Faculty of Graduate Studies

REUSING OF TREATED WASTE WATER IN CONCRETE PRODUCTION

إعادة استخدام المياه المعالجة في صناعة الخرسانة

Submitted By:
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A thesis submitted in fulfillment for the Master Degree in Water and Environmental Engineering to the Faculty of Graduate Studies at Birzeit University – Palestine

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The finding, interpretation and conclusions expressed in this study do not necessary express the views of Birzeit University, the views of the individual members of the MSc-committee of the views of their respective employers.

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إعداد

ولاءعقل

المشرف

د. نضال محمود

آذار ,2015

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Abstract

The present consumption of potable water for concrete production creates indirectly a great burden of cost, especially these days in light of the global water crisis which is summarized in a great demand on water against the limited resources. This Project was conducted to study the feasibility of usage of treated waste water in concrete production, in an attempt to provide tap water for other purposes and so to reduce the total cost of concrete production.

In this research, water samples were taken from the effluent of Al-Tireh (MBR)Treatment Plant, Al-Bireh (EA) Treatment Plant, Al-Quds University(RO) Treatment Plant, in addition to the wastewater samples at Biologically treated wastewater, MBR treated wastewater, and effluent of Al-Tireh Treatment Plant as a second phase in the research, all specimens were tested and then used as mixing water in concrete production. The resulted concrete tests were in comparison with the potable water-mixed concrete. Compressive strength, slump, setting time, air content, permeability, and specific gravity were tested to all concrete mixtures. All tests in this research made taking into consideration the criteria and requirements of the standard specifications of the ASTM.

The compressive strength was 281, 299, 286, 288 at 7 days, 394, 394, 392, 380kg/cm^{2}at 28 days, and 417, 413, 416, 402 kg/cm^{2}at 56 days for potable water, Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater respectively. With a values of 258, 311, 288, 282 kg/cm^{2}at 7 days, 358, 410, 391, 390 kg/cm^{2}at 28 days, 377, 425, 408, 403 kg/cm^{2}at 56 days for potable water, Biologically treated wastewater, MBR treated wastewater, and the effluent respectively. The slump values were 123, 119, 127, and 125 mm for potable water, Al-Bireh treated wastewater, Al-Tireh treated wastewater, and Al-Quds University treated wastewater respectively. With values of 123, 137, 132, 132 mm for potable water, biologically treated wastewater, MBR treated wastewater, and the effluent respectively. The initial setting time was 4:50, 4:50, 5:00, 5:50 hours for potable water, Al-Bireh treated wastewater, Al-Tireh treated wastewater, and Al-Quds University treated wastewater respectively. And 4.5, 6.0, 5.0, 4.5hours for potable water, biologically treated wastewater MBR treated wastewater, and the effluent respectively.

On the other hand the final setting time was 8:50, 8:30, 8:40, and 8:35 hours for potable water, biologically treated wastewater, MBR treated wastewater, and the effluent respectively, and 8:50, 8:30, 8:40, and 8:35 hours for potable water, Al-Bireh treated wastewater, Al-Tireh treated wastewater, and Al-Quds University treated wastewater respectively. The permeability was 3, 2, 2, 3 mm for potable water, Al-Bireh treated wastewater, Al-Tireh treated wastewater, and Al-Quds University treated wastewater respectively. And 3, 1, 2, 2 mm for potable water, biologically treated wastewater, MBR treated wastewater, and the effluent respectively. The specific gravity values were 2.40, 2.40, 2.42, 2.41for potable water, Al-Bireh treated wastewater, Al-Tireh treated wastewater, and Al-Quds University treated wastewater respectively. And 2.40, 2.42, 2.42, 2.41 for potable water, biologically treated wastewater, MBR treated wastewater, and the effluent respectively. Finally the percent of air content was measured, values were 1:30%, 1:50%, 1:40%, 1:20% for potable water, Al-Bireh treated wastewater, Al-Tireh treated wastewater, and Al-Quds University treated wastewater respectively, and 1:30%, 1:10%, 1:10%,

1:40%for potable water, biologically treated wastewater, MBR treated wastewater, and the effluent respectively.

Comparing tests results of the treated waste water with potable water, the results were all within the tolerable limits, according to ASTM standards. The research shows that treated waste water can be used successfully in preparing concrete at various used treating techniques or either treating stages.

الملخص

يشكل الاستهلاك الحالي للمياه المحلاة لإنتاج الخرسانة عبئا كبيرا من حيث التكلفة ، وخاصة في الوقت الراهن في ظل أزمة المياه العالمية, والتي تتلخص في الطلب الكبير على المياه مقابل مصادر المياه المحدودة. تم اجراء هذا البحث لدراسة جدوى استخدام مياه الصرف الصحي المعالجة في إنتاج الخرسانة، في محاولة لتوفير المياه المحلاة لأغراض أخرى وذلك للحد من التكلفة الإجمالية لانتاج الخرسانة على الدول.

في هذا البحث، تم أخذ عينات المياه من محطة الطيرة، محطة البيرة، ومحطة جامعة القدس لمعالجة المياه العادمة، بالإضافة إلى عينات مياه الصرف الصحي المعالجة بمراحلها المختلفة من محطة الطيرة لمعالجة المياه العادمة كفصل اضافي في البحث، تم فحص جميع العينات ومن ثم استخدامها كمياه خلط في إنتاج الخرسانة. وتمت مقارنة نتائج جميع عينات المياه المعالجة مع نتائج مياه الشرب. أجريت الفحوصات التالية غلى الخرسانة: قوة الضغط، الهبوط في الكتلة، زمن الشك الابتدائي و النهائي، ومحتوى الهواء, النفاذية، والوزن النوعي لجميع الخلطات الخرسانية جميع الاختبارات في هذا البحث تمت مع مراعاة معايير ومتطلبات المواصفات القياسية لل ASTM.

عند قياس قوة الضغط للخرسانة كانت النتائج كالتالي 281, 299, 286, 288 كجم/سم^2 عند الكسر على 7 ايام, 394, 394, 392, 380 كجم/سم^2 عند الكسر على 28 يوم, 417, 413, 416, 402 كجم/سم^2 عند الكسر على 56 يوم للعينات التاليه على الترتيب : مياه الشرب, محطة معالجة البيرة, محطة معالجة الطيرة, محطة معالجة جامعة القدس. في حين كانت النتائج 258, 311, 288, 282 كجم/سم^2 عند الكسر على 7 ايام, 358, 410, 391, 390 كجم/سم^2 عند الكسر على 28 يوم, 377, 425, 408, 403 كجم/سم^2 عند الكسر على 56 يوم وذلك لمياه الشرب, المياه المعالجة بيولوجيا قبل الاغشية, المياه المعالجة بالاغشية, و المياه الخارجة من المحطة على التوالي. كانت نتائج فحص الهبوط 123, 119, 127, 125 مم للعينات التاليه على الترتيب : مياه الشرب, محطة معالجة البيرة, محطة معالجة الطيرة, محطة معالجة جامعة القدس. في حين كانت 123, 137, 132, 132 مم وذلك لمياه الشرب, المعالجة بيولوجيا قبل الاغشية, المياه المعالجة بالاغشية, و المياه الخارجة من المحطة على التوالي. زمن الشك الابتدائي كان 4:50, 4:50, 5:00, 5:50 ساعه للعينات التاليه على الترتيب : مياه الشرب, محطة معالجة البيرة, محطة معالجة الطيرة, محطة معالجة جامعة القدس. و أعطى النتائج التالية لمياه الشرب, المعالجة بيولوجيا قبل الاغشية, المياه المعالجة بالاغشية, و المياه الخارجة من المحطة على التوالي 4:50, 6:00, 5:00, 4:50 ساعة. اما عن زمن الشك النهائي فكان 8:50, 8:30, 8:40, 8:35 ساعة لمياه الشرب, محطة معالجة البيرة, محطة معالجة الطيرة, محطة معالجة جامعة القدس على التوالي. في حين كانت النتائج 8:50, 9:30, 9:00, 8:35 ساعة لمياه الشرب, المعالجة بيولوجيا قبل الاغشية, المياه المعالجة بالاغشية, و المياه الخارجة من المحطة على التوالي.

اما بالنسبة لفحص النفاذية فكانت القيم 3, 2, 2, 3 مم لمياه الشرب, محطة معالجة البيرة, محطة معالجة الطيرة, محطة معالجة جامعة القدس على التوالي و 3, 1, 2, 2 مم لمياه الشرب, المعالجة بيولوجيا قبل الاغشية, المياه المعالجة بالاغشية, و المياه الخارجة من المحطة على التوالي. الوزن النوعي كان 2:40, 2:40: 2:42, 2:41 لمياه الشرب, محطة معالجة البيرة, محطة معالجة الطيرة, محطة معالجة جامعة القدس على التوالي.. و 2:40, 2:42: 2:42, 2:41 لمياه الشرب, المعالجة بيولوجيا قبل الاغشية, المياه المعالجة بالاغشية, و المياه الخارجة من المحطة على التوالي. أخيرا تم فحص محتوى الهواء و أعطى النتائج 1:30%, 1:50%, 1:40%, 1:20% لمياه الشرب, محطة معالجة البيرة, محطة معالجة الطيرة, محطة معالجة جامعة القدس على التوالي. و 1:30%, 1:10%, 1:10%, 1:40% لمياه الشرب, المعالجة بيولوجيا قبل الاغشية, المياه المعالجة بالاغشية, و المياه الخارجة من المحطة على التوالي. بمقارنة نتائج الفحص باستخدام المياه العادمة المعالجة مع مياه الشرب كانت النتائج جميعها ضمن الحدود المسموح بها, وفق ما جاء بمعايير ال ASTM.

أظهرت نتائج البحث أن المياه العادمة المعالجة على اختلاف مراحل المعالجة او التقنيات المستخدمة صالحة للاستعمال كمياه خلط في الخرسانة.

Key words

Treated wastewater; Concrete production; Impurities in concrete; Self-healing; Compressive strength; Setting time; Permeability; Air content; Specific gravity

DEDICATION

This work is dedicated to the following;

My parents, my grandfather and grandmother, my everything Sawsan

My husband Moath

My sisters Thanaa, Reem, Reham, and Siwar

My brothers Tareq and Zaid

My daughters Zeina, Maram, and Lucein

My friends

Dr. Nidal Mahmoud and all my doctors in the department

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LIST OF ABBREVIATIONS

PW	Potable Water
PTWW	Primary Treated Waste Water
STWW	Secondary Treated Waste Water
TTWW	Tertiary Treated Waste Water
COD	Chemical Oxygen Demand
BOD	Biological Oxygen Demand
DO	Dissolved Oxygen
TS	Total Solids
TDS	Total Dissolved Solids
MBR	Membrane Bioreactor
EA	Extended Aeration
RO	Reverse Osmosis
ASTM	American Standard Testing Methods
WCED	World Commission on Environment and Development
UNEP	United Nations Environmental Programme
USAID	U.S. Agency for International Development
EPA	U.S. Environmental Protection Agency
PCA	Portland Cement Association
OPC	Ordinarily Portland Cement
WHO	World Health Organization
EC	Electrical Conductivity

Chapter 1
Introduction

1.1 Background

Water scarcity is increasingly becoming of great global concern due to the very rapid population growth. In light of the global water crisis, the search for non-conventional water resources, like treated effluent reuse is becoming a main goal for scientific research especially in the industrial sector (Lee *et al*., 2001). Great attention is specifically given to the large water consumers industries. In the particular case of Palestine, considering the very rapid urbanization, concrete industry is becoming one of the biggest industries that are also a major consumer of water. It is estimated that the annual water consumption of the concrete industry is about 3.20 mcm (Palestinian Concrete Society, 2013). Therefore, the concrete industry imposes a big pressure on the scarce water resources in Palestine, as well as other countries of similar urban and environmental status.

Concrete is the most widely used construction material in the world and the largest water consuming industry (Friedler, 1999). Approximately 150 liters of water is required per cu. m. of concrete mixture, without considering other applications of water at the concrete production. The importance of continuous sustainable development of environmental friendly concrete industry is motivated by population growth and lack of water (Haarhoff & Merwe, 1996). The world population doubled from 1959 to 1999, increasing from three billion to six billion. According to the United States Census Bureau, the world population is projected to reach nine billion by 2043; or an increase of 50% relative to 1999. Thus, it is expected that the water demand will have an increasing trend; leading to water recycling and conservation (Sethuraman, 2006) as a necessity.

There is no clear specification of the quality of concrete mixing water.Butthe standard rolling among the public is the validity of this water for drinking, cleanliness and the authorization of harmful substances. However, these criteria may not be the best suited in practice, concrete with better quality may be produced from water does not apply to these standards (Muniandy, 2009).

1.2 Research Objectives

The overall objective of this research is to assess the appropriateness of using various types of treated effluent as mixing water in concrete industry.

1. To assess the impact of using treated wastewater on concrete:
   - ✓ Compressive strength.
   - ✓ Slump.
   - ✓ Initial setting time.
   - ✓ Final setting time.
   - ✓ Air content.
   - ✓ Permeability.
   - ✓ Specific Gravity.
2. To compare the impact of treated effluents source (from Al-Tireh membrane bio-reactor (MBR), Al Bireh extended aeration (EA) treatment plant, and effluent polished by reverse osmosis (RO) in Al-Quds University) on concrete properties.
3. To compare the treated wastewater characteristics with recommended water quality for concrete production by ASTM.

1.3 Scope of Research

The scope of research was in balance with the Utilization of treated waste water, the manufacture of concrete. The study try to minimize the high cost of potable water usage in concrete production, the reuse of reclaimed water had been analyzed for this purpose.

The importance of this research lies in the expansion of its scope. Previous researches were limited to less extent aspects, while this research excellence in the comparison between several aspects, it includes a comprehensive study of various types of waste water techniques with multiple stages of treatment, except for the multiplicity of engineering tests conducted to examine the concrete, in an unprecedented scientific accurate framework in order to obtain more comprehensive results. Finally, it is wished that the results from this research may be attached as a useful reference of reusing waste water in concrete production and the future prospect of the Palestinian construction industry.

Chapter 2

Literature Review

2.1 The "Environment" in sustainable development

After the 1972 Stockholm Conference on the Human Environment and the 1980 World Conservation Strategy of the International Union for the Conservation of Nature, the awareness of the seriousness of the environmental situation was growing, and the importance of binding conferences to ensure sustainable development for the environment was underlined (Strong, 1999). In October 1987, World Commission on Environment and Development (WCED), known as “Brundtland Report” was contracted (Rist, 2007). In which WCED coined, and defined the meaning of the term "Sustainable Development (WCED, 1987).

Rio +20 calls to achieve applicable sustainable goals (SDGs) (Jane&Nicole, 2012) that meet the environmental, social and economic aspects of sustainable development. Countries underlined this at Rio+20 by “green economy” (UNCTAD, 2012). During this time, a fourth dimension, “peace and security” has been recommended by the UN Task Team on the post-2015 UN Development Agenda1 and the Sustainable Development Solutions Network. The UN Secretary-General’s High-Level Panel of Eminent Persons on the Post-2015 Development Agenda has presented a report on the matter, while additional ideas on the post-2015 agenda are being composed by the UN Development Group at national, regional and global thematic consultations (ECOSOC, 2012).

During the last 20 years the attention of governments and companies was focused around the protection of the environment (Drexhage and Murphy, 2010), which led to the promotion of the concept of green technology and seeking to invest in them. The globally follow-up protection of the environment, including renewable energy sources leads to the development and implementation of water conservation. One indicator of the serious fact that is “nearly80 percent of then at Ural resources used in each year, are consumed by about 20 percent of the world's population (Drexhage & Murphy, 2010)." This huge level needs to be analyzed briefly to solve the environmental gap nowadays and throughout the future.

2.2 Wastewater and Sustainability

Water is one of the world's highest values resources (FAO, 2011), due to its importance accompanied with its scarcity, as the climate change, the drought and increasing population growth increases the water crisis in the world. Recently studies were focused on the use of reclaimed water to reduce this crisis (Liu, 2014).

Thus, water recycling is the reuse of reclaimed wastewater for several applications, such as irrigation, industry, and toilet flushing. Wastewater treatment and re-use limits the consumption amount of surface water and groundwater, and can limit the polarization of water from sensitive ecosystems (Hanak1 *et al.*, 2009). In addition, there-use of water may protect water ways from the risk of pollution resulted from leakage of nutrients into it (South, 2003). Higher Attention was focused on water supply than waste water treatment (Copeland, 2010). But recently the awareness of the seriousness of waste water on lakes and rivers was increasing; sewage treatment has received great support from the World Bank and the governmental organizations (Jhansi and Mishra, 2013). A management system has been developed for the wastewater treatment to ensure the reduction of pathogens at surface water and groundwater to promote public health (Corcoran *et al.*, 2010). In the developing urban areas, the wastewater invention averages is usually 30-70 cubic meters per person per year (Jhansi and Mishra, 2012).According to the World Bank, "The greatest challenge in the water and sanitation sector over the next two decades will be the implementation of low cost sewage treatment that will at the same time permit selective reuse of treated effluents for agricultural and industrial purposes" (Green Arth, 2012). The US Environmental Protection Agency's *Guidelines for Water Reuse* represents the international standard for best practices in water reuse. The document was developed under a Cooperative Research and Development Agreement between the U.S. Environmental Protection Agency (EPA), the U.S. Agency for International Development (USAID), and the global consultancy CDM Smith (EPA, 2003).

In general, reusing wastewater is subject to the follow guidelines (Nabegu, 2010):

- ✓ Treated wastewater must meet the WHO (1989) specification.

- ✓ Source-point measures require extensive industrial pre-treatment interventions, monitoring and control programs, and incentives for the community to not dispose of any harmful matter into the sewers.
- ✓ Participation of local communities in the plan of wastewater re-uses.

2.3 Background on wastewater production and treatment

The worldwide wastewater generation is rising at an exponential rate, due to fast population growth and urbanization (EAE, 2014). Environment Outlook of the United Nations Environmental Programme (UNEP) reports that "about one third of the world's populations currently live in countries suffering from moderate-to-high water stress, where water consumption is more than 10% of renewable freshwater resources"(SOE, 2002). An estimated guess of international wastewater production is about 1,500 km3 per day (CWHW, 2010). An enormous amount of untreated wastewater is discharged directly into our water resources, blustering human health, ecosystems, biodiversity, food security and the water resources sustainability. Just a tiny fraction of the total quantity of wastewater generated in developing cities is treated to the secondary treatment level (Zandaryaa, 2011). The Shortage of treatment of wastewater is a super health and environmental concern. Table 1 shows wastewater treatment by world regions for several regions.

Table 1: Wastewater treatment by world regions

Regions	Population with sewerage connection in large cities, %	Portion of wastewater treated to secondary level, %
Northern America	96	90
Europe	92	66
Asia *incl. Japan, Korea)*	45	35
Latin America and Caribbean	35	14
Africa	18	<1

Source: WHO/UNICEF Global Water Supply and Sanitation Assessment 2000 Report.

Recently, the challenge of wastewater leads to new and different ways of looking at wastewater reuses (UNEP, 2010), considering wastewater as "valuable resource", Stimulates sensitize decision-makers and the public to tackling sanitation and wastewater problems.

Despite the challenges magnitude facing there-use of wastewater by politicians and policy-makers, and giving Sustainable Wastewater Management less provision rank. Wastewater remains a driving motivating force to be used strongly as a basic resource, as these water contains super proportion of water, (even the best local sewage is more than99% of the water) (RICS, 2011). Figure 1shows the quantities of treated wastewater reused in countries of the Eastern.

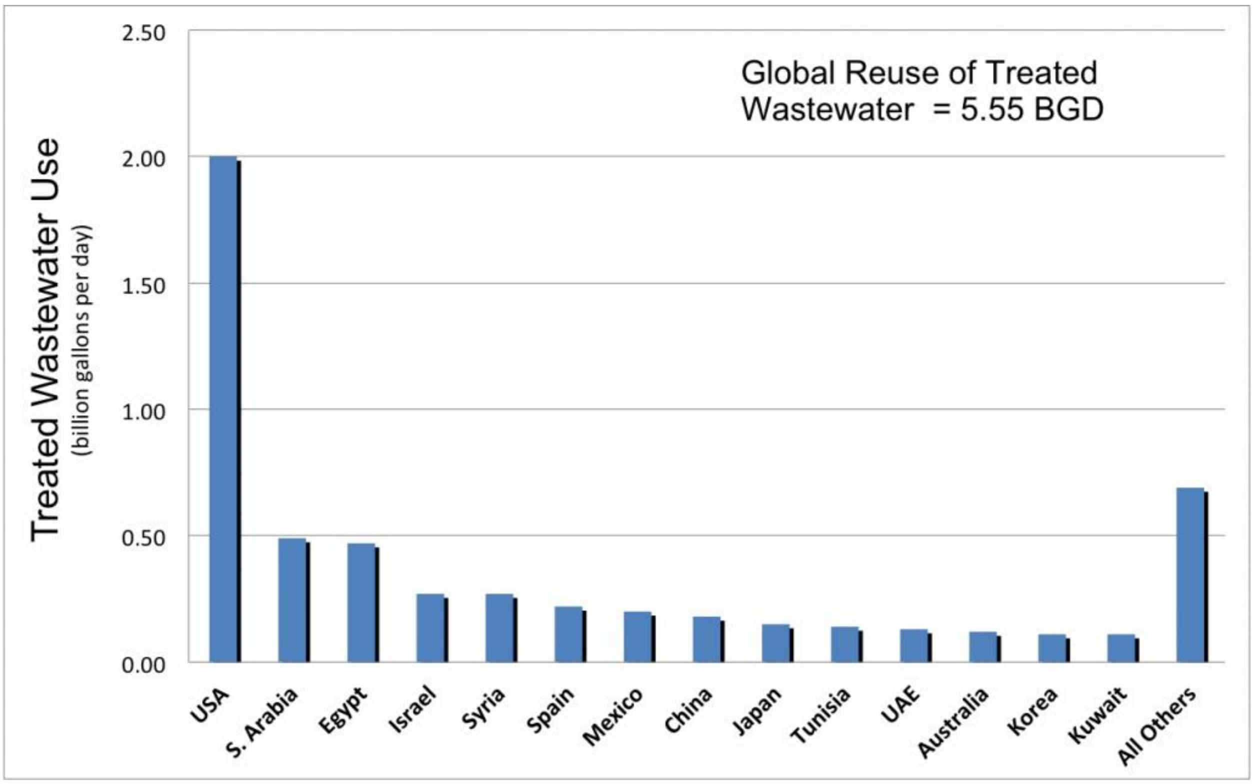

Figure 1: Quantities of treated wastewater reused in countries of the Eastern. Source: (Jiménez and Asano, 2008).

The quantities of wastewater generated treated and reused in eleven countries of the Eastern Mediterranean at the various years: 1991-2000 were presented in figure 2, showing spaced ratios between each other.

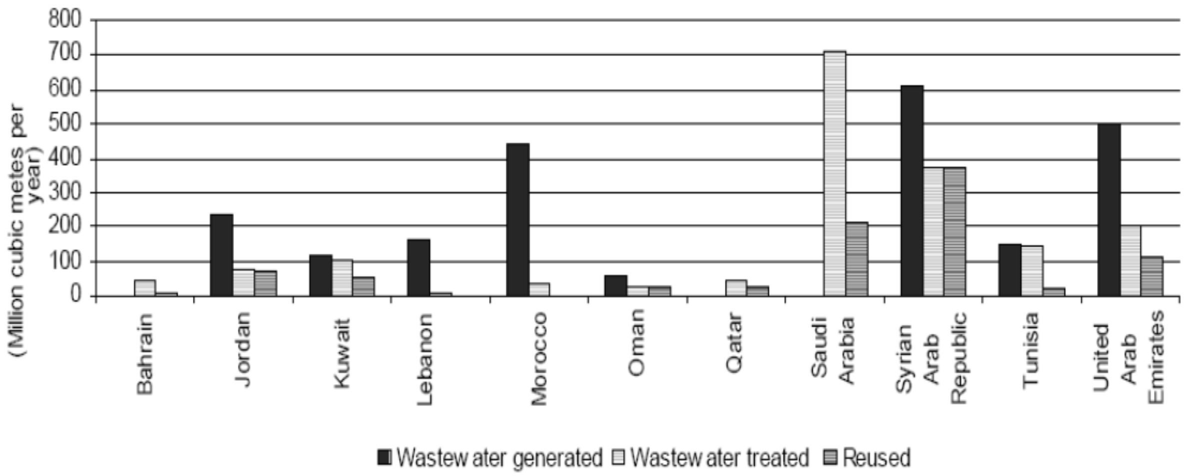

Figure 2: Quantities of wastewater generated treated and reused in eleven countries of the Eastern Mediterranean (various years: 1991-2000)
(*Source*: WHO Eastern Mediterranean, 2005).

2.4 Background on wastewater treatment technologies

All the water resulted from the home that poured into the drains or the sewage collection systems is considered as wastewater. Such wastewater resources are as baths, showers, sinks, dishwashers, washing machines, and toilets. Figure 3 shows the tree of water resources recycling. Small factories and companies are often generates great amounts of wastewater of sewage collection systems, while others have their own wastewater treatment systems.

Conventional wastewater treatment consists of the following stages: preliminary, primary, secondary, and disinfection.

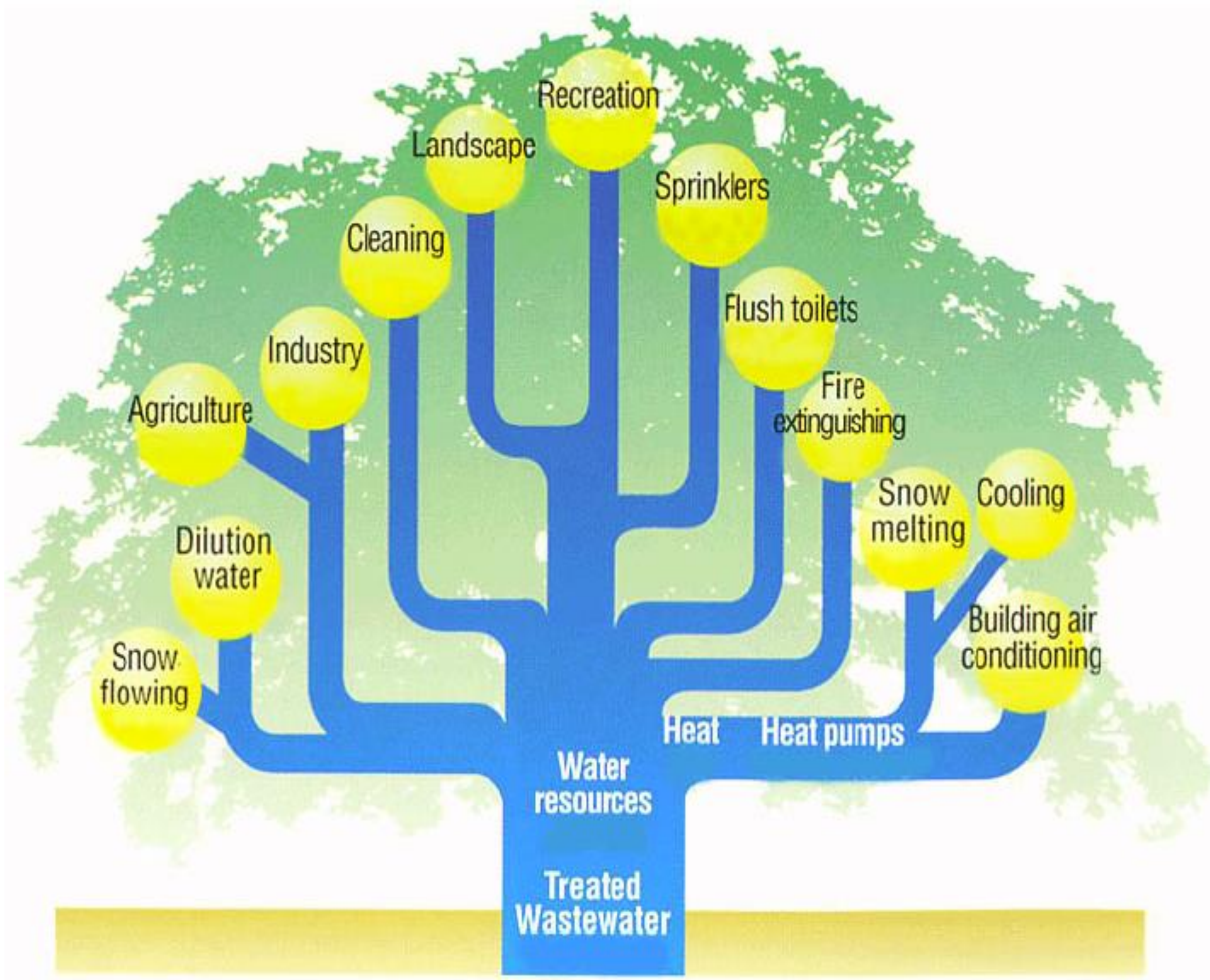

Figure 3: Tree of water resources recycling. Source: (MLIT, 2001)

A typical sewage treatment system includes sub-treatment stages: primary treatment, secondary treatment, tertiary treatment, and disinfection. In the pre- treatment step, raw wastewater run through screens and grates, where sand, gravel, and bigger substances are mechanically removed. At primary wastewater treatment settling, skimming, and often chlorination are used to remove solids, floating materials, and pathogens. In the secondary stage microorganisms degrade the popular organic material that residue in wastewater. Nutrients such as phosphorous and nitrogen and most suspended solids are removed at tertiary treatment. Finally, the water is subjected to disinfection, where chemicals destroy pathogens (MMSD, 2009).

Municipal wastewater treatment plants are on several types, such as extended aeration technologies, membrane Filtration Technologies: RO, MBR.

- ✓ Membrane Bioreactor Treatment Plant

Suspended growth activated sludge treatment system by means of membranes for liquids/solids separation. It has the advantages of high effluent quality, no sludge settling problems, and lowered volume requirements. Due to microfiltration MBR provides great physical disinfection removals 5-6 log bacteria, 2-3 log viruses, in addition to the complete removal of pathogenic protozoa (Kitis, 2010). On the other hand the system suffers from the membrane fouling, and the high operational costs. Biological reactor and membrane filtration is utilized as a united system for the secondary treatment of wastewater. Membranes carry out the separation of the final effluent from the biomass through filtration which is run by the submission of a pressure gradient.

- ✓ Reverse Osmosis Treatment Plant

Reverse osmosis is a commonly proven conventional unit operation for water purification.RO is widely used in industrial applications which require demineralized or deionized water , since it is efficiently removes various contaminants such as dissolved salts, natural organic matter, microorganisms and particulate matter.

“Reverse Osmosis is capable of removing up to 99%+ of the dissolved salts (ions), particles, colloids, organics, bacteria and pyrogens from the feed water (although an RO system should not be relied upon to remove 100% of bacteria and viruses)”(Kumar, 2013) The molecular removal by RO membranes depends on the size and the charge of them. In which a molecular weight more than 200 is well rejected by a appropriately operating RO membrane (AWT, 1998). The advantages of the RO process that make it mainly preferred for dilute aqueous wastewater treatment include the simplicity in design and operating, low maintenance requirements, facilities of expand the system; efficient removal for both inorganic and organic pollutants; success recovering of waste process streams without any effects on the material being recovered; less energy consumption, moderate operating and capital costs (Hüfner, 2010).

Despite their advantages, the RO membranes have some disadvantages include the potential to beat of function due to the presence of various size and shape of contaminants, which might immobilize the membrane's functions. Otherwise, the extended use of disinfectant chlorine may harm the membrane (IWA, 2011). The removal of some pesticides and chlorine particles can't be achieve since their molecules is smaller than that of water .For this reason, carbon filter are commonly used to ensure the chlorine removal from water (Hassinger *et al*.,1994). Else, the process generates a huge amount of water as a waste, RO system limits the natural structure of water, since it blocks the healthy, naturally-presenting minerals in the water. These blocked minerals are essential in providing the natural taste of water in addition to the necessity to human body by approximately a 3:1 wasted water\purified water gallons ratio (spectra pure, 2011).

- ✓ **Extended Aeration Treatment Plant**

The Extended Aeration Treatment system is an original activated sludge process via extended retention of biological solids to generate an awfully stable, easily, efficient operated framework. The process has the advantages of maximum stability operation, high efficiency treatment, the low-cost construction, and simple operation. The system utilizes a Low-loaded activated sludge technology. This also identified as SRT (Solids Retention Time) or MCRT (Mean Cell Residence Time). In the other hand it suffers from some disadvantages in which it can't achieve denitrification or phosphorus removal without additional unit process. A longer aeration periods are requires more energy. And, the Adapting effluent requirement due to regulatory changes is not flexible.

2.5 Treated wastewater reuse history

Re-use of waste water in irrigation goes back to 5000 years. There are indications of reuse treated wastewater at agricultural applications since 16th and 18th centuries; respectively. India and China have a long history of irrigation by reclaimed water two.

During 1840s and 50s epidemics were spread in the world due to the indirect use of the treated wastewater in the drinking water suppliers without ensuring plane efficiency (Vigneswaran & Sundaravadivel, 2014). Later, engineers developed improved water sources by the means of reservoirs and aqueduct systems, relocation of water intakes, and water and wastewater treatment systems. Regular wastewater irrigation has been accomplished in sewage farms many countries in Europe, America and Australia until now. National governments recently realized the value of the re-use of treated wastewater, and worked to strengthen the future plans related about it in many countries (WESRDD, 2004).

2.6 Wastewater parameters

There are many parameters to indicate water quality; either it refers to the property of water (color, taste, etc.) or to the composition of water (the concentration of specific compounds). Each parameter has its own effects; water temperature affects chemical reactions and reaction rates, low temperature affects bacterial growth, Optimum temperature for bacterial activity is in the range of 25°C to 35, it also means low methanogenic activity and low hydrolysis rate. pH value affects chemical and biochemical reactions in addition to the biological activities, many inhibitory substances for methanogenic bacteria are proscribed by pH. Solid material in wastewater is a significant parameter in which may be dissolved, suspended, or settleable. While hydrolysis of suspended solids (SS) cause disintegration of granular sludge and results in lower methanogenic activity. Polymeric constituents (COD) they consist mainly of carbohydrates, proteins and lipids and should be removed with treatment. They compose the major part of the COD of wastewater. The presence of chloride may have an impact on the final use of treated wastewater. High concentration of sulphate causes inhibition of methanogenesis. Another important parameter maybe Biological Parameters, include pathogenic microorganisms, and all other organisms participating in biological conversions. Coliform bacteria is also a parameter in which is regulated according to reuse purpose: Fecal coliforms < 500/100 ml (disposed into recreational waters) < 1000/100 ml for irrigations (Rabah, 2014). The presence of Nutrients leads to microbial growth in which causes health risks.

2.7 Concrete

2.7.1 Introduction

Concrete is the basic building material produced from the reaction between hydraulic cement and water. Concrete is the most widely used material apart from water (Chemistry world, 2008) in all communities around world as it is a safe, lower cost, strong and simple construction material. About 2.35 billion tons of concrete are produced annually. This means a cubic meter (about a 3.2- by 3.2- by 3.2-foot cube) per capita per year, according to researchers at MIT (Jeffries, 2009).

According to a December report by the global conservation organization WWF Concrete production will rise quickly, it has nearly quadrupled since 1970 and the estimations indicates that it will reach 5 billion metric tons by 2030 due mainly to growth in China and India (DLS Consultancy,2009).Concrete is a strong consumer of water, rather than the water placed in the water storage tanks , approximately 150 liters of water is required per cu. M, a typical plant produces (Silva & Naik,2010), also it can be used as a mixing water about 150-300 gallons of washing water discharge per day at each concrete mixture tank (Chini & Mbwambo,1996). Therefore, a detailed analysis of concrete is essential in order to optimize the construction world.

2.7.2 The constituents of concrete:

Concrete is made by mixing cement, water, coarse and fine aggregates, and maybe admixtures. Concrete properties are affected by the amount of each material. See figure 4.

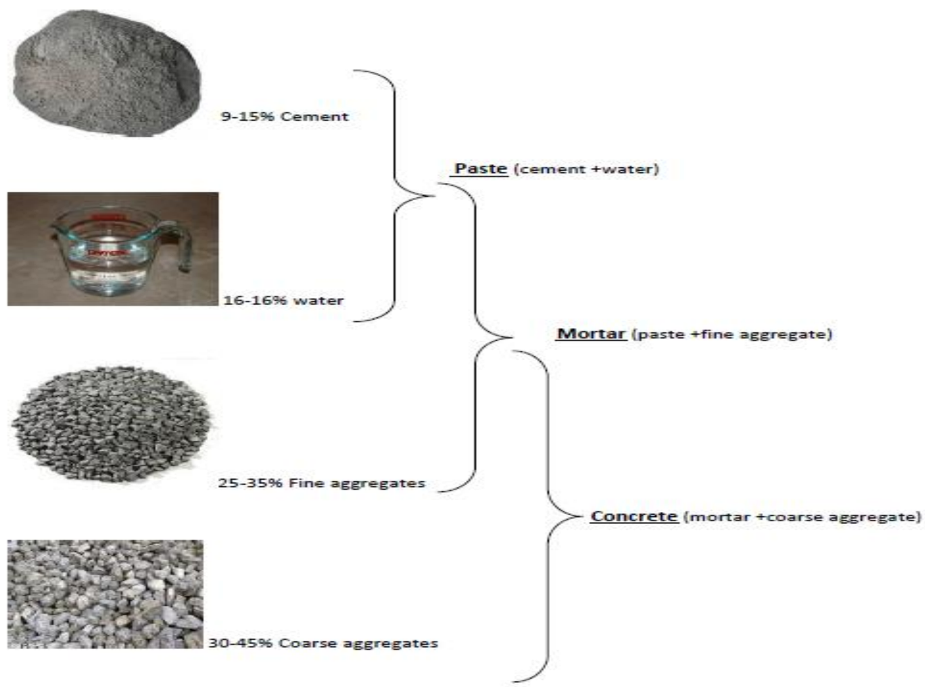

Figure 4: Percentage of concrete materials (values are depicted from www.concretenetwork.com)

2.7.2.1 Cement

Cement is a glow substance that consolidates and hardens after drying and can still stable under water. Cement reacts with water forming a paste acts as a binder which joins aggregates together. It consists basically of hydraulic calcium silicates, usually containing calcium sulfate. Blended cements consist of Portland cement and more than 5% of fly ash, ground slag, silica fume, or a combination of these. Figure 5 summarized hydration mechanism.

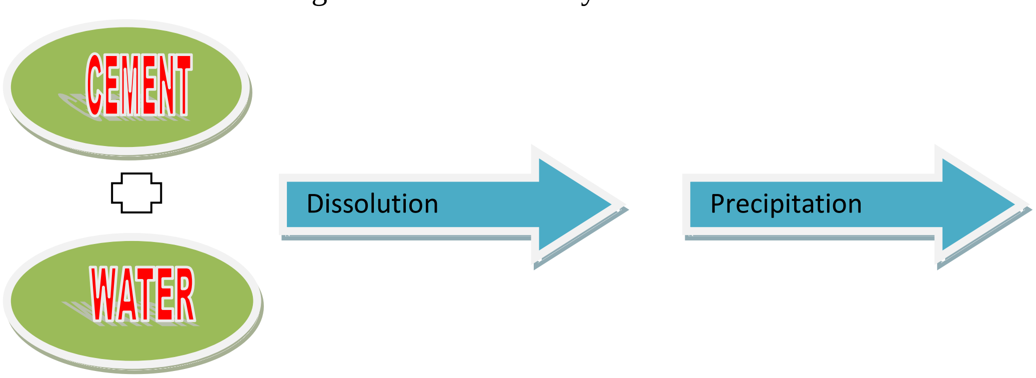

Figure 5: Hydration Mechanism

The presence of Tricalcium C3S and Dicalcium C2S in Portland cement is responsible for inhancment of the strength. In earlier gain C3S supports the strength while C2S contributes the later one. Tricalcium aluminate C3A presence in cement is not attractive since it reacts with sulfates to form extended calcium sulphoaluminate, which may cause commotion. Tricalcium aluminoferrate C4AF cause acceleration in the hydration of the silicates (DJW & CPWD, 2002).
The general types of Portland cement designated by the ASTM:

1. Type I- *Ordinary Portland Cement(GP)* for General Purposes of Portland cement.
2. Type II- *Modified Cement(GB);* moderate heat of hydration and sulfate resistance (C3A < 8%) : general construction blended cement, sea water, mass concrete.
3. Type III- *Rapid-hardening Portland Cement (HE);* high early strength (C3A < 15%) emergency repairs, precast, winter construction.
4. Type IV- *Low-heat Portland Cement(LH);* low heat (C3S < 35%, C3A < 7%, C2S > 40%) :mass concrete.
5. Type V- sulfate resistant (SR) (C3A < 5%) : sulfate in soil, sewers.

These cement types are closely similar , each five types contains approximately 75 wt% calcium silicate minerals, and the concrete properties made with any of the five types nearly the same. Upon this Similarity these five types are also known as the “Ordinary Portland Cement”, or OPC. Other than the mentioned types, less commonly used types are exists such as high alumina cement and white and colored cement. In addition, there are also some special types of cement such as antibacterial cement, hydrophobic cement, masonry cement, expansive cement, oil-well cement and natural cement.

2.7.2.2 Aggregates

Aggregates are inert granular materials found in the basic constituents of concrete in two types, coarse and fine aggregates. Coarse aggregates are crushed rock, gravel or screenings. While fine aggregates are fine and coarse sands and crusher fines. Since aggregates are the major proportion material composes the concrete (65-80%) it is highly affects the strength and the durability of concrete (CCAA, 2004), see figure 6.

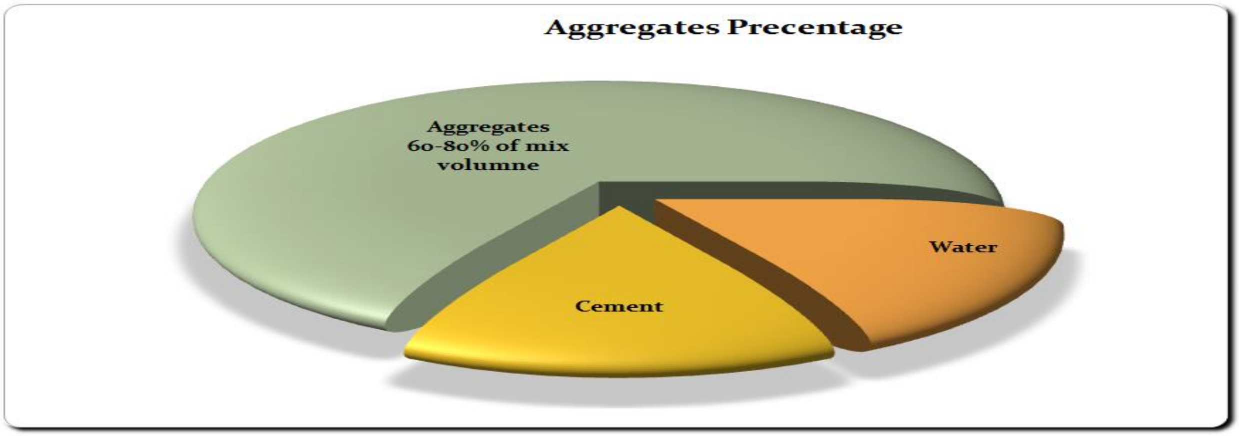

Figure 6: Aggregates percentage

2.7.2.3 Water

Water mixed with cement creating the binding property .Both the quality and the quantity of water plays a specific rule in producing concrete. High amount water\cement ratio gives lower strength. The quality of water affects the quality of concrete (NRMCA, 2014). Despite that no comprehensive standard specifications of mixing water is exists in general, water containing any dirt , excessive sulfates, chlorides, clay, and rubbish substances and unwanted chemical must not be used as the mixing water (CCAA, 2007). Water reacts with cement to form the pastes and to set the cement hardening within curing stage, water wets aggregates surfaces enhancing the adhesion with cement pastes. Likewise, water imparts workability of concrete to assist the insertion in the desired location. Sea water may rust the steel reinforcement in the concrete (South, 2014). Therefore a clear division is essential between the effects on hardened concrete and the quality of mixing water.

2.7.2.4 Determination the suitability of wastewater in concrete mixture

To insure the suitability of concrete mixing water quality, the results of cement setting time and concrete strength for the tested water must be compared with the potable water, with a difference of about 10% is allowed (ASTM C94, 2012). This testing procedure is applied when a certain data of the mixing water is not recorded. The following table indicates the maximum allowed limit of impurities:

Table 2: Maximum limits of suitable water parameter (Source: ASTM, 2008)

Quality parameter	Maximum limit (ppm)
Total Solids	50,000
SO3	500
SO4	3000
Chloride	500
Alkali carbonates and bicarbonates	1000
Turbidity	2000
PH	<8

Note: AASHTO T 26 has the same standard with the only different in chloride value with a 1000 ppm. Portland Cement Association (PCA) also permits the use of wash water for mixing concrete with a tolerance of up to 50,000 ppm of total solids (Chini & Mbwambo, 1996).

High suspended solids containing water adversely affect the introducing of clay in concrete and creating pores, while high alkalinity water affects the hardening of concrete. The presence of algae in the mixing water allows air incorporation and hence lowering of the strength. Sea Water contains a huge salinity causes the reducing of the finished strength, despite it increases the strength at earlier stages in addition to the reducing of the initial setting without any effects of the final setting time. Sea Water contains about 35,000 mg\l dissolved salts or more, was found safe to use as a mixing water in concrete (Al Ghasain & Terro, 2003). Water containing large amount of chlorides tends to create Constant humidity and a rash concrete surfaces, on the other hand concrete with embedded steel will submitted to corrosion in the chloride medium. The "bacterial concrete" is a recent expression in the concrete world (Jonkers *et al*., 2008), in which engineers employ the biological since in self-healing of the concert, by enhancement the mixture by a quantity of bacteria. Water in concrete acts as a proper stimulation medium for the dormant bacteria (Jonkers *et al*., 2010), which improve the properties of concrete by the metabolically mediated calcium carbonate precipitation.

Although the medium in concrete is not suitable for several types of bacteria due to its acidity and lack of bacterial nutrients, but some bacteria are able to adapt in similar conditions, these types limits concrete segregation given higher strength (Rao *et al.*, 2013).

2.7.2.5 Self-healing concrete

Developed materials design as self-healing materials follows the concept of damage management as introduced by vander zwaag (2007). Bioconcrete is a self-healing concrete that biologically produce limestone by bacteria, enhancing healing cracks of the concrete structure. Bioconcrete has another advantage summarizing in increasing the durability of steel reinforced concrete by consuming the oxygen at bacterial activity. The essential point of the self-healing concrete is the type of bacterial concrete.

Cement and water have a ph value up to 13, most organisms die a ph value higher than 10, it was found that only high alkali-resistance bacteria still alive in concrete (Jonkers & Schlangen, 2008). The healing bacteria must be able to form endospores, to resist high mechanically and chemically stress (Sagripanti & Bonifacino, 1996), and to be viable to long periods (Schlegel, 1993), such alkali-resistance healing bacteria are genus Bacillus. Other healing agents work along with bacteria are nitrogen, phosphorous, and calcium lactate which consider as a carbon source that provides biomass, that also give a 10% increasing in compressive strength of a concrete specimen(Jonkers *et al.*, 2010).

However, when the bacteria become in contact with organic compounds and water, the bacteria become active, oxygen is consumed, and the soluble calcium lactate is converted to insoluble mineral calcium carbonate known as “limestone” to seal and block segregations.Figure6 explains the mechanism of calcium carbonate precipitation by bacterial activation, eventually sealing cracks.

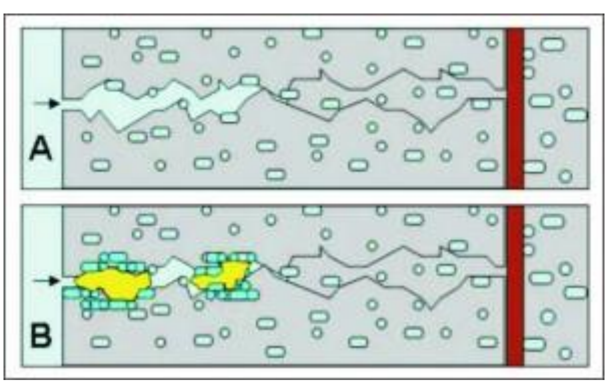

Figure 7: Self-Healing of Concrete, (Source: Jonkers 2011)

Calcium carbonate is produced from a carbonation reaction where carbon dioxide reacts with the hydration product calcium hydroxide as Eq(1).

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O \quad (1)$$

Microbial healing occurs when the bacteria converts incorporated mineral precursor compound to calcium carbonate. In case of calcium lactate the reaction is as Eq(2).

$$Ca(C_3H_5O_2)_2 + 7O_2 \longrightarrow CO_3 + 5CO_2 + 5H_2O \quad (2)$$

The produced carbon dioxide in Eq(2) is later reacts with calcium hydroxide from the concrete matrix , producing more calcium carbonate as noticed in Eq(1).

It was found that one viable bacterial cell is enough to start self healing process. However, existing of large amount of cells and mineral compounds gives enhanced concrete properties (Mors & Jonkers, 2012). As recent data, it was suggested that the addition of healing agents is not necessary when the mixture is already contains bacteria to metabolically produce calcium carbonate (Jonkers, 2011).

2.8 Concrete Properties

2.8.1 Concrete Compressive Strength

Compressive strength is the most common property measured to indicate the resistance of concrete to an axial load. It can be measured by comprising concrete in a testing machine. The specimens respond to the load upon their strength, either by fracture or by irreversible deformation. Compressive strength is a basic indictor in construction. Given figure 9 the compressive strength machine is also known as a “Universal Testing Machine”.

Figure 8: Universal Testing Machine

Concrete compressive strength depends on the quality and proportions of the constituents, in addition to the curing situation. In practical conditions, approximately 90% of concrete strength is completed in the first 28 days.

2.8.2Concrete Workability:

The fresh concrete property which is measured by the amount of practical internal work fundamental to completely mix, place, finish, and compact the concrete without of flowing or segregation in the final product. The slump test is a good indicator on the concrete workability, as Figure 10 indicates.

Workability is influenced by several factors, such as water content, amount and characteristics of cement, and aggregate grading, shape & surface texture.

Figure 9: The mechanism of slump test of fresh concrete (measuring the reduction of fresh concrete mass)

2.8.3 Concrete Setting Time

The setting time test is a test measure the time required to set concrete particulars. Setting time is considered as an indication of the rate of the toughness of concrete. It is determined by a Proctor penetration test. Good results must not have a very early initial setting time or a very late final setting time. The initial set of concrete happens after the withstand ability of a penetration of 3.5 MPa and pursue, while the final setting time is achieved after the point in which concrete can resist a penetration of 27.6 MPa (Suraneni, 2011).

The setting time depends on several items such as water-cement ratio, granular texture, and the addition of admixtures.

Figure 10: Concrete setting time test

2.8.4 Concrete Permeability

Permeability is the property that controls the rate of flow of a liquid through an absorbent solid. Permeability plays a key role affecting the sustainability of concrete and because the entry of aggressive elements such as alkloraydat, sulfates, carbon dioxide, oxygen and water vapor in the concrete governs by the permeability of concrete. The permeability of concrete are affected by several factors such as aggregates size and proportion, cement type and quantity, water-cement ratio, the presence of admixtures, and preparation, casting, and curing methods. The mixing water is commonly accountable for the permeability of the hydrated cement paste; this refers to its content, which determines the total space at early step and later the unfilled space when the water is consumed by either cement hydration reactions or curing stage (Mehta & Monteiro, 2013).

Figure 11: Permeability test

2.8.5 Concrete Air Content

The entry of air into concrete mixes affects the characteristics of both the fresh and the hardened concrete. In fresh concrete small air bubbles play a positive role in the enhancement of the workability and slump. Also the bubbles acts as a third aggregate due to their small size they work as fines giving the possibility to limit the amount of the required sand. In hardened concrete, the exceptional attributes of air entrainment are the enhanced weather ability and resistance to scaling afforded. Freezing of concrete destroy the concrete by forming a pressure higher than the tensile strength of the cement paste. This is happened as enough ice forms in the capillaries.

Figure 12: Air content test

2.9 Using treated wastewater in concrete production

Various researches around the world have deliberated the use of treated wastewater in concrete production, with a different range of success (Silva& Naik, 2010). Overall, it was found that concretes made with recycled water are durable and reveal the similar properties as concretes prepared with potable water or fresh water (Chini and Mbwambo, 1996). The feasibility of using reclaimed wastewater in concrete mixtures has also been studied in Indonesia by Tay and Yip (1987). They noticed that concrete with enhanced initial compressive strength could be made with treated wastewater used partially or totally in lieu of the mixing water. Also, the use of potable and treated waters was tested in Saudi Arabia, where setting time and compressive strength of concrete were evaluated. Results showed that the treated wastewater tested in this study was suitable for making concrete (Sethuraman, 2006). The suitability of using treated wastewater for mixing concrete was examined in Kuwait. Concrete cube specimens were cast using potable water, preliminary treated wastewater, secondary treated wastewater, and tertiary treated wastewater obtained from the local wastewater treatment plants.

It was found that the type of concrete mixing water used did not affect concrete slump and density. On the other hand it affects the setting times which increase with worsening water quality (Al-Ghusain and Terro, 2003). In addition, concrete made with water from the primary and secondary treatment showed lower strengths for ages up to one year and the possibility of steel corrosion increased too. Overall, tertiary treated wastewater was found to be suitable for mixing concrete without adverse effects (Al-Ghusain and Terro, 2003). Cebeci and Saatci (1989) also noticed that treated wastewater was not exposed to have poor effects on concrete. But, raw sewage reduced the 3- and 28-day compressive strength by 9%. The results (setting time, and mortar and concrete strength tests) revealed that biologically treated average domestic sewage is similar from potable water when used as mixing water.

In the similar study conducted by Cebeci and Saatci (1989), the results (setting time, mortar, and concrete strength test) showed that biologically treated average domestic sewage is indistinguishable from potable water when used as mixing water. Lee *et al*. (2001) showed that treated effluent increases the compressive strength and setting time when compared with potable water. In Malaysia, researchers carried out two tests to determine the feasibility of using treated effluent for concrete mixing. Their results showed that treated effluent increases the compressive strength and setting time when compared with potable water and that treated effluent could be used as mixing water in concrete (Lee *et al.*, 2001).The quality of mixing water used in concrete has important effects on fresh concrete properties. Impurities contained in the mixing water may interfere with the setting time of the cement, may affect drying, shrinkage, durability, strength, workability and may also lead to corrosion of the reinforcement (Mullapudi *et al.*, 2013). In the glow of the present information, it is not possible to issue a specification for water in producing concrete but only for the approximate composition value of using such water; this was explained due to the several parameters existing in water and affect the concrete properties at a complex reactions may depends on each other.

Chapter 3
Methodology

3.1 Introduction

In this chapter, the research methodology has been followed in details, all the initial information in which the research based upon was attached from trusted sources, in preparation for results detection, and analysis. Methodology discussed in this chapter should be taken as a comprehensive approach in satisfying the dominant objectives of this study.

3.2 Methods

- *Three time-interval composite samples of* treated effluents *from Al-Tireh MBR, Al Bireh EA treatment plant, and effluent polished by RO in AlQuds University were collected.*
- *Three time-interval composite samples of* treated effluents *from Al-Tireh MBR with various treatment stages were collected.*
- Concrete mixture with sufficient quantities will be collected.
- Concrete will be prepared using the treated wastewaters, each time wastewater is collected,
- Treated wastewater composition was examined for various parameters including EC, TDS, pH, Temp, TS, COD, BOD, DO, NH4-N,PO4-P.
- The properties of prepared concrete were assessed by conducting the following tests (slump test; compressive strength; initial setting time; final setting time; specific gravity; permeability; air content).

3.3 Materials

Potable water, various types of treated wastewater, sand, foulieh, addass, Somsom, Portland cement (POC), admixture.

3.4 Added Water

The mixing water was at various degrees of treatment, in addition to the potable water as a reference source. Waste water was collected at two phases:

- One from the different waste water treatment plant to compare the feasibility of various wastewater treatment technologies in concrete production.
- The second phase was applied by taking different treatment stages of Al-Tireh Wastewater Treatment Plant to test the feasibility of various wastewater treatment degrees.

The specimens were taking as composite specimens at three stages between 8 a clock and 1 a clock, and were choking well before the addition to the concrete mixture.

All specimens were directly used either for analyzing or for concrete mixture according to the standard methods for the examination of water and wastewater (APHA, 1992).

3.5 Concrete preparation

The concrete mix design was designed according to Neville (1989) to achieve a compressive strength of 25 MP, with constituents of 25 mm, 10 mm, 4 mm, 1 mm for Foulieh, Addass, Somsom, Sand respectively.

Table 3: Concrete ready mix design

Mix Design	Composition									
	Sand	**Foulieh**	**Addass**	**Somsom**	**Cement**	**Water**	**Admixture dosage**	**Cement ratio**	**Admixture type**	**Total used kg**
B300	7370 gm =35%	6400 gm =30%	2009 gm =10%	5330 gm =25%	3300 gm	1760 gm	33 gm =1%	53%	Chemix ultra	26.169 kg =100%

The components were dried in oven at 110 cº. After taking the weight of each one, they were mixing using a specific quality of water each time.

3.6 Concrete testing

The fresh concrete was examined for the slump test; final setting time; water; specific gravity; permeability; and air content. The hardened concrete of 2×4 cubes was removed from molds and saved at water to the compressive strength of 7,28 ,56 days. Finally, statically analysis was done to check the obtained results.

3.7 Testing Criteria

The use of water and recycled water for the production of new concrete is covered in National Standards such as: ASTM C94—05 Specification for Ready Mixed Concrete, which refers to ASTM C1602 – 06 Standard Specification for Mixing Water Used in the Production of Hydraulic Cement-Concrete. ASTM C94states that the mean 7-day compressive strength of the mortar or concrete samples prepared with the water must be at least 90% of the mean strength of the control samples (prepared with distilled or potable water). The setting time test was carried out with freshly mixed concrete according to the ASTM C403/C403M-99. C403/C403M-99, Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance, in which Setting time is From 1:00 hr earlier to 1½ hrs later than control. ASTM C1202-09, ASTM C-642, ASTM C231 for permeability, specific gravity, and air content respectively set a percent of 90% of the control sample value.

Chapter 4

Results and Discussion

4.1 Introduction

In this chapter, data of the research study were tabulated and analyzed. In order to prevent deviation from the framework of the survey, the investigation must be in line with the outcome as referred to the both laboratory concrete mix and water laboratory.

4.2 Characteristics of treated waste water (TW) and potable water (PW)

Several parameters were investigated in water tests, such as: Temp, EC, PH, TDS, TS, PO_4-P, NH_4-N, COD, BOD, TSS, FC and DO. Water tests were done at the Hebron Center for Water and Environment in Hebron City. With a high degree of accuracy; all tested water was taken directly to the laboratory to avoid the Wastewater characteristics alteration with time passage. As expected and shown in table 4, the differences in results are high when comparing different treatment stages unlike results of the same stage at different plants, where the results will be close to each other as shown in Table 5.

Table 4: Characteristic of treated waste water (TW) from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

Test number	Parameter	Al-Bireh treated wastewater	Al-Tireh treated wastewater	Al-Quds university treated wastewater	Unit
1	Temp	16.30 (0.360)	17.13 (1.050)	17.00 (1.000)	Cº
2	EC	470.60 (10.06)	507.33 (14.18)	457.66 (19.65)	µs/cm
3	PH	7.57 (0.040)	7.22 (0.220)	7.16 (0.115)	-
4	TDS	235.66 (5.131)	254.66 (22.85)	49.40 (0.840)	mg/l
5	TS	486.33 (10.01)	494.66 (18.92)	200.33 (10.32)	mg/l
6	PO4-P	4.03 (0.251)	5.03 (1.001)	4.16 (0.550)	mg/l
7	NH4-N	13.13 (0.450)	11.30 (0.871)	7.63 (0.873)	mg/l
8	COD	20.56 (1.436)	31.11 (4.556)	11.38 (0.760)	mg/l
9	BOD	14.66 (1.527)	27.33 10.96)	6.68 (0.410)	mg/l
10	DO	4.60 (0.365)	4.83 (0.115)	4.83 (0.230)	mg/l

Note: Standard Deviation is between brackets

Table 5: Characteristic of treated waste water (TW) from Al-Tireh Wastewater Treatment Plant

Test number	Parameter	Biologically treated wastewater	MBR treated wastewater	Effluent treated wastewater	Unit
1	COD	57 (13.11)	33 (6.082)	25 (5.567)	mg/l
2	TSS	11 (3.000)	3 (0.000)	2 (0.000)	mg/l
3	Total nitrogen	35 (10.44)	7.3 (0.709)	5.4 (0.400)	mg/l
4	Total phosphorus	5 (1.000)	.08 (0.005)	.03 (0.000)	mg/l
5	TDS	280 (10.40)	250 (13.22)	238 (15.39)	mg/l
6	BOD	10.1 (1.509)	2.2 (0.400)	2.1 (0.793)	mg/l
7	Ph	7.7 (0.173)	7.4 (0.251)	7.1 (0.510)	mg/l
8	Temperature	18 (0.000)	17 (3.000)	17 (0.000)	C^{o}
9	FC	57000 (13.00)	-	-	MPN/100 ml

Note: Standard Deviation is between brackets

4.3 Properties of the mixed concrete

The properties of concrete were tested for the slump, permeability, initial and final setting time, and the Specific Gravity of the fresh concrete, and for the compressive strength of the hardened concrete, wither the specimens were from the various treatment stages of Al-Tireh Treatment Plant, or from the effluent of Al-Tireh, Al-Bireh, Al-Quds University Treatment plants, in addition to the potable water.

Table 6: The summary of project results

Mixing water source	Compressive strength at 7 days curing age (kg/cm^2)	Compressive strength at 28 days curing age (kg/cm^2)	Compressive strength at 56 days curing age (kg/cm^2)	Slump (mm)	Initial setting time (Hours)	Final setting time (Hours)	Air content %	Permeability (mm)	Specific Gravity
Potable water1	257.58	357.42	377.42	123.33	04:50	08:50	01:30	2.67	02:40
Al-Tireh biologically treated wastewater	310.50	409.83	424.83	137.08	06:03	09:30	01:10	1.00	02:42
Al-Tireh MBR treated wastewater	288.42	390.92	407.52	131.67	05:03	09:03	01:10	2.33	02:42
Al-Tireh Effluent 1	282.00	389.83	402.50	131.92	04:51	08:35	01:40	2.33	02:41
Potable water 2	281.08	394.50	416.83	123.25	04:50	08:50	01:30	3.00	02:40
Al-Tireh effluent	286.33	391.55	416.33	126.50	05:03	08:40	01:40	2.00	02:42
Al-Bireh effluent	298.75	394.00	413.50	119.08	04:50	08:30	01:50	2.33	02:40
Al-Quds University effluent	287.58	380.08	401.67	125.33	05:36	08:35	01:20	2.67	02:41

4.3.1 Statistical analysis of the results

The appropriate analysis for this problem is the Kruskal-Wallis Test(non parametric) instead One way ANOVA(parametric) For all the variables except the final setting time and the air content, since the Homogeneity test in table 2 shows that all the variable are not homogenous except the final setting time and the air content. The appropriate analysis for final setting time and the air content is Oneway ANOVA(parametric). The Null Hypothesis stated that: there is no significant difference between the means of each variable above among the eight district. While the Alternative Hypothesis stated that: there is no significant difference between the means of each variable above among the eight districts. The analysis below shows that the F-statistic and the P-value for the variable final setting time and air content are as follows:

Table 7: Test of ANOVA

ANOVA					
		df	Mean Square	F	Sig.
Final setting time	Between Groups	7	4575685.714	6.818	.001
	Within Groups	16	671100.000		
	Total	23			
Air content	Between Groups	7	2356607.143	18.483	.000
	Within Groups	16	127500.000		
	Total	23			
	Total	23			

So with a 0.05 level of significant, the null Hypothesis is rejected and the alternative is Accepted, there is a significant difference between the means of the final setting time and air content among the districts.

Table 8: Test of Homogeneity of variances

Type	Levene Statistic	df1	df2	Sig.
Compressive strength at 7 days curing age	7.577	7	88	.000
Compressive strength at 28 days curing age	4.349	7	88	.000
Compressive strength at 56 days curing age	3.036	7	88	.007
Slump	2.699	7	88	.014
Initial setting time	4.185	7	16	.008
Final setting time	2.485	7	16	.062
Air content	2.218	7	16	.089
Permeability	6.857	7	16	.001
Specific Gravity	2.950	7	16	.035

The analysis below shows that the Chi-statistic and the P-value for the six variables are as follows NPar Tests - Kruskal-Wallis Test

Table 9: Statistics test a,b

Test	Chi-square	Df	Asymp. Sig.
Compressive strength at 7 days curing age	71.497	7	.000
Compressive strength at 28 days curing age	71.509	7	.000
Compressive strength at 56 days curing age	77.777	7	.000
Slump	91.305	7	.000
Initial setting time	15.926	7	.026
Permeability	14.154	7	.049
Specific Gravity	1.576	7	.980
a. Kruskal Wallis Test			
b. Grouping Variable: dist			

so with a 0.05 level of significant, the null Hypothesis is rejected and the alternative is Accepted, there is a significant difference between the means of the for all the variables above except the specific Gravity the sig is more than 0.05 so there is no significant difference for the mean of specific gravity among the districts .The tables below shows the scheffe method for dividing the districts to a subset of districts for each variable based on the homogeneity of the district with other districts

Table 10: Means - Homogeneous Subsets (Compressive strength at 7 days curing age)

Compressive strength at 7 days curing age					
Scheffea					
Dist	N	Subset for alpha = 0.05			
		1	2	3	4
Potable water1	12	257.58			
Potable water 2	12		281.08		
Al-Tireh Effluent 1	12		282.00		
Al-Tireh effluent	12		286.33		
Al-Quds University effluent	12		287.58		
Al-Tireh MBR treated wastewater	12		288.42		
Al-Bireh effluent	12			298.75	
Al-Tireh Biologically treated wastewater	12				310.50
Sig.		1.000	.282	1.000	1.000
Means for groups in homogeneous subsets are displayed.					
a. Uses Harmonic Mean Sample Size = 12.000.					

Table 11: Means - Homogeneous Subsets (Compressive strength at 28 days curing age)

Compressive strength at 28 days curing age					
Scheffe[a]					
Dist	N	Subset for alpha = 0.05			
		1	2	3	4
Potable water1	12	357.42			
Al-Quds University effluent	12		380.08		
Al-Tireh Effluent 1	12			389.83	
Al-Tireh MBR treated wastewater	12			390.92	
Al-Tireh effluent	12			391.55	
Al-Bireh effluent	12			394.00	
Potable water 2	12			394.50	
Al-Tireh Biologically treated wastewater	12				409.83
Sig.		1.000	1.000	.553	1.000
Means for groups in homogeneous subsets are displayed.					
a. Uses Harmonic Mean Sample Size = 12.000.					

Table 12: Means - Homogeneous Subsets (Compressive strength at 56 days curing age)

Compressive strength at 56 days curing age						
Scheffea						
Dist	N	Subset for alpha = 0.05				
		1	2	3	4	5
Potable water1	12	377.42				
Al-Tireh Effluent 1	12		402.50			
Al-Quds University effluent	12		401.67			
Al-Tireh MBR treated wastewater	12		407.52	407.42		
Al-Bireh effluent	12			413.50	413.50	
Al-Tireh effluent	12				416.33	
Potable water 2	12				416.83	416.83
Al-Tireh Biologically treated wastewater	12					424.83
Sig.		1.000	.410	.371	.938	.079
Means for groups in homogeneous subsets are displayed.						
a. Uses Harmonic Mean Sample Size = 12.000.						

Table 13: Means - Homogeneous Subsets (Slump)

Slump						
Scheffea						
Dist	N	Subset for alpha = 0.05				
		1	2	3	4	5
Al-Bireh effluent	12	119.08				
Potable water 2	12		123.25			
Potable water1	12		123.33			
Al-Quds University effluent	12			125.33		
Al-Tireh effluent	12			126.50		
Al-Tireh MBR treated wastewater	12				131.67	
Al-Tireh Effluent 1	12				131.92	
Al-Tireh Biologically treated wastewater	12					137.08
Sig.		1.000	1.000	.252	1.000	1.000
Means for groups in homogeneous subsets are displayed.						
a. Uses Harmonic Mean Sample Size = 12.000.						

Table 14: Means - Homogeneous Subsets (Initial Setting Time)

Initial setting time			
Scheffea			
Dist	N	Subset for alpha = 0.05	
		1	2
Al-Tireh Effluent 1	3	04:51	
Potable water1	3	04:50	
Potable water 2	3	04:50	
Al-Bireh effluent	3	04:50	
Al-Tireh MBR treated wastewater	3	05:03	05:03
Al-Tireh effluent	3	05:03	05:03
Al-Quds University effluent	3	05:36	05:36
Al-Tireh Biologically treated wastewater	3		06:03
Sig.		.089	.051
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 3.000.			

Table 15: Means - Homogeneous Subsets (Final Setting Time)

Final setting time			
Scheffea			
Dist	N	Subset for alpha = 0.05	
		1	2
Al-Bireh effluent	3	08:30	
Al-Quds University effluent	3	08:35	
Al-Tireh Effluent 1	3	08:35	
Al-Tireh effluent	3	08:40	
Potable water1	3	08:50	08:50
Potable water 2	3	08:50	08:50
Al-Tireh MBR treated wastewater	3	09:03	09:03
Al-Tireh Biologically treated wastewater	3		09:30
Sig.		.148	.148
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 3.000.			

Table 16: Means - Homogeneous Subsets (Air Content)

Air content				
Scheffea				
Dist	N	Subset for alpha = 0.05		
		1	2	3
Al-Tireh Biologically treated wastewater	3	01:10		
Al-Tireh MBR treated wastewater	3	01:10		
Al-Quds University effluent	3	01:20	01:20	
Potable water1	3	01:30	01:30	01:30
Potable water 2	3	01:30	01:30	01:30
Al-Tireh effluent	3		01:40	01:40
Al-Tireh Effluent 1	3			01:41
Al-Bireh effluent	3			01:50
Sig.		.068	.068	.068
Means for groups in homogeneous subsets are displayed.				
a. Uses Harmonic Mean Sample Size = 3.000.				

Table 17: Means - Homogeneous Subsets (Permeability)

Permeability			
Scheffea			
Dist	N	Subset for alpha = 0.05	
		1	2
Al-Tireh Biologically treated wastewater	3	1.00	
Al-Tireh effluent	3	2.00	2.00
Al-Tireh MBR treated wastewater	3	2.33	2.33
Al-Tireh Effluent 1	3	2.33	2.33
Al-Bireh effluent	3	2.33	2.33
Potable water1	3		2.67
Al-Quds University effluent	3		2.67
Potable water 2	3		3.00
Sig.		.150	.449
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 3.000.			

4.3.2 Compressive Strength

4.3.2.1 The compressive strength from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW).

Table 18: The compressive strength from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

Specimen type	Compressive strength at 7 days curing (kg/cm^2)	Compressive strength at 28 days curing (kg/cm^2)	Compressive strength at 56 days curing (kg/cm^2)
Potable water	281 (3.000)	394 (1.154)	417 (0.577)
Al-Bireh treated wastewater	299 (3.214)	394 (0.577)	413 (2.516)
Al-Tireh treated wastewater	286 (2.081)	392 (0.577)	416 (2.516)
Al-Quds University treated wastewater	288 (0.577)	380 (1.000)	402 (2.516)

Note: Standard Deviation is between brackets

As shown in table 6 the compressive strength of treated wastewater in most cases gave higher values than potable water, when comparing Al-Bireh treated wastewater the percentages of success rates were106.40%, 100%, 99,04% at 7, 28, 56 days respectively. While at Al-Tireh treated wastewater the percentages were 101.77%, 99.49%, 100.72% with a percentages of 102.49%, 96.44%, 96.40% at Al-Quds University treated wastewater at the same tests periods.

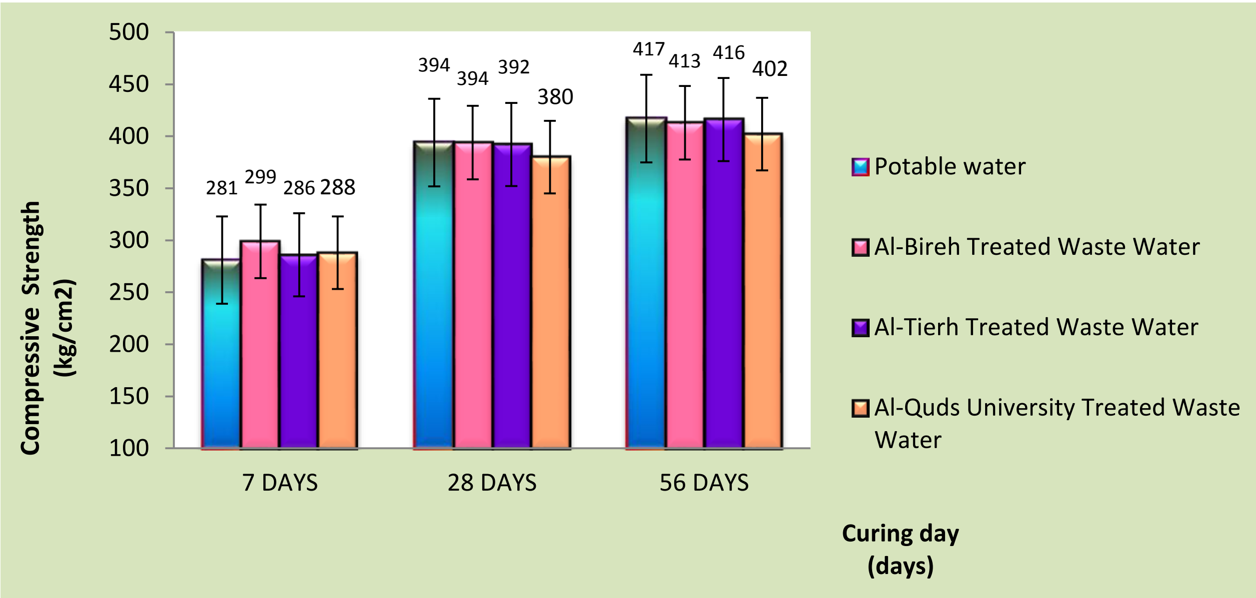

Figure 13: The compressive strength of Al-Bireh treated wastewater, Al-Tireh treated waste water, Al-Quds university treated wastewater and potable water (PW) at 7, 28, 56 days.

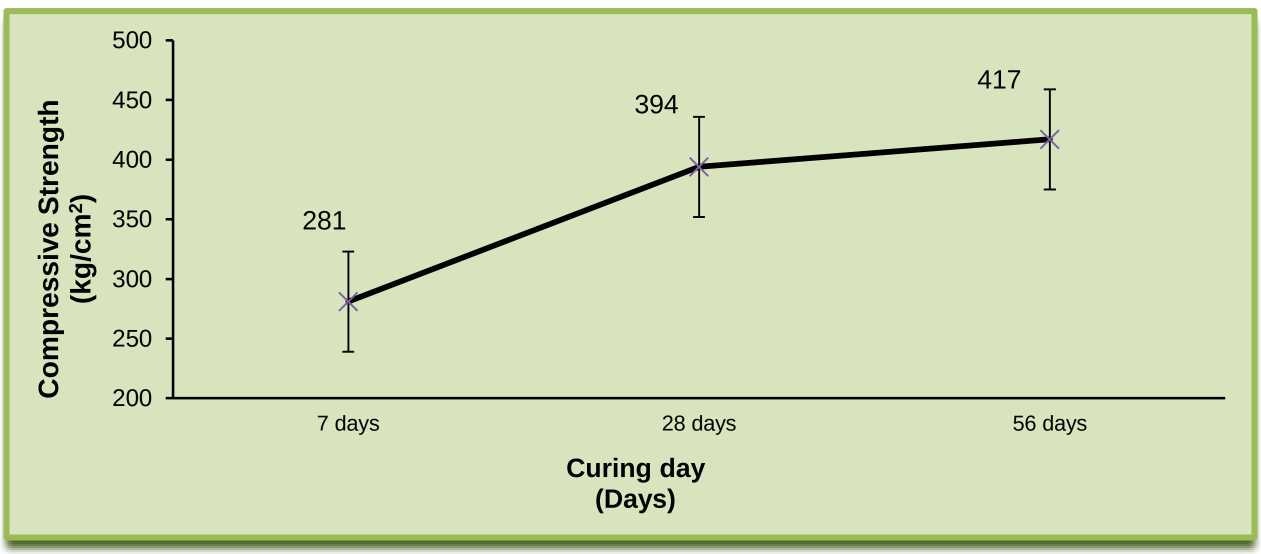

Figure 14: The compressive strength of potable water at 7, 28, 56 days

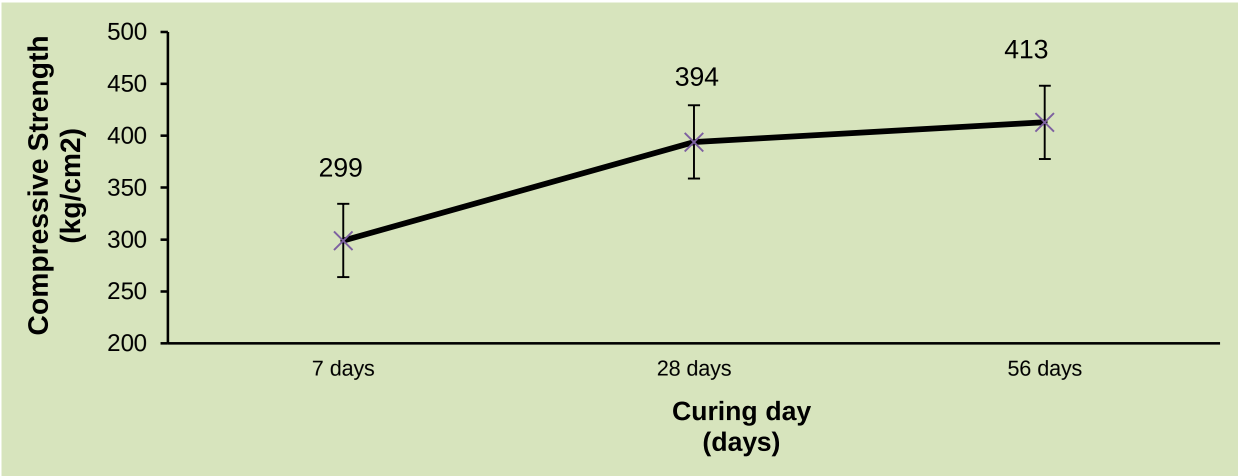

Figure 15: The compressive strength of Al-Bireh treated wastewater at 7, 28, 56 days

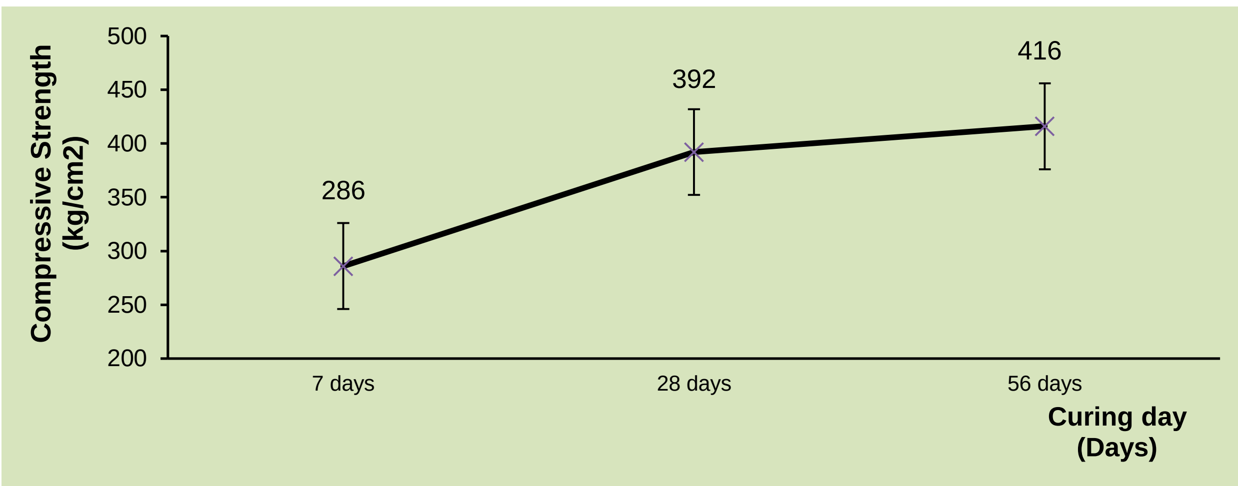

Figure 16: The compressive strength of Al-Tireh treated wastewater at 7, 28, 56 days

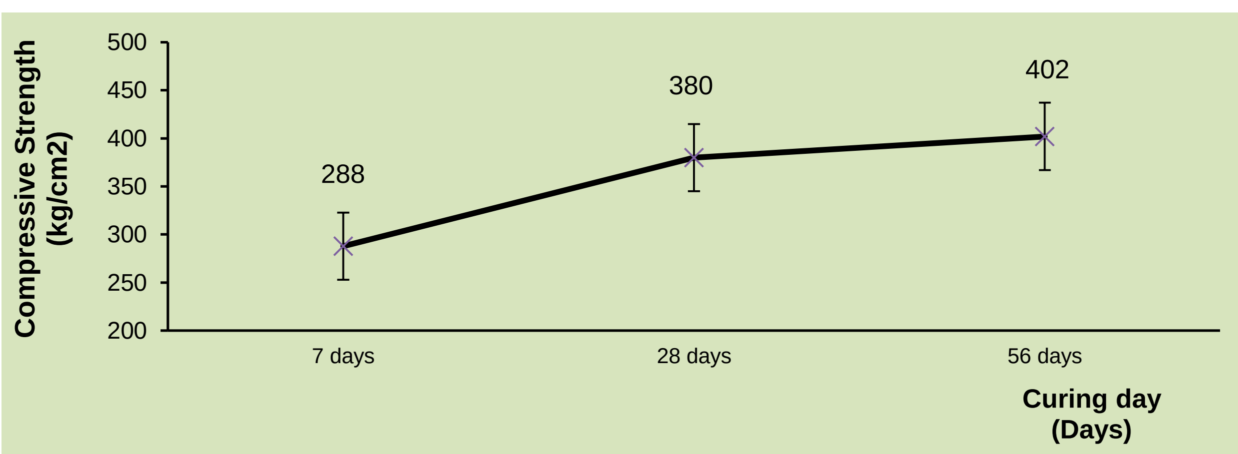

Figure 17: The compressive strength of Al-Quds University treated wastewater at 7, 28, 56 days.

4.3.2.2 The compressive strength for treated waste water from Al-Tireh Wastewater Treatment Plant and Potable Water.

Table 19: The Compressive strength for treated waste water from Al-Tireh Wastewater Treatment Plant and Potable Water

Specimen type	Compressive strength at 7 days curing (kg/cm^2)	Compressive strength at 28 days curing (kg/cm^2)	Compressive strength at 56 days curing (kg/cm^2)
Potable water	258 (1.154)	358 (1.527)	377 (0.577)
Biologically treated wastewater	311 (2.309)	410 (1.732)	425 (2.309)
MBR treated wastewater	288 (1.154)	391 (2.645)	408 (1.527)
Al-Tireh effluent treated wastewater	282 (2.645)	390 (1.732)	403 (2.645)

Note: Standard Deviation is between brackets

The average compressive strength of the concrete cubes made with the various quality treated water was more than 90% of the average strength of the control cubes. With 120.54%, 114.52%, 112.73% of the biologically treated wastewater, 111.62%, 109.21%, 108.22% of the MBR treated wastewater, and 109.30, 108.93%, 106.89% to Effluent treated wastewater at 7, 28, and 56 respectively. By comparing each treatment stage together it was found that the biologically treated waste water gave superior results at all test days; this refers to the high percent of bacteria which serve as a bender in concrete mixtures. The results of the MBR treated waste water were closed to effluent results.

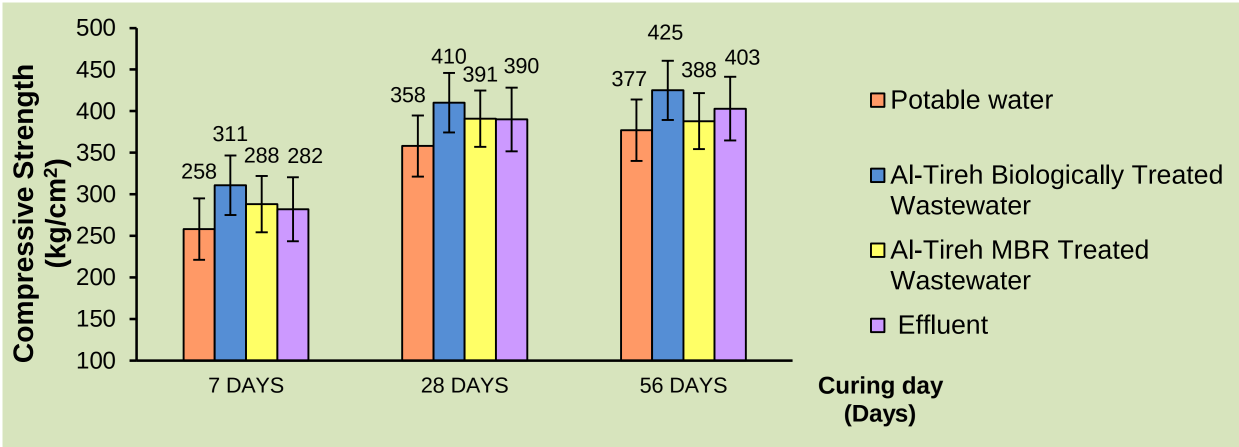

Figure 18: The Compressive strength for treated waste water from Al-Tireh Wastewater Treatment Plant and Potable Water, and potable water (PW) at 7, 28, 56 days

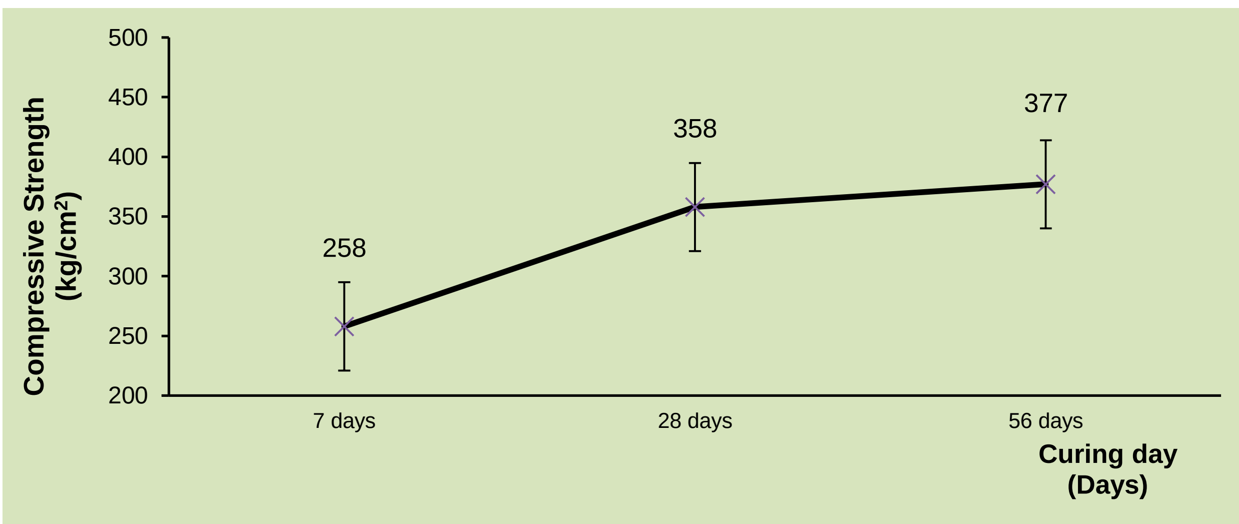

Figure 19: The compressive strength of potable water at 7, 28, 56 days

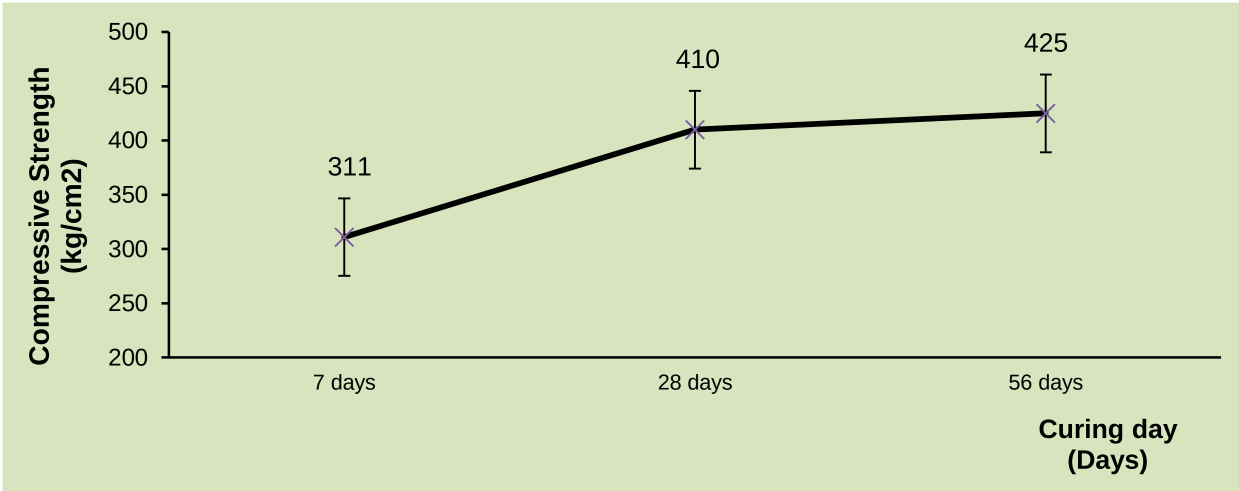

Figure 20: The compressive strength of Al-Tireh biologically treated wastewater at 7, 28, 56 days

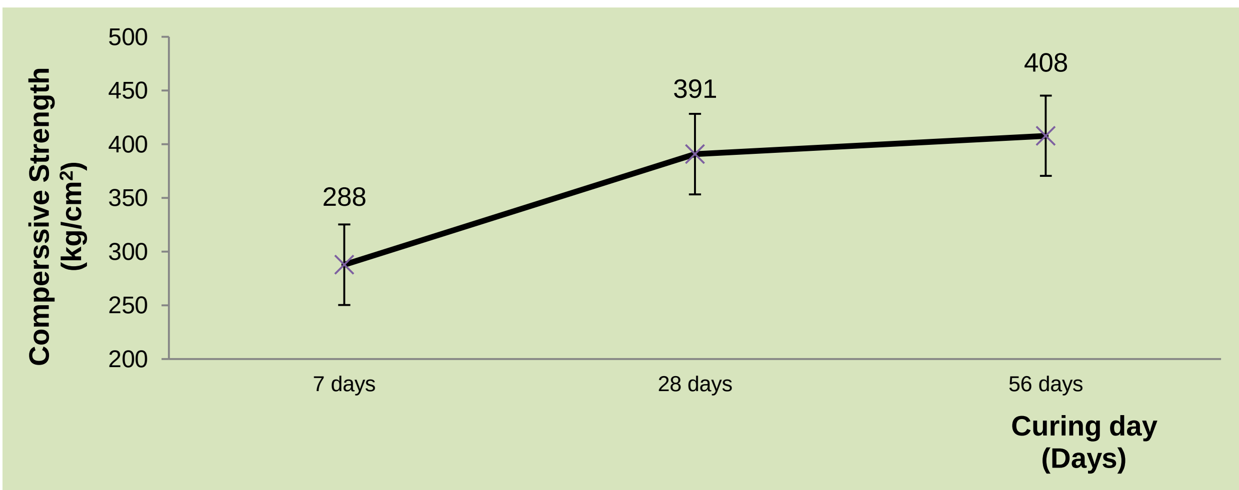

Figure 21: The compressive strength of Al-Tireh MBR treated waste water at 7, 28, 56 days

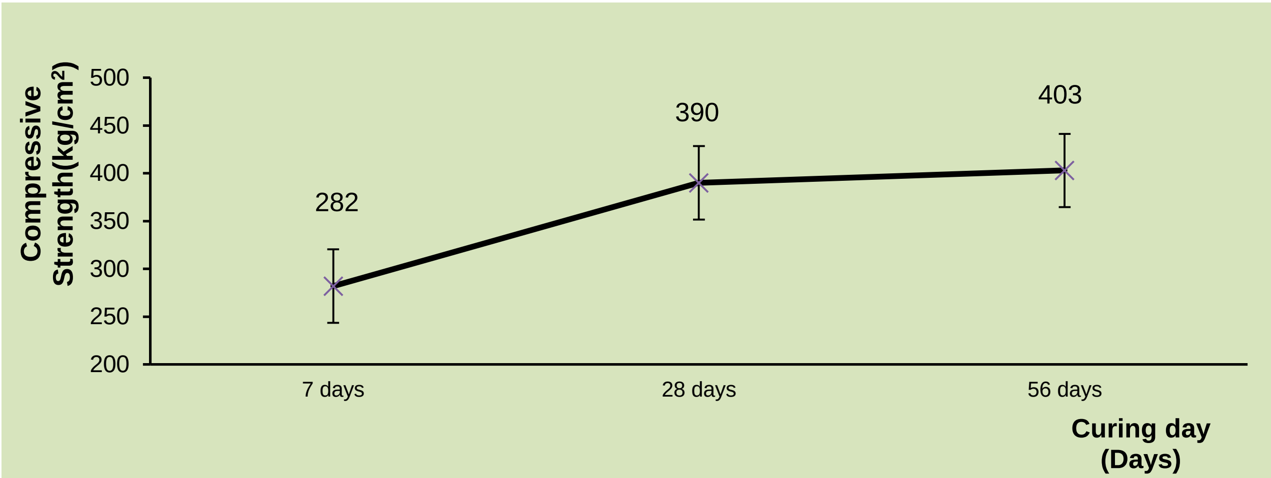

Figure 22: The compressive strength of Al-Tireh effluent treated wastewater at 7, 28, 56 days

Naser Alenezi (2010) reported that the results obtained from tertiary wastewater have no adverse effects on compressive strength. Alenezi found that the compressive strengths for ages three months and beyond were the same as to the strengths of concrete made with potable mixing water.

Terro and Al-Ghusain (2003) and Tay and Yip (1987) founded that at early concrete ages the compressive strength was increasing with treated wastewater, but start decreasing after three month ages and later. While more et, al.(2014) recorded decreasing in compressive strength at earlier concrete ages for STWW with an increasing at the end of 60 days compared with potable water. Shackarchi *et al.*, recorded an acceptable results of compressive strength for different type of treated waste water with a slight reduction of STWW and a clear increase of TTWW. The increase in compressive strength of TTWW was referred to the filling effect of solid particles.

4.3.3 Slump Test

4.3.3.1 The slump values for treated waste water from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW).

Table 20: The slump values for treated waste water from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

Specimen type	Slump mm
Potable water	123 (0.577)
Al-Bireh treated wastewater	119 (0.577)
Al-Tireh treated wastewater	127 (0.577)
Al-Quds University treated wastewater	125 (0.577)

Note: Standard Deviation is between brackets

The Average slump results of concrete mixed with the treated water to concrete mixed with potable water was 96,74% to Al-Bireh treated wastewater, 103.25% to Al-Tireh treated wastewater, and 101.62% to Al-Quds University treated wastewater. In general treated water gives higher slump values.

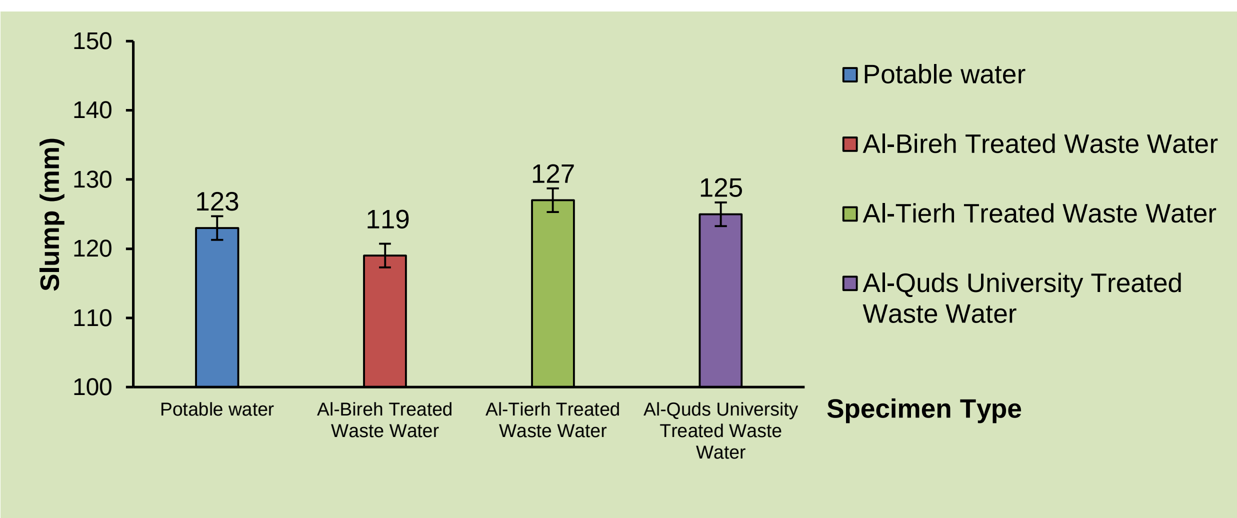

Figure 23: The slump values for treated waste water from Al-Tireh, Al-Bireh, AL-Quds University treatment plants, and potable water

4.3.3.2 The slump values for treated waste water from Al-Tireh wastewater treatment plant and potable water.

Table 21: The slump values for treated waste water from Al-Tireh wastewater treatment plant, and potable water.

Specimen type	Slump (mm)
Potable water	123 (0.050)
Biologically treated wastewater	137 (0.577)
MBR treated wastewater	132 (0.500)
Tireh effluent treated wastewater	132 (1.000)

Note: Standard Deviation is between brackets

The Average slump results of concrete mixed with the treated water to concrete mixed with potable water was 111.38%, 107.31%, 107.31% at Biologically treated wastewater, MBR treated wastewater, effluent treated wastewater respectively . Secondary treated waste water had the highest slump; due to the attaching of particles by bacteria.

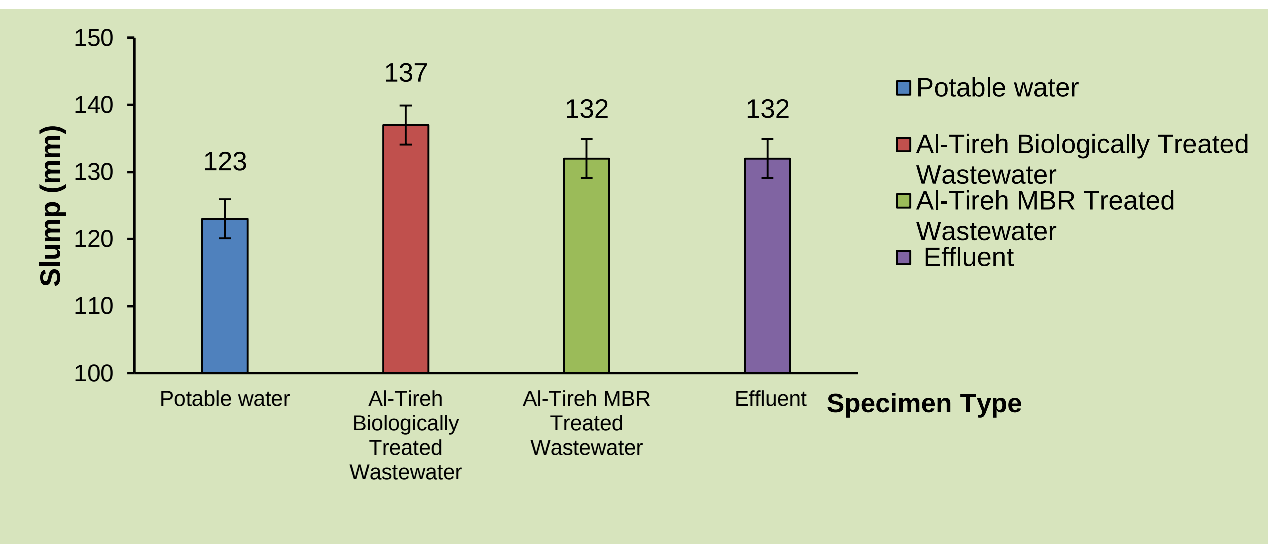

Figure 24: The slump values for treated waste water from Al-Tireh wastewater treatment plant, and potable water.

(More *et al.*,2014) and. Ghusain and Terro (2003) reported that water quality have no effects on the slump values, this compete with neville (1981) who reported that the slump depends on water content not water quality. While shekarchi *et. al*, (2012) reported that the slump is slightly decrease with treated waste water due to the presence of dissolved solids.

4.3.4 Concrete Initial Setting Time

4.3.4.1 The initial setting time from Al-Bireh treated wastewater, Al-Tireh treated wastewater Al-Quds University treated wastewater, and potable water (PW).

Table 22: The initial setting time from Al-Bireh treated wastewater, Al-Tireh treated wastewater Al-Quds University treated wastewater, and potable water (PW).

Specimen type	Initial Setting Time (hours)
Potable water	4.5 (0.030)
Al-Bireh treated wastewater	4.5 (0.020)
Al-Tireh treated wastewater	5.0 (0.020)
Al-Quds University treated wastewater	5.5 (0.006)

Note: Standard Deviation is between brackets

As ASTMC403/C403M-99 the resulting setting time from treated waste water is in the allowable range, and close to that with potable water.

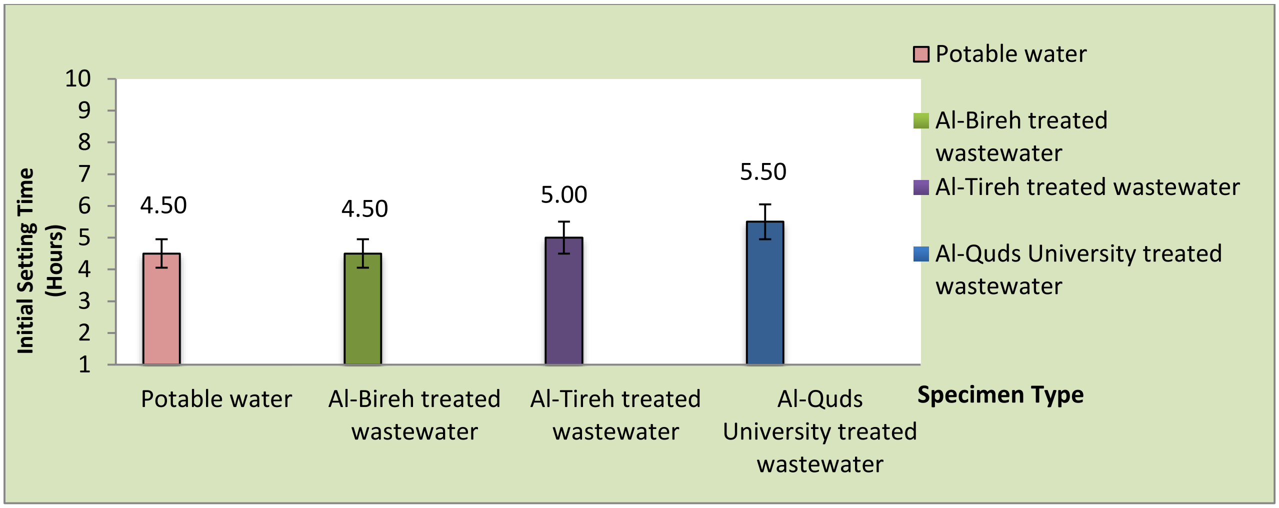

Figure 25: The initial setting time from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

4.3.4.2The initial setting time for Al-Tireh Waste Water Treatment Plant and Potable Water

Table 23: The initial setting time for Al-Tireh Waste Water Treatment Plant and Potable Water

Specimen type	Initial Setting Time (hours)
Potable water	4.50 (0.000)
Biologically treated wastewater	6:00 (0.004)
MBR treated wastewater	5:00 (0.010)
Tireh effluent treated wastewater	4.50 (0.004)

Note: Standard Deviation is between brackets

The results of the initial setting time at all stages were good with a higher value obtained from the biologically treated waste water with 6 hours. This may refers to dissolved organic matter.

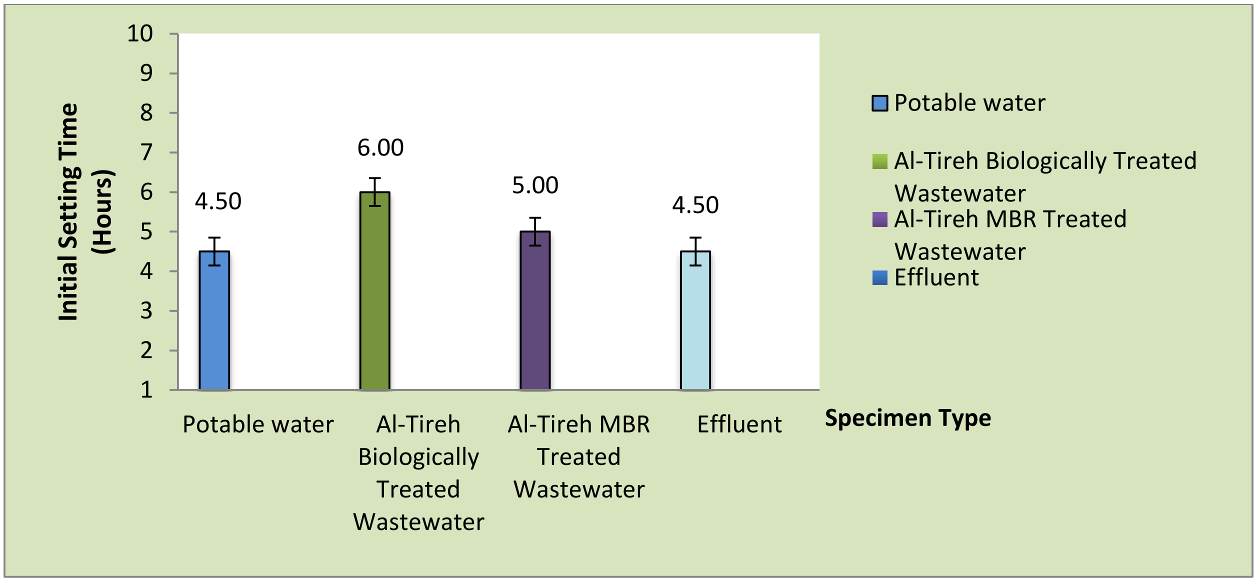

Figure 26: The initial setting time from Al-Tireh treated wastewater and potable water PW

Thavamalar A/P Muniandy (2009) and shekarchi et al., (2012) noticed that Initial setting time is higher for treated waste water, Setting time were found to increase with deteriorating water quality.

Terro and Al-Ghusain (2003) observed a super initial setting time value for STWW with 5.78 hours, while it was near 4.5 hours to each of potable water, PTWW, and TTWW. Terro and Al-Ghusain noting that this refers to the large amount of ammonia in the STWW as Neville (1981) reported that ammonia salts cause bleeding action.

(More *et al.*,2014) reported that the increase in initial setting time of STWW is due the presence of dissolved organics and salts.

4.3.5 Concrete Final Setting Time

4.3.5.1 The Final Setting Time from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

Table 24: The Final Setting Time from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

Specimen type	Final Setting Time (Hours)
Potable water	8:50 (0.003)
Al-Bireh treated wastewater	8:30 (0.004)
Al-Tireh treated wastewater	8:40 (0.006)
Al-Quds University treated wastewater	8:35 (0.040)

Note: Standard Deviation is between brackets

In comparison with the final setting time of potable water, the maximum delay did not exceed 20 minutes, which is compatible to ASTM criteria.

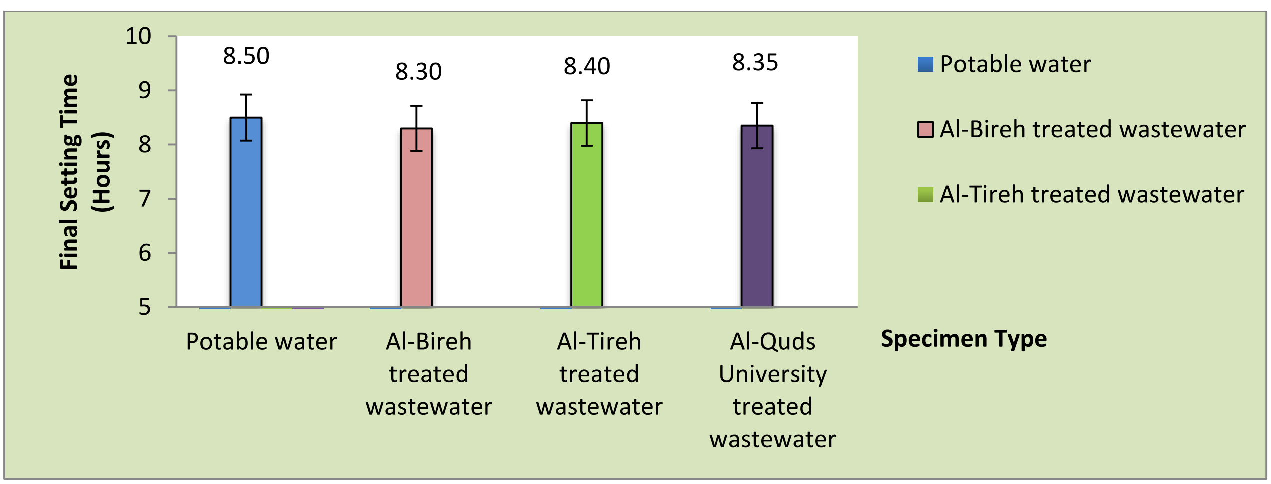

Figure 27: The Final Setting Time from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

4.3.5.2 : The final setting time for Al-Tireh Waste Water Treatment Plant and Potable Water

Table 25: The final setting time for Al-Tireh Waste Water Treatment Plant and Potable Water

Specimen type	Final Setting Time (Hours)
Potable water	8:50 (0.010)
Biologically treated wastewater	9:30 (0.020)
MBR treated wastewater	9:00 (0.020)
Tireh effluent treated wastewater	8:35 (0.010)

Note: Standard Deviation is between brackets

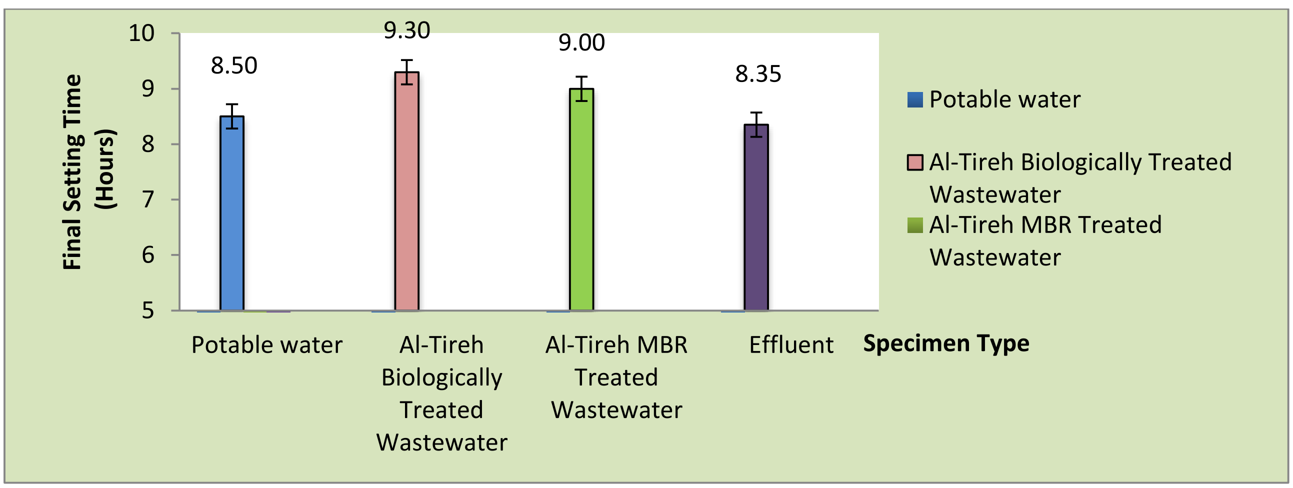

Figure 28: the Final Setting Time from Al-Tireh treated wastewater and potable water (PW)

Higher impurities quantities gave higher final setting time, due to solids effect on the setting time. Terro and Al-Gusain (2003) and shekarchi et, al. (2012) reported that using water with lower quality retards the setting time. The final setting time is affected by the dissolved organics contents implied by the COD (Neville, 1981). Cebeci and saatci (2003) recorded a two hours delay in the final setting time of secondary treated waste water over the potable water. More et, al. (2014) reported the same result noting the retardation in the final setting time was due to the presence of organics and salt.

4.3.6 Permeability

4.3.6.1 The Permeability from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

Table 26: The Permeability from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

Specimen type	Permeability mm
Potable water	3 (0.000)
Al-Bireh treated wastewater	2 (0.577)
Al-Tireh treated wastewater	2 (0.000)
Al-Quds University treated wastewater	3 (0.577)

Note: Standard Deviation is between brackets

The permeability percentage of treated wastewater to potable water was 150% for Al-Bireh treated wastewater and Al-Tireh treated wastewater, and 100% for Al-Quds University treated wastewater.

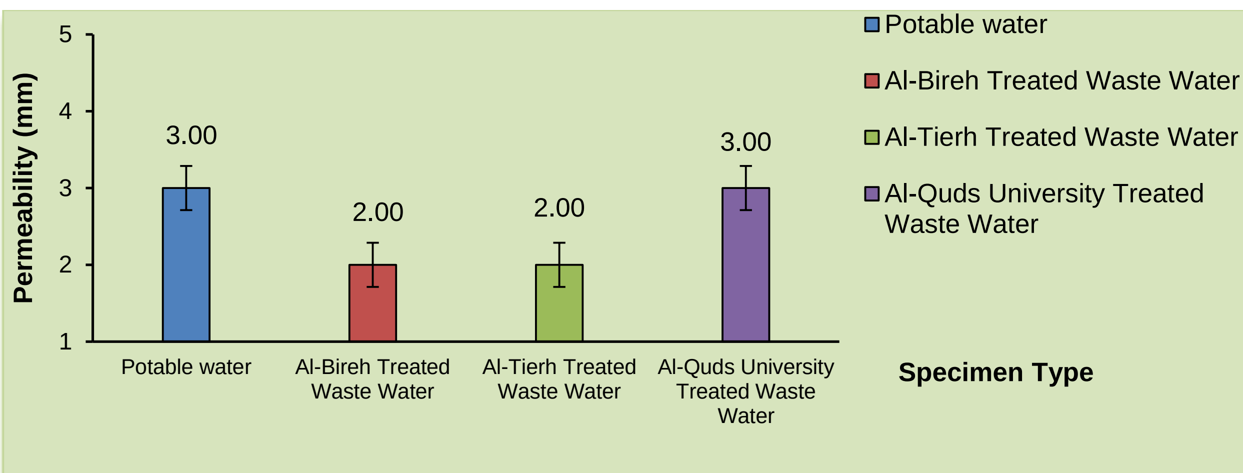

Figure 29: The Permeability from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

4.3.6.2 : The permeability for Al-Tireh Waste Water Treatment Plant and Potable Water

Table 27: The permeability for Al-Tireh Waste Water Treatment Plant and Potable Water

Specimen type	Permeability (mm)
Potable water	3 (0.577)
Biologically treated wastewater	1 (0.000)
MBR treated wastewater	2 (0.577)
Tireh effluent treated wastewater	2 (0.577)

Note: Standard Deviation is between brackets

Permeability values of MBR treated wastewater and Al-Tireh effluent treated waste water were slight lower than potable water, except samples of biologically treated waste water which gave a lowest result. This may be to self healing of bacterial concrete and solids filling, and dispersion action of organic contents.

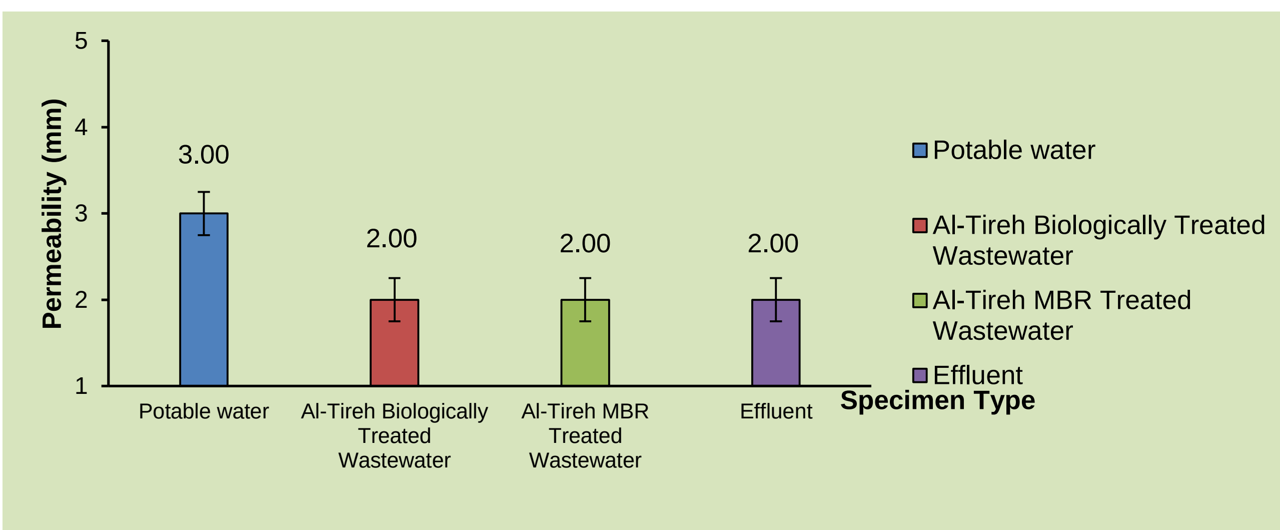

Figure 30: The Permeability from Al-Tireh treated wastewater and potable water (PW)

Shekarchi *et al.*, (2012) reported that water quality have no effects on permeability.

4.3.7 Concrete Specific Gravity

4.3.7.1: The Specific Gravity from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

Table 28: The Specific Gravity from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

Specimen type	Specific gravity
Potable water	2.40 (0.005)
Al-Bireh treated wastewater	2.40 (0.004)
Al-Tireh treated wastewater	2.42 (0.002)
Al-Quds University treated wastewater	2.41 (0.004)

Note: Standard Deviation is between brackets

The results of treated water specific gravity were close to that of potable water, and agree with the ASTM criteria.

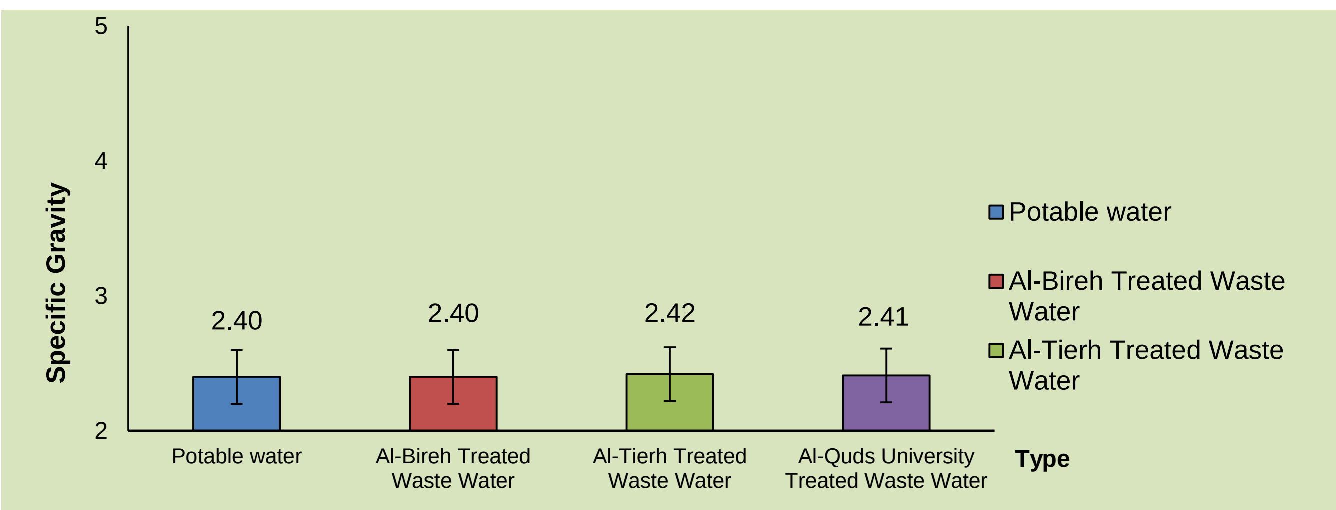

Figure 31: The Specific Gravity from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

4.3.7.2 The specific gravity for Al-Tireh Treated Waste Water Treatment plant and potable water (PW)

Table 29: The specific gravity for Al-Tireh Treated Waste Water Treatment plant and potable water (PW)

Specimen type	Specific Gravity
Potable water	2:40 (0.003)
Biologically treated wastewater	2:42 (0.002)
MBR treated wastewater	2:42 (0.002)
Tireh effluent treated wastewater	2:41 (0.003)

Note: Standard Deviation is between brackets

The table shows no effects on treated wastewater at any stage on the specific gravity of concrete.

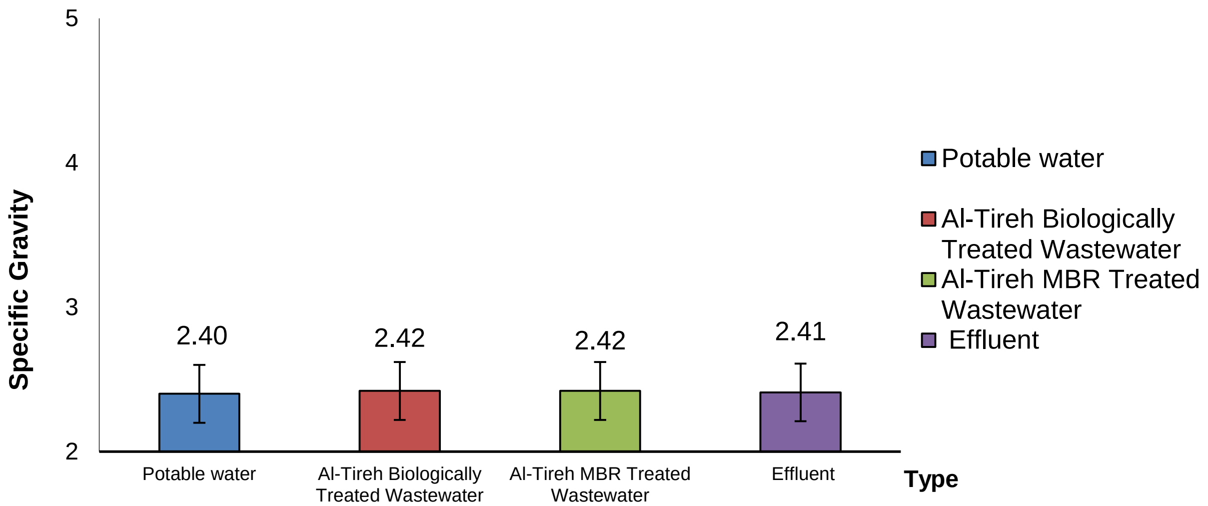

Figure 32: The Specific Gravity from Al-Tireh treated wastewater, and potable water (PW).

Terro and Al-Ghusain (2003) noticed that water quality have no effects on concrete density.

4.3.8 Concrete Air content

4.3.8.1 The air content from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW).

Table 30: The air content from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW).

Specimen type	Air Content (%)
Potable water	1:30 (0.100)
Al-Bireh treated wastewater	1:50 (0.003)
Al-Tireh treated wastewater	1:40 (0.006)
Al-Quds University treated wastewater	1.20 (0.003)

Note: Standard Deviation is between brackets

Despite that Al-Bireh treated wastewater gave a percentage of 86.66% which is below the allowed value by the ASTM, but due to other effluent values in addition to the small difference it can be neglected.

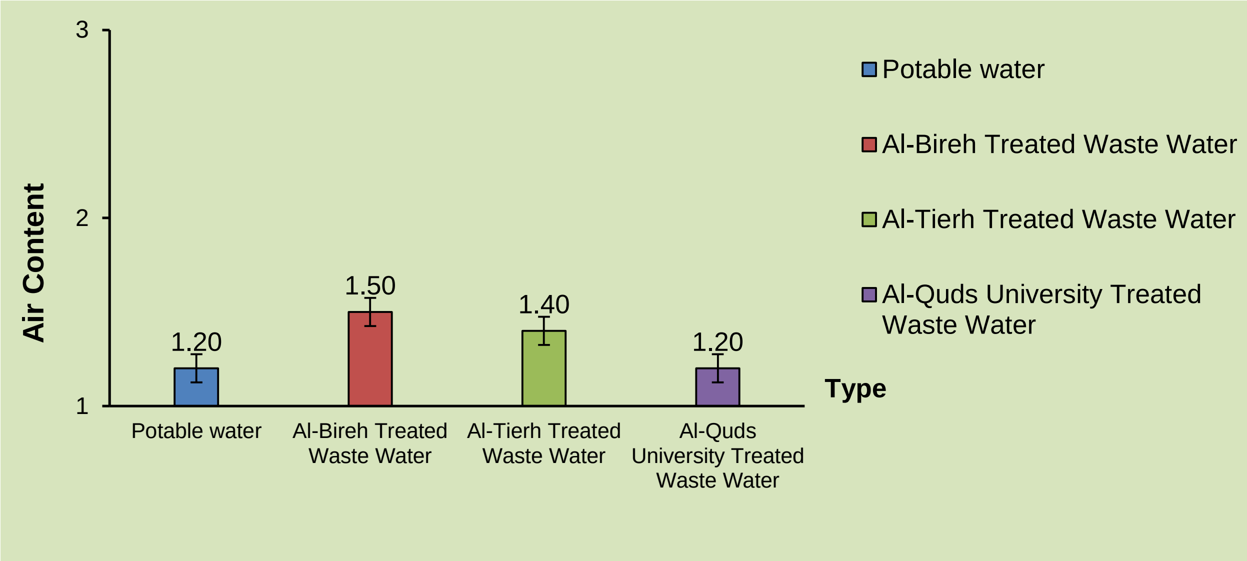

Figure 33: the air content from Al-Bireh treated wastewater, Al-Tireh treated wastewater, Al-Quds University treated wastewater, and potable water (PW)

4.3.8.2 The air content for Al-Tireh Waste Water Treatment Plant and Potable Water

Table 31: The air content for Al-Tireh Waste Water Treatment Plant and Potable Water

Specimen type	Air Content (%)
Potable water	1:30 (0.003)
Biologically treated wastewater	1:10 (0.003)
MBR treated wastewater	1:10 (0.000)
Tireh effluent treated wastewater	1:40 (0.004)

Note: Standard Deviation is between brackets

Air content values of treated wastewater specimens were around the tap water, with lowest values for biologically and MBR treated wastewater due to the filling action of impurities.

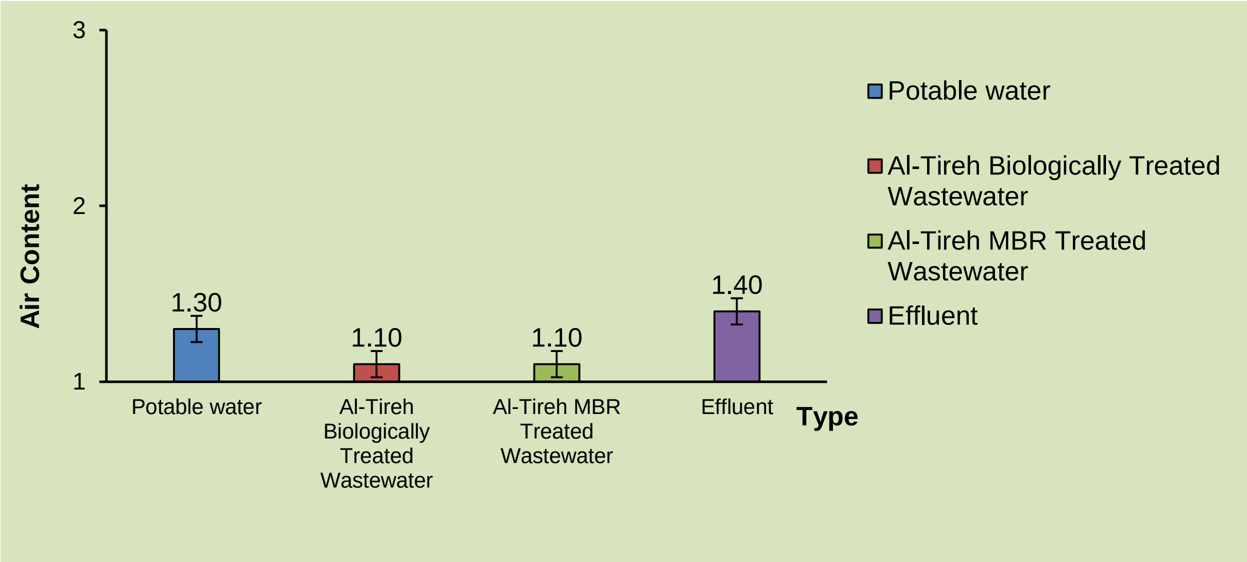

Figure 34: The air content from Al-Tireh treated wastewater and potable water (PW)

Cebeci and Saatci (1989) and (Shekaria *et al*,. 2012) reported that water quality have no effects on air content.

Table 32 summarizes the updated results of this project over the previous researches.

Table 32: Trade-off between this research and previous researches on the use of treated waste water in the concrete production

Applied WWT technology	Quality of the mixed water	Performed concrete tests	Main results	Reference
1-MBR 2-RO 3-EA	-Domestic treated waste water 1-Biologically Treated waste water 2-MBR treated waste water 3-Effluent of various treatment systems 4-Potable water	1-Compressive strength	The compressive strength was higher with treated waste water with a unique values of Biologically Treated waste water. Organic content may be acting as a dispersing agent.	This research
		2-Slump	In general TWW gave a higher slump values comparing of tap water, with a unique values for MBR treated waste water and Biologically Treated waste water due to water demand of treated water of STWW and TTWW.	
		3-Setting time	The setting time was affected by the type of the mixing water. Biologically Treated waste water was found to have the highest values of retarding time. COD retards setting time.	
		4-Specific gravity	Concrete specific gravity was not affected by the type of the mixing water.	
		5-Air content	Air content values of Treated wastewater specimens were around the tap water, with lowest values for Biologically Treated waste water and MBR treated waste water. Due to the filling action of impurities.	
		6-Permeability	Permeability values of treated specimens were close to potable water, except samples of Biologically Treated waste water which gave a lowest result. This may be to self healing of bacterial concrete.	

1-EA	-Industrial treated waste water 1-PTWW 2-STWW 3-TTWW 4-Potable water	1-Compressive strength	PTWW and STWW had lower strength at earlier stages than potable water, and a high decreases at ages up to one year. TTWW was slightly higher than potable water.	Al-Ghusain and Terro (2003)
		2-Slump	Slump of concrete is not affected by water quality.	
		3-Setting time	Higher water quality gave lower setting time, dissolved organics matter (COD) retard final setting time.	
		4-Specific gravity	Specific gravity of concrete is not affected by water quality.	
1-EA	-Domestic treated waste water 1-TTWW 2-Potable water	1-Compressive strength	Partially or fully using of TTWW increases compressive strength for earlier ages, but at ages of three months and beyond values were similar to the strength of concrete made with 100% potable mixing water.	Al-Enezi (2010)
		2-Air content	Concrete laboratory using TTWW had the highest percentage of voids due to salt corrosion attack.	
1-RO	- Domestic treated waste water 1-STWW 2-Potable water	1-Compressive strength	STWW has improved strength. Organic content may be acting as a dispersing agent, improving the dispersion of particles of cement and reducing clumping.	Silva and Naik (2010)
		2-Slump	Workability of the STWW was lower than that of potable water due to organic content.	

1-MBR	-Domestic treated waste water 1-PTWW 2-STWW 3-TTWW 4-Potable water	1-Compressive strength	The compressive strength with STWW had a reduction up to 10% at all curing ages except 28 days, since suspended solids exceeds the tolerable limits. TTWW was higher than potable water at all ages due to the filling effects of solid particles.	Shekarchi et al. (2012)
		2-Slump	Higher water quality gives higher slump. TDS slightly decrease slump	
		3-Setting time	Higher water quality gives lower setting time. Dissolved solids affect the setting time, high content of bicarbonates and alkali aggregates accelerate setting time.	
		4-Air content	Air content of concrete is not affected by water quality.	
		5-Permeability	Permeability for STWW is slightly higher than other water quality's.	
1-RO	-Domestic treated waste water 1-GW 2-PTWW 3-STWW 4-Potable water	1-Compressive strength	STWW gave the same compressive strength of potable water at 7 days curing, but higher value at 28 days curing, organic content may be acting as a dispersing agent, improving the dispersion of particles and reducing clumping.	More et al. (2014)
		2-Slump	Slump of concrete is not affected by water quality.	
		3-Setting time	Setting time is increased for STWW as compared to potable water due to salts and dissolved organic matter.	
1-EA	-Industrial treated waste water 1-Effluent 2-Potable water	1-Compressive strength	Higher compressive strength was achieved for treated waste water compared to potable water	Muniandy(2009)

		2-Slump	The water demand for treated waste water is higher than potable water	
		3-Setting time	Initial and final setting time is slightly higher for treated waste water	
.-EA	-Domestic treated waste water 1-Effluent 2-Potable water	1-Compressive strength	Treated effluent increases the compressive strength compared with potable water due to the higher concentration of sodium and calcium salt of chloride which acts as a catalyst.	LEE et al. (2001)
		2-Setting time	Initial and final setting times are slightly higher for treated effluent paste compared to the control paste due to salts that react actively as retarders.	

Chapter 5
Conclusions and Recommendations

5.1 Introduction

This chapter presents the conclusions including contribution of work to the body of knowledge and lastly, recommendations for future research. These conclusions and recommendations are related to the materials and conditions used in this research study.

5.2 Conclusions

From the results of this study, the properties of the used treated effluent with variable degrees of treatment were found to be at the tolerable limits from the various researchers. Higher properties were achieved for concrete cube with treated effluent compared to the concrete cube with potable water. In general, Waste water treated with membranes technologies gave a slit better quality than that treated with aeration tank. As comparing results I was found that biologically treated waste water was the highest quality, MBR treated wastewater gave better properties than the effluent one which gave results closed to tap water.

- Both initial and final setting times of cement paste mixed with treated effluent were affected by the type of the mixing water. Biologically treated wastewater was found to have the highest values of retarding time.
- Concrete specific gravity was not affected by the type of the mixing water.
- Air content values of Treated wastewater specimens were around the tap water one, with lowest values for biologically treated wastewater and MBR treated wastewater.
- Permeability values of treated specimens were close to potable water, except samples of biologically treated wastewater which gave a lowest result.
- In general MBR treated wastewater gave a higher slump values comparing of tap water, with a unique values for MBR treated wastewaterand biologically treated wastewater.
- The compressive strength was higher with MBR treated wastewater comparing to potable water, with unique values of biologically treated wastewater.
- No odor problems may observe and constrain the final concrete usage.

- Cement color exceeds the mixing water color, with a slight darkness at biologically treated wastewater mixture.
- Public acceptance is in harmony with the objectives of the research.
- several potential outcomes and donations of this research are: to minimize the necessitate for the use of potable water; get rid of the need to enlarge potable water supply for utilize in the concrete industry; reduce the need to create more water treatment services due to population growth; keep potable water for drinking objectives; make sewage treatment plants become more cost-effectively by reusing water before its final treatment; and, other similar objectives to achieves sustainable developments.

The results obtained from this study indicates that treated effluent is suitable for used as mixing water in concrete with each of Biologically treated wastewater, MBR treated wastewater, Treated Effluent. Further research is needed because there is a strong need to manufacture concrete in a more sustainable manner.

5.3 Recommendations

- To alert public to interface with governmental policies and decision makers to clarify the applicability of sewage treatment water in concrete, mainly when human handling and experience is a possibility.
- Other concrete properties can be examined such as, tensile strength; bending strength; water absorption; and coefficient of compaction.
- Replace the potable water with the treated wastewater as concrete mixing water is recommended.
- Biologically treated wastewater usage is preferred to higher environmental and economical savings.
- To develop programs for use of recycled water, according to various applications and human experience.
- Feasibility of implementing the project in the market should be determined by a full cost-benefit analysis.

Chapter 6
References

- Al-Enezi, N., Evaluation and Assessment of Concrete Produced by Utilizing of Treated Wastewater, Concrete Sustainability Conference, 2010.
- Al-Ghusain, I. and Terro, M. J., 2003. Use of treated wastewater for concrete mixing in Kuwait. *J. Sci. Eng*., 30(1), 213-228.
- American Society for Testing and Materials International Standard Worldwide. *Mixing and Curing Water for Concrete.* ASTM.
- American Society for Testing and Materials, West Conshohocken, PA, 2001.
- Annual book of ASTM standards. 1994, ASTM, Philadelphia.
- Association of water Technologies (AWT), Application of bacteria as self-healing agent for the development of sustainable,Reverse Osmosis Technology: Fundamentals and Water Applications*, 1998.
- ASTM C1602-06, *Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete*, USA.
- ASTM C94 – 05, *Specification for Ready Mixed Concrete* USA.
- Cebeci, O. Z., Saatci, A. M., 1989. Domestic Sewage as Mixing Water in Concrete. *ACI Materials Journal*, 86(5), 503-506.
- Cement Concrete & Aggregates (CCAA),Concrete Basics: A Guide to Concrete Practice, Australia,2004. At www.*elearning.vtu.ac.in*
- Cement Concrete & Aggregates Australia (CCAA), Use of Recycled Water in Concrete Production, August 2007. At www.concrete.net
- Chemistry world, concrete conundrum, 2008. At www. Chemistry world.org
- Chini, S. A. and Mbwambo, W. J. (1996). "Environmentally friendly solutions for the disposal of concrete wash water from ready mixed concrete operations." In *Proceedings of CIB W89 Beijing International Conference*.
- Copeland, C., Terrorism and Security Issues Facing the Water Infrastructure Sector, Congressional Research Service, Vol. 21, 2010.
- Corcoran, E., C. Nellemann, E. Baker, R. Bos, D. Osborn, H. Savelli, *Sick Water?* The central role of wastewater management in sustainable development, Vol. 88, united nations, 2010.
- CWHW, 2010. World Water Quality Facts And Statics, 2010. Report. http://www.unwater.org/wwd10/downloads/WWD2010_LOWRES_BROCHURE_EN.pdf

- *Davis Langdon & Seah Consultancy (DLS),* Environmentally Friendly Concrete, Executive Summaries *for the practitioner,* Volume 9 Issue 7: December 2009, MICA(P) No. 276/05/2008.
- DJ(W), CPWD, Handbook on Repair and Rehabilitation of RCC Structures, Central Public Works Department (CPWD), Government of India, New Delhi, 2002.
- Drexhage, J., Murphy, D., 2012. Sustainable Development: From Brundtland to Rio 2012, International Institute for Sustainable Development (IISD), New York.
- EAE (Environmental Advisors and Engineers), Wastewater Flow Forecasting Using Population and Land Use, 2014. Report.
- *ECOSOC. (2015).* Development Agenda 2012.Post 2015 UN Development Framework, 4 April 2012. Report.
- EPA, 2003. Guidelines for Environmental Management: Use of Reclaimed Water (Publication 464.2), EPA, Victoria. Report.
- FAO. (2011). The State Of The Worlds Land And Water Resources For food And Agriculture. Report.
- Friedler, E. 1999. The Jeezrael Valley Project for Wastewater Reclamation and Reuse, Israel. *Water Sci.Tech*., 40(4-5), 347–354.
- Green Arth (2012). Industrial Wastewater. http://www.greenarth.com/industrialwastewater.html.
- Haarhoff, J., Van der Merwe B., 1996. Twenty-five Years of Wastewater Reclamation in Windhoek, Namibia. *Water Sci. Tech.*, **33**(10-11), 25–35.
- *Hanak1 E., Lund2 J., Dinar2 A., Gray2 B. (2009).* Myths of California Water - Implications and Reality, West Northwest, Vol. 16, No. 1, 2010, California.
- Hassinger, E., Doerge, A., Baker, B., Water Facts: Number 6 Reverse osmosis units, The University of Arizona, College of Agriculture, Arizona, 1994.
- Hüfner, E., Flexible Measuring and Control in Reverse Osmosis Systems: What advantages do modular multi-channel controller for central tasks in water treatment have, 2010.
- IWA (2011), Reverse Osmosis and Removal of Minerals from Drinking Water. Report. At www.iwawaterwiki.org.
- Jane A. Leggett, Nicole T. Carter, Rio+20: The United Nations Conference on Sustainable Development, volume 17,18 June 2012.
- Jeffries A. (2009). Inhabitat magazine, is it green?: concrete. At www.inhabitat.com
- Jhansi, S., Mishra, S.,Emerging Technology in Urban Areas of Developing Countries for Sustainable Wastewater Treatment and Reuse, Global Journal of Environmental Research 6 (3): 91-99, 2012.
- Jhansi, S., Mishra, S., Wastewater Treatment and Reuse: Sustainability Options, *Consilience: The Journal of Sustainable Development* ,Vol. 10, Iss. 1 (2013), Pp. 1 – 15.
- Jimenez, B. and Asano, T. (Eds.) (2008) *Water reuse: an international survey of current practice, issues, and needs*. Scientific and Technical Report No. 20. London, UK: International Water Association Publishing.
- Jonkers, H. M., E. (2011) Bacteria-based self-healing concrete, *HERON Vol. 56 (2011) No. ½*. Delft, the Netherlands.

- Jonkers, H.M., and Schlangen, E. (2008) Development of a bacteria-based self healing concrete. In *Tailor made concrete structures - new solutions for our society. Proc. Int. FIBsymposium* (ed. J. C. Walraven & D. Stoelhorst), pp. 425-430. Amsterdam, the Netherlands.
- Jonkers, H.M., Thijssen, A., Muyzer, G., Copuroglu, O., and Schlangen, E. (2010) Application of bacteria as self-healing agent for the development of sustainable concrete. *Ecological Engineering* 36(2): 230-235.
- Kitis M., Membrane Bioreactors (MBRs) in wastewatertreatment andreclamation,Dept. of Environmental Engineering Süleyman Demirel University, Turkey, 2010.
- Kumar V., basics-of-reverse-osmosis, 2013. At www.scribd.com
- Lee, O S., Salim, M. R., Ismail, M. and Ali, M. I. (2001). "Reusing treated effluent in concrete technology." *Jurnal teknologi*, 34(F), 1–10.
- Liu, Sh., Sustainable and Safe Use of Non-conventional Waters-Reclaimed Water and Desalinated Water, Lund University, 2014.
- Milwaukee Metropolitan Sewerage District (MMSD) (2009). "Treatment Process" <http://v3.mmsd.com/TreatmentProcess.aspx> (Sep. 21, 2009)
- Ministry of Land, Infrastructure and Transport (MLIT) (2001), *Sewage Works in Japan 2001*, Tokyo, Japan.
- Monteiro, M., Mehta, K., Permeability of concrete, Concrete: Microstructure, Properties, and Materials,4th edition, 2013.
- More, A. B., Ghodake, R. B., Nimbalkar, N., Ghandake, P., Maniyar, P., Narute, D., Reuse of treated domestic wastewater in concrete- A sustainable approach, Volume : 4, Issue : 4, Apr 2014, India.
- Mors, M., Jonkers, M., BACTERIA-BASED SELF-HEALING CONCRETE – INTRODUCTION: Second International Conference on Microstructural-related Durability of Cementitious Composites, Amsterdam, 2012.
- Mullapudi, T.R.S., Gao, D., and Ayoub, A.S., "Nondestructive Evaluation of Carbon-Nanofiber Concrete*," Magazine of Concrete Research*, ICE, V. 65 (18), 2013, pp. 1081-1091.
- Muniandy, T. (2009), Reusing of treated waste water in concrete, Malaysia Technology University, Malaysia.
- Nabegu, B., Domestic Wastewater Management In Peri-Urban Settlements Of Kano Metropolis, International Journal of Environmental Issues, Volume 7, Number 1, June 2010,Nigeria.
- Neville, A. M. 1981. Properties of concrete. Third edition. Longman Scientific and technical, Essex, England.
- NRMCA Organization ,mixing water quality of concrete,2014. at www.nrmca.org
- Palestinian Concrete Society, *2013* at www.pcs-pal.org.
- Rabah, F., Physical, chemical and biological characteristics of wastewater, The Islamic University of Gaza, 2014.
- Rao, M.V., Reddy, V.S., Hafsa, M., Veena, P., and Anusha, P., Bioengineered Concrete - A Sustainable Self-Healing Construction Material, *Research Journal of Engineering Sciences*, Vol. 2(6), 45-51,India, June 2013.
- RICS Research, Water Scarcity and Land Use Planning, 2011.

- Rist, G., (2007). 'Development as a buzzword', Development in Practice, Volume 17, Numbers 4–5, Geneva.
- Sagripanti, J.L. & Bonifacino, A. 1996. Comparative sporicidal effects of liquid chemical agents. Appl. Environm. Microbiol. 62(2):545-551.
- Schlegel H.G. 1993. *General microbiology*, 7th edition. Cambridge University Press, Cambridge.
- Sethuraman, P. (2006). “Water reuse and recycling - a solution to manage a precious resource?”<http://www.frost.com/prod/servlet/market-insight-top.pag?docid=90081832> (Sep. 21, 2009).
- Sethuraman, P. (2006). “Water reuse and recycling - a solution to manage a precious resource?”<http://www.frost.com/prod/servlet/market-insight-top.pag?docid=90081832> (Sep. 21, 2009).
- Shekarchi, M., Yazdian, M., Mehrdadi, N., Use of biologically treadted domestic waste water in concrete, 2012, Kuwait. *J. Sci. Eng.*, 39(2B), pp.97-111, 2012, Tehran, Iran.
- Silva, M., Naik, R., Sustainable Use of Resources – Recycling of Sewage Treatment Plant Water in Concrete, Coventry University and The University of Wisconsin Milwaukee Centre for By-products Utilization, Italy, 2010.
- SOE (State of Water and Environment), Fresh Water, 2002. Report.
- South,B., Salt Water Concrete—A Reality, 2014. At www.monolithic.org.
- Spectra Pure, Reverse Osmosis Technology, 2012. At www.hydroponics.net.
- Strong, M. (1999). *Hunger, Poverty, Population and Environment. The Hunger Project Millennium Lecture, 7 April 1999*, Madras, India.
- Suraneni, P., Ultrasonic wave reflection measurements on self-compacting pastes and concretes, University of Illinois at Urbana-Champaign, Urbana, 2011.
- Tay, J. H. & yip, W. K. 1987, use of reclaimed wasteawater for concrete mixing. Resources, Conservation and Recycling 2(3): 211-227.
- UNCTAD. (2012). Road to Rio (+20) 2012. Report.
- UNEP, 2010. Sick Water? The central role of wastewater management in sustainable development., 2010. Report.
- Vigneswaran, S., Sundaravadivel, M., Encyclopedia Of life Support Systems EOLSS,recycle and reuse of wastewater, sydney, Australia, 2014.
- WCED. (1987). Our Common Future 1987. Report.
- WESRDD. (2004). West Bank and Gaza wastewater treatment and reuse policy note. Report.
- WHO (2005), *Global water supply and sanitation 2000 report*. Report. At http://www.who.int/water_sanitation_health/Globalassessment/, accessed 7 April, 2005).
- WHO/UNICEF, 2000. Global Water Supply and Sanitation Assessment 2000. Report. At *www.who.int*.
- Zandaryaa, S., “Global challenge of waste water – example from different continents,” presented at the 2011 World Water Week in Stockholm, 2011.
- Zwaag van der, S., 'Self healing materials: an alternative approach to 20 centuries of materials science' (Springer, Dordrecht, 2007).

APPENDICES

Appendix 1
Wastewater Tests
Three Time Intervals Composite Specimens Tests
Phase 1

Wastewater Tests:

The following tables indicate the effluent composition of each of Al-Bireh Wastewater Treatment plant, Al-Tireh Wastewater Treatment plant, and Al-Quds University Wastewater Treatment plant, respectively. Each plant has three time effluent tests to ensure the accuracy.

I. Al-Bireh Wastewater Treatment plant.

- The first specimen test.

Test Number	Parameter	Unit	Effluent
1	Temp	Cº	16.6
2	EC	Us\cm	460
3	PH	\	7.61
4	TDS	Mg\1	237
5	TS	Mg\1	496
6	PO4-p	Mg\1	4.3
7	NH4-n	Mg\1	13.1
8	COD	Mg\1	22.2
9	BOD	Mg\1	13
10	DO	Mg\1	4.2

- The second specimen test.

Test Number	Parameter	Unit	Effluent
1	Temp	Cº	16.4
2	EC	Us\cm	472
3	PH	\	7.53
4	TDS	Mg\1	230
5	TS	Mg\1	487
6	PO4-p	Mg\1	4.0
7	NH4-n	Mg\1	13.6
8	COD	Mg\1	19.5
9	BOD	Mg\1	15
10	Do	Mg\1	4.9

- The third specimen test.

Test Number	Parameter	Unit	Effluent
1	Temp	Cº	15.9
2	EC	Us\cm	480
3	PH	\	7.58
4	TDS	Mg\1	240
5	TS	Mg\1	476
6	PO4-p	Mg\1	3.8
7	NH4-n	Mg\1	12.7
8	COD	Mg\1	20.0
9	BOD	Mg\1	16
10	Do	Mg\1	4.7

II. Al-Tireh Wastewater Treatment Plant tests.

- The first specimen test.

Test Number	Parameter	Unit	Effluent
1	Temp	Cº	16.1
2	EC	Us\cm	492
3	PH	\	7.45
4	TDS	Mg\1	225
5	TS	Mg\1	473
6	PO4-p	Mg\1	3.9
7	NH4-n	Mg\1	11.7
8	COD	Mg\1	29.3
9	BOD	Mg\1	15
10	DO	Mg\1	4.9

-The second specimen test.

Test Number	Parameter	Unit	Effluent
1	Temp	Cº	17.1
2	EC	Us\cm	510
3	PH	\	7.01
4	TDS	Mg\1	266
5	TS	Mg\1	508
6	PO4-p	Mg\1	5.8
7	NH4-n	Mg\1	11.9
8	COD	Mg\1	38
9	BOD	Mg\1	36
10	Do	Mg\1	4.7

- The third specimen test.

Test Number	Parameter	Unit	Effluent
1	Temp	Cº	18.20
2	EC	Us\cm	520
3	PH	\	7.21
4	TDS	Mg\1	263
5	TS	Mg\1	503
6	PO4-p	Mg\1	5.4
7	NH4-n	Mg\1	10.3
8	COD	Mg\1	36
9	BOD	Mg\1	31
10	Do	Mg\1	4.9

III. Al-Quds University Wastewater Treatment Plant tests.

- The first specimen test.

Test Number	Parameter	Unit	Effluent
1	Temp	Cº	18
2	EC	Us\cm	460
3	PH	\	7.1
4	TDS	Mg\1	50.00
5	TS	Mg\1	189.00
6	PO4-p	Mg\1	4.8
7	NH4-n	Mg\1	9.6
8	COD	Mg\1	12.12
9	BOD	Mg\1	6.22
10	DO	Mg\1	4.7

- The second specimen test.

Test Number	Parameter	Unit	Effluent
1	Temp	Cº	16
2	EC	Us\cm	458
3	PH	\	7.1
4	TDS	Mg\1	48.80
5	TS	Mg\1	209.20
6	PO4-p	Mg\1	3.9
7	NH4-n	Mg\1	8.4
8	COD	Mg\1	10.60
9	BOD	Mg\1	6.83
10	DO	Mg\1	5.1

- The third specimen test.

Test Number	Parameter	Unit	Effluent
1	Temp	Cº	17
2	EC	Us\cm	425
3	PH	\	7.3
4	TDS	Mg\1	46.37
5	TS	Mg\1	202.80
6	PO4-p	Mg\1	3.8
7	NH4-n	Mg\1	7.9
8	COD	Mg\1	11.44
9	BOD	Mg\1	7.00
10	Do	Mg\1	4.7

Appendix 2
Wastewater Tests
Three Time Intervals Composite Specimens Tests
Phase 2

- The first specimen test.

Test number	Parameter	Biologically treated wastewater	MBR treated wastewater	Effluent treated wastewater	Unit
1	COD	71	40	31	Mg/l
2	TSS	11	3	2	mg/l
3	Total nitrogen	28	6.6	5.4	Mg/l
4	Total phosphorus	5	.08	.03	Mg/l
5	TDS	952	265	255	Mg/l
6	CBOD	10.3	2.6	1.2	Mg/l
7	Ph	7.9	7.5	7.7	Mg/l
8	temperature	18	20	17	C°
9	FC	50000	-	-	MPN/100 ml

- The second specimen test.

Test number	Parameter	Biologically treated wastewater	MBR treated wastewater	Effluent treated wastewater	Unit
1	COD	55	30	24	Mg/l
2	TSS	14	3	2	mg/l
3	Total nitrogen	30	7.5	5.8	Mg/l
4	Total phosphorus	6	.08	.03	Mg/l
5	TDS	290	240	234	Mg/l
6	CBOD	8.5	1.8	2.7	Mg/l
7	PH	7.6	7.3	7.0	Mg/l
8	temperature	18	14	17	C°
9	FC	65000	-	-	MPN/100 ml

- The third specimen test.

Test number	Parameter	Biologically treated wastewater	MBR treated wastewater	Effluent treated wastewater	Unit
1	COD	45	29	20	Mg/l
2	TSS	8	3	2	mg/l
3	Total nitrogen	50	8	5.0	Mg/l
4	Total phosphorus	4	.07	.03	Mg/l
5	TDS	250	245	225	Mg/l
6	CBOD	11.5	2.2	2.4	Mg/l
7	PH	7.6	7.0	6.7	Mg/l
8	temperature	18	17	17	C°
9	FC	55000	-	-	MPN/100 ml

Appendix 3
Concrete Tests
Phase 1

- **Compressive Tests:**

The following tables indicate the compressive strength of each cube made with a specific water quality either it was potable water or an effluent from Al-Bireh Wastewater Treatment plant, Al-Tireh Wastewater Treatment plant, and Al-Quds University Wastewater Treatment plant, respectively.

Each concrete mixture of each WWTP has three times interval water-quality with four concrete cubes of each time to ensure an accurate compressive strength tests.

I. The compressive strength of Al-Bireh Wastewater Treatment plant concrete.

- The first specimens.

Specimen Number	7 days	28 days	56 days
1	280	390	410
2	290	400	415
3	310	398	418
4	300	388	419
Average	295	394	416
Standard deviation	11.18	5.09	3.50

- The second specimens.

Specimen Number	7 days	28 days	56 days
1	288	386	405
2	294	402	418
3	320	390	413
4	302	396	419
Average	301	394	413
Standard deviation	12.0	6.06	5.54

- The third specimens.

Specimen Number	7 days	28 days	56 days
1	302	390	405
2	300	395	415
3	304	399	416
4	295	394	409
Average	300	395	411
Standard deviation	3.34	3.20	4.49

II. The compressive strength of Al-Tireh Wastewater Treatment plant concrete.

- The first specimens.

Specimen Number	7 days	28 days	56 days
1	271	386	418
2	280	392	408
3	294	390	424
4	308	394	425
Average	288	391	419
Standard deviation	14.0	2.96	6.76

- The second specimens.

Specimen Number	7 days	28 days	56 days
1	276	384	408
2	282	394	400
3	291	390	425
4	300	398	423
Average	287	392	414
Standard deviation	9.09	5.17	10.41

- The third specimens.

Specimen Number	7 days	28 days	56 days
1	279	396	408
2	283	394	419
3	282	380	415
4	290	397	423
Average	284	392	416
Standard deviation	4.03	6.87	5.54

III. The compressive strength of Al-Quds University WWTP concrete.

- The first specimens.

Specimen Number	7 days	28 days	56 days
1	282	376	398
2	291	386	403
3	288	390	412
4	288	374	400
Average	287	381	403
Standard deviation	3.27	6.69	5.35

- The second specimens.

Specimen Number	7 days	28 days	56 days
1	280	370	395
2	290	385	406
3	292	388	405
4	288	372	394
Average	288	379	400
Standard deviation	4.56	7.85	5.52

- The third specimens.

Specimen Number	7 days	28 days	56 days
1	288	380	405
2	288	388	401
3	290	376	405
4	286	376	396
Average	288	380	402
Standard deviation	1.41	4.89	3.70

IV. The compressive strength of the potable water concrete.

- The first specimens.

Specimen Number	7 days	28 days	56 days
1	280	394	415
2	286	397	417
3	272	388	425
4	286	394	411
Average	281	393	417
Standard deviation	5.74	3.27	5.09

- The second specimens.

Specimen Number	7 days	28 days	56 days
1	286	398	417
2	290	400	422
3	278	390	413
4	282	392	417
Average	284	395	417
Standard deviation	4.47	4.12	3.19

- The third specimens.

Specimen Number	7 days	28 days	56 days
1	273	398	417
2	275	399	418
3	283	390	420
4	282	394	410
Average	278	395	416
Standard deviation	4.32	3.56	3.76

- **Slump tests**

The following tables indicate the slump of each cube made with a specific water quality either it was potable water or an effluent from Al-Bireh Wastewater Treatment plant, Al-Tireh Wastewater Treatment plant, and Al-Quds University Wastewater Treatment plant, respectively.

Each concrete mixture of each WWTP has three times interval water-quality with four fresh concrete specimens of each time to ensure an accurate slump tests.

I. The slump tests of Al-Bireh Wastewater Treatment plant concrete.

- The first specimens.

Specimen number	Slump Value
Al-Bireh WWTP 1	120
Al-Bireh WWTP 2	121
Al-Bireh WWTP 3	115
Al-Bireh WWTP 4	119
Average	119
Standard deviation	2.28

- The second specimens.

Specimen number	Slump value
Al-Bireh WWTP 1	120
Al-Bireh WWTP 2	120
Al-Bireh WWTP 3	119
Al-Bireh WWTP 4	119
Average	120
Standard deviation	0.54

- The third specimens.

Specimen number	Slump value
Al-Bireh WWTP 1	120
Al-Bireh WWTP 2	119
Al-Bireh WWTP 3	117
Al-Bireh WWTP 4	120
Average	119
Standard deviation	1.22

II. The slump tests of Al-Tireh Wastewater Treatment plant concrete.

- The first specimens.

Specimen number	Slump value
Al-Tireh WWTP 1	125
Al-Tireh WWTP 2	127
Al-Tireh WWTP 3	128
Al-Tireh WWTP 4	127
Average	127
Standard deviation	1.09

- The second specimens.

Specimen number	Slump value
Al-Tireh WWTP 1	125
Al-Tireh WWTP 2	126
Al-Tireh WWTP 3	128
Al-Tireh WWTP 4	128
Average	127
Standard deviation	1.30

- The third specimens.

Specimen number	Slump value
Al-Tireh WWTP 1	125
Al-Tireh WWTP 2	127
Al-Tireh WWTP 3	126
Al-Tireh WWTP 4	126
Average	126
Standard deviation	0.81

III. The slump tests of Al-Quds University Wastewater Treatment plant concrete.

- The first specimens.

Specimen number	Slump value
Al-Quds University WWTP 1	125
Al-Quds University WWTP 2	125
Al-Quds University WWTP 3	126
Al-Quds University WWTP 4	125
Average	125
Standard deviation	0.50

- The second specimens.

Specimen number	Slump value
Al-Quds University WWTP 1	125
Al-Quds University WWTP 2	125
Al-Quds University WWTP 3	125
Al-Quds University WWTP 4	126
Average	125
Standard deviation	0.50

- The third specimens.

Specimen number	Slump value
Al-Quds University WWTP 1	126
Al-Quds University WWTP 2	125
Al-Quds University WWTP 3	126
Al-Quds University WWTP 4	125
Average	126
Standard deviation	0.57

IV. The slump tests of the potable water concrete.

- The first specimens.

Specimen number	Slump value
Potable water 1	123
Potable water 2	122
Potable water 3	124
Potable water 4	123
Average	123
Standard deviation	0.81

- The second specimens.

Specimen number	Slump value
Potable water 1	124
Potable water 2	124
Potable water 3	123
Potable water 4	123
Average	124
Standard deviation	0.57

- The third specimens.

Specimen number	Slump value
Potable water 1	123
Potable water 2	123
Potable water 3	124
Potable water 4	123
Average	123
Standard deviation	0.50

- **The final setting time**

The following tables indicate the final setting times of the three interval fresh concrete mixture for either the potable water or an effluent from Al-Bireh Wastewater Treatment plant, Al-Tireh Wastewater Treatment plant, and Al-Quds University Wastewater Treatment plant, respectively.

I. Final setting time for Al-Bireh Wastewater Treatment Plant Concrete.

Specimen number	Final setting value
Al-Bireh water 1	8:30
Al-Bireh water 2	8:20
Al-Bireh water 3	8:20
Average	8:30
Standard deviation	0.004

II. Final setting time for Al-Tireh Wastewater Treatment Plant Concrete.

Specimen number	Final setting value
Al-Tireh water 1	8:50
Al-Tireh water 2	8:35
Al-Tireh water 3	8:35
Average	8:40
Standard deviation	0.006

III. Final setting time for Al-Quds University Wastewater Treatment Plant Concrete.

Specimen number	Final setting value
Al-Quds University water 1	8:33
Al-Quds University water 2	8:33
Al-Quds University water 3	8:40
Average	8:35
Standard deviation	0.040

IV. Final setting time for the potable water Concrete.

Specimen number	Final setting value
potable water 1	8:50
potable water 2	8:55
potable water 3	8:45
Average	8:50
Standard deviation	0.003

- Air Content.

The following tables indicate the air content of the three interval fresh concrete mixture for either the potable water or an effluent from Al-Bireh Wastewater Treatment plant, Al-Tireh Wastewater Treatment plant, and Al-Quds University Wastewater Treatment plant, respectively.

I. The Air content for Al-Bireh Wastewater Treatment Plant Concrete.

Specimen number	Air content value
Al-Bireh water 1	1:45
Al-Bireh water 2	1:55
Al-Bireh water 3	1:50
Average	1:50
Standard deviation	0.003

II. The Air content for Al-Tireh Wastewater Treatment Plant Concrete.

Specimen number	Air content value
Al-Tireh water 1	1:50
Al-Tireh water 2	1:35
Al-Tireh water 3	1:35
Average	1:40
Standard deviation	0.006

III. The Air content for Al-Quds University waste water Treatment Plant Concrete.

Specimen number	Air content value
Al-Quds University water 1	1:20
Al-Quds University water 2	1:20
Al-Quds University water 3	1:20
Average	1:20
Standard deviation	0.000

IV. The Air content for the potable water Concrete.

Specimen number	Air content value
potable water 1	1:30
potable water 2	1:20
potable water 3	1:40
Average	1:30
Standard deviation	0.100

- **The Specific Gravity**

The following tables indicate the Specific Gravity of the three interval fresh concrete mixture for either the potable water or an effluent from Al-Bireh Wastewater Treatment plant, Al-Tireh Wastewater Treatment plant, and Al-Quds University Wastewater Treatment plant, respectively.

I. The Specific Gravity for Al-Bireh Wastewater Treatment Plant Concrete.

Specimen number	Specific gravity
Al-Bireh water 1	2:40
Al-Bireh water 2	2:40
Al-Bireh water 3	2:40
Average	2:40
Standard deviation	0.000

II. The Specific Gravity for Al-Tireh Wastewater Treatment Plant Concrete.

Specimen number	Specific gravity
Al-Tireh water 1	2:40
Al-Tireh water 2	2:45
Al-Tireh water 3	2:40
Average	2:42
Standard deviation	0.002

III. The Specific Gravity for Al-Quds University Wastewater Treatment Plant Concrete.

Specimen number	Specific gravity
Al-Quds University water 1	2:41
Al-Quds University water 2	2:42
Al-Quds University water 3	2:40
Average	2:41
Standard deviation	0.000

IV. The Specific Gravity for potable water Concrete.

Specimen number	Specific gravity
potable water 1	2:50
potable water 2	2:35
potable water 3	2:40
Average	2:40
Standard deviation	0.005

- **The Initial setting time.**

The following tables indicate the initial setting time of the three interval fresh concrete mixture for either the potable water or an effluent from Al-Bireh Wastewater Treatment plant, Al-Tireh Wastewater Treatment plant, and Al-Quds University Wastewater Treatment plant, respectively.

I. Initial setting time for Al-Bireh Wastewater Treatment Plant Concrete.

Specimen number	initial setting value
Al-Bireh water 1	4:40
Al-Bireh water 2	4:55
Al-Bireh water 3	4:55
Average	4:50
Standard deviation	0.006

II. Initial setting time for Al-Tireh Wastewater Treatment Plant Concrete.

Specimen number	initial setting value
Al-Tireh water 1	5:00
Al-Tireh water 2	4:35
Al-Tireh water 3	5:35
Average	5:00
Standard deviation	0.020

III. Initial setting time for Al-Quds University Wastewater Treatment Plant Concrete.

Specimen number	initial setting value
Al-Quds University water 1	5:00
Al-Quds University water 2	6:00
Al-Quds University water 3	5:50
Average	5:50
Standard deviation	0.020

IV. Initial setting time for the potable water Concrete.

Specimen number	initial setting value
potable water 1	4:50
potable water 2	4:55
potable water 3	4:45
Average	4:50
Standard deviation	0.03

- **The Permeability**

The following tables indicate the initial setting time of the three interval fresh concrete mixture for either the potable water or an effluent from Al-Bireh Wastewater Treatment plant, Al-Tireh Wastewater Treatment plant, and Al-Quds University Wastewater Treatment plant, respectively.

I. The permeability for Al-Bireh Wastewater Treatment Plant Concrete.

Specimen number	Permeability value
Al-Bireh water 1	2
Al-Bireh water 2	3
Al-Bireh water 3	2
Average	2
Standard deviation	0.577

II. The permeability for Al-Tireh Wastewater Treatment Plant Concrete.

Specimen number	Permeability value
Al-Tireh water 1	2
Al-Tireh water 2	2
Al-Tireh water 3	2
Average	2
Standard deviation	0.000

III. The permeability for Al-Quds University Wastewater Treatment Plant Concrete.

Specimen number	Permeability value
Al-Quds University water 1	3
Al-Quds University water 2	2
Al-Quds University water 3	3
Average	3
Standard deviation	.577

IV. The permeability for the potable water Concrete.

Specimen number	Permeability value
potable water 1	3
potable water 2	3
potable water 3	3
Average	3
Standard deviation	0.000

Appendix 4
Concrete Tests
Phase 2

- **Compressive Tests:**

The following tables indicate the compressive strength of each cube made with a specific water quality either it was potable water or a secondary treated wastewater, tertiary treated wastewater, and the effluent of Al-Tireh Wastewater Treatment plant, respectively.

Each concrete mixture of each stage has three times interval quantity with four concrete cubes of each time to ensure an accurate compressive strength tests.

I. The compressive strength of concrete of the Secondary treated specimens -Al-Tireh waste water treatment plant.

- The first specimens.

Specimen Number	7 days	28 days	56 days
1	309	411	420
2	309	411	422
3	310	410	422
4	304	411	425
Average	308	411	422
Standard deviation	2.708	.500	2.061

- The second specimens.

Specimen Number	7 days	28 days	56 days
1	311	412	430
2	313	413	430
3	313	410	420
4	310	410	425
Average	312	411	426
Standard deviation	1.500	1.500	4.787

- The third specimens.

Specimen Number	7 days	28 days	56 days
1	311	409	418
2	311	411	426
3	312	410	430
4	313	400	430
Average	312	408	426
Standard deviation	0.957	5.066	5.656

II. The compressive strength of concrete of the tertiary treated specimens -Al-Tireh waste water treatment plant.

- The first specimens.

Specimen Number	7 days	28 days	56 days
1	289	394	409
2	290	394	408
3	290	392	408
4	288	390	409
Average	289	393	409
Standard deviation	.957	1.914	0.577

- The second specimens.

Specimen Number	7 days	28 days	56 days
1	290	390	408
2	288	394	408
3	289	395	409
4	290	391	408
Average	289	392	408
Standard deviation	.957	2.380	.5000

- The tertiary specimens.

Specimen Number	7 days	28 days	56 days
1	288	392	407
2	288	383	407
3	285	388	400
4	286	388	408
Average	287	388	406
Standard deviation	1.50	3.68	3.69

III. The compressive strength of concrete of the effluent specimens -Al-Tireh waste water treatment plant.

- The first specimens.

Specimen Number	7 days	28 days	56 days
1	276	390	400
2	280	390	382
3	279	392	406
4	281	395	402
Average	279	392	399
Standard deviation	1.87	2.04	9.20

- The second specimens.

Specimen Number	7 days	28 days	56 days
1	279	391	406
2	284	388	402
3	284	387	405
4	286	390	403
Average	283	389	404
Standard deviation	2.986	1.825	1.825

- The third specimens.

Specimen Number	7 days	28 days	56 days
1	286	390	403
2	284	388	402
3	284	389	401
4	281	388	406
Average	284	389	403
Standard deviation	2.061	.957	2.160

IV. The compressive strength of the potable water concrete.

- The first specimens.

Specimen Number	7 days	28 days	56 days
1	259	350	372
2	257	358	379
3	260	350	380
4	252	364	382
Average	257	356	378
Standard deviation	3.559	6.806	4.349

- The second specimens.

Specimen Number	7 days	28 days	56 days
1	261	355	370
2	256	358	378
3	259	364	380
4	259	360	380
Average	259	359	377
Standard deviation	2.061	3.774	4.760

- The third specimens.

Specimen Number	7 days	28 days	56 days
1	259	358	377
2	259	358	370
3	252	350	379
4	258	364	382
Average	257	358	377
Standard deviation	3.366	5.744	5.099

- **Slump tests**

The following tables indicate the slump of each cube made with a specific water quality either it was potable water or a secondary treated wastewater, tertiary treated wastewater, and the effluent of Al-Tireh Wastewater Treatment plant, respectively.

Each concrete mixture of each WWTP has three times interval water-quality with four fresh concrete specimens of each time to ensure an accurate slump tests.

I. The slump tests of the secondary treated wastewater concrete.

- The first specimens.

Specimen number	Slump value
secondary water 1	136
secondary water 2	137
secondary water 3	137
secondary water 4	137
Average	137
Standard deviation	0.500

- The second specimens.

Specimen number	Slump value
secondary water 1	137
secondary water 2	137
secondary water 3	137
secondary water 4	137
Average	137
Standard deviation	0.000

- The third specimens.

Specimen number	Slump value
secondary water 1	138
secondary water 2	138
secondary water 3	137
secondary water 4	137
Average	138
Standard deviation	0.577

II. The slump tests of the tertiary treated wastewater plant concrete.

- The first specimens.

Specimen number	Slump value
Tertiary water 1	133
Tertiary water 2	131
Tertiary water 3	131
Tertiary water 4	132
Average	132
Standard deviation	0.957

- The second specimens.

Specimen number	Slump value
Tertiary water 1	133
Tertiary water 2	131
Tertiary water 3	132
Tertiary water 4	132
Average	132
Standard deviation	0.816

- The third specimens.

Specimen number	Slump value
Tertiary water 1	132
Tertiary water 2	131
Tertiary water 3	131
Tertiary water 4	131
Average	131
Standard deviation	0.5000

III. The slump tests of the treated wastewater effluent concrete.

- The first specimens.

Specimen number	Slump value
Disinfection water 1	132
Disinfection water 2	132
Disinfection water 3	131
Disinfection water 4	132
Average	132
Standard deviation	0.5000

- The second specimens.

Specimen number	Slump value
Disinfection water 1	133
Disinfection water 2	132
Disinfection water 3	133
Disinfection water 4	133
Average	133
Standard deviation	0.5000

- The third specimens

Specimen number	Slump value
Disinfection water 1	132
Disinfection water 2	131
Disinfection water 3	131
Disinfection water 4	131
Average	131
Standard deviation	0.5000

IV. The slump tests of the potable water concrete.

- The first specimens.

Specimen number	Slump value
Potable water 1	124
Potable water 2	123
Potable water 3	123
Potable water 4	124
Average	124
Standard deviation	0.577

- The second specimens.

Specimen number	Slump value
Potable water 1	124
Potable water 2	124
Potable water 3	124
Potable water 4	121
Average	123
Standard deviation	1.500

- The third specimens.

Specimen number	Slump value
Potable water 1	123
Potable water 2	122
Potable water 3	124
Potable water 4	124
Average	123
Standard deviation	0.957

- **The final setting time.**

The following tables indicate the final setting times of the three interval fresh concrete mixture for either the potable water or a secondary treated wastewater, tertiary treated wastewater, and the effluent of Al-Tireh Wastewater Treatment plant, respectively.

I. Final setting time for the secondary treated mixing water Concrete.

Specimen number	Final setting value
Secondary water 1	10:0
Secondary water 2	9:30
Secondary water 3	9:00
Average	9:30
Standard deviation	0.020

II. Final setting time for the tertiary treated mixing water Concrete.

Specimen number	Final setting value
Tertiary water 1	9:00
Tertiary water 2	8:50
Tertiary water 3	9:20
Average	9:03
Standard deviation	0.010

III. Final setting time for the effluent mixing water Concrete.

Specimen number	Final setting value
Disinfection water 1	8:45
Disinfection water 2	8:45
Disinfection water 3	8:20
Average	8:35
Standard deviation	0.010

IV. Final setting time for the potable mixing water Concrete.

Specimen number	Final setting value
Potable water 1	8:50
Potable water 2	8:50
Potable water 3	8:50
Average	8:50
Standard deviation	0.000

- **Air Content.**

The following tables indicate the air content of the three interval fresh concrete mixture for either the potable water or a secondary treated wastewater, tertiary treated wastewater, and the effluent of Al-Tireh Wastewater Treatment plant, respectively.

I. The Air content for the secondary treated mixing water Concrete.

Specimen number	**Air Content**
Secondary water 1	1:05
Secondary water 2	1:10
Secondary water 3	1:15
Average	1:10
Standard deviation	0.003

II. The Air content for the tertiary treated mixing water Concrete.

Specimen number	**Air Content**
Tertiary water 1	1:10
Tertiary water 2	1:10
Tertiary water 3	1:10
Average	1:10
Standard deviation	0.000

III. The Air content for the effluent mixing water Concrete.

Specimen number	Final setting value
Disinfection water 1	1:45
Disinfection water 2	1:45
Disinfection water 3	1:35
Average	1:40
Standard deviation	0.004

IV. The Air content for the potable mixing water Concrete.

Specimen number	**Air Content**
Potable water 1	1:25
Potable water 2	1:30
Potable water 3	1:35
Average	1:30
Standard deviation	0.003

- **The Initial setting time.**

The following tables indicate the initial setting time of the three interval fresh concrete mixture for either the potable water or a secondary treated wastewater, tertiary treated wastewater, and the effluent of Al-Tireh Wastewater Treatment plant, respectively.

I. Initial setting time for the secondary treated wastewater mixing Concrete.

Specimen number	initial setting value
Secondary water 1	6:00
Secondary water 2	6:10
Secondary water 3	6:00
Average	6:00
Standard deviation	0.004

II. Initial setting time for the tertiary treated wastewater mixing Concrete.

Specimen number	initial setting value
Tertiary water 1	5:00
Tertiary water 2	5:20
Tertiary water 3	4:50
Average	5:00
Standard deviation	0.010

III. Initial setting time for the secondary treated wastewater mixing Concrete.

Specimen number	initial setting value
Disinfection water 1	4:45
Disinfection water 2	4:45
Disinfection water 3	4:35
Average	4:40
Standard deviation	0.004

IV. Initial setting time for the potable mixing water Concrete.

Specimen number	initial setting value
Potable water 1	4:50
Potable water 2	4:50
Potable water 3	4:50
Average	4:50
Standard deviation	0.000

- **The Specific Gravity**

The following tables indicate the Specific Gravity of the three interval fresh concrete mixture for either the potable water or a secondary treated wastewater, tertiary treated wastewater, and the effluent of Al-Tireh Wastewater Treatment plant, respectively.

I. The Specific Gravity for the secondary treated mixing wastewater Concrete.

Specimen number	Specific gravity
Secondary water 1	2:40
Secondary water 2	2:45
Secondary water 3	2:40
Average	2:42
Standard deviation	0.002

II. The Specific Gravity for the tertiary treated mixing wastewater Concrete.

Specimen number	Specific gravity
Tertiary water 1	2:40
Tertiary water 2	2:40
Tertiary water 3	2:45
Average	2:42
Standard deviation	0.002

III. The Specific Gravity for the effluent mixing wastewater Concrete.

Specimen number	Permeability
Disinfection water 1	2:43
Disinfection water 2	2:40
Disinfection water 3	2:40
Average	2:41
Standard deviation	0.001

IV. The Specific Gravity for the potable mixing water Concrete.

Specimen number	Specific gravity
Potable water 1	2:40
Potable water 2	2:35
Potable water 3	2:45
Average	2:40
Standard deviation	0.003

- **The Permeability**

The following tables indicate the permeability of the three interval fresh concrete mixture for either the potable water or a secondary treated wastewater, tertiary treated wastewater, and the effluent of Al-Tireh Wastewater Treatment plant, respectively.

I. The permeability for the secondary treated mixing wastewater Concrete.

Specimen number	Permeability value
Secondary water 1	1
Secondary water 2	1
Secondary water 3	1
Average	1
Standard deviation	0.000

II. The permeability for the tertiary treated mixing wastewater Concrete.

Specimen number	Permeability value
Tertiary water 1	2
Tertiary water 2	2
Tertiary water 3	3
Average	2
Standard deviation	0.577

III. The permeability for the effluent mixing wastewater Concrete.

Specimen number	Permeability value
Disinfection water 1	3
Disinfection water 2	2
Disinfection water 3	2
Average	2
Standard deviation	0.577

IV. The permeability for the potable mixing wastewater Concrete.

Specimen number	Permeability value
Potable water 1	3
Potable water 2	3
Potable water 3	2
Average	3
Standard deviation	0.577