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Saudi Arabia Confronts with Water Scarcity: An Insight

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Abstract: The Kingdom of Saudi Arabia is being considered as a semi-arid or arid region and its available water resources are limited. Growth of population, development of economic regions, climate change (Global warming), poor awareness of how to optimally use and save water, use of conventional water resources like ground water or rains, in addition to the use of traditional methods of irrigation, all increase the water demand. Based on Human Development Report (2006), 1700 m^3/ca.year and 1000 m^3/ca.year are the limits of water stress and water shortage/scarcity respectively. This paper focuses on the problem of water shortage in KSA along with the contemplation of the integrated solutions or the efforts exerted by the government represented by the Water and Electricity Ministry (WEM-SA) to minimize the gap between water supply and demand. The paper identifies some of the principal causes of the water shortage in KSA, discusses the current situation of water supply and demand and presents some essential elements of reasonable, cooperative and sustainable water solutions.

Key words: Desalination · Saudi Arabia · Scarcity · Virtual waters · Water demand · Water shortage · Water supply

INTRODUCTION

Water is being considered as one of the basic and imperative needs of the human beings to such an extent that without it life is impossible to think of. That is why till now it is being believed and realized that the only planet in the whole universe where life is existent is the Earth because of the availability of water. It is this planet which is regarded as the blue planet because of its composition. Almost 75% of the earth's surface is composed of water. It is being considered as one of the most abundant resources on the face of the Earth covering nearly three fourth of the planet's surface but 97% of its water is saline forming the oceans. Most of the remainder is held up in the Antarctic ice caps or deep underground aquifers hard to access, leaving behind just less than 1% available for human use in the form of accessible freshwater lakes and rivers; out of which lakes contain most of it [1-3]. If properly managed and utilized this small seeming proportion would be sufficient to serve the basic supply of water to human kind because Almighty God has not put us to the shortage of water as it is infinitely renewable resource but the supply is finite and the distribution of water is also uneven. Globally, there is more than enough water to go round: the problem is that some blessed countries get a lot more than others creating a sense of scarcity in the less fortunate ones. Some countries like Brazil and Canada, receive far more water than they can use while some other places such as countries in the Middle East, get much less than they require [3] thus creating a sense of water scarcity in these countries.

General Water Situation in Saudi Arabia: Saudi Arabia is one such country which is regarded as the largest arid country in the Middle East region, covering nearly 2.24 million km^2 of the Arabian Peninsula. It has limited water supplies to fulfill the water demand of the country's population. The surface water is very much limited due to the low precipitation and high evaporation rates along with the absence of perennial rivers, streams or lakes. According to Abdulrazzak, [4] the annual rainfall in Saudi Arabia in 1990 was around 75 mm/ year, in the same time the annual evaporation was in-between 3500 and 4500 mm/year, which represents ratio of evaporation to rainfall in average more than 50. Rainfall is also highly irregular. At one period of time it rains sufficiently high and at other

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moments of time there is barely any rainfall to account for. Also, nearly all precipitation occurs between the months of November and April keeping the rest of the year dry and hot. As a result of desert climate, a major portion of the rainfall evaporates; sometimes nearly 15-30 times the annual rainfall. However, Surface runoff, can occur during rainstorms mainly in the coastal areas and highlands of the southwest due to the relative abundance and regularity of rainfall in these regions. To tap this water the government has constructed dams throughout the country so as to utilize the surface runoff water [5]. They are basically used to trap the surface water after frequent flash floods. Their numbers are increasing year by year accounting for 232 in the year 2012 compared to 223 in the year 2004 (WEM-SA). These dams collect an estimated 12.83 million cubic meters (453 million cubic feet) of runoff annually in their reservoirs. Some of the largest of these dams are located in the Riyadh, Mekkah, Assir. Al-Madinah, Wadi Jizan, Wadi Fatima, Wadi Bisha and Najran, region with the total storage capacity of 836 million cubic meters, distributed all across the kingdom for variant purposes like drinking, control, recharge and irrigation [6]. This water is used primarily for agriculture and is distributed through thousands of kilometers of irrigation canals and ditches to vast tracts of fertile land that were previously fallow but even then the absence of a reliable and adequate surface water supply has resulted in a heavy reliance on ground water for meeting the municipal needs with some limited alternative sources as desalination. This was the only substantial means for Saudi Arabia before 1990's. Also the quality of groundwater resources varies from area to area, however, most groundwater is classified as brackish and contains over 1000 ppm of total dissolved solids (TDS) asking for treatment. Furthermore, over the past few years there has been a dramatic increase in the demand for water [5].

Thus it can be said that faced with a steadily rising demand and inadequate and unreliable sources of surface water, until 1990's the country was mainly dependent on ground water resources and about 75-85% of the total water supply came from ground water which receives very limited natural recharge and is, thus, classified as fossil or non renewable water [5]. Thus Aquifers were a major source of water in Saudi Arabia. They are vast underground reservoirs of water. In the 1970s, the government undertook a major drive to locate and map such aquifers and estimate their capacity. As a result, it became possible to drill tens of thousands of deep tube wells in the most pledging areas for both agricultural and urban use which forms the important source of supply during those times. Currently, also, there is a heavy reliance on tube-wells for meeting the daily demands which is getting reduced day by day but still the contribution of wells towards meeting the water demand is on the higher side which should be reduced so as to bring about a sense of better water management in the kingdom of Saudi Arabia.

Water Production Scenario in Saudi Arabia: The fast depletion of ground water resources and deterioration of their quality occurs due to the mining of ground water which is a direct consequence of the excess rate of withdrawal of water compared to the net recharge. For Saudi Arabia the annual extraction of groundwater is far in excess of natural replenishment but this groundwater mining cannot continue indefinitely in the light of the problems that are already occurring and others are expected to occur. The outcome of this may be adverse economic consequences integrated with the negative environmental and social effects [5]. Then the government has to resort for other options to meet their soaring high demands which has resulted in the following up of the desalination of sea water as an alternate means of water supply to the masses. It is the only nearly inexhaustible source of water. However, their high salinity is their main drawback which can be judiciously exploited to turn it into an advantage by desalinating this water to offer an attractive solution to the problem of water shortage. It then becomes the sole responsibility of the desalination engineers to fight back the problem of water shortage when demand far surpasses the supply [7]. The purpose of a desalination system is to clean or purify brackish water or seawater and supply water with total dissolved solids within the permissible limit of 500 ppm or less [8] in contrast to the concentration of salt in sea water which normally ranges from 35000 to 45000 ppm (WHO). Desalination of sea (or saline) water has been practiced regularly for over 50 years and is a well-established means of water supply in many countries including Saudi Arabia but the production was not very high initially. Abdulrazzak, [4] recorded 795 million m^3 as the desalination water that produced in Saudi Arabia in 1990, which in this time, only domestic and industrial water use was more than 1700 million m^3, in additional to around 14,600 million m^3 for agriculture use. It is now feasible, technically and economically, to produce large quantities of water of excellent quality from desalination processes. Many countries are now considering desalination as an important source of water supply. It is now gaining considerable attention from scientists,

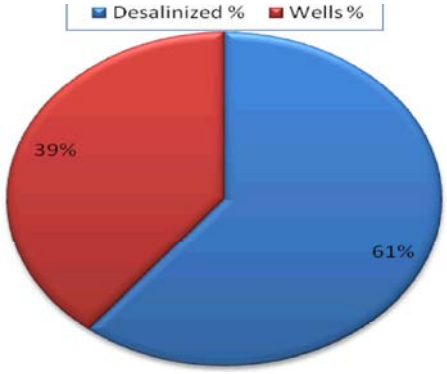

Fig. 1: Desalinated water to wells water ratio in KSA.

resource planners, policy-makers and other stakeholders and is a feasible option that can cover the wide gap between the available capacities and the accelerating demands. The main driving force for this renewed interest in water desalination process is the remarkable technological improvement in desalination processes, which has recently led to a much lower cost of desalinated water than was previously achievable. In addition to the lower unit cost of desalination, increasing high cost of conventional water supplies due to overexploitation and scarcity have aided desalination in becoming one of the top options for boosting potable water supply [9].

The newer technological interventions and advancements in water production practices have dramatically changed the situation compared to the past. The water sources used for municipal domestic water supply in Saudi Arabia included conventional surface and groundwater withdrawals and alternative sources, i.e. desalination [10]. As per WEM-SA [11] report currently nearly 40% of the country's water production relies mainly on the supply through the wells and 60% on desalination which is reflected from the Fig. 1, thus bringing down the reliance on ground water extraction from 75-85% in the year 1990 to merely 40% nowadays.

But the above figure itself is very much misleading. It does not reflect anything about the total amount of water withdrawn from wells rather it only indicates about the percentage production of water through desalination and wells. This means that the total quantity of water extracted from the wells cannot be worked out by the above figure. It only indicates the percentage of the contribution of wells towards meeting the water demand without shedding a light on the total quantity extracted thus disguising that the dependence on wells has reduced to a much pronounced extend.

In other words it only reflects that to meet the growing demand of water more and more desalination plants are being installed and commissioned producing more quantities of water compared to the past keeping the reliance on wells somewhat constant. That is to say that although there is an overall reduction in the percentage contribution of wells towards meeting the water demand but the overall amount of water withdrawn from the wells has not reduced rather it is somewhat constant which is very clear from Table 1.

The table indicates that still now, the extraction of water from wells has not gone down but kept somewhat constant over the years which is again a big concern keeping in view the geological condition of Saudi Arabia. As an ideal condition this dependence on ground water extraction should preferably be lowered down to an extent that can easily be replenished which is not the case right now. The government should take initiative in this direction by further looking in more alternative means.

Bremere *et al*. [10] suggested that for meeting the water demand of the middle east region where severe water shortage exists, Desalination of seawater may become an important alternative. It is increasingly seen as a good means of additional water supply to meet municipal domestic needs of urban population [12]. Out of all the available sources of water, it is the one which has become the major source of supply of water surpassing all other available sources to an extent that the major portion

Table 1: Water supply in Saudi Arabia through desalination and wells

Period	Desalinized water (DW) m^3	DW%	Wells Water (WW) m^3	WW%	Total Supply m^3
2005-2006	395,061,256	33	804,858,695	67	1,199,919,951
2006-2007	1,036,988,746	55	838,266,625	45	1,875,255,371
2007-2008	1,065,416,361	54	909,100,024	46	1,974,516,385
2008-2009	1,070,068,541	53	940,043,207	47	2,010,111,748
2009-2010	1,029,015,372	51	981,055,536	49	2,010,070,908
2010-2011	1,330,741,178	57	1,007,774,136	43	2,338,515,314
2011-2012	1,495,238,880	60	979,740,464	40	2,474,979,344

of Saudi Arabia's water supply is dependent on desalination turning it as an indispensable industry [9]. The capacity of production has also increased manifolds over the past few years putting Saudi Arabia on the global scale as the largest producer of desalinized water. An expansion of this sort was related to the ever increasing population growth and the regular groundwater availability depletion in whole of Saudi Arabia [10].

Once considered as an expensive last resort solution for marginal municipal domestic and industrial water supply, desalination technology is now becoming increasingly affordable. It is finding new outlets in water scarce regions where it was never previously being considered as a viable long term resource. Some of the interesting applications includes; providing alternatives to major water transport schemes, supplying water to meet growing domestic consumption and supplying water to sea resorts [13]. Within a passage of 10 years from 2001, with increasing water supply problems in many MENA (Middle East and North African) countries, more and more desalination plants are being commissioned [14]. Saudi Arabia already has acknowledged a concerted approach in increasing the number of desalination plants from very few earlier to substantial nowadays. Moreover it is not just number of plants to account for but also the magnitude of the capacity, of production from each plant to be considered in deciding about the production capacity of the country as a whole. In this regard Saudi Arabia tops the ranking by compounding their production capacity to around four times within 6 years (Table 1) putting her on the global scale as the largest producer of desalinized water.

Wangnick [15] reported the installed desalination capacity (sea and brackish water desalination plants >500 m^3/d) of Saudi Arabia as 4.015 million m^3/day through desalination of sea water, out of which 0.88 million m^3/d of water was used for municipal domestic purposes and 1.065 million m^3/d through desalination of brackish water, out of which 0.73 million m^3/d of water was used for municipal domestic purposes. Now Saudi Arabia is the world's largest producer of desalinated water. Currently The **S**aline **W**ater **C**onversion **C**orporation (**SWCC**) operates 27 desalination stations that produce more than four million cubic meters a day of potable water. These plants provide a major portion of the water used in cities, as well as a sizeable portion of the needs of industry. They are also a major source of electric power generation. But day by day the water demand of the country is increasing and the government is bound to increase

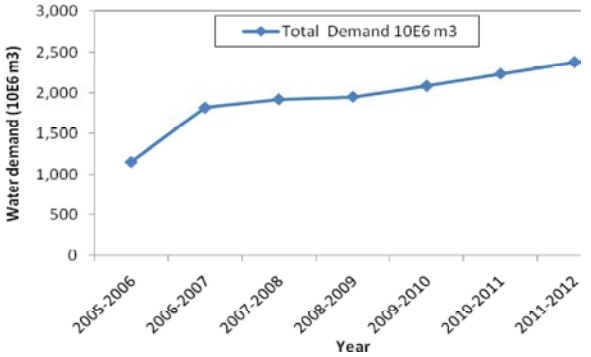

Fig. 2: Graphical representation of Water demand in KSA (m^3/year)

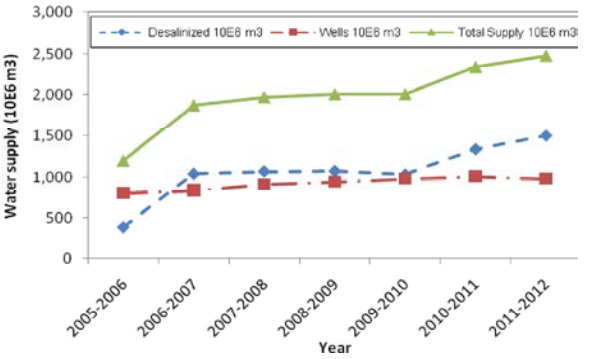

Fig. 3: Graphical representation of Water supply in KSA (m^3/year)

the supply as well. Fig. 2 demonstrates the yearly water demand of KSA in million m^3 from the year 2005 till 2012 which is being compared with the country's annual water supply in million m^3/year in Fig. 3. Also the contribution of wells and desalination plants in satisfying the needs is also depicted in the same figure along with the total water supply.

A comparative representation of the water demand to supply is also being made and illustrated in Fig. 4, which shows that the difference between supply and demand is marginal and the government is successful to some extend in meeting the current demands to a convincing level but the challenges are still there to be taken and the journey towards water security is long and exhaustive as well.

The current scenario of water supply and demand in Saudi Arabia raises serious concerns and issues about the country's water balance, along with the qualitative deterioration of water due to the full dependency on the fixed methods. Large-scale development in the Kingdom (either urban or agricultural) largely depends upon the ability to pump fossil groundwater and desalinate brackish water and seawater [16].

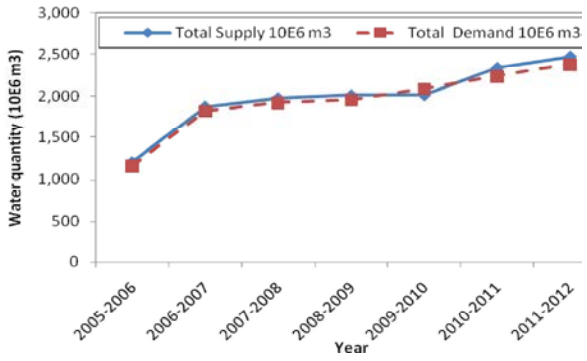

Fig. 4: Comparison between water demand and water supply in KSA

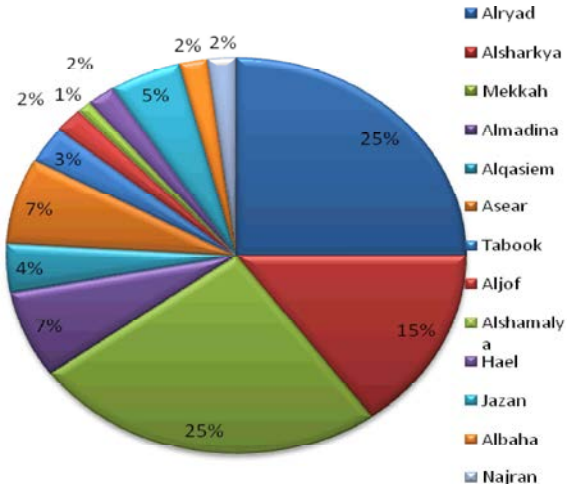

Fig. 5: Percentage distribution of population based on zones

With Saudi's population expected to continue to rise, the gap between water supply and demand threatens to widen significantly. UN Population Projections [17] and The State of World Population [18] reported that total population of Saudi Arabia as 18.2 millions in the year 1995 (out of which 80% of the population lived in urban areas), 20.9 millions in the year 2000 (out of which 87% of the population lived in urban areas). Currently the population of Saudi Arabia is around 28.8 millions. It was also projected that by the year 2025 the population of Saudi Arabia would turn up to 42.4 million accounting for almost a double growth within 25 years but the projected percentage of people living in urban areas would be the same 87%.

To provide a better elaboration and illustration of the subject all 13 provinces of Saudi Arabia are being taken into the domain of the study which further throws great deal of light on the regional status of Water confrontation scenario in the Kingdom of Saudi Arabia.

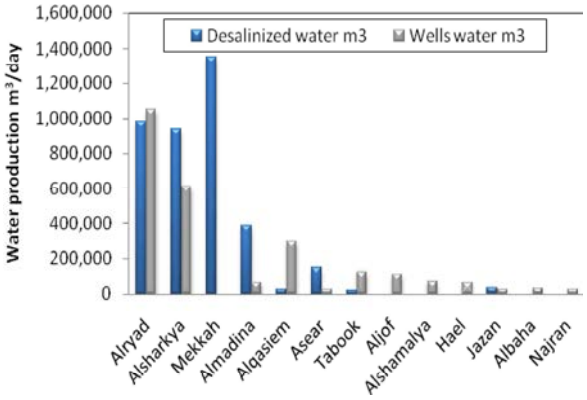

Fig. 6: Zonal Water production of KSA per day

Role of Saudi Arabia's Provinces at a Glance: WEM-SA [4] worked out the current percentage population distribution for all the 13 Zones/ provinces of Saudi Arabia and is depicted in the Fig. 5, which clearly indicates that nearly 65% of the country's population resides in the zones of Alryad, Alsharkya and Makkah region. Therefore it can be said that out of all the 13 zones only 3 zones are highly populous and thus requires more water supply compared to the other regions.

The population growth and economic development are increasing demand on the available water resources, which affect not only the quantity, but also the quality of water resources. With the increase in water demand the country is bound to increase the water production to meet the soaring high demand. In an attempt to do so the country has increased the water production by increasing the production capacity of the existing desalination plants as well as installing new plants wherever possible. The country has gone into a drive for increasing the capacity in almost all the 13 provinces which is shown in Fig. 6.

To give a better illustration of the dependence of Saudi Arabia on wells and desalination plants in meeting the water demand of the country, the contribution of wells and desalination plants is being plotted in the Fig.7, which explicitly reflects the current situation of water production in all thirteen provinces of the country.

A graphical representation on the participation ratio of each zone or water production in KSA is illustrated in Fig. 8, which indicates that the cumulative contribution of water production of the three most populous zones is around 77%. It indicates that the participation of other zones in water production is very less compared to these three and thus can be seen as a possibility for future expansion if the country has to increase its potential.

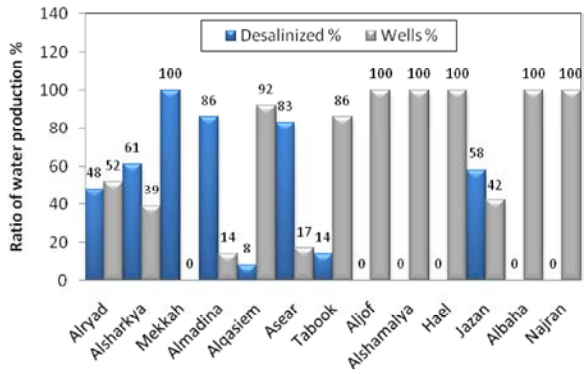

Fig. 7: Production capacity of desalinized to wells water in KSA based on Zones.

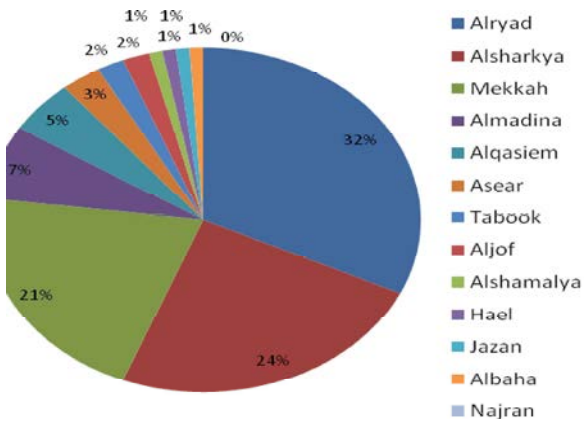

Fig. 8: Participation Ratio for each zone in KSA water production

The demand for water has grown substantially over the years against a scarce and dwindling water supply. This growing imbalance has been dealt mainly by increasing water supply, while water-demand management has either being neglected or overlooked. Thus the critical issue now is how to reconcile the rapidly increasing demand with limited and deplete able resources.

Probable Solutions of Water Scarcity for the Kingdom of Saudi Arabia: Now the current situation demands the need and the urgency of adopting conservation and water-demand management programs to achieve an acceptable balance between water needs and availability. There is a considerable scope for improving the efficiency of water use in various sectors. The government of Saudi Arabia should work in parallel in supply development and demand management to avoid wasteful, inefficient uses of critical and non renewable water resources. That is to say that it should not only depend upon the water supply development but also focus on the demand management as well.

The agricultural sector is the largest and the most inefficient user of water which needs to be addressed in priority [19]. Some of the methods that can be employed in Saudi Arabia so as to efficiently use the water are being listed down below merely as a guideline for further improvement and development. These are merely the proposals or ideas that can be further analysed and implemented based on the feasibility and utility. The possibilities are there for improvement and the whole responsibility lies on the shoulders of engineers, government and public to bring about a change the way water is being utilised and conserved. Keeping this in mind the following paragraph on efficient management of water would definitely guide many of the involved. The methods that have been suggested to increase the water supply, includes but not limited to:

- The government of Saudi Arabia should not focus only on the supply development but also emphasize on the demand management to avoid wasteful, inefficient uses of critical and non renewable water resources.
- Intensive capturing of rainwater be done through harvesting along with the built up of micro- and macro-dams for storing water. The existing water harvesting structures should be assessed, if any, by hydrological studies, analytical tests and determining the sediments amount in these structures.
- Desalination of seawater and wastewater should be practiced using renewable energy sources against the heavy dependence on non renewable energy sources.
- Employing proper and appropriate treatment technologies for treating industrial wastewater containing heavy metals so as to make it reusable.
- The plants should be irrigated mainly by the treated wastewater against the fresh supply water.
- The heavy losses of drinkable water through leakage can effectively be reduced by implementing proper maintenance to water distribution network
- Increasing the water supply for meeting the growing needs by decreasing the consumption [20].
- Encouraging the recycling and reuse of water to a better extent by encouragement the research in water resource field, which can be carried out by research canters and universities or other related agencies.
- More dependency should be shown on Virtual water imports which are another supply-side option for attenuating water stress. When countries import food items like cereals and other agricultural products,

they in turn, are also importing the water embedded in the produce. The importing countries bring about water savings for themselves as well as for the whole globe through Virtual water trade due to the differential in the water productivity between the exporters and importers. Some analysts observe virtual water trade as an attractive and prudent way for water-scarce countries in saving the water by importing it from countries that face lower opportunity costs in water use and higher productivity. From this perspective virtual water trade is seen as a lucrative exercise in comparative advantage that overcomes the constraints on trading water itself [3].

- More stringent pricing policy of water use should be implemented so as to restrict the user from wasteful practices.
- Encouraging the use of more and more advanced water saving devices in public and residential places against the conventional ones.
- Encouraging the public to alter their water usage practices from casual habits to alert routine exercises by educating the public in this regard. The government should take initiatives to organize lots of awareness camps and workshops on a regular basis targeting the whole country.
- The idea of water conservation should be promulgated to the general public and not be confined to the conferences and discussion forums only. This is one of the most difficult and heavy task to accomplish but is seriously needed to secure a sustainable water supply society. Public participation in this regard is hence earnestly required.

Some initiatives are already been taken in the shape of a new practice of using recycled water better. Right now in KSA an expanding source of water is the use of recycled water. The Kingdom aims to recycle as much as 40 percent of the water used for domestic purposes in urban areas. To this end, recycling plants have been commissioned in Riyadh, Jeddah and other major urban industrial centres. Recycled water is now being used for irrigation of farm fields and urban parks.

CONCLUSION

Arid-region cities like that of Saudi Arabia are on the verge of a severe water shortages, although current unsustainable practices like the groundwater drawdown, heavy reliance on high-energy solutions to solve the water problems and depriving in-stream flows camouflage the true magnitude of future problems. These problems require a new set of patterns for water science and planning that will not only cope with the interconnectivities, feedbacks and tradeoffs in critical urban resource systems but also deals with the uncertainties of climate change.

Finally, this paper concluded that, the water desalination based on non renewable source of energy as a conventional water resource in conjunction with the latest increasing shift in the desalination technology based on renewable source of energy should be considered as an imperative measure for water security in the Kingdom of Saudi Arabia. It becomes the need of the time to lay more emphasis on the production of water by employing the renewable source of energy in lieu of the unsustainable non renewable source of energy. The future use of such much needed resource for variant purposes will largely depend on the rate of improvement that can be brought about in the technologies used for desalination and the cost of needed power. Apart from these, new technological interventions are becoming the need of the times so as to bring about a change the way water is being utilized. The full dependency on one particular technology may paralyse the continuous functioning in the near future, in turn bringing the whole system to a standstill. So it is looked upon with foresightedness to explore beyond the available options and resort for better ways and options for improvement in the practice so that the coming generations may get benefitted out of it without experiencing the full exhaustion of the supply.

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