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Conservation Strategy for Water Supply in the GCC, State of Kuwait: A Case Study

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Abstract: The Gulf Cooperation Countries (GCC) is facing with high growing gap between the demand and water supply. This has push Gulf countries to implement wise plans and policies toward water shortage. This paper presents the State of Kuwait as an example of GCC for taking the steps to utilize all existed water sources within the policy of water supply strategy to meet the challenges of water shortage. Kuwait has four main sewage treatment plants in Jahra, Rekka, Um Al-Haman and Sulibiya. In addition to these plants, there are other treatment plants are not operated by the Ministry of Public Works (MPW) and used for a special purposes and not connected to MPW networks at places such as airports, aerial bases and army gather centers. These four plants produce more than 600,000 m^3/d of treated wastewater. But, part of the tertiary treated wastewater effluents from these four plants are directed to the farms areas, while the remaining effluents discharged to the coastal seasides through the sea outfalls. Because of the declining in water supply to the famers and agricultural areas, however, the interest in water conservation policy has increased and recommended special programs and steps toward limited in water supply. As a part of the conservation plan, treated wastewater in the municipal water sector is being used as a water supply to the agriculture and conservation areas By these efforts, more water is available and negative impact to the environment will be reduced.Coordinating the efforts between concern parties has created a new water supply source and efforts are widely practiced among concern sectors. This paper outlines the comprehensive conservation strategy for water supply in Kuwait. It describes the way of finding enough dependable water supplies for years to come in order to meet the country demand. The proposed program and its benefits to the country are also highlighted.

Key words: Conservation · Plants · Sewage · Water · Wastewater

INTRODUCTION

Water resources in Kuwait are very limited. The scarcity of future supplies of fresh water is expected in Kuwait as other Gulf Cooperation Council Countries [GCC] under present policies of water and supply programs. Shortages in water will affect not only the economic prosperity of the States but also the security and well-being of its inhabitants [1]. In Kuwait, the average yearly rain fall equals to 76 mm with 90% of the rain falling between October until April [2]. Drinkable groundwater resources are very scarce and they contribute to less than 5% to the total yearly fresh water production. The remaining 95% is being produced by seawater desalination plants [3]. The annual consumption of fresh water is steadily increasing from 671MG in 1957 to 67674 MG in 1996 [4]. The Multi Stage Flash Distillation (MSF) technology is considered to be the most successful one of sea water desalination than reverse osmosis (RO).

Due to the rapid increase in the development and population over the past decades the demand on water supply has increased significantly. Since State of Kuwait has one of the highest water consumption rates in the world for capita. This has led to review of the other available water options in Kuwait as well as in other GCC [5]. Nevertheless, the use of treated municipal wastewater could impose serious threats to surface and groundwater as well as to public health [6]. Therefore, several criteria should be considered when there is a plane

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to reuse the treated wastewater. These criteria should be evaluated thoroughly and ranked based on their socioeconomic and environmental impacts before implementation [7]. Currently, municipal wastewater reuse is widely practiced in Kuwait and other GCC for growing crops and not recommended as fresh water. Abu Sada [8] reported that brackish groundwater found in large quantities and it is mainly used for irrigation of public gardens, farms and it mixed with distilled water to make the water is drinkable, However, the production of brackish water from the existing and future water wells fields will not be sufficient to cope with the present demand [9, 10]. Furthermore, the lack of more information on the reliability and availability assessment for RO plants in Kuwait and the comparison with existing power plants may delay the acceptance of RO process as a major alternative for desalination of sea water. On the contrary, the majority of GCC countries are suffering with shortage of fresh water as well as with uneven distribution of water distribution of water supply in time and space. Thus finding ways and means to deal with increased droughts becomes a major task for water authority [11]. Therefore, it is important to seek holistic and integrated adaptation solutions toward water shortage. On the other hand increased in water scarcity in GCC countries has led to look fo alternative avenues for maintaining water security [12]. They added with 70% of water withdrawals and used in agriculture will require significant quantities of water to sustain production. El-Ashry *et al*. [13] indicated that the GCC countries are lack of national policies to support municipal wastewater reuse. In fact, there are many questions remain to be answered in the area of municipal wastewater reuse which is of particular concern in the light of increasing demand for water supply. Incomplete analysis of municipal wastewater, reuse options, inefficient irrigation systems and unclear water conservation strategy have not been investigated at all [14]. Kajenthira *et al*. [15] reported that with increasing water demand for potable water supply in Saudi Arabia in the next two decades has led to encourage the local services and industrial sectors to reclaim and reuse of wastewater. In Kuwait, discharge of sewage wastewater has effected seawater quality which has led in to increase in the nutrients loading and reducing in the capacity of sea area to purify itself [16], who suggested that with total utilization of treated municipal wastewater will lead to reduce the pollution level in sea area and increases reuse water supply. Feng and Chu [17] reported that municipal wastewater reuse issue became an important subject to the general public as highly demand and unreliable water resources. Crook [18] indicated that the planned reuse of sewage wastewater has been practiced for many years and undoubtedly now will play a big role since water supply becomes scare. Furthermore, he highlighted that more municipal wastewater is becoming available than before and when properly treated and managed can be used for so many purposes. Al-A,Ama and Nakhla [19] reported that due to high cost of installation and operation of desalination plants and diminishing groundwater in Saudi Arabia, the Saudi government has put a policy to utilize the municipal wastewater as a water source. In Kuwait water criteria usages were established. Accordingly, the water can be treated easily according to their uses [20]. Other study, Al-Muzaini [21] showed that with treatment of municipal wastewater will reduce the level of pollutants discharge to the marine environment, thereby, there will be improve in water quality in GCC Gulf seawater [22]. This will lead to improvement in water management and will contribute to meeting the increased in water demand. At the same time, the treated municipal wastewater will provide a valuable source of water supply mainly for landscaping irrigation at low cost and additional these exercises may expand green areas in the State of Kuwait. Goff and Busch [23] reported that with rapid development in GCC countries a water reclamation program is needed and should be implemented to meet the total future water supply needs [24]. Therefore, such program for reuse of treated municipal wastewater will be essential. Moreover, cost of both treating wastewater and producing treated wastewater should not be passed to the customer but it should be considered in the political decision making [25]. Akber *et al*. [26] reported that the reuse of treated wastewater is becoming an important source now days. With rapid increase demand for freshwater and high cost of installation and maintenance of desalination plants, reuse treated of municipal wastewater is becoming an important source. Therefore, municipal wastewater sector could provide an opportunity to water supply sustainability [27]. This is because of the natural water resources are limited. Additionally, this calls for a careful planning and a wise utilization of drinking water. A strategy planning in water sector is an important and essential step towered future demand in water supply [28]. Gagne and Vaccaro [5] reported that purified municipal wastewater will satisfy agricultural requirement which currently uses drinking water supply.

To meet the demand for water supply several countries took serious steps to reuse of municipal wastewater as the city of Chandler, Arizona, USA. It has implemented a program for total reuse of its municipal effluents for reclaiming desert lands and recreational lakes [23, 18]. Obviously, it has been recognized that stopping discharged of municipal wastewater will help to reduce pollution in the discharging areas and the capacity of discharged area can purify itself [29, 30, 31, 32]. Therefore, any such approach can be initiated to ensure that the quality of receiving areas are not to be effected and this is to be done by full utilization of municipal wastewater [33, 34, 35, 36]. Smith [37] discussed water supply policy in Rhode Island, USA. He indicated that the development of management program in water issue is an important issue in order to preserve the quality and the demand of the water supply for future use. However, there are countries who have lack of national policies and unclear strategies to support municipal wastewater reclamation approaches [37]. However, inefficient irrigation plans and unclear policies of waste management systems do not allow for effective reuse [14]. Therefore, such plans if successfully executed could significantly could convert treated municipal wastewater into a new source of water supply. Ideally, this paper takes an approach by evaluating the potential use of municipal treated wastewater as a water supply source and its application as reuse source.

To response to the water demand, Kuwait government has put a strategy to utilize all treated wastewater in the municipal sectors for various potential reuse especially in the agriculture. Landscaping and for growing crops items aiming to reduce the demand on fresh water supply which is currently low. Such a strategically procedure if successfully executed could significantly reduce the demand on water supply and could convert the treated wastewater into a new source for water supply.

This paper outlines the conservation strategy for water in the municipal sector and to assess the present technologies developed over years in municipal water sector as well as to highlight solutions for water shortages.The paper also addresses reuse options, in addition to that, quality of municipal wastewater will be described followed by a conservation strategy in municipal sector.

Municipal Plants and Treatment Levels: In Kuwait, tap water is provided for 95% of the population and 80% enjoy sewer system. The municipal wastewater generation is estimated to be 80% of the freshwater consumption per capita. However, the sewage generation is effected by the many factors such as, per capita water consumption, change in population, time of the year, percent of population discharging to the sewer net work, household consumption and industrial discharging.

Currently, there are six municipal wastewater plants in operation namely, Jahra, Sulibiya, Rekka, Um Al-Haymann, Wafra and Failaka. The expected municipal wastewater received by the main four plants [Jahra, Salibiya, Rekka and Um Al-Hayman] is in the range from $600x10^3$ and $700\ x10^3\ m^3/d$.The total outlet of treated municipal wastewater is range of $430x10^3\ m^3\ /d$ and $460x10^3\ m^3/d$.

The Jahra municipal wastewater treatment plant was commissioned in 1982 with a design capacity of $65x10^3\ m^3\ /d$. The plant serves the north and eastern part of Kuwait city. Presently, the plant receives about $133x10^3\ m^3/d$. There are plan to increase the capacity and improve the performance of the plant. The Rekka municipal wastewater treatment plant was designed to treat $85x\ 10^3\ m^3/d$ and was put in operation in 2001 with the total capacity of $180x\ 10^3\ m^3/d$. Due to growing in population near the plant, the authority decided to increase the plant capacity more than $180x\ 10^3\ m^3/d$. However, presently, the plant is able to handle $200x\ 10^3\ m^3/d$ of municipal wastewater. The plant collects the municipal wastewater from the coastal areas and part of south cities. Ever since it was started it has been continuously expanded to sever a greater area. Jahra and Rekka plants are equipped with tertiary treatment methods. The outflow of treated municipal wastewater from these two plants is estimated $130x\ 10^3\ m^3/d$ and $196x\ 10^3\ m^3/d$ respectively. The umm Al Hayman municipal treatment plant is designed to able to handle about $4500m^3/d$ but there are plans to increased its designed capacity to treat $27x\ 10^{10}\ m^3/d$.presently, the plant receives about $22x10^3\ m^3/d$ of wastewater. The Failaka municipal treatment plant is located in Failaka and was designed to serve the island of Failaka which is use contact stabilization ponds. The Filaka island is located about 30km off the coast of Kuwait City. The capacity of the plant is about $4x\ 10^3\ m^3/d$ of municipal wastewater but, presently, the plant is under maintenance [21]. The Wafra municipal treatment plant came into operation in 2002 and collects the municipal wastewater from Wafra city and farms areas. The plant can treat $4x\ 10^3\ m^3/d$ of municipal wastewater however, the design capacity is about $10x\ 10^3\ m^3/d$. The Wafra treatment plant is equipped with the submerged biological reactor, [SBR] system. The Sulibiya municipal treatment plant was built in 2000 and commissioned in 2002. The plant has a design capacity of $425x\ 10^3\ m^3/d$. The plant has expanded its capacity to be able to treat $600x\ 10\ ^3m^3/d$ municipal wastewater. Presently the plant receives about $440x\ 10^3\ m^3/d$ of municipal wastewater. This plant is owned and

Table 1: Design Capacity and Sewage Flow reaching Municipal Treatment Plants

Treatment Plants in Kuwait				
Plant	Treatment Process	Date Commissioned	Present Design Capacity (m^3/d)	Sewage Inflow (m^3/d)
Jahra	Primary units, extended aeration, activated sludge, clarifier unit thickener, sand drying beds, sand filter, tertiary treatment with pre and post chlorination.	1981	100,000	70,000
Rekka	Primary units, extended aeration, activated sludge, clarifier unit thickener, sand drying beds, sand filter, tertiary treatment with pre and post chlorination.	1981	150,000	100,000
Umm Al-Hayman	Primary units, oxidation ditches clarifier unit thickener, sand filter, thickener units, sand drying beds, tertiary treatment with ultra-radiation.	2002	27,000	5,000
Faliaka	Primary settling, oxidation ponds, extended aeration, sand filters, pre-and post-chlorination, tertiary treatment.	1984	10,000	4,000
Wafra	Primary settling, SBR units, sand filter, secondary treatment with ultra-radiation.	2002	10,000	4,000
Suliabyia	Primary settling, extended activated sludge units, clarifier units, thickener, dewatering unit/press unit, dry beds, tertiary treatment with ultra-radiation.	2003	555,000	435,000

operated by a private company, however, the supervision is implemented by MPW. The plant is equipped with the advance biological treatment processes. Actually, it consists of screening unit, grit removal unit, extended aeration tanks, clarifier basins, sand filter units, RO units, thickener tanks and sludge drying beds. The daily flow of municipal wastewater is about 425x 10^3 m^3/d and the treated flow is about 340x 10^3 m^3/d. Furthermore, there are attempts by the plant owner to increase the capacity of the out flow of the treated municipal wastewater. Table 1 presents information on the design capacity, sewage flow and type of treatment [9]. Figure 1 presents the locations of sewage treatment plants and outfalls in Kuwait.

Quality of Treated Wastewater: Table 2 presents the quality of inflow of municipal wastewater and treated wastewater for both tertiary and RO effluents. The pH values of inflow were between 6.5 and 8.0 unit. However, for tertiary effluent, the pH values were in the ranged from 6.5 and 7.5 units. However, for RO effluent the pH values were ranged between 6.0 and 8.0 units. The conductivity values were in the ranged from 1200 and 3000 us/cm but for the effluent the conductivity values were from 1100 and 2200 us/cm. However, the total suspended solids [TSS] values were in the range of 100 and 500 mg/l of inflow. But for tertiary effluent the TSS values were below 10 mg/l. For RO effluent the TSS concentrations were below 1 mg/l. The concentrations of volatile suspended solid [VSS] in the inflow were ranged between 70 and 350 mg/l. For tertiary effluent, VSS concentrations were less than 7 mg/l, but for RO effluent were than 1 mg/l. The level of chemical oxygen demand [COD] in the raw sewage were ranged between 250 and 750 mg/l, however COD in the tertiary effluents was below 40 mg/l. The levels of biological oxygen demand [BOD] and oil/ grease [O/G] in raw sewage were ranged from 100 to 400 mg/l and 10 to 50 mg/l respectively. However, for tertiary effluents the levels for BOD and O/G were very nil, but for RO effluent the concentrations of BOD and OG were also below 1 mg/l. The total dissolved solids [TDS] concentrations incoming flow were ranged between 700 and 1800 mg/l but for effluent it was in the ranged of 800 and 1500 mg/l. But for RO effluent TDS concentrations were below 100 mg/l. The levels of chloride, ammonia and nitrite in the raw sewage were ranged from 200 to 400 mg/l, 15 to 50 mg/l and 0.04 to 0.7 mg/l respectively. However, for tertiary effluent, the levels of chloride, ammonia and nitrite were ranged between 200 to 400 mg/l, 1 to 5 mg/l and 0.1 to 1.5 mg/l respectively. But for the OR effluent, the levels were below 1 mg/l. The concentrations of total Coli, *E. coli* and *Salmonella* in the inflow were 3.20 E+08, 4.10E+07 and 4.5E+06 colony/100ml. But for the tertiary effluent the concentrations were 400, 10 and nil colony/100ml. However, the concentration of Streptococci and fungi in the raw sewage, the levels were 1.40E+07 and 2.10E+05. But for the tertiary effluent the concentration of *Streptococci* was nil however for the fungi the level was ranged between 2 and 100 colony/100ml. While for RO effluent the concentration for both *Streptococci* and fungi were nil. Laboratory results show that the level of the detected pollutants and conventional parameters were

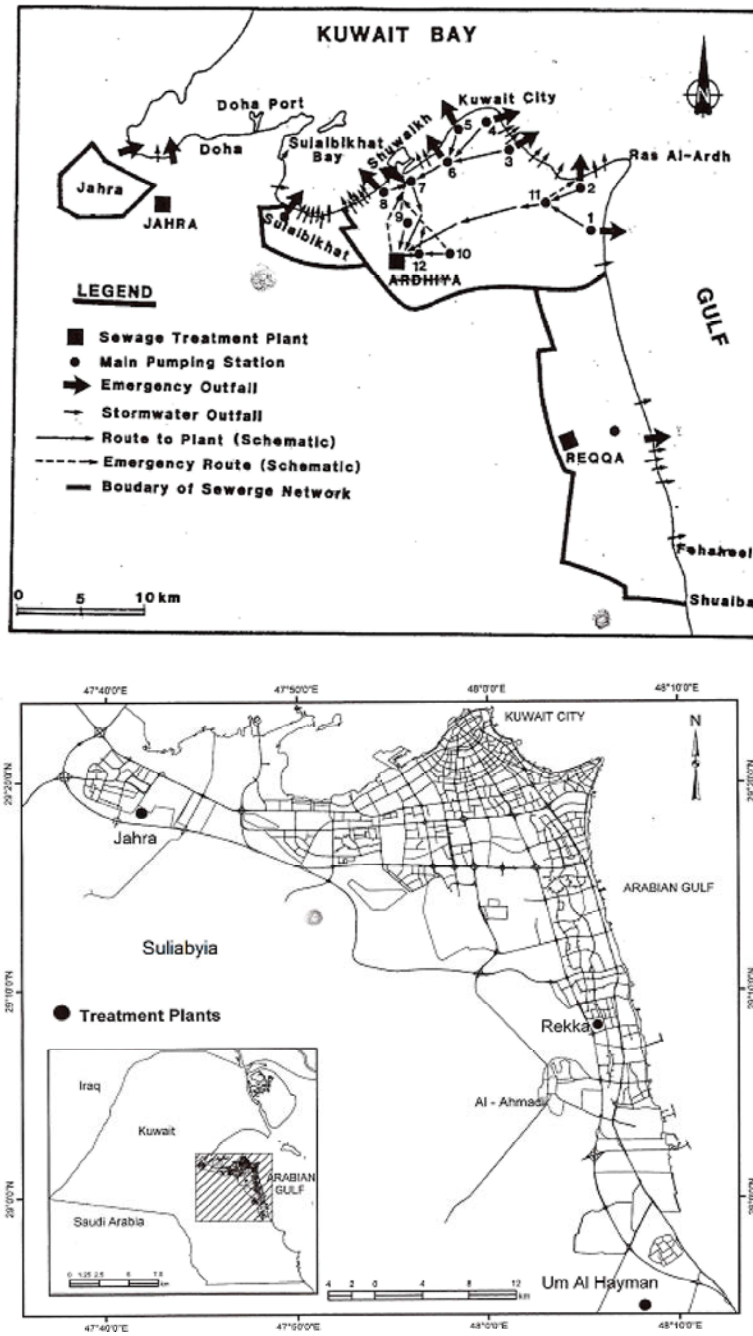

Fig. 1: Locations of sewage treatment plants, pumping stations, emergency outfalls and outfalls in Kuwait

reduced after tertiary treatment (Table 2). The percentage removal for the physical and chemical parameters at the treatment plants were signifitgintly high. The results demonstrated that the produced treated municipal wastewater could be reuse for greening and agricultural purposes. This is a good deal of evidence supports the possibility of utilizing of municipal treated wastewater for reuse. The municipal treatment plants in Kuwait are comply with the quality standards set by local authority for reuse. The produced treated water will satisfy agricultural requirements which are currently used the drinking waters supply. Therefore, the strategy of wastewater reuse should be encouraged in the municipal sector.

Table 2: Characteristic of Raw and Treated Sewage Municipal Wastewater

Parameter	UNIT	INFLOW	TERTIARY	R.O	Parameters of irrigation water	MEW Parameters of Drinking water
pH	-----	6.5-8	6.5-7.5	6-8	6.5-8	6.8-7.5
Conductivity	µs/cm	1200-3000	1100- 2200		1500	515
T.S.S.	mg/L	100-500	< 10	< 1	15	_
V.S.S.	mg/L	70-350	< 7.0	< 1	_	_
C.O.D.	mg/L	250-750	< 40		100	_
B.O.D 5	mg/L	100-400	< 10	< 1	20	_
Grease and Oil	mg/L	10-50	NIL	< 0.05	5	_
T.D.S.	mg/L	700-1800	800-1500	< 100	_	400
Chloride	mg/L	200-400	200-400		_	103
Ammonia	mg/L	15-50	1-5	< 1	15	_
Nitrite	mg/L	0.04-0.7	0.1-1.5	< 1	_	_
Total Count	colony/100mL	2.40E+09	1E+03	NIL	_	NIL
T. coli	colony/100mL	3.20E+08	400	NIL	400	NIL
F. coli	colony/100mL	4.10E+07	0-10	NIL	20	NIL
Salmonella	colony/100mL	4.50E+06	NIL	NIL	_	NIL
Streptococci	colony/100mL	1.40E+07	NIL	NIL	_	NIL
Fungi	colony/100mL	2.10E+05	2-100	NIL	_	NIL

Conservation Strategy in Municipal Sector: The increase demand for drinking water has led the Kuwait government to build six giants desalination plants. However the consumption of freshwater has grown significantly. In 1975, the total consumption of drinking water in Kuwait was $12x10^9$gal/yr, while by 2012 it had jumped to 453x 10^9gal/yr [38]. This is due to the expansion of new cities, wasting and the use of drinking water for agricultural purposes instead of brackish water. Besides the desalination plants, Kuwait has two areas with natural fresh underground water including Rawadatin and Umm Al-Aish. Their capacity is about $22x10^3m^3/d$ and it could be increased to $50x10^3m^3/d$ [4]. However, this water is being used mainly for bottling purposes. On the other hand, the brackish groundwater wells which are located in the south and southwest of State of Kuwait has salinity concentrations ranged between 3000 and 8000 mg/l and this water is used mainly for agricultural purposes [39], while, the ones located in the north and central areas of Kuwait have the salinity in the ranged between 10000 and 100000 mg/l with high concentration of salinity, it makes it difficult to be used for agriculture purposes but it can be used for agriculture irrigation. At present, the total volume of municipal wastewater is about $700x10^3$ m^3/d. The treated volume of municipal wastewater is about $460x10^3$ m^3/d and this amount is used completely for agriculture purposes, forestry, landscaping and growing un eatable crops. However, the unused treated municipal wastewater which is reached in the amount of $220x10^3$ m^3/d has been discharged to the coastal sea areas. It is expected this amount to increase more in the near future due to the expansion in the municipal wastewater plants. Additionally the MPW has a plan to use the remaining percent of treated wastewater for agriculture purposes as part of the conservation strategy plan for water supply in State of Kuwait. Therefore, if such plan is successfully implemented it will significantly convert the entire treated municipal wastewater in to a new source of water supply. Parabicoli [40] reported that municipal waste water is seen as to be the way ahead where resources are scarce. Furthermore, Sala *et al*. [41] showed that Spain suffers and struggles with uneven distribution of water supply as well as with high demand of water for agricultural irrigation over the last few years has pushed the authorities to find new ways of water supply. Thus finding ways and means to deal with water supply shortages become a major task for concern authorities in so many countries [11]. He explained that the majority of the world particularly developing countries are struggle with shortage in water resources but it is important to seek an integrated solution for water supply. In fact, the availability of water supply has been an essential condition for agriculture and human [6]. Yamacata [42] reported that in Japan most the treated wastewater is been used mainly for non-potable urban use. In Europe, water resources are under great pressure as population expands and the climate becomes extreme [36]. As a result municipal wastewater reuse is being integrated into water resources management strategies. Therefore, the concept of water reuse to alleviate scarcity is gradually being integrated into water resources management. Therefore, the reuse concept becomes widely accepted as a main source for water supply. Furthermore, water reuse is not only water saving solutions but also a water source for shortages in the water supply. Indeed governments have obligations to priorities water conservation by adopting a long-term strategic plans [43]. Realizing this fact, it is important that the government should provide direct investment for urban water system also provide guidance, subsidy and security for the water business. On the contrary, government role in water supply needs to be strengthened [44]. Therefore, it is important to seek new ways toward water shortages. In Kuwait, 80% of municipal treated wastewater is being used for land application and agricultural irrigation. This amount of reuse has been steadily increasing over the past of years, since, the first project on reuse project was implemented and operated in Kuwait in 1978. Then, the concept of reuse of municipal treated wastewater has had considerable publicity. Implementing this project and others has resulted demand for more water than over the past years. Presently, the reuse treated water intended for landscaping and golf courses. Treatment technologies for municipal wastewater has improved considerably over the past years. More projects by MPW are undertaken and arisen the quality level of services. In this connection, more projects by MPW are undertaken to reuse treated municipal wastewater as a part of conservation strategy policy. Furthermore, MPW has already devoted big budget to build water reuse facilities in order to promote water reuse policy and that will force to be less rely on drinking water supply resources and adapt a strategy plan toward water supply. These initiatives will devote several millions of gallon of treated municipal wastewater to become a valuable new resource for water supply in the State of Kuwait. Presently, Kuwait has a reliable and complementary source of water for agricultural and landscape irrigation if treated effluents are directed to reuse, not directed to the sea areas.

CONCLUSION AND RECOMMENDATION

Ninety percentage of Kuwaiti population is served by tertiary treatment plants, 80% of treated municipal wastewater has been reuse for plantation purposes and the remaining percent has been discharged to the coastal areas. In addition to that, there are plans to improve the efficiency of the municipal treatment plants and more investment to be done in the municipal sectors to ensure more effective water reclamation and reuse. Due to the shortage in water supply Kuwait government is already established a conservation strategy for water supply by utilization of treated municipal wastewater particularly in agriculture. This conservation strategy program will expand green areas in Kuwait by effectively utilizing the valuable resources that is already been treated. Simultaneously, such this approach would conserve the drinking water supply and that is likely to help to prevent to build unnecessary desalination plants.

In order to satisfy the need for more drinking water it is recommended that more research should be done on the technology of desalination plants in order to deliver the sea water in to the fresh water in a safe and reasonable price. More researches should take place on the MFS technology compared with RO technology related to the reliability, quality and risk. Reuse of treated sewage in agriculture and irrigation have environmental impact on both surface water and groundwater. A long term monitoring program should be initiated to observe the positive and negative impact on the environment. The risk of groundwater pollution and soil pollution is possible if only treated wastewater is used. More investigation in this area should be highlighted. The negative health impacts due to the use of treated wastewater in agriculture are main concern for public health. Therefore, a health risk evaluation of using wastewater is recommended. Desalination results in the production of concentrated brine which may affect coastal water quality and marine life. The long-term environmental effects of these methods remain unknown. Therefore, it is important to acknowledge and understand the impact of desalination plants on the coastal water quality and marine life. A careful integrated planning would be helpful to come up with a clear wastewater conservation and reuse plan to include all resources. Such plan would be helpful to conserve non-renewable groundwater, water reuse and energy consumption.

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