers (FAO, 2013).

Unaccounted-for-water (UAW)

The definition of unaccounted-for-water (UAW) varies from nation to nation. In Germany, UAW is defined as the difference between the quantity of water entering a system and the sum of water billed, including the water which is measured for some unpaid for reasons. Hong Kong defines UAW as unrecorded water consumption subtracted from the recorded consumed water in domestic, commercial and industrial supplies. Malaysia and Philippines equate UAW with non-revenue water (NRW) (WRC, 2018). In a generalized context, UAW can be defined as the difference between the measured volume of water in a water distribution system and the billed volume of water that leaves the distribution system at a specified time. This includes leakage, wastage and illegal connections. Water is lost through leaking pipes and drains (IRIN, 2011).

Fig. 11: Leaking water pipe (IRIN)

Water wastage occurs in all water supply systems, but the volume of loss varies, depending on the features of the pipe network and other local factors. Going by WHO specifications, UAW in urban areas can be categorized broadly into two namely: real losses and apparent losses. Real losses of water or physical losses of water include losses through leakages from pipes, joints and fittings as well as storage tank overflows. Apparent water losses include accounting errors, illegal connections, inaccurate customer meters, bypass meters and other unknown uses(WHO, 2001).

In a report by the International Water Services Association (IWSA 1991), the percentage ranges of UAW in various nations were categorized thus: % UAW in developed countries ranges between 8-24% of available volume of water, in newly industrialized countries 15-24% and finally in developing nations 25-45%. A report carried out on European nations by Lallana revealed that water leakage in Germany is about 5%, 30% in France and Italy, 20% in United Kingdom, 40% in Slovenia and 50% in Bulgaria(Lallana, 2003). Additionally, based on a study carried out by Environment Canada, Eichenberger was able to infer that 13% of Canadian public water is reported as leakage(Eichenberger, 2005). In Asia, according to State of the World Report (2004), the percentage of UAW in Asian countries is between 20-40%(UNICEF, 2004). Based on several case studies, UAW loss in Iran is in the neighbourhood of 35-40%(Tabel, et al 2001).

Progress is being made by several nations to curtail water leakage and significant headways have been made by developed nations. For example, through active leakage reduction program,

between 1992 and 2001, England has been able to reduce network losses from 30 to 22% while South Korea and Singapore have been able to reduce UAW from 10.6 to 6.2 % from 1989 to 1995. From the foregoing, it can be clearly seen that UAW reduction is really lagging in developing nations of the world.

Water Resource Planning and Management

Water resource planning can be defined as harnessing and distribution of adequate, inexpensive and sustainable supply of potable water to human and natural ecosystem. Water resource planning is essential to put alternative measures in place that may increase available water supplies and enhance water quality as well as aquatic ecosystem. Over time, several water resource planning and management schemes have been put up in various regions of the world with a common aim of combating water scarcity.

UNICEF has been able to developa Water Sanitation and Hygiene (WASH) scheme with the vision of realization of the human rights to water and sanitation. The scheme is a long term scheme that will cover from year 2016-2030 and the objectives are to achieve universal and equitable access to safe and affordable drinking water; as well as to achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations (UNICEF, 2016).

Challenges of existing water resource planning and management schemes

In developed nations of the world, significant headways have been made in the area of water resource planning and management however, most low-income nations are far behind in this area. The failure of most water resource planning and management schemes in developing nations of the world are traceable to the following:

- Inappropriate, inadequate, and degraded infrastructure.
- Poor and uncoordinated management.
- Poor operation and maintenance of water infrastructures.
- By-passing accountability for performance has truncated several water planning and management schemes as well as disabled many existing ones.
- Absence of financial discipline resulting in mismanagement of funds.
- Unreliable service delivery.

Potable Water Distribution Using Autonomous Water Tankers

Water distribution can be defined as supply of water to consumers as at when due. Water can be conveyed in a variety of different containers either specifically designed for the purpose or fabricated to meet an urgent need. However, specially designed water tankers are safe and more reliable than fabricated ones. Water tankering (also known as water trucking) is a medium of water conveyance to areas in need in case of emergency. However, tankering operations are pricey and relatively time-consuming to administer. An ideal water distribution scheme is expected to deliver quality service at minimal latency. However, existing water distribution schemes in developing nations use human-driven tankers; these have not been able to discharge duties excellently in most cases. There are cases of delay in service delivery as well as instances when much havoc would have been wreaked before the tanker arrived destination where needed in cases of emergencies such as fire outbreak. For example, in Nigeria, there was a fire outbreak on 5th January 2020 at Akesan Market, a major market in Oyo town, Oyo State, Nigeria which consumed the entire market. Although a fire service station was close to market but eye-witnesses reported that when the fire-fighters were called the response was there was no water to extinguish the fire. This is one of the many scenarios when there will be cases of fire outbreak and it is either a story of non-availability of water or fuel or delayed service delivery in some cases. Autonomous water tankers will be efficient in water distribution especially in cases of emergencies.

Autonomous water tankers are self-driven or driverless water tankers that can be used for conveyance and distribution of water to users at minimal latency. Unlike human-driven tankers, the vehicle is assigned to driving task and it is coordinated. Autonomous tankers are better than human-driven tankers in terms of safety, reduced congestion, and land use; they also save energy, and increase mobility since they automated. Furthermore, there is better use of travel time and low fuel consumption as well as removal of driver stress. To minimize encounter with other vehicles, a dedicated lane can be created for the autonomous tanker conveying water to users.

Towards Effective Water Distribution Scheme Using Autonomous Water Tankers

Water distribution scheme using autonomous water tankers consists of three entities namely:

1. Regulatory bodies
2. Service providers
3. Consumers/ users

Regulatory bodies: These are the duty bearers for service delivery. They develop water supply assets and create enabling environments. In addition, they regulate the service providers by establishing service standards and tariffs for good service delivery. Regulatory bodies issue operating license to service providers. They can sanction service providers or revoke license of operation if service providers fail to meet up with service standards and can also cut-off users that default in payment of tariffs from the service so as to ensure excellent and sustained delivery of service. Efficient regulatory bodies will help combat mismanagement of the scheme; this is achievable because the service providers and the users are accountable at different levels to the regulatory bodies.

Service providers: These are the owners of the autonomous tankers. They are responsible for conveyance and delivery of potable water to users in line with the norms and policies that govern service provision. The service provider can be government, private sector or communities. The service providers ensure that the water being supplied to consumers is healthy and safe for human consumption. The service providers register with the regulatory bodies so as to obtain license of operation.

Consumers/users: These are registered with the service providers. They utilize the service in accordance with the contracts and established norms which include payment for services that meet a specified standard.

The interactions between the three entities will either make or mar the effectiveness of the water distribution scheme. A proper and positive interaction will tremendously contribute to the efficacy of the scheme. Since the activities of the service providers are monitored, they will work towards excellent delivery of service to avoid sanctions and litigations. On the other hand, users will also avoid defaulting in payment of tariffs so as not to be cut-off the service since the service is effective. Furthermore, service providers will ensure proper maintenance of facilities in order to meet up with stipulated service standards by the regulatory bodies.

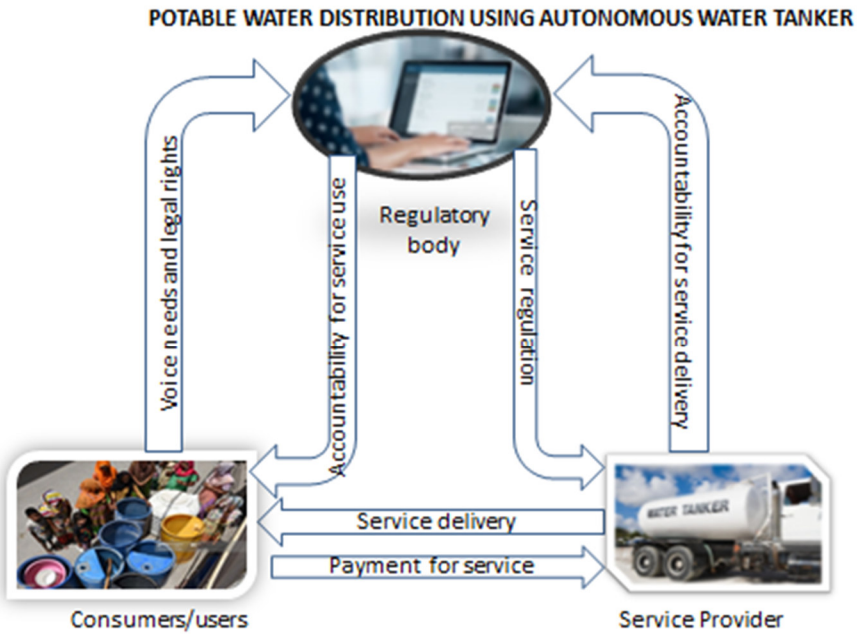

Fig. 12: Portable water distribution using autonomous water tanker

Conclusion

Autonomous water tankers will go a long way in improving potable water delivery in developed and developed nations of the world for human sustainability. Although, the initial cost may be exorbitant, but the long-run benefits will overwrite the initial costs.

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