ABSTRACT

Climate change is now widely recognized as the major environmental problem facing the globe. The UN Secretary General Ban Ki Moon and UNEP Executive Director Achim Steiner agreed on the fact that we must no longer discuss whether our climate is changing, but rather at which rate the climatic changes will occur (UNEP, 2009). Although it is difficult to calculate the precise effects of climate change, various changes can be felt on the various sectors, especially in the water sector. A reduction in overall precipitation and changing patterns of precipitation for the past century, increase in flash flooding, sea level rise, more frequent heat waves and a constantly varying temperature are already been recorded, and these consequently impact on the availability of fresh water.

Mauritius, being a small island state, constantly faces the challenge to ensure a reliable supply of good quality of fresh water. But with climate change affecting the island, reliability of supply of water may not be ascertained. According to the United Nations Development Programme (UNDP) Human Development Report, Mauritius is already being faced with a problem of water supply. In fact it has a supply of 1083 m³ per person per year which is below the standard of 1700 m³ per person per year. On the demand side, there is a constant increase, as population and standards of living are increasing. On the supply side, a reduction in fresh water availability owing to climate change will further increase the vulnerability of the water resource sector. Taken together, an increase in water demand and a decrease in water availability, the net effect of this will present major challenges to future management of water resources for human and ecosystem development.

The need to adapt to climate change is already being felt worldwide and it owing to the varying severity and nature of climate impacts, most adaptation initiatives will have to be taken at the regional or local levels. It has been recognised, that the ability to cope and adapt also differs across populations, economic sectors and regions in the world. Countries are being encouraged to identify adaptation measures that are likely to be successful. Rainwater harvesting technology, reuse of treated wastewater, artificial recharge, desalination technology, sustainable consumption of water, water demand management are some of the strategies that many countries are considering as adaptation strategies. For the purpose of this study, the adaptation technologies; the rainwater harvesting, artificial recharge and desalination were investigated. A cost benefit analysis indicated that the rainwater harvesting technology is likely to be used for secondary uses, and will be successful in the upper lands. The desalination technology, which is already being implemented in the hotel sector, remains an expensive and a costly option, but can be an effective option based on optimum treatment capacity. The artificial recharge process using treated wastewater is not yet an attractive option, owing to the high treatment cost.
INTRODUCTION

Water is a key resource for sustaining life and society. No community and no economy will prevail without water of sufficient quality and quantity. The changing pattern of rainfall is adding pressure to the already existing threats on freshwater resources and water management systems. It increases water stress in already dry areas, and undermines water quality in areas flooded either by rain or by sea water. The Intergovernmental Panel on Climate Change (IPCC) is confident that the overall net impact of climate change on water resources and freshwater ecosystems will be negative due to diminished quantity and quality of available water, increasing the vulnerability of the water sector, more specially that of the small islands developing states (SIDS). Vulnerabilities related to climate change in SIDS can further result in loss of lives, and damage to property and infrastructure that can easily cripple their small economies. Most small islands have a limited water supply, and water resources in these islands are especially vulnerable to future changes and distribution of rainfall. Throughout the world water resources management practices should be adapted to become less vulnerable to climate changes.

Adaptation in the water sector will need to be not just about water, but also about the people who use the resource and who are affected by the variations triggered by climate change. Climate change adaptation is therefore as much an issue of water management as it is a matter of water governance, as well as a matter of infrastructure development.

CLIMATE CHANGE IMPACTS IN MAURITIUS

The impacts of climate change are already being noted in Mauritius, with flood type rainfall, frequent flash flooding, storm surges and higher temperatures. A study carried out by Boodhoo (2009) showed the different variations in rainfall and temperature recorded at different places in Mauritius for the past century. In fact all the results obtained indicated that the climate is changing in Mauritius. Figure 1 illustrates how the annual rainfall over Vacoas climatic station has been varying over the past 50 years, a decreasing trend (red line) can be observed. Overall the island has been recording an 8% decrease in rainfall since 1950. The temperature recorded is increasing over time (Figure 2).

Climate models have been used to simulated likely changes in the future. The results have indicated a potential rise in temperature in the range of 0.51 °C
to 3.77 °C and sea level rise between 18 cm to 59 cm by 2100. The report highlighted the following potential future impacts:

- Decreasing trend in rainfall
- Increased in heavy precipitation events with increased risk of flash flood
- More frequent heat waves in summer
- Milder winter
- Increase in number on intense tropical cyclones
- Increase in duration of dry spell.
- Increase events of high energy waves impacting the shores.

THE WATER SECTOR IN MAURITIUS – An overview

Mauritius exploits both surface water and groundwater to cater for its demands. With existing storage facilities, less than 33% of the total rainfall is harnessed annually. The rest goes out to the sea through the fast flowing rivers. Over the last 20 years the increasing demand for water has exerted great pressure on the fresh water bodies of the island. It has been noticed that from 1990 to 2006, water demand has increased by 56% (Proag, 2006). In 2010, water demand was estimated to be 935 Mm³ of which 43% was used for agriculture (irrigation), 32% was used for hydropower and the remaining was used for domestic, industrial and tourism purposes. The mean amount of rainfall recorded in the island, was 1,609 mm in 2012, down by 17.3% as compared to 2011. However, the total volume of potable water treated by the different treatment plants went up by 5.9% from 203 to 215 million cubic metres (Mm³) in 2012, (Statistical Digest, 2012).

Water demand is likely to further increase in the future, owing to the increase in population, economic development, the increasing standard of living, the flourishing tourism sector and in the domestic sector. According to the UNDP, Mauritius is expected to be prone to water scarcity by 2020 with a projected 974m³ per person per year based on an estimated population of 1,335,000. It is also to be noted that by 2040, total water demand is estimated around 1,200 Mm³ per year which is almost near the country’s total utilizable water potential of 1,300Mm³ with a possible daily domestic water consumption of 200 l/capita. This means that if there is no proper management of the water resources, the water demand threatens to use up the supply within 50 years.
A study by Ramroop in 2008, noted that there will be high demand of potable water in the domestic sector which is mainly expected by the growing population as well as a major increase in the industrial sector. This is due to the expected developments around the island in the coming years. However, a decrease in agricultural irrigation water will be noted, as this will be due to the fact that many agricultural lands will be converted for infrastructural projects.

ADAPTATION TO CLIMATE CHANGE

With the increasing of global warming caused by several factors, climate change is certainly a great threat to the existence of the human species. The demand of the hour is to find adaptation measures to the changing climate and mitigation options so as to reduce and prevent further damage that can be caused by global warming. While mitigation measures refer to any strategy or action that are taken in order to reduce the emission of green house gases into the atmosphere or even to remove the released gases from our atmosphere, adaptation refers to the ability of a system to face the climate change to reduce its vulnerability and be able to counteract the observed impacts of climate change. The IPCC defines it as the adjustment in natural or human systems to a new one or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic effects (Know climate change, 2012).

Some adaptation measures consist of:

- Improving water use efficiency and planning for alternative water source (such as treated wastewater or desalination), and making changes to water allocation
- Protection of groundwater resources nearby the coast from sea water intrusion
- Protecting facilities against extreme weather events.
- Promoting behavioural changes and encouraging sustainable consumption of water

In Mauritius, water adaptation measures that can be considered are promotion of rainwater and stormwater harvesting for secondary usage, reuse of treated wastewater for irrigation purposes, improved water management, enhancing further development of the water infrastructure, promoting artificial recharge and encouraging sustainable consumption of water resources. The cost of these technologies will influence the adaptation strategies in both the short and long term. An economic analysis of the rainwater harvesting technology, the desalination technology and the artificial recharge was carried so as to highlight the financial implications of these adaptation measures.

ECONOMIC ANALYSIS OF THE POTENTIAL ADAPTATION MEASURES IN MAURITIUS

Rainwater Harvesting

Rainwater harvesting is not a new concept. It is an old technology which is now gaining popularity in a new way. Capture of rain water from rooftops and land catchments can be used for various purposes. Harvesting during rainy days in summer can provide a source of water for the dry spells between rain events. The rain water collected can be stored for direct use as cars washing, watering gardens and landscape or even toilet flushing. These activities do not require treated water and are the biggest water consumers; hence RWH can reduce the monthly water bill. By diverting the rainwater into trenches, pits or wells, recharge of ground water can be achieved. Rain water can also be diverted to micro treatment plants to treat water to make it potable and hence used for drinking purposes. Implementing a rain water harvesting system is suitable in both rural and urban areas and it is relatively simple and does not require skilled labour for operation and maintenance.

For the purpose of this analysis, a simple rainwater harvester was considered. The capacity of the storage tank was estimated using monthly rainfall recorded in February. The roof top was assumed to be 100m² with a collection efficiency of 0.7, and the potential storage capacity was estimated at 500 litres. The lifetime of the RWH system was taken as 15 years and for the fittings and accessories, a
lifespan of 5 years was considered. A cost benefit analysis was carried out based on the following factors; capital investments for the storage tank and the fittings, maintenance and operation costs and the volume of rainwater used for secondary purposes. The revenues for the RWH system were estimated from the savings made on the monthly water bills. It was assumed that all the volume of rainwater captured was used efficiently. Therefore a tariff of Rs 6.00 /m³ was used for domestic purposes. The cost benefit analysis was based on a discounting factor of 8% is used for all the water harnessing solutions. Two areas were studied, the northern and the central areas. For the system in the north it was estimated that a volume of 104 m³ could be saved each year whereas for the center this amounted to some 205 m³.

Given that the volume of rainfall recorded in both areas vary considerably, the results indicate that the rainwater harvesting technology is a sound option in the central part of the island, with a benefit to cost ratio of 1.07, but a less viable project as compared to the northern part, with a ratio of 0.64. Various types of storage facilities will need to be investigated in order to lower the cost, and make the project acceptable in areas recording lower rainfall.

Artificial Recharge

Artificial recharge is the replenishment of the aquifers with surface water. In this way it increases the amount of fresh water that can be abstracted from the aquifer. The process of artificial recharge can improve groundwater storage, water quality, water management and provide for ecological benefits. Implementing artificial recharge schemes can be carried out by various methods: direct methods and indirect methods of recharging. Direct methods of recharging consist of conveying water from surface sources or from storage tanks above the aquifer, where it is allowed to percolate and recharge the aquifer. Examples of these techniques are infiltration ponds, spreading basins, percolation tank, borehole injection wells and recharge pits. Indirect methods include the installation of ground water pumping facilities near hydraulically connected surface lakes or streams to lower the groundwater levels and to allow infiltration in other places in the aquifer. Two indirect techniques commonly used are namely, induced recharge from a surface source and aquifer modification.

The need for artificial recharge in Mauritius is supported by high surface runoff and exploitation practices of groundwater. Artificial recharge can help in increasing the level of ground water and this will prevent sea water intrusion along the coastal regions. Treated water from the different waste water treatment plants in Mauritius to recharge the aquifers was considered in this analysis. For the artificial recharge, borehole injection was considered, with high quality treated waste water, with treatment required of up to tertiary level. About 25% of the Mauritian population is connected to sewer lines and the remaining still uses the conventional on site sanitation. This number is due to increase to 50% by 2015 and to 80% by 2030 (Muksoodhally, 2011). For the purpose of this study, the cost elements considered were the capital, operational, the maintenance costs. The depth of injection well was assumed as 50 m.

The results of the benefit to cost analysis reported a ratio of 0.005, making this option not attractive for Mauritius. From the economic analysis, it was found that if the minimum cost of 1m³ of water is taken as Rs 12.55, the project neither makes profit nor loss at the end of the 50 years. This price included the cost of treating wastewater of Rs 7.50 /m³. The economic analysis of the proposed artificial recharge project yielded a negative NPV due to the high cost associated with the project. These results definitively cancelled out the feasibility of this project.

Desalination Technology

With increasing water demand, it has been observed that reservoirs are depleting quickly, since volumes of fresh water extraction is more than that can be replenished by natural processes. The oceans make up 97% of the world’s volume of water. Using the state of the art technology such as desalination, this vast reservoir of saline water can be harnessed to obtain fresh potable water. This technology is best
exploited in regions where sea water is readily available to reduce the cost of pumping sea water inlands. This is one of the reasons why we can consider desalination in Mauritius. Desalination techniques may be categorized into two types: thermal and membrane based technologies. The thermal technologies use distillation which consists of evaporation and condensation of water whereas membrane technologies use membranes to separate salts from the product water.

For the purpose of this study, the Reverse Osmosis method was considered. The benefits were considered by assuming that the water saved would be sold to the hotel sector. The cost elements considered were the capital, operation, fittings replacement and maintenance costs. Different treatment plant capacity, 100m³/d, 125m³/d, 350m³/d and 450m³/d were analysed, and the results of the cost benefit analysis indicated that this option will be an effective one. The best results were obtained for a plant capacity of 350m³/d, with a benefit to cost ratio of 1.19. Despite the use of energy filtering technologies like Reverse Osmosis which is a cost effective technology, the cost of 1 m³ of desalinated water revolves around Rs 30. From the economic analysis of the desalination project, a positive NPV was obtained which makes the project economically viable. It has been found from the economic analysis that after 15 years of operation, the desalination project starts giving up profits up to its lifetime, 20 years.

The minimum cost of desalinated water per cubic meter was found to be Rs 27.55. However, the desalination project was considered as an effective option for hotels since they buy water from the CWA at a higher rate which increases when water is bought from tankers during the dry periods. Hence it was concluded that the proposed desalination project would be beneficial to hotel sector.

**DISCUSSION & CONCLUSION**

For years, water demand has been met by the dams and aquifers. It is still the same nowadays; potable water demand is being met by the existing reservoirs, dams and aquifers. This practice is not sustainable in the long term. Development in the water infrastructure sector needs to be supported with other adaptation strategies in order to ensure water security in the future.

The economic analysis carried out highlighted that the rainwater harvesting and the desalination technology are potential adaptation strategies for conditions discussed in the previous sections. The artificial recharge is a sound adaptation technology, and could be an attractive adaptation measure if considered with flood waters. In addition, for adaptation strategies to work there will be a need for a change in behaviour. Aggressive awareness campaigns coupled with appropriate legislation will be needed in order to promote sustainable development and consumption of water.

Many countries have already embarked on adaptation strategies and policies in order to ensure water security. In Mauritius, the sustainable consumption and production project, the technology needs adaptation project together with the Maurice Ile Durable project are addressing adaptation strategies, but there are still under represented. The United Nations policy brief (2010) highlighted that responding to the challenges of climate change impacts on water resources requires adaptation strategies at the local, regional, national and global levels. Countries are being urged to improve and consolidate their water resources management systems and to identify and implement “no regrets” strategies, which have positive development outcomes that are resilient to climate change.
REFERENCES


