Sustainable household water model: Abasan Al-Kabera as a case study

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Abstract— In this study, a viable model at household level is adopted to reuse the grey and stormwater at a household level. Abasan Al-Kabera is studied specifically due to its rural and urban characteristics. The model constitutes of rainwater collection from rooftops of houses as well as graywater reuse in flashing the toilet while the surplus will be injected to the groundwater. The total inflow to the aquifer from storm water accounted for 1,756,875 m^3/year out of it 146,060 collected from the rooftops of public buildings and household while the recovery of greywater is 571,536 m^3/year. Additionally the estimated return flow from irrigation equals 506220 m^3/year. The outflow for domestic and agricultural equals 738,895 and 1,687,400 m^3/year, respectively. In conclusion the water balance is achieved, but it requires a proper storm water collection system. Moreover the greywater treatment and reuse systems should be developed and enhanced to guarantee the quality of groundwater recharge.

Index Terms—Rooftops, Greywater, Water balance, Rainwater, Absan Al-Kabera.

I INTRODUCTION

Researchers adopt water balance models prepared for the developed countries in countries lacking the capacity to implement these models due to the lack of experience and economical situation. Gaza Strip is one of the semi-arid area where rainfall is falling in the winter season from September to April, whereas the long term average rainfall rate in all over the Gaza Strip is between 200 mm/ year in the southern area to 400 mm/year in the northern areas (MOA, 2009; PWA, 2015). Groundwater aquifer is considered the main water supply source for all kind of human usage in the Gaza Strip (domestic, agricultural and industrial). Groundwater has been ovehelmed and deteriorated in both quality and quantity due to the increased in the urban areas which led to a decrease in the recharge quantity of the aquifer, also increasing the population will increase the demand and therefore, deplete the groundwater aquifer leading to seawater intrusion (Qahman, 2009; Shomer, 2010; CMWU, 2016 a) .

The groundwater aquifer beneath Gaza Strip is limited in its area, while the natural boundary of this aquifer reach Haifa in the North and goes to Sinai in Egypt in the south, and it's also bounded from Hebron in the East till the Meditation Sea in the west (Metcalf and Eddy, 2000; PWA, 2003; Mohd S. Abu Jabal *et al*., 2017).

The groundwater quality is monitored through all the cation's and anion's twice a year with the cooperation of both MOH and CMWU (Cl, NO_3, Mg, Ca, Na, K, F, NH_3, SO_4, TDS, EC, pH, Alkalinity and Hardness) is monitored through all municipal wells and some agricultural wells distributed all over the Gaza Strip (CMWU, 2016). The groundwater quality is varies from place to another and from depth to another. The chloride ion concentration varies from less than 250 mg/l in the sand dune areas as the northern and south-western area of the Gaza Strip to about more than 10,000 mg/l where the seawater intrusion has occurred.

The fresh groundwater area in the Gaza aquifer (Cl $\leq$ 250 mg/l) is existing in limited part of the aquifer located in the north of Gaza and west of Khan Younis (Mawasy) see Figure 1. The major parts of the aquifer have a Cl concentration of 500 -1500 mg/l, while along the coastal line exceeds 2000 mg/l of Cl concentration because of seawater intrusion influence. The map shows also that the Cl concentration in the southeastern part of the Gaza Strip is more than 1500 mg/l reflecting the upward leakage of the high saline water from the underneath water horizons (PWA 2015).

While the source of the nitrate ion in the groundwater chemical components has resulted from different sources *i.e.* intensive use of agricultural fertilizers beside the existence of septic tanks to dispose the domestic wastewater in the areas where there is no proper wastewater collection system. The nitrate ion concentration reaches a very high range in different areas of the Gaza Strip, while the WHO standard recommended nitrate concentration less than 50 mg/l for drinking purpose. As shown in Figure 2, it is clear that the NO_3 concentration in the pumped domestic water is ranging between 50 mg/l and > 300 mg/l. Where the high NO_3 concentration mainly occurred in the different residential areas of Gaza Strip reflecting the percolation of the wastewater to the underneath aquifer through the networks or cesspits.

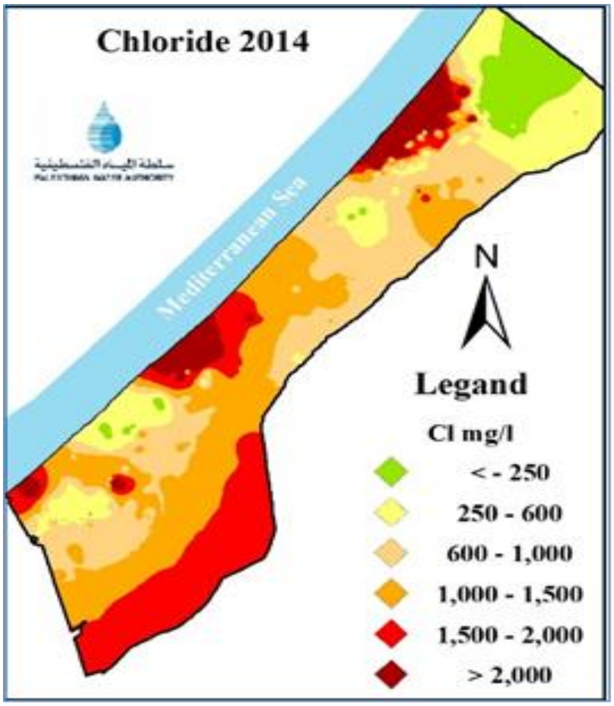

Figure 1 Chloride contour map (PWA, 2015)

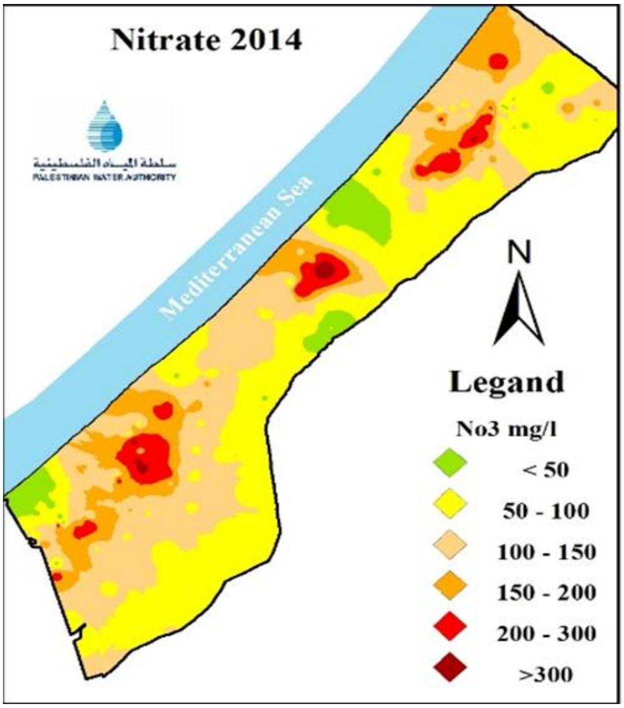

Figure 2 Nitrate contour map (PWA, 2015)

Khan Younis and specially Absan Al-Kabera has the highest concentration since most of the residential area is not served by sewerage system and many areas are still served by cess-pits facilities and characterized by rural areas where fertilizers used intensively (Al-Najar, *et.al.,* 2014). Moreover, Abu Jabal *et. al.*, 2014 and 2015, discussed new parameter from Khanyounis domestic wells showing high Flouride concentration.

The prevoisely metioned facts about the groundwater beneath Khanyounis governorate in general and Abasan Al-Kabera in particular agree with the United Nation (UN) report concerning the Gaza Strip environmental and health status "Gaza in 2020 is a liveable place?" (UN, 2012). The report briefly emphasizes that, without remedial action now, Gaza's problems in water, education and health will only get worse over the coming years, the top United Nations official for humanitarian and development aid in the occupied Palestinian territory, Maxwell Gaylard, warned today. "Gaza will have half a million more people by 2020 while its economy will grow only slowly. In consequence, the people of Gaza Strip will have an even harder time getting enough drinking water. Mr. Gaylard, together with Jean Gough of UNICEF and Robert Turner of the United Nations Relief and Works Agency for Palestine Refugees (UNRWA), launched a new report of the United Nations that summaries trends in Gaza and forecasts for the year 2020. The report says that the population of the Gaza Strip will increase from 1.6 million people today to 2.1 million people in 2020, resulting in a density of more than 5,800 people per square kilometer. Infrastructure in electricity, water and sanitation, municipal and social services are not keeping pace with the needs of the growing population. Gaza's population of about 1.6 million is still overwhelmingly groundwater and urban areas. By all accounts, demographic pressures in the Gaza Strip in terms of population density, growth rate, poverty and unemployment are extraordinarily high compared to neighboring countries and regions. The population pressure, combined with limited resources, places immense strain on the natural environment. Politicians and planners are faced with many competing claims for the use of scarce water and land in the Gaza Strip to fulfill the growing demand for development. The aim of the current research is an emergency action to highlight the possible means to remediate the resources and sustainable water cycle as a response to the UN 2020 report to save water for the coming generations. Absan Al-Kabera was discussed as a case study due to its special rural and urban characteristics.

II Study area and Methodology

To achieve the planned objectives of water sustainable cycle in the Gaza Strip, Abasan Al-Kabera is proposed as a model. The approach is to start from the household water cycle to reach the large scale water cycle. The main source of domestic water is the 6 municipal groundwater wells: N9, N22 and Rashwan 1,2,3,4. The water distributed from 2 main reservoirs (ground reservoir 2000 m^3 and high reservoir 300 m^3). As shown in Fig. 3 and Table 1, Abasan structural plan area is 7028 dunums (1 dunum = 1000 m^2) out of it 42.84% is residential area while the agricultural residental areas represent 43.66%, the rset represent the commercial, roads and green areas (MOAK, 2016).

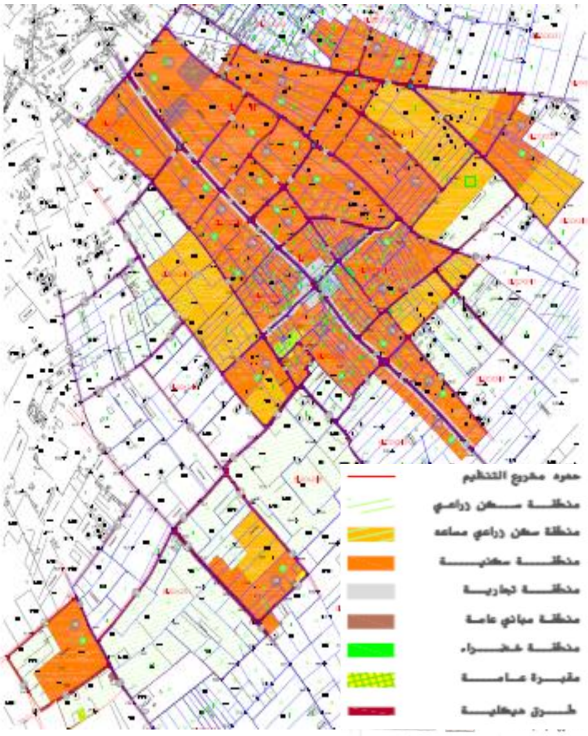

Figure 3 The structural plan of Abasan Al-Kabera, 2016

The population is 22,493 person (PCBS. 2016) and the number of water connections are 3042 customer (CMWU. 2016 b). Irrigation water requirement is estimated by modeling of average meteorological data for the last ten years by using CropWat Version 8.0. It is a program that uses the FAO (2004) Penman-Monteith method for calculating reference crop evapotranspiration and the irrigation water requirements. Agricultural water demand in addition to domestic water demand is calculated and compared with the registered data at the municipality archive.

Table 1 The landuse of Abasan Al-Kabera structural plan 2007

Landuse	Dunum	%
Agricultural residential area	2052	29.2
Assistant agricultural residential area	1016	14.46
Resiential area	3011	42.84
Commercial area	189	2.69
Public buildings	176	2.5
Green area	56	0.8
Cemetry	28	0.4
Main streets	499.5	7.11

III WATER CYCLE AT HOUSEHOLD LEVEL

A. STORMWATER COLLECTION

As stated previously, the increasing urbanization in the Gaza Strip represents a significant land use change, which has affected the major components of the overall water balance within the Gaza Strip. The recommended safe yield of the coastal aquifer in the Gaza Strip is 55 million cubic metres a year (PWA, 2012) and it would be good if a significant proportion of this could be returned to the aquifers through natural recharge. However, while urbanization will increase overland runoff, this will be at the expense of infiltration and groundwater recharge making the attainment of this objective difficult (Al-Najar and Adeloy, 2005; Hamdan *et.al.*, 2007; PWA, 2007). So while the use of a comprehensive modelling tool might be desirable, it is certainly a matter for the future as far as the Gaza Strip is concerned.

As an interim solution, an attempt was made to estimate the quantities of water that can potentially be available from rainwater from rooftops of the houses. To estimate the annual collected volumes, the basic water balance equation is used: Q = AP, where Q is the annual collected volume from the rooftop, A is the roof area, P is the annual rainfall. From the data of water custmor services, the number of connections are 3042 giving estimation about the number of houses. Considering the total population and the number of houses resulting in 7 persons per house. Assuming the averge rooftop surface in Abasan Al-Kaberia is 120 m^2 and the annual rainfall is 250 mm (MOA, 2016), the total collected rainwater from each house is 30 m^3. The required water supply per year per house equals 0.09 m^3/capta/day x 7 persons x 365 = 230 m^3/year per household. Thus, the collected rainwater from each house represent 13% of total family demand. The collected rainwater should be directly infiltrated to the groundwater to minimize the area of storage and to prevent the growth of mibncroorganisems as Gaza Strip experienced bad water quality due to the lack of monitoring programs and prevalence of water borne diseases (WHO, 2006; Yassin *et. al.* 2006; Sadallah and Al-Najar, 2015).

B. GREYWATER TREATMENT AND REUSE

Greywater reuse is a promising alternative water source, which could be exploited on a continuous basis and treated for non-potable uses (Chong *et al.*, 2015). The decentralized household grey and wastewater treatment units in Gaza strip were used for long time in rural areas in a conventional form that is a cylindrical shape constructed from concrete bricks for external walls without any lining in the bottom. These units consist of unsanitary construction system and depend mainly on infiltration of the wastewater that contaminated the ground water. Another case of onsite treatment units in Palestine was adding a separation rectangular tank before the septic tank. It is estimated that 40% of the houses in Gaza have such conventional septic tank (Al-Najjar, 2013). The idea of decentralized wastewater treatment plants (DEWATS) has been used by the local community as a tradition. Unsanitary septic tank system was used for long time as a result of unavailable sewerage (El-Halabi, 2005). The first initiative to develop the decentralized treatment system was adapted by the NGO's at the beginning of last decade to treat gray water in the rural as the following:

Twenty five septic tanks were implemented by the Union of Agricultural Work committees (UAWC) using the traditional system but with some additional sanitary measures as tank ground lining and totally closed walls of tank that prevented to some extent the infiltration to the ground water, but with very small fraction in treatment efficiency. The main two NGO's were the Palestinian Hydrology Group (PHG) through their Wastewater treatment and reuse in Agriculture project and Palestinian Agricultural Relief Committees (PARC).

Palestinian Hydrology Group (PHG) model was one of the first trials in Gaza strip to treat wastewater in rural areas. The system was designed to treat gray water and to utilize the system as a potential source for treated wastewater reuse. The system was implemented in many parts of Gaza strip specially in the rural areas where treated wastewater can be reused. The aim of the system implementation were to protect the environment and to enhance the nontraditional water resources use and decreasing the use of Cesspools.

The Palestinian Agricultural Relief Committees (PARC) model has been implemented in West Bank and Gaza in the rural areas to reuse treated wastewater in irrigating farms. The Action Against Hunger (ACF) has installed 25 units in the eastern villeges of Khanyounis including Absan Al-Kabera (ACF, 2016). The decentralized wastewater management approach on the other hand could be a valuable alternative to conventional, centralized approaches, if low cost processes adapted to the local conditions are applied and properly maintained (EPA, 2008). Water is increasingly becoming a scarce resource. Large and small scale users need to take action to conserve it not only because it is prudent practice to do so for their own benefit, but also because it is an active demonstration of their concern about the global pollution and environmental problems. Acquiring innovation capacity in developing and implementing grey water recovery technology on the residential areas is essential to alleviate the sequences of water scarcity.

IV Water balance in Abasan Al-kabera

Considering the number of the family in Abasan Al-Kaberia of 7 persons, the need to flush the toilet is 2 times per person a day producing around 8 liters/person/day as a wastewater (i.e. 56 liters/ family/day). Traditionaly the residents use part of the water supply to irrigate the surrounding garden and wash the yard leading to generated wastewater (both blackwater and greywater) equals to 90% of water supply. The rest of the water supply [(90-0.9) - 8 = 73 L/person/day) generated as greywater, the potential recovery of greywater per family per year equals 0.073 m^3 x7 persons x 365 days of the year = 186 m^3/year. The water supply per family per year equals 230 m^3, the percentage of greywater recovery represents 81%. To make the balance of water supply, balckwater generation, grey water recovery and rainwater collection, around 94% of the water suppy could be recovered (81% greywater + 13% rooftop rainwater collection). This calcuation model is nearly fixed where the use of flushing the toilet is restricted, the people use the water in huge amounts in the bathroom, kitchen, washing machines which all produce greywater in other words if the water supply increase, as a consequence the grywater production increase. As showin in Fig. 4, not all the produced greywater could be used to flush the toilet only 56 L/famil/day could be utilized, the rest 511-56 = 455 L/ day should be infiltrated to the groundwater through the rainwater injection boreholes. The reuse of grey system is very suitable in the agricultural and assistant agricultural residential areas which represent 43.66% of the toal area of Abasan see Table 1. Moreover, the greywater could be used to irrigate the agricultural lands which cultivated with olives, Guava and citrus and the rest should be infiltrated.

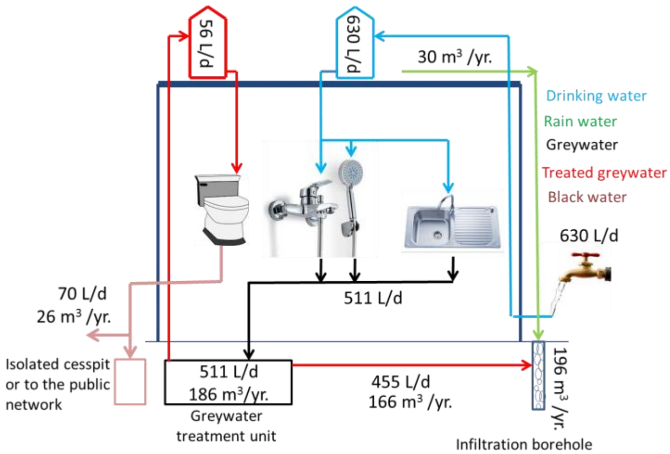

Figure 4 Recovery model of greywater and rainwater collection

As shown in Table 1, the pure residential area represents only 42.84% of the toal area of Abasan, thus it is characterised as urban area, while 43.66 is agricultural and assistant agricultural with scattered buildings. This area is characterized as rural areas. The recovery model Figure 4, is designed for the houses which accounted for 3402 houses, the total collected rainwater from household rooftops is 30 m^3/ house x 3,402= 102,060 m^3/year. While the public buildings represents 176 dunum as shown in Table 1, thus the collected rainwater from the public buildings rooftops equals 44,000 m^3/year. The collected rainwater could be infiltrated to the groundwater. The total entire area of Abasan is 7027.5 dunums, the quantity of rainwater that could be collected equals 1,756,875 m^3/year out of it 146,060 collected from the rooftops of public buildings and household rooftops.

The water cycle in Abasan consists of abstraction from the groundwater for domestic and irrigation water and the recharge of the groundwater as the following:

a) Outflow from the groundwater:

Domestic demand 90l/c/d x 22493 person x 365= 738,895 m^3/year.

Agricultural demand in agricultural and assistant agricultural areas = 3068 dunum x 550 m^3/dunum = 1,687,400 m^3/year assuming all the agricultural and assistant agriculture are cultivated and planted. It is clearly the agricultural demand is two times higher than the domestic demand.

b) Inflow to the groundwater:

Rainwater = 1,756,875 as a total rainwater volume, but lets assume 20% lost by runoff, the recharge of the groundwater from rainwater = 1,405,500 m^3/year.

Return of irrigationwater to the groundwater = 0.3 x

1,687,400 = 506220 m^3/year

Recovery of greywater = 168 m^3/household x 3402 = 571,536 m^3/year. Finally, the outflow from the groundwater accounted for 2,426,295 while the inflow from stormwater/ or greywater reuse accounted for 2,483,256 m^3/year.

In conclusion the water balance is achieved in case of Absan, but it is required to adopt proper stormwater collection system in the level of household and from agricultural areas. Moreover the greywater treatment and resue systems should be developed and enhanced to gurantee the quality of groundwater recharge based upon the Palestininan standards.

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