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Graduates Studies and

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Water and Environment
Center (WEC)

Evaluation of WASH at Sana'a University as per IWRM Perspective

A thesis submitted in partial fulfillment of the requirements for the **Master Degree** in Integrated Water Resource Management

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تقييم المياه و الاصحاح البيئي بجامعة صنعاء من منظور الادارة المتكاملة للموارد المائيه

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Abstract

The IWRM is consider a key in achieving a sustainable improved WASH sector. Water supply and sanitation are among two of the most essential sectors of development which enhance the community water supplies and sanitation results in improved social, economic and health conditions. Girls and boys students are likely to be affected in different ways by inadequate Water, Sanitation and Hygiene (WASH) conditions in schools and universities, and this may contribute to unequal learning opportunities and may adversely affect the educational attainment rate. Due to the importance of the WASH sector in improving the community's level and standards, this master thesis will help to evaluate the WASH at Sana'a University, and assess the WASH infrastructure of the university which includes water resources and sanitation, the challenges that the university faces, and the required improvements.

A multi-disciplinary approach to reach the objective targeted in this thesis has been used, literature review: an intensive literature review has been conducted; questionnaires: a closed-ended questionnaire was developed adopting WHO and Sphere standards for emergencies situation to collect the required data from the beneficiaries; site observation: a checklist was developed to be used to acquire the required data and information from the fields and meet face-to-face with the key informants of each faculty of Sana'a university; field visit to the FAO waste water treatment plant to evaluated and recommended this plant for research and education purposes and data analysis: all the data and information from the questionnaire and site observation was collected and analyzed using Kobo Toolbox and Microsoft Excel 2016.

The finding of the thesis showed that the concept of the IWRM was missing technically, institutionally, legally, and environmentally which caused degradation of the WASH sector at the university. The university owns its WASH infrastructure that could meet the university needs from water, sanitation and hygiene if managed in an integrated way. The weak water and sanitation institution was caused by the lack of the communication between the university officials, lack of the human and financial resources; the water needs of the university were not meet. While the university owns five boreholes, the quality of these boreholes was not monitored. Only 27% of the university water needs are supplied by the water pipeline network that need to be inspected, while the minimum water need of the university are 687m^3/day as per sphere and 229 m^3/day as per WHO educational standards. There is an absence of the maintenance, which made the water physically contaminated. Only one third of the sanitation infrastructure (toilets and handwashing basins) of the university was functioning, while the other two thirds were closed or out of operation due to absence of the maintenance as mentioned before, while as per standards there must be 462 toilets for boys, 602 toilets for girls and 88 toilets for staff. On other hand the sewer network that solved a very big challenge for the university which was dependent on the cesspits previously. There isn't any types of hygiene campaigns or workshops within the university campuses at all which negatively reflecting to the health of the environment as a result of the irregular cleaning and poor solid waste management.

The recommendations were based on the findings to improve the WASH sector within the university as per IWRM perspective to establish a WASH sector department in each faculty, establish a purifying plant for drinking water, adopt rooftop rainwater harvesting techniques, inspect the existing water pipeline network to prepared it to function properly, construct a new block of *toilet*s outside each faculty, adopt FAO Yemen waste water treatment plant for education and research purposes, and conduct hygiene campaigns within the university to improve personal hygiene within the student and working staff of the university and build environment-friendly surrounding and encourage the researcher to conduct studies in WASH sector of Yemen, in addition to encourage the NGOs to support the university technically and financially .

الملخص

تعتبر الإدارة المتكاملة للموارد المائية عنصرًا رئيسيًا في تحقيق استدامة قطاع المياه والإصحاح البيئي و تعد المياه والصرف الصحي من بين اثنين من أهم قطاعات التنمية التي تعزز إمدادات المياه و خدمات الصرف الصحي مما يؤدي إلى تحسين خدمات و الظروف الاجتماعية والاقتصادية والصحية للمجتمع. من المحتمل أن يتأثر الطلاب و الطالبات بطرق مختلفة بسبب خدمات المياه والاصحاح البيئي غير الكافية في المدارس والجامعات ، وقد يساهم ذلك في فرص التعلم غير المتكافئة و الحضور المنخفض. نظرًا لأهمية قطاع المياه والإصحاح البيئي في تحسين مستوى المجتمع ، ستساعد هذه الأطروحة في تقييم المياه والإصحاح البيئي بجامعة صنعاء ، وتقييم البنية التحتية للمياه والصرف الصحي في الجامعة والتي تشمل موارد المياه والصرف الصحي ، والتحديات التي تواجهها و تبني الحلول اللازمة لذلك.

تم استخدام طرق متعددة لجمع البيانات للوصول إلى أهداف هذه الأطروحة ، من بينها مراجعة الأدبيات السابقة: تم مراجعة الأدبيات السابقة بشكل مكثف محليا و دوليا ؛ الاستبيانات: تم إعداد استبيان شبه مغلق بناءا على معايير منظمة الصحة العالمية وأسفير لجمع البيانات المطلوبة من المستفيدين - طلاب و طالبات وعاملين في الجامعة - النزول الميداني: تم إعداد قائمة تدقيق لاستخدامها للحصول على البيانات والمعلومات المطلوبة من موقع الدراسة والإلتقاء وجهاً لوجه مع المسؤولين الرئيسيين لكل كلية في جامعة صنعاء ؛ بالإضافة إلى زيارة ميدانية إلى محطة معالجة مياه الصرف الصحي التابعة لمنظمة الغذاء و الزراعة و تقييمها و توصية بها للابحاث و الاغراض التعليمه في الجامعة و أما بالنسبة لتحليل البيانات: تم جمع وتحليل جميع البيانات والمعلومات من الاستبيانات والنزول الميداني باستخدام برنامج الاكسل 2016 و تطبيق الكوبو.

أوضحت نتائج الأطروحة أن مفهوم الإدارة المتكاملة للموارد المائية مفقود من الناحية الفنية والمؤسسية والقانونية والبيئية مما تسبب في تردي قطاع المياه والإصحاح البيئي في الجامعة. تمتلك الجامعة بنية تحتية للمياه والصرف الصحي التي يمكن أن تلبي احتياجات الجامعة من خدمات المياه والصرف الصحي والنظافة الشخصية إذا تم إدارتها بالطريقة المتكاملة. سبب ضعف قطاع المياه والإصحاح البيئي هو قلة التواصل بين الجهات الرسمية في الجامعة ونقص الموارد البشرية والمالية. لم تلبى احتياجات الجامعة من المياه و التي هي بناءا للمعايير الأسفير 687 متر مكعب في اليوم و منظمة الصحة العالمية للجهات التعلمية 229 متر مكعب في اليوم . بينما تمتلك الجامعة خمسة آبار عميقة ، و كذلك لم تتم مراقبة جودة مياه هذه الآبار. حيث يتم توفير 27٪ فقط من احتياجات الجامعة من المياه من خلال شبكة أنابيب المياه التابعة للجامعة ويجب فحص هذه الشبكة لكي تتمكن من العمل بالشكل المطلوب بالإضافة إلى عدم وجود صيانة مما جعل مصادرالمياه تتلوث فيزيائيا. فقط ثلث البنية التحتية للصرف الصحي من المراحيض ومغاسل غسل اليدين بالجامعة تعمل بالشكل المطلوب ، بينما الثلثان الآخران مغلقان وغير قابلان للاستعمال بسبب عدم وجود الصيانة المنتظمة بينما احتياج الجامعة من الحمامات 462 حمام لطلاب و 602 حمام للطالبات و 88 حمام للموظفين. بينما شبكة الصرف الصحي حلت تحديًا كبيرًا جدًا للجامعة التي كانت تعتمد على نظام البيارات سابقا . لم تكن هناك أي نوع من حملات النظافة و التوعية بالنظافة الشخصية داخل حرم الجامعة على الإطلاق مما أثر ذلك سلبا الى تدهور بيئة الجامعة و كذلك خدمة النظافة غير المنتظمة وسوء إدارة المخلفات الصلبة.

بناء التوصيات وفقا للنتائج التي تم الحصول عليها لتحسين قطاع المياه والإصحاح البيئي للجامعة وفقًا لمنظور الإدارة المتكاملة للموارد المائية من بينها إنشاء قسم للمياه والاصحاح البيئي في كل كلية يعمل تحت إدارة الجامعة ، وإنشاء محطة لتنقية مياه الشرب ، واعتماد تقنيات حصاد مياه الأمطار من سطوح الكليات ، ومفاقدة الآبار وشبكة أنابيب المياه الحالية وترميمها لتعمل بالشكل الصحيح ، وبناء مرفق حمامات خارجية للكليات ، واقتراح محطة لمعالجة مياه الصرف الصحي بناءا على محطة تابعة لمنظمة الغذاء و الزراعة لأغراض التعليم والبحث و الاستفادة من مياهها في زراعة المسطحات الخضراء في الجامعة ، وإجراء حملات النظافة و التوعية داخل حرم الجامعة لتحسين مفهوم النظافة الشخصية و بناء محيط صديق للبيئة بالإضافة الى حث الباحثين للقيام بدراسة علمية في هذا المجال و حث المنظمات الإنسانية لتقديم الدعم المالي و الفني للجامعة .

List of Abbreviations

IWRM: Integrated Water Resource Management.

WASH: Water, Sanitation and Hygiene.

WSS: Water Supply and Sanitation.

WWTP: Wastewater Treatment Plant.

HP: Hygiene Promotion.

NWRA: National Water Resource Authority

SU: Sana'a University.

WEC: Water and Environment Center.

WHO: World Health Organization.

UNICEF: United Nation International Children's Emergency Fund.

UNDP: United Nation Development Program.

FAO: Food and Agriculture Organization of the United Nation.

SWSLC: Sana'a Water Supply and Sanitation Local Cooperation.

CSA: Central Statistical Authority.

NCI: National Center of Information.

MDGs: Millennium Development Goals.

SDGs: Sustainable Development Goals.

NGOs: Non-government Organization.

INGOs: International Non-government Organization.

GWP: Global Water Program.

BOD: Biological Oxygen Demand.

COD: Chemical Oxygen Demand.

MCA: Multi-Certira Analysis

Kobo Toolbox: Data Collection and Analysis Tool

Table of Contents

Lists of Figures:

Chapter (1)

Introduction

1.1 Background

The concept of integrated water resources management (IWRM), in which the various uses of finite water resources are recognized as being interdependent, should be applied during the planning and implementation process of water resource management. Adopting the IWRM approach will help avoid quality degradation, enhance the water supply systems, and provide adequate sanitation services and hygiene (Al-Sakkaf 2006).

The lack of safe drinking water and poor sanitation practices are the leading causes of poor health in many developing countries. It is reported that thousands of deaths could be prevented annually by providing access to safe water for half the population currently without such access. Studies undertaken in developing countries have shown that the provision of safe drinking water and sanitation contributes to a significant reduction in the incidence of people mortality and diseases, such as ascariasis, diarrhea, schistosomiasis, and trachoma among the population (Sam 2011). In addition, access to potable water, basic sanitation, and good hygiene habits are principal factors involved in reducing the incidence of illness among the people and the community (BORGES, et al. 2018).

1-1-1 Integrated Water Resources Management (IWRM)

The integrated water resources management (IWRM) is “a process that promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (GWP, 2011).

The IWRM concept was established upon four guiding principles which were formulated during the International Conference on Water and Environment in Dublin in 1992 (GWP 2011, Meyer 2013).

Principle 1: Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.

Principle 2: Water development and management should be based on a participatory approach, involving users, planners, and policy-makers at all levels.

Principle 3: Women play a central part in the provision, management, and safeguarding of water.

Principle 4: Water is a public good and has social and economic value in all its competing uses.

(Suchorski, 2007; Biswas, 2008; Meyer, 2013; Taher et al 2013) discussed the concept of IWRM as following:

With such surpassing management complications, many of the water professionals started to seek a new paradigm for management, which would solve the existing and the expected problems in several parts of the world. However, the solution that was chosen and which became popular was not modern. It was the rediscovery of a concept more than 60 years old which could not be successfully implemented previously: integrated water resources management (IWRM). Many who discovered this concept were not aware that the new concept wasn't new, but had been around for several decades with a dubious implementation record, which had never been objectively, comprehensively and critically assessed.

This management tool considers that all uses are met and equipoised in the most sustainable manner possible without compromising particular functions of water at the stake of others. IWRM is also important due to the bounded nature of freshwater and the increasing pressure that the population is placing on this indispensable resource. Globally, we are in the middle of facing a water catastrophe that will rise unless changes are made in the current time.

In Yemen, the fragmented and sub-sectoral approaches have led to uncoordinated management of the limited water resources, each focusing on diverse water uses. Water goals were inappropriate to address the increased use and misuse of freshwater systems linked to the rapid social change. Freshwater is vital for sustaining life, promoting development, and maintaining the environment and here comes the importance of IWRM as a management system. The IWRM will systematically lead to avoiding fragmented approaches and will aim IWRM at Sana'a basin as follows:

(i) Equilibrating the use of available groundwater resources for different users in order to satisfy sustainable conditions of groundwater abstraction and reinforcing and enabling community involvement and participation.

(ii) Building up the legal and institutional framework required for sustainable water resources management in the Basin and improving the mechanisms to achieve financial sustainability.

(iii) Enabling the roles of women in most, if not all, parts of the management of water resources according to the cultural and social aspects.

The IWRM processes do not necessarily require making all these changes at once, nor do they imply starting in a broad-based manner (ESCWA, 2005A).

1-1-2 Water Sanitation and Hygiene (WASH)

Water supply and sanitation are among two of the most essential sectors of development (Bendahmane 1993). Enhancement of community water supplies and sanitation results in improved social and economic conditions and improved health (Davis et al. 1993). The advantages of safe water supply and sanitation are many, including prevention of disease, improved basic health care, better nutrition, increased access to institutions such as health centers and schools, better water quality, increased quantity of and access to water, saving of the time and effort required for water collection, promotion of economic activity, strengthening of community organization, improvements in housing, and ultimately, improved quality of life (Okun 1988). At the commencement of 2000, 1/6 (1.1 billion people) of the global population did not have access to improved water supply and two-fifths (2.4

billion people) did not have access to improved sanitation (UNICEF 2018a). The majority of these people lives in Asia and Africa. Africa has the lowermost water supply coverage among the global regions (Africa, Asia, Latin America and the Caribbean, Oceania, Europe, and North America) and is second to Asia in terms of lowest sanitation coverage. Now, 62% of the African population have access to improved water supply and 60% have access to improved sanitation, but the situation is worse in rural areas—only 47% of the villages or rural population have access to improved water supply and 45% have access to improved sanitation (Telmo 2002) (UNICEF 2018b).

At any given time, close to ½ of the people in the developing world are suffering from one or more of the main diseases associated with inadequate provision of safe water and sanitation, such as diarrhea, guinea worm, trachoma and schistosomiasis (UNDP, 2006). Diarrhea is one of the leading diseases that cause death and illness, killing 1.8 million people and causing approximately 4 billion cases of illness every year. Ninety percent of diarrheal deaths are children under the age of five, mostly in developing countries (UN-Water, 2009)(Center of Affordable 2011).

The Millennium Development Goals (MDGs) were developed in the United Nations Millennium Summit in 2000. The eight MDGs were international development goals that United Nations member states dedicated to achieving. Goal 7 was to ensure environmental sustainability targeted to halve the proportion of the population without sustainable access to safe drinking water and basic sanitation. Joint Monitoring Programme definitions of improved and unimproved drinking water and sanitation, 2000-2015 (Morrison 2016).

The Sustainable Development Goals (SDGs) adopted by 193 Member States at the UN General Assembly in 2015 aim to substantially improve water and sanitation globally and include two specific targets within Goal 6 for drinking water, sanitation and hygiene (Wolf et al. 2018):

- 6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all.
- 6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end

open defecation, paying special attention to the needs of women, girls and those in vulnerable situations.

Achieving the SDG and WASH objectives will be challenging. In 2015, only 68% of the world population used improved sanitation, meaning that 2.4 billion people still needed simple sanitation facilities like pit latrines and septic tanks(Wolf et al. 2018). Though 91% of the world population used improved drinking water sources in 2015, 663 million people still used unimproved sources such as insecure springs, wells, and surface water (Wolf et al. 2018).

1- 2 Problem Statement

Sana'a University is considered the pillar of the education sector in the Republic of Yemen thousands of students around —27,741 male students and 18,052 female students (SU 2018) including both postgraduates and undergraduates study there to acquire different education degrees. However, since the commencement of the ongoing crisis in March 2015, the university has been degraded, as there is no proper maintenance for its infrastructure, especially water and sanitation. There is a lack of sufficient amounts of water and adequate sanitation facilities in most of the faculties and sections of the university. Furthermore, no attention is given to the university's surrounding environment. Water availability, adequate sanitation facilities, and proper hygiene practice is a basic need for every individual studying or working in the university, in other words, we can say that there is an absence of the WASH program at the university. This study will be very useful for the university's WASH sector improvement in the future.

1-3 Objectives:

The main objective of the thesis is:

Evaluation of the WASH at Sana'a University as per the IWRM perspective.

The sub-objectives:

In order to achieve the above-mentioned objective, the following sub-objectives have been intended:

- To assess the water supply, sanitation and hygiene facilities and infrastructure at university faculties.
- To determine beneficiaries' access to WASH facilities.
- To recommend necessary solutions to improve the WASH sector as per the IWRM for students and staff.
- To suggest and adopt a pilot Sanitation as per FAO – Yemen for Students educational and research purposes.

1-4 The Research Questions:

In order to achieve the above objectives, the following questions must be answered:

- What are the problems and challenges that face the water supply, sanitation and hygiene facilities?
- What are the requirements to improve the water supply, sanitation and hygiene facilities?
- To what extent are the Yemeni WASH standards meet within the university campus?
- What are the recommended solutions to improve the WASH program?

1-5 The Study Area

The university was established in 1970 as the first and primary university in the Yemen Arab Republic. When Sana'a University was first established, it had two faculties: the Faculty of Sharia and Law and the Faculty of Education which also included the specialties of Colleges of Arts, Sciences and Education. In 1974, those specialties were developed and three new faculties were formed: Arts, Science, and Education. The Faculty of Sharia and Law celebrated the launch of the Business Department which became an independent faculty a year later. By that time, the university included five faculties, and it continued expanding until it included the rest of the specialties. In 2000, the university included 17 faculties, including all types of academic specialties, ten of which were in Sana'a; the rest were spread around the country.

1-5-1 Location

Sana'a University is located at the center of Sana'a city within the Al-Ma'ain district where there are residential areas. The city has undergone many heavy airstrikes and bombardments during the ongoing crisis which began in March 2015, and the infrastructures were damaged very rapidly, especially the water and sanitation infrastructure. The center of university located at 15°20′53.16″N 44°11′26.83″E,. (NCI 2018). See Figure (1-1)

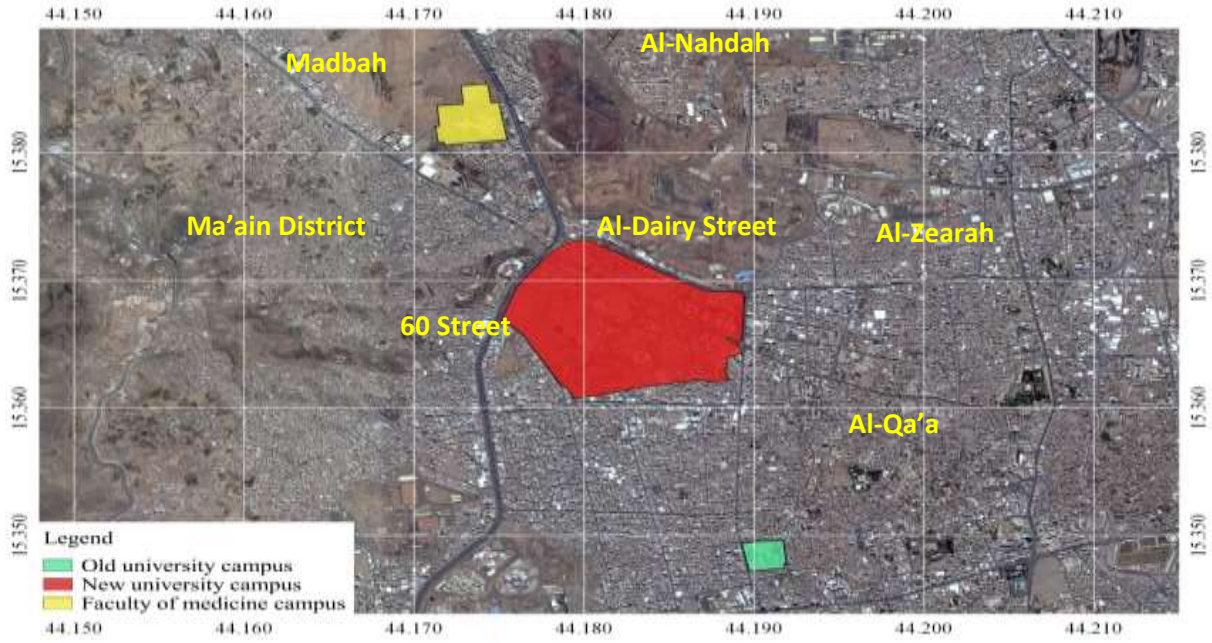


Figure (1-1): Study Area

1-5-2 Area and Land Use

The estimated area of Sana'a University's three campuses was estimated to be more than one Km^2 based on Google Earth measuremnt. Most of the area was allocated to administrative buildings such as faculties, centers, and administrative blocks, whereas the remaining area was kept vacant without any utilization of the land.

1-5-3 Population

Sana'a University is considered to be the pillar of the high education sector in the Republic of Yemen as almost 47,548 students and staff where, 27,741 of which are male and 18,057 of which are female approximately who study there to acquire different education degrees including both undergraduate and postgraduate degrees, in addition, 1750 administrative and academic working staff work at the university, the number of the student may be more than mentioned as the students in some of the faculties attended on alternative basis not at same time (SU 2018).

1-5-4 Climate and Rainfall

As the Sana'a University is located within the city, the average summer temperature is about 25° C, and the average winter temperature is around 15° C (NCI 2018), the rain fall is moderate between the month of March and April, whereas , the rainfall is a little bit higher between the months of August – October. The average rainfall in Sana'a city is estimated to be 200 mm. (NCI 2018).

Chapter (2)

Literature Review

This chapter provides details of the literature that has been published in international journals, books, reports and locally executive reports of the INGOs in WASH sector in Yemen and around the world and used in this thesis as references.

2-1 Water

Water is life. Every human being, now and in the future, should have enough clean water for drinking and sanitation and enough food and energy at a reasonable cost. Supplying suitable water to meet these basic needs must be done in an equitable manner that works in harmony with nature. For water is the foundation for all living ecosystems and habitats and part of an immutable hydrological cycle that must be respected if the development of human activity and well-being is to be sustainable (UNICEF 2018b).

The greatest obvious uses of water for people are drinking, cooking, bathing, cleaning, and— for some—watering family food plots. This residential water use, though crucial, is only a small part of the total water use.

2-2 Sanitation

Sanitation is a system of interventions used to reduce human exposure to disease by creating a clean living environment and instituting measures to break the cycle of disease. These interventions usually involve hygienically managing human and animal excreta, solid waste, and wastewater, controlling disease vectors, and providing washing facilities for personal and domestic hygiene. Environmental sanitation requires that both behaviors and facilities work together to form a hygienic environment (Center of Affordable, water and sanitation technology 2011).

Selection of Appropriate Sanitation Options:

Many people simply want to be told which technology or solution is the best or most effective. Unfortunately, because there are so many factors to consider, there is no easy formula that will answer this question. The best ought to be determined by a number of factors (Center of Affordable 2011) including the following:

- Socio-cultural acceptability
- Physical, environmental and technical acceptability
- Political and regulatory acceptability
- Stakeholder acceptability

2-3 Hygiene Promotion

Hygiene promotion is a planned approach to preventing diarrhea and other WASH-borne diseases through the widespread adoption of safe hygiene practices. It begins with and is built on what local people know, do and want (Corps 2009).

The purpose of hygiene promotion is to prevent the spread of water and sanitation-related diseases by the adoption of safe hygiene practices. Hygiene promotion should have a measurable impact on the target population. In general, a small number of hygiene-related behaviors – the ones with the biggest overall health impact – should be identified and targeted. Several studies have indicated that the element of WASH projects that contribute most to a reduction of diarrhea is not an improvement in water quality or water quantity but is actually an improvement in handwashing practices (Cross 2014).

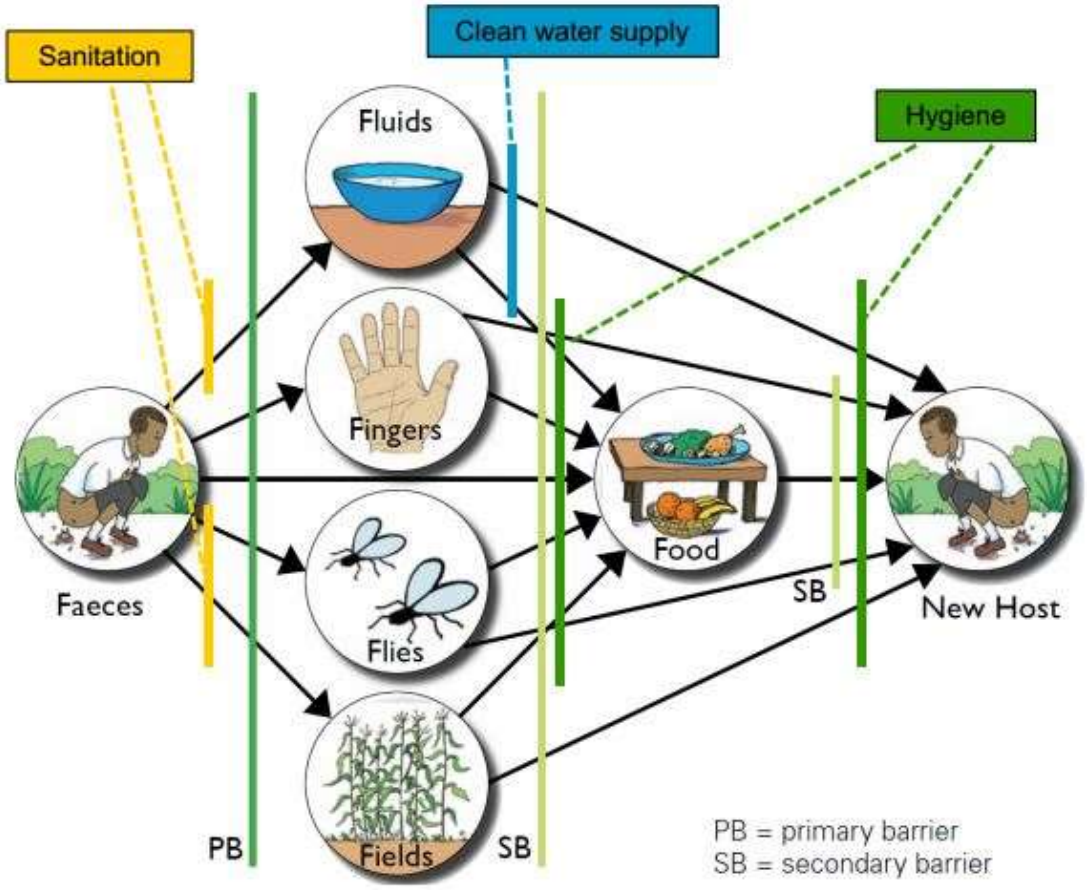


Figure (2-1): The F-Diagram transmission and protective barriers (Cross 2014)

Handwashing with soap is the most effective way to avoid diarrheal diseases and has the highest impact on improved health status. Handwashing is considered a central element of community hygiene where people bring home new habits and teach their family members and peers. Making the difference between clean and dirty hands visible to others has a lasting impact (Cross 2014) as shown in the (Figure 2-1) the barriers the protect the human health from the diseases transmission that start from hands.

2-4 Water, Sanitation and Hygiene (WASH) in Schools and Educational Institutes

WASH in schools and educational institutes not only promotes hygiene and increases access to quality education but also supports national and local interventions to establish equitable, sustainable access to safe water and adequate sanitation services in schools (UNICEF 2018b,WHO 2007).

WASH in schools and educational institutes aims to improve the health and learning performance of school-aged children, by extension, that of their families – by declining the incidence of water and sanitation-related diseases. Every child-friendly school and educational institute requires appropriate WASH initiatives that keep the school environments clean and free of smells and inhibit the transmission of harmful bacteria, viruses and parasites(UNICEF 2018b,WHO 2007).

WASH in schools and educational institutes also focuses on the development of life skills and the mobilization and involvement of parents, communities, governments, and institutions to work together as one hand to develop hygiene, water, and sanitation conditions. While there are many approaches based on differing cultural insights and environmental and social realities, any Water, Sanitation and Hygiene (WASH) intervention in schools should include (UNICEF 2018b,WHO 2007):

- Safe water supply facilities, handwashing stands, and sanitation facilities.
- Fully integrated life skills education, focusing on key hygiene behaviors for schoolchildren
- Participatory teaching techniques.

A competently and effectively implemented WASH in schools programme will lead to students who (UNICEF 2018b,(WHO 2007):

- Are healthier.
- Perform better in school.
- Positively influence hygiene practices in their homes, among family members, and in the wider community.
- Monitor, communicate, cooperate, pay attention and carry out decisions about hygienic conditions and practices for themselves, their friends and younger siblings whose hygiene they may care for (skills they may apply in other aspects of life).
- Change their current hygiene behavior and continue better hygiene practices in the future.

- Study about female menstrual hygiene and physical and emotional behavior changes during puberty (learning to avoid menstrual odor, discomfort and urinary or vaginal infections will encourage girls to come to school during menstruation).

Girls and boys students are likely to be affected in different ways by inadequate water, sanitation and hygiene conditions in schools and universities, and this may contribute to unequal learning opportunities. For example, lack of adequate, separate and secure toilets and washing facilities may discourage parents from sending girls to school, and lack of adequate facilities for menstrual hygiene can contribute to girl students missing days at school or dropping out altogether at puberty (WHO 2007).

2-5 The Situation of WASH in Yemen

Yemen is considered as the world's most water-scarce country. The conflict in Yemen has made matters worse, particularly for the communities that depend on clean drinking water and adequate sanitation for good health and survival (UNICEF 2018).

After four years of bombarding and ground fighting, as well as fuel unavailability experienced by local water corporations and soaring costs of commercial, the water trucking become the main source of water; millions of people do not have access to clean water and sanitation. Of these, 50% have been directly cut off from these basics of life by the crisis (UNICEF 2018).

The WASH sector in Yemen is facing serious challenges including water scarcity, high population growth, urbanization, insufficient funds, and lack of technical capacity (GLAAS 2015). Moreover, only 55% of the population has safe water to use, whereas only 53% of the population has access to adequate sanitation services (SWSLC 2010).

WASH plays a major role in emergency situations – including natural disasters, conflicts and disease outbreaks – which are occurring at increasing rates and affecting a growing number of people. Currently, more than a billion people are potentially threatened by conflict and violence around the

world (YATES, et al. 2018). Moreover, in areas of crisis, such as our situation, lack of sufficient water, sanitation and hygiene facilities typically lead to more deaths than any other cause. With this in mind, all schools, universities and educational facilities should have adequate water, sanitation and hygiene facilities to ensure the health of their students and staff. So, the WASH program is very important aspect in Sana'a University to maintain a better environment and good health of the students and staff studying, teaching and living there.

2-6 Studies Conducted Globally

Morgan Pommells et al. studied "The Gender Violence as a Water, Sanitation, and Hygiene Risk: Uncovering Violence against Women and Girls" as it pertains to poor WASH access. The purpose was to better understand the gender violence risks that exist in communities where poor WASH access is a known problem. The data was collected by focus group and key informant interviews The results shed light on the complex intersections between water access and violence and have significant implications for achieving gender equity and universal access to WASH (Pommells et al. 2018).

Kelly T. Alexander et al. argued "Do Water, Sanitation and Hygiene Conditions in Primary Schools Consistently Support Schoolgirls Menstrual Needs?" A Longitudinal Study in Rural Western Kenya, where the data was gathered through observation and teachers reports, they concluded that the advances in WASH conditions for all students, and menstrual hygiene facilities for schoolgirls, needs further support, a defined budget, and regular monitoring of WASH facilities to maintain standards (Alexander et al. 2018).

Travis Yates and et al conducted a study named "Efficacy and effectiveness of water, sanitation, and hygiene interventions in emergencies in low- and middle-income countries: a systematic review" in which hundreds of literature were reviewed. They found that WASH interventions consistently reduced both the risk of disease and transmission in emergency contexts; however, programme design

and beneficiary preferences were important considerations to ensure WASH intervention efficacy and effectiveness (Yates et al. 2018).

João Paulo et al. studied the "Assessment of WASH scenarios in urban and rural schools of a small city in the Brazilian Amazon" and found that all schools presented water contamination with total coliforms and did not conduct any type of water treatment. The number of toilets in all schools was insufficient. The presence of flies was observed as well as the accumulation of rubbish in the schools. Information was assembled from a field survey by questionnaire and checklist (Borges-pedro et al. 2018).

Caroline Fernandes et al deliberated "the Evaluation of WASH Implementation in Nama Sub-County, Uganda". The aim of the study was to find the effectiveness of WASH programs in villages compared to control villages that meet the entire WASH requirement. This was measured using tests and Pearson Correlation Coefficients (R) (Fernandes et al. 2017).

Prince Antwi-Agyei et al. conducted a study titled "Water, sanitation and hygiene (WASH) in schools: results from a process evaluation of the National Sanitation Campaign in Tanzania". The study assessed the improvements made in sustainable WASH in terms of access to WASH facilities and the presence of an enabling environment that can contribute to better health and quality education in primary schools in Tanzania (Antwi-agyei et al. 2017).

Roland S. Kabange determined the low-cost sanitation technology options for low-income and high-density peri-urban communities in developing countries. He concluded that the achievements of the Sustainable Development Goals (SDGs) on sanitation coverage can only be a reality if focus and attention are given to simple but cost-effective proper sanitation technologies options with low water requirements (Kabange 2017).

Alexandra Morrison evaluated the World Vision Water, Sanitation, and Hygiene (WASH) Project in Tanna, Vanuatu. The aim of the study was to reduce child malnutrition with short- and medium-term

objectives to increase WASH infrastructure and improve caregiver WASH and nutrition knowledge and practices. The data were collected through a survey, site observation, and quality test of the water source. The study achieved most of its short- and medium-term objectives to improve WASH and nutrition infrastructure, knowledge, and practices (Morrison 2016).

Yousef Saleh Khader studied the water, sanitation, and hygiene in Jordan's healthcare facilities. The aim of the study was to determine healthcare WASH service availability and readiness and healthcare waste management services in Jordan's healthcare facilities. The data gathered through assessment tool, site observation and key informant interview of the targeted hospital (Khader 2016).

Tania Jordanova et al. studied the Water, Sanitation, and Hygiene In Schools in Low Socio-Economic Regions in Nicaragua: A Cross-Sectional Survey. The objectives were to assess WASH conditions in schools and to determine possible solutions for improving conditions and informing future planning, programs, and research. It was concluded that students need adequate and safe WASH in schools to maximize health and educational outcomes (Jordanova et al. 2015).

Leslie Deroo, Elynn Walter and Jay Graham monitored and evaluated the WASH in schools programs: lessons from implementing organizations. The aim was to characterize how implementers and donors conduct M&E with the goal of identifying trends in the sector and providing recommendations to improve the effectiveness and sustained impact of these programs (Graham 2015).

Ryan Cronk, Tom Slaymaker, and Jamie Bartram conducted a review for drinking water, sanitation, and hygiene in non-household settings: Priorities for policy and practice. The aim was to review WASH in non-household settings, develop a typology of settings and assess the viability of monitoring by examining the evidence, international standards, national and international actors, and available monitoring initiatives (R. Cronk, Slaymaker, and Bartram 2015).

Eva Estevan Rodriguez conducted a study titled"Study of the applicability of low-cost wastewater treatment effluents for the urban agricultural plots of Bhubaneswar city, Odisha (India)", to find low-cost wastewater treatment technologies for agricultural use. The selection was made by a scoring multi-criteria evaluation process (MCA) of the collected data (Estevan et al. 2014).

Daniela Giardina, Fausta Prandini and Sabrina Sorlini studied the integrated assessment of the water, sanitation and hygiene situation in Haitian schools in the time of emergency. The data were collected by participatory assessment and formal survey. The objectives of the study were to carry out an integrated assessment of 42 schools in the West Department and provide some suggestions came from a programmatic point of view for a more sustainable recovery phase. The major constraints to improving the water, sanitation, and hygiene services were found to be related to lack of funding and infrastructure losses after the earthquake (Giardina, Prandini, and Sorlini 2013).

Ryan Cronk demonstrate the Drinking-Water, Sanitation, and Hygiene Beyond the Household: A Global Review and Situational Assessment of Ghana found there was limited evidence describing benefits of WASH or the impact of poor WASH conditions in most settings through systemtic review of the literatures (R. D. Cronk 2013).

David O. Olukanni conducted a research titled "Assessment of WASH Program in Public Secondary Schools in Western Africa ". The study revealed that the present WASH practice in many of the schools is not adequate through evaluation of the UNICEF WASH standards assessment tools (Olukanni 2013).

Josephine-Mary conducted a study titled "How Does Improved Access to Clean Water Impact the Rural Communities in the Ajumako-Enyan-Essiam District of Ghana". The findings showed that improved access to clean water enhanced economic opportunities for women's and children's education in both villages (Olukanni 2013).

Colin M. Casey conducted the study “An Assessment of the Water and Sanitation Infrastructure at Primary Schools in Rakai District, Uganda”. Researchers were specifically interested in learning which technologies were being used and why they were or were not effective. The data collected by as assessment tool (Casey 2012).

Katharina Gerlinde Aspalter determined the WASH safety plans and their application in rural growth centers in Uganda. The aim of the research was to manage water supply and sanitation on a regional level by water supply and sanitation boards (Aspalter 2012).

A case study conducted by Sulaiman Issah-Bello titled “An Assessment of Sustainability of Water and Sanitation Interventions in Northern Region: A case study of Nanumba North District”. The data collected through questionnaire, key informant interview and site observation. The aim was to assess the sustainability of water and sanitation. The study found the more difficult technology was to use, the more difficult adoption would be by the beneficiaries (Issah-Bello 2011).

Fatuma Nanserkeo evaluated “The Adequacy and Utilization of Sanitation Facilities in Secondary Schools in Mpigi District”. The aims were to find out the different kinds of sanitation facilities, assess the adequacy of sanitation facilities, assess the utilization of sanitation facilities and examine students’ awareness of the consequences of poor sanitation. The data collected through depth interview, focused group discussion and site observation. The conclusion was that the cleanliness of the available sanitation facilities was not at its best, and this forms part of the reason why some of the students ignore using the facilities, choosing, instead, the use of bushes around the schools (NANSEREKO 2010).

Andrea C. Telmo conduct a study with the objective of the study was to assess the water supply and sanitation situation in the village of Gouansolo, Mali in West Africa. This study found that the most common water supply problems reported were erosion at the top and bottom of traditional hand-dug

wells and seasonal availability of water in these wells. The most common sanitation problem reported was the deterioration of latrine floors, all the data were collected by survey (Telmo 2002).

John Butterworth and John Soussan determined the water supply and sanitation & Integrated Water Resources Management: why seek better integration. The paper examines the role of water supply and sanitation in livelihoods, and the importance of addressing water supply and sanitation (WSS) in poverty-focused programs (Butterworth and Soussan 2001).

Mustafa Sikder et al. analyzed the data collected in southern Syria to identify effective WASH response activities for this context and found that the market forces to manage WASH services, quantity, and targeting emergency response activities on increasing affordability with well-targeted subsidies and improving water quality and regulation via WSPs can be an effective, scalable, and cost-effective strategy to guarantee water and sanitation access in protracted emergencies with local markets the required data were gathered through a household survey (Sikder M et al 2018) .

2-7 Studies Conducted in Yemen

In Yemen, there were no such studies that are related to WASH at the household level nor educational or health care facilities. All the reports are either NGOs or INGOs executive reports of the cities or country's WASH situation and status. Such of these reports are:

The Unicef report for the month of October 2018 highlighted that the number of people having access to drinking water is about 4,500,000 capita and the number of people with access to adequate sanitation (through emergency latrine construction or rehabilitation) is about 481,000 during the emergency. The Unicef Executive director, mentioned: "millions of desperate children and families across Yemen could soon be without food, clean water or sanitation services because of the deepening economic crisis and unrelenting violence in the port city of Al Hudaydah." (UNICEF 2018c)

The Unicef report for the month of November mentioned that WASH needs remain high all over the country. Public water and sanitation systems need increased support to provide the minimum level of

services and avoid collapse. Sanitation and wastewater treatment services are overwhelmed: an estimated 46 % of urban populations are connected to moderately functioning public water networks, whilst the lack of electricity or revenues creates significant reliance on humanitarian support.

The humanitarian response plan for 2017 and 2018 has determined three objectives to be achieved for the WASH sector in Yemen. Those objectives are to (Yemen 2018)(Cluster 2017):

- Maintain sustainable water and sanitation systems to improve public health and resilience.
- Provide emergency and lifesaving WASH assistance to the most vulnerable so as to reduce excess morbidity and mortality.
- Ensure sufficient sectoral and inter-sectoral coordination and capacity to respond at the national and sub-national levels.

The humanitarian response plan for 2019 committed to undertake everything possible during 2019 to assist civilians in Yemen survive violence, secure food and receive the nutrition, health, WASH, shelter, education and protection support they are entitled to under international humanitarian and human rights law. For the WASH cluster, they have highlighted the following objectives (Cluster 2019):

- Provide emergency water sanitation and hygiene services and assistance to highly vulnerable people.
- Restore and maintain sustainable water and sanitation systems, particularly in high-risk areas.

There was a study conducted by the water and environment center in Sana'a University with the collaboration of Meta Meta (a Netherland research company) titled "The Humanitarian Aspects of WASH in Yemen" which mentioned that the public water and sanitation systems are hanging by a string. Water infrastructure is repeatedly targeted and damaged by parties to the conflict, and internally displaced people are struggling to find sufficient safe drinking water, sanitation, and hygiene services. The aim of the study was to help the donors reserve fund for improving and

restoring the country's WASH inventory. This includes rehabilitating WASH projects and replacing and repairing existing WASH works. Also, the following four objectives were defined (Center 2017):

- Assess damage/impact scientifically and prioritize the most affected and vulnerable.
- Assess the urgent needs for recovering.
- Seek to mitigate the devastating impact of war on Yemen's most vulnerable through reasonable, possible, sustainable, and innovative responses to reduce the impact through the increase of people (men and women, boys and girls) to be reached by any future humanitarian assistance.
- Ensure the proposed action supports resilience and sustainable recovery.

There was a study conducted by the NOGs and INGOs titled "Water, Sanitation and Hygiene Assessment in Yemen" as the ongoing crisis which started in March 2015 deeply affected the humanitarian situation in the country. Results show that nearly half of respondents (48%) rely on unimproved sources for drinking water which requires more than 30 minutes for fetching of the water. Access to improved latrines decreased from 71% in 2006 to 53% in 2012, and open defecation has been spread widely all over the country. The solid waste also has been affected as a result of the crisis. In terms of hygiene, the minority of respondents said they wash their hands at all five critical times (Cluster and REACH 2018).

Chapter (3)

Methodology

This chapter presents the thesis approach used in this study, the quantitative method, data collection, and data analysis methods

The methodology adopted in this thesis was a quantitative approach, Quantitative data is an information about quantities, and therefore numbers and statistics, while qualitative data is descriptive, and regards phenomenon which can be observed but not measured. Quantitative research gathers data in a numerical form which can be put into categories, or in rank order, or measured in units of measurement (MNISI 2011).

The purpose of using closed-ended questionnaires in this study was to:

- Quantify data and generalize results from a sample of the population of interest.
- Measure the incidence of various views and opinions in a chosen sample.
- Collect sample data from a large population.
- Collect numerical data for data representation and process.

3-1 The Conceptual Framework

The conceptual framework of this thesis was based on the application of the IWRM concept, and water, sanitation, and hygiene should be linked to integrated water resources management (IWRM). First, since water quality/quantity for WASH is dependent on water resources management and secondly because sanitation service waste can pollute water resources. Correlating WASH and IWRM is needed to ensure sustainable WASH services. WASH/IWRM linkages are an integral part of Sustainable Development Goal 6 (SDG6) (van der Male 2017). Linkages from a "narrow" problem-based perspective seem most feasible but they can also be addressed within a wider, holistic catchment or landscape approach.

Achieving Sustainable Development Goal 6 (SDG 6) will require closer links between water, sanitation, and hygiene (WASH) and integrated water resources management (IWRM) as they depend on each other. To ensure a sustainable supply of good drinking water quality for all, water sources should be properly managed with adequate sanitation practice in addition to the proper method of hygiene (Kobusingye 2018).

One practice can constrain others by limiting access to not only adequate amounts of water but also to safe water, adequate sanitation, and hygiene. All water consumers are potential polluters, adding substances to water that make it unfit for further use. Therefore, a well-coordinated and regulated framework is necessary for sustainable water resources management. As such, integration is the central concept of IWRM, entailing the challenge of coordinating among various government, academic, industrial and civil society stakeholders.

It is very important to search for the IWRM concept within the WASH sector as IWRM's goals focus on delivering economic efficiency, social equity, and environmental sustainability. In addition, it's based on the sustainable quantitative and qualitative management of the interacting components – surface waters, aquifers (groundwater) and coastal waters in order to support not only social and economic development but also to preserve ecosystem functions. Ecologically, economic and social objectives must be linked together.

3-2 The Research Design (Framework)

According to Kombrabail (2009:1), a research design is the description of methods and procedures for acquiring the information needed. A multi-disciplinary approach was used to reach the objective targeted in this thesis, so the following steps were taken as shown in (figure 3-1) (MNISI 2011):

- Literature review: an intensive literature review has been done while searching for similar topics globally, regionally, and locally. Most literature adopted in this thesis are peer-reviewed articles and internationally published books, in addition to NGOs and INGOs

reports to acquire the required data as it is considered the only source for actual data available about the current situation of Yemen.

- Questionnaires: a closed-ended questionnaire was developed with the help of some INGOs standards such as WHO, UNICEF and Sphere to collect the required data from the beneficiaries (students and administrative and academic staff). It was formatted and design using the Kobo Toolbox that is used for humanitarian response situations. See annex (1).
- Size Sampling: the sampling has been defined according to Glenn, Israel, the sampling has been done by using the Stephen Thamson and Robert Mason equation which depends on the precision and confidential level (Israel 2003).
- Site Observation: a checklist was developed that was used by the researcher to acquire the required data and information from the fields and meet face-to-face with the key informants of each faculty (see annex (2)). Besides the actual site observation, the current status and situation of each faculty, water sources, drinking water points, sanitation infrastructure (toilets) and the hygiene promotion activity was observed by the researcher. The FAO WWTP has been visited to evaluate the WWTP. In addition, water samples from the wells have been taken for quality tests.
- Data Analysis: all the gathered data and information from the questionnaire and site observation was collected and analyzed with help Kobo Toolbox. Every individual questionnaire was given a unique code and the analysis was reviewed manually with the help of Microsoft Office Excel 2016 and formed in a tabular form.

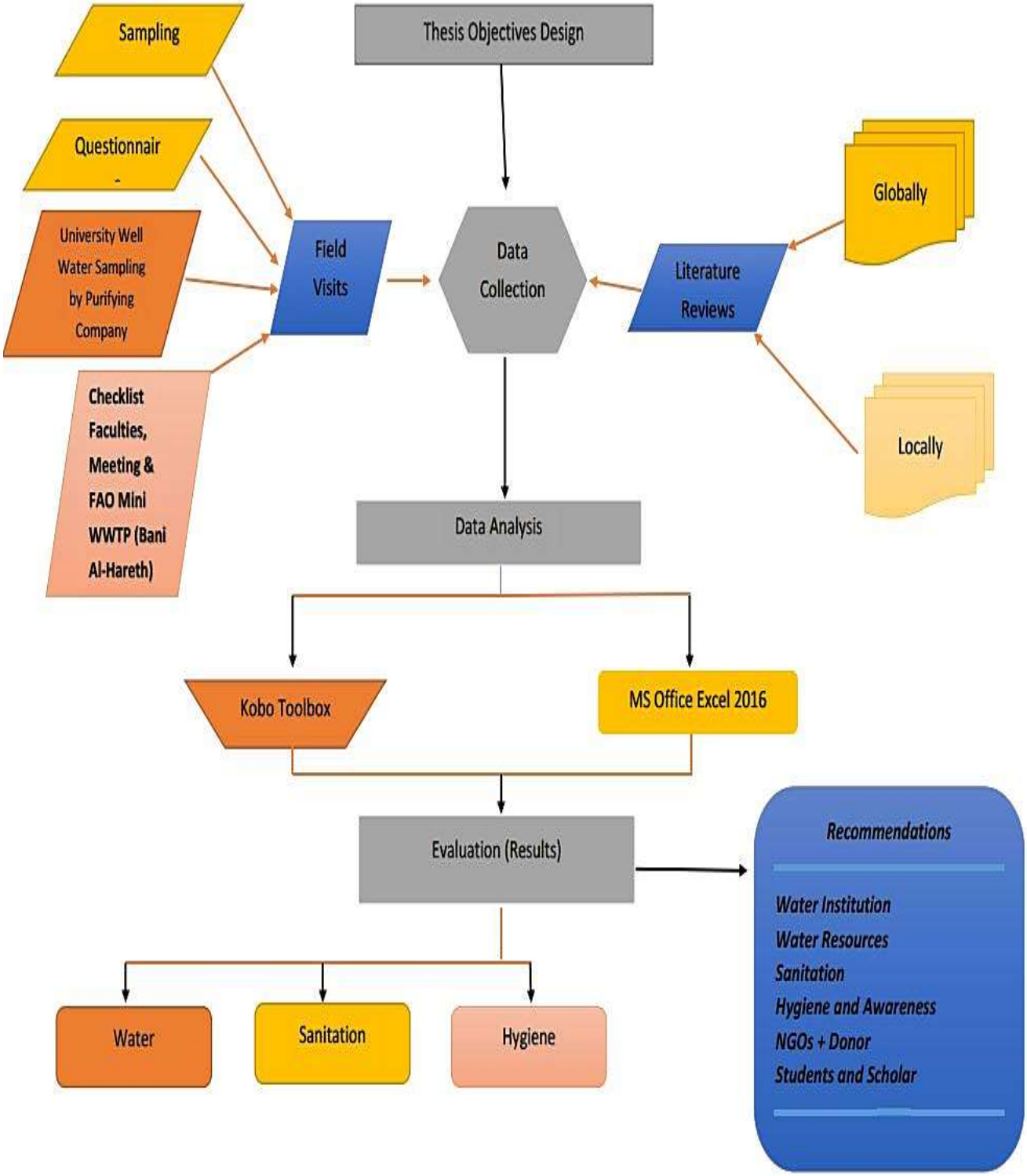


Figure (3- 1) : Thesis Flow Chart

3-3 Literature Review

A literature review was utilized to collect secondary data. The information was obtained from journals, official water reports, approved dissertations, and the internet. The data and information were collected from international, continental and local documents. International, continental and local documents were referred to in order to understand water, sanitation and hygiene problems in schools as well as healthcare and public institutions throughout the world. The researcher tried to adopt the methodology followed by most of these literature review which was a qualitative research approach. In addition, the monthly, quarterly, and annual reports of the NGOs and INGOs working in water, sanitation and hygiene sector in Yemen such as UNICEF, WHO, and Yemen WASH cluster have been reviewed.

3-4 Questionnaire

The thesis employed the use of questionnaires utilizing Kobo toolbox, which was founded by the Harvard Humanitarian Initiative, is an open foundation suite of tools for data collection and analysis in humanitarian emergencies and other inspiring environments. (Initiative HH 2019). Questionnaires were used to collect quantitative data (closed-ended questions). The questionnaires were distributed personally also with help of volunteer students, who were studying in the in each faculty in the university three campuses: old, new, and faculty of medicine, some part of it was shared with social media group of the university student that could be filled by them online/off-line and filled form were sent automatically whenever connected to the internet as shown in (figure 3-2).

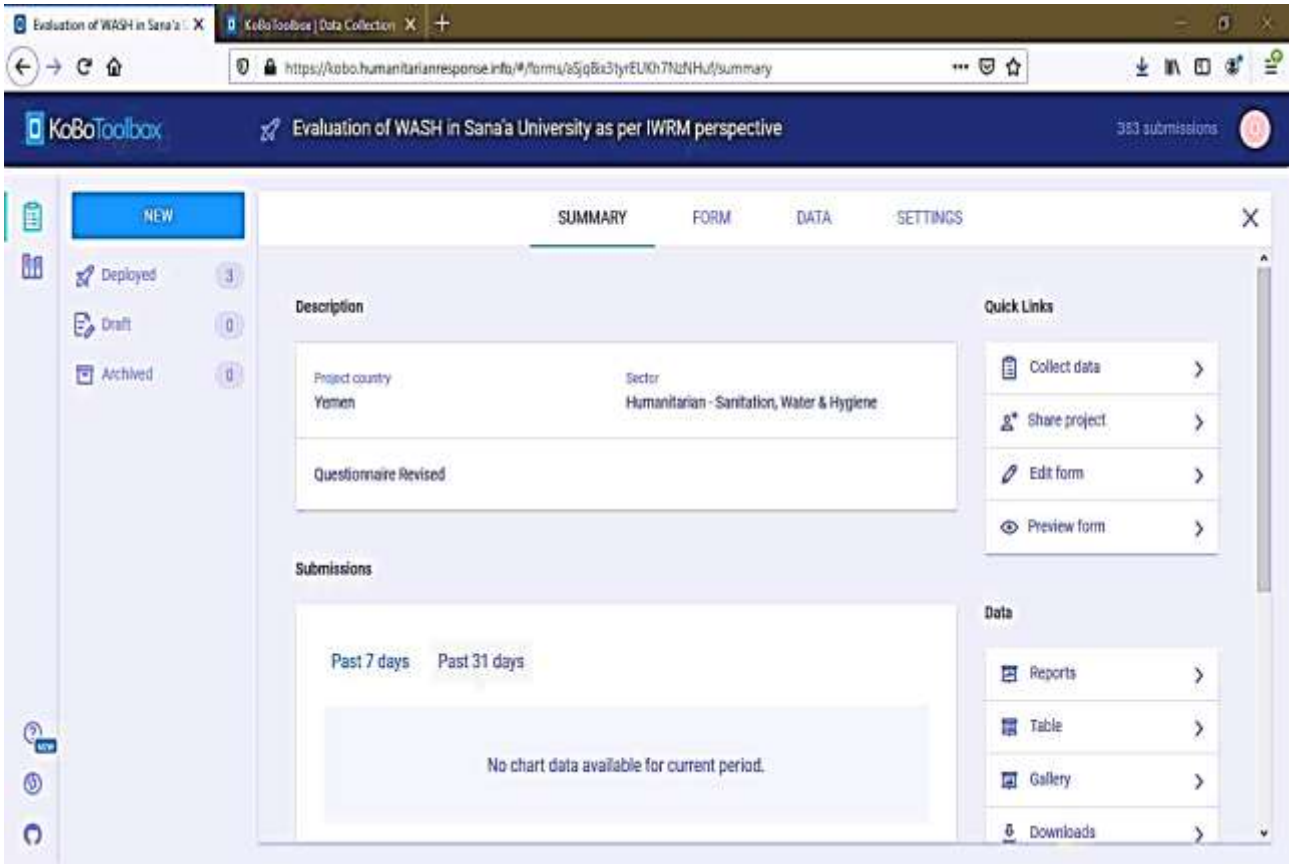


Figure (3- 2) : Kobo Toolbox Frontage - Source Kobotoolbox Website

Closed-ended questions: the questionnaire included mostly closed-ended questions because these types of questions are easy to analyze since they are made of numbers rather than opinions. The questionnaires were multiple choice questions where the respondents were asked to choose one answer from among a set by checking the box which was next to the answer and some semi ended questions were added to see the repondents views (Israel 2003).

An introductory part was added on the first page of the questionnaire which was formatted in such a way that the first part asked for general information about the student/staff: his/her gender, faculty, and level of study. The second section inquired about the necessary data concerning the faculty water resources and drinking water point status in terms of quality and the quantity, consumption, cost and the problems. The third section was about the sanitation, hand-washing basins and toilets infrastructure of the faculty in terms of ease of access, status, privacy, water availability, availability of handwashing basin nearby and the sanitation problems. The final part

of the questionnaire was about the hygiene activities done in the faculty in terms of cleanliness, waste accumulation, food preparation within the faculty cafeteria, past illness history from water-borne diseases and finally s/he asked about his/her opinion on how to improve the WASH sector in the faculty. See the annex (1)

The questionnaire constructed was guided by the research objectives and questions. Once the questionnaire was finalized, it was tested before it was used on a large scale of students to see if it was obtaining the required results. This was done by asking the supervisor and some statistics professionals to read it through and see if there were any ambiguities that might have gone unnoticed. They commented on what needed to be correct, including the length, structure, and wording of the questionnaire. They also commented on its suitability and comprehensibility by the students and staff, then it was simplified in order to be understood by students of all levels. The questionnaire was shared with the social media group of the students and part of it was distributed in hardcopy with help of volunteer's students from the university. In addition, for the ease of the analysis it was transalted from Arabic to English for interpretation.

3-5 Sampling

Sample size is a count of individual samples or questionnaires in any statistical setting, such as a scientific experiment or a public opinion survey. Albeit a relatively straightforward concept, choice of sample size is a critical determination for a thesis. Too small a sample yields unreliable results, while an overly large sample demands a good deal of time and resources (Zamboni 2018).

Two equations have been used in this thesis to determine the sample. Steven Thamson (Vincent and Thompson 2017) provides a simplified formula to calculate sample sizes. This formula was used to calculate the sample size:

$$n = \frac{NPQ}{\frac{(N-1)e^2}{z^2}+PQ} \quad \ldots\ldots\ldots\ldots \quad 1$$

Population size (P), Q, and z disappeared because they were replaced by actual values.

Population size, P is assumed to be 0.5, which automatically results to a Q value of 0.5 since Q = 1-P = 1-0.5 = 0.5. The number 0.5 is the P value that yields the highest possible of precision

Where

n is sample size

N population size (47548 students+ Working staff)

P Nuteral Levels 0.5

e percentage of error 5%

z the standards score crossponding to significance Level 95% is 1.96

The another formula to calculate the sample size was given by Robert Mason (Balachin 2017) which is as below:

$$n = \frac{N}{((N-1)z^2/PQ)+1} \quad \ldots\ldots\ldots\ldots\ldots \quad 2$$

Where

n is sample size

N population size (47548 students+ working staff)

z the standards score crossponding to significance Level 95% is 0.02551

After applying the values in the above equation, it was concluded that the total number of questionnaires required for this thesis was 381 which were to be distributed equally all over the university's three campuses and faculties between the students and staff. In total, 400 questionnaires were distributed as shown in (table 1) out of which 17 questionnaire was neglected due wrong representation of information.

Table (1) Distribution of the Questionnaire

S.No.	Faculty	Distributed Questionnaire	Male Student	Female Student	Staff
1	Agriculture	30	19	9	2
2	Computer Science	38	25	11	2
3	Commerce	34	22	10	2
4	Dentistry	38	25	11	2
5	Education	25	16	7	2
6	Engineering	38	25	11	2
7	Language	36	24	10	2
8	Literature	30	19	9	2
9	Mass Communication (Media)	38	25	11	2
10	Medicine	38	25	11	2
11	Science	30	19	9	2
12	Sharia and Law	22	15	6	1
13	WEC	3	1	1	1
Total		400	260	116	24

Random sampling was used to select the students and staff; this is because random sampling gives each individual an equal chance to be selected.

3-6 Site Observation

Another method used was site observation. Time was spent in the university and each individual faculty was visited, observing water sources, sanitation facilities, and hygiene methods that were currently used by the students and staff. The observation was done by taking photos of water resources and toilets facilities that are currently used within the university with a smartphone camera. Extensive notes were written during picture-taking in order to assist the researcher in remembering important information when analyzing the data.

A checklist had been prepared in order to simplify the field observation data and information collection for the researcher while observing the adequacy and utilization of the water resource, drinking water points, and sanitation facilities in each individual faculty that he visited. The first part of the checklist was to collect data about the faculty in general. The next part was about the water resource observation and drinking water points, the faculty satisfaction of its water requirement, water source contamination, and sufficient drinking water points. The third part of the checklist was to seek information about sanitation facilities, toilets and handwashing basins as well as their location, ease of access, cleanliness, availability of water in taps and handwashing basins in addition to the availability of soap and maintenance. The last part of the checklist was the hygiene behavior and cleanliness practice in the faculty, such as food preparation, awareness campaigns, and availability of a healthcare center within the faculty. The above checklist was prepared with the help of the standards checklist prepared by the INGOs such as WHO and Sphere who are working in WASH sectors in the schools, educational institutions, and health care centers. See annex (2).

During the field visit to each faculty, the researcher set and meet with the key informants of each faculty such as , the dean, general secretary, and service and maintenance in charge of the faculty, because they are considered to be the key members within the faculty who are most knowledgeable about the faculty's situation and problems. The purpose of the meeting was to get clarity on some information that was necessary to draw conclusions. A number of questions were prepared for the meeting beforehand and the answers were recorded immediately through writing notes. The meeting

was arranged one day before through a personal visit with an official letter from the Water and Environment Center (WEC). Most of the faculties welcomed the thesis and were willing to discuss the real problems that they faced and find solutions. In addition, the water samples have been taken from the wells (Presidency block and Madbah) of the University for testing by the one Purifying Company for drinking water quality tests as per WHO 2018 standards as requested by them and offered by the university (figure 3-2 and table 2) show that the location of the wells within university campus and coordination.

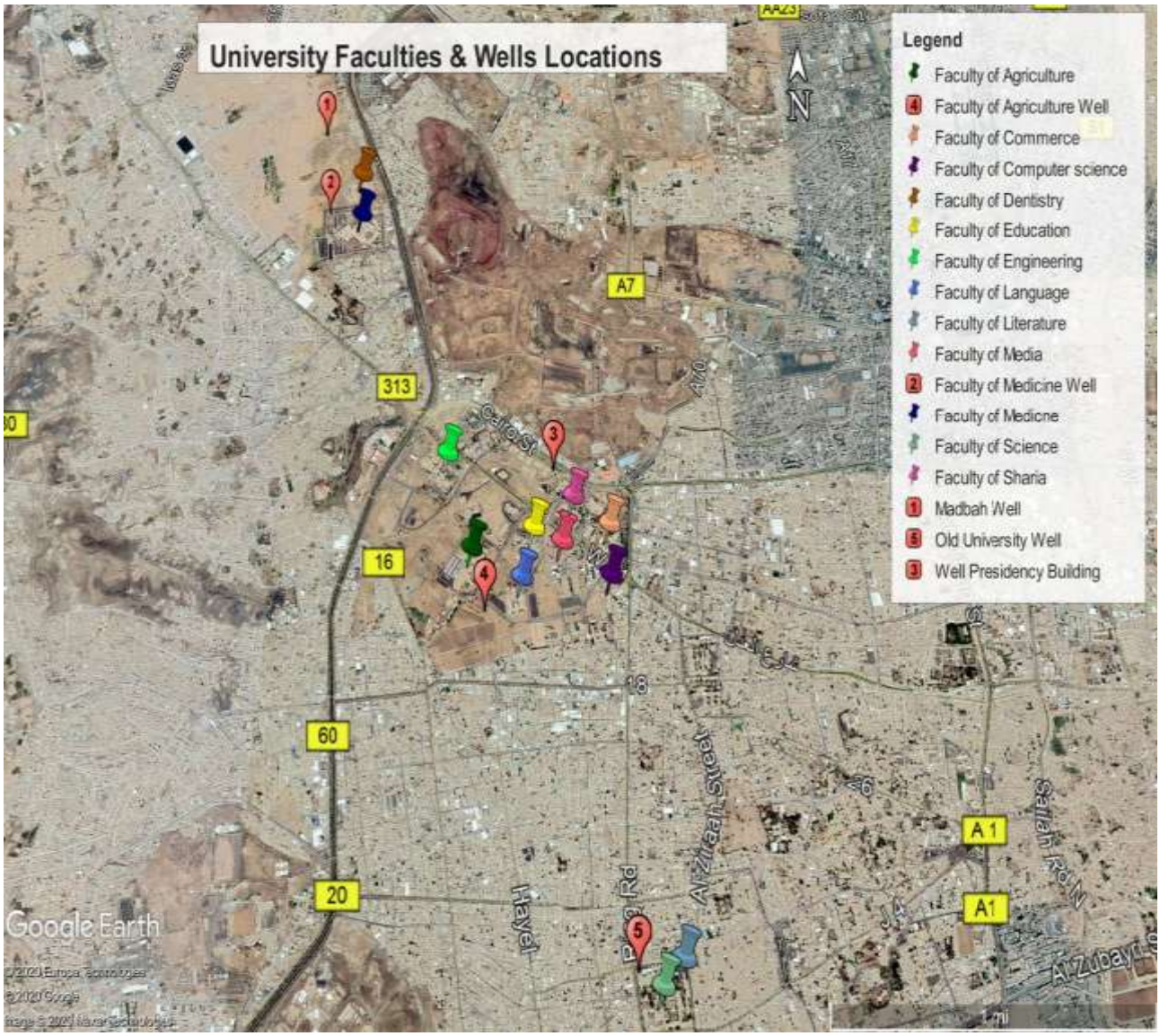


Figure (3- 3) : Location of wells and Faculties - Source Google Earth

Table (2) Well's and Faculties Coordination

S.No	Description	Coordination
1.	Madbah Well	15.231704N 44.10160E
2.	Faculty of Medicine	15.23017N 44.101852E
3.	Agriculture Well	15.21582N 44.105808E
4.	Presidency Block Well	15.2212N 44.11692E
5.	Old University Well	15.2057N 44.122183E
6.	Faculty of Literature	15.205668N 44.112844E
7.	Faculty of Science	15.205216N 44.112444E
8.	Faculty of Education	15.215961N 44.1159E
9.	Faculty of Sharia and Law	15.23385N 44.11259E
10.	Faculty of Commerce	15.222662N 44.111760E
11.	Faculty of Mass Communication (Media)	15.215579N 44.11824E
12.	Faculty of Agriculture	15.215718N 44.105714E
13.	Faculty of Language	15.214772N 44.11102E
14.	Faculty of Computer Science	15.215153N 44.111667E
15.	Faculty of Engineering	15.221379N 44.104556E
16.	Faculty of Medicine	15.225512N 44.102574E
17.	Faculty of Dentistry	15.23477N 44.102448E

For better understanding, the researcher visited onsite sanitation treatment to observe the processes. There was a visit to the mini wastewater treatment plant constructed by the Food and Agricultural Organization United Nations (FAO) Beat Handal, Bani Al-Hareth district, Sana'a – Yemen. This area is famous for growing the variety of vegetables that supply most of the Sana'a city markets. Most of these vegetables are irrigated directly from wastewater that comes from Sana'a city where there is a main canal of wastewater passing the area on its way to the wastewater treatment plant which is located nearby. In addition, due to the ongoing crisis, most of the infrastructure was damaged including water and sewage facilities. Moreover, to counteract the cholera epidemic that spread rapidly in Sana'a city during the cholera outbreak and as per the Yemeni WASH cluster report, there were almost around 9000 suspected cases—2000 of which are confirmed. Based on that and to mitigate the cholera epidemic, the Food and Agricultural Organization United Nations (FAO) thought to establish a Mini Wastewater Treatment Plant to help reduce the contaminator concentration of the wastewater which is reused in irrigation of the vegetables. The researcher evaluated the FAO WWTP

based on the engineering design criteria that apply in Yemen (Al-Nozaily F, Haidera M 2013) see annex (3).

3-7 Data analysis

Data analysis was carried out using Kobo Toolbox on the month of June 2019. A database was created. Every single answer item on the questionnaire was carefully entered as a numbered code. Each questionnaire was carefully entered in the Kobo Toolbox database going through each questionnaire after entering data was done for accuracy as well as referring back to the aims of the study.

After that, the analysis was checked manually by MS Excel 2016 to confirm the analysis. The database downloaded from Kobo Toolbox was organized into pivot tables and charts in a Microsoft Excel 2016 worksheet that was used to draw graphs. The graphs used were bar and pie charts for data presentation. The graphs used contained frequencies and percentages which were important in illustrating the findings.

Chapter (4)

Results and Discussions

In this chapter, the results and the findings of the evaluation of WASH at Sana'a University are presented in the form of graphical shapes and tabular forms. The findings are discussed in according to the three sub-objectives of the thesis which are:

- To assess the water supply, sanitation and hygiene facilities, and infrastructure at university faculties.
- To determine beneficiaries' access to WASH facilities.
- To recommend necessary solutions to improve the WASH sector as per the IWRM for students and staff.
- To suggest and adopt a pilot Sanitation as per FAO – Yemen for Students educational and research purposes.

All the above are discussed in depth in three main parameters of the WASH as well as IWRM as made clear in the following figures and paragraphs

4.1 Respondents Distribution for The Questionnaire

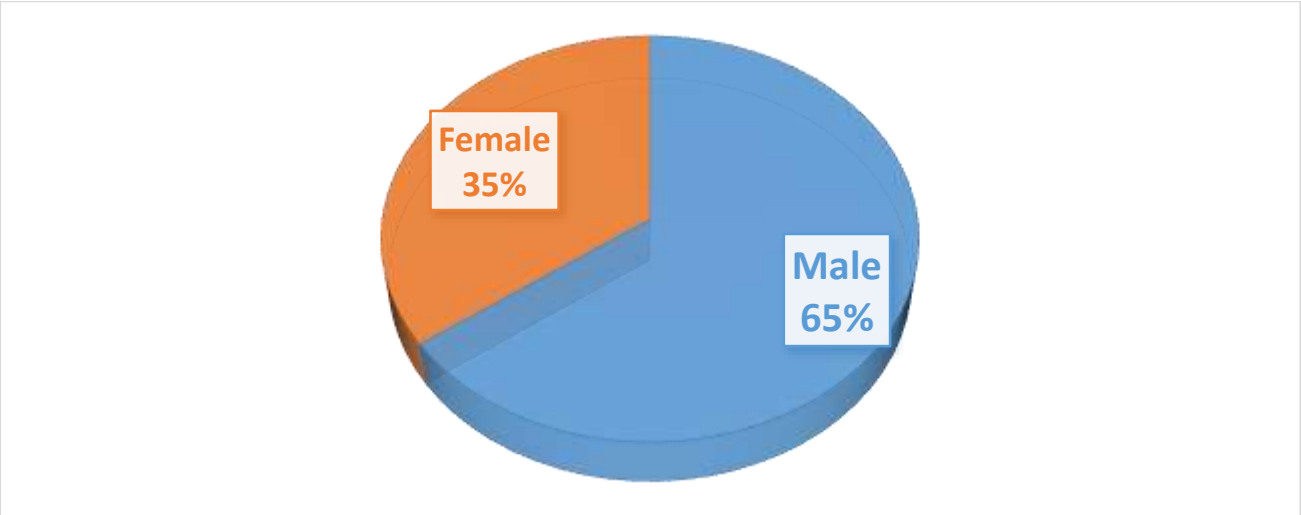


Figure (4-1): Gender of the Respondents

The (figure 4-1) that shows the percentage of the respondents in terms of gender. It is shown that 65% of the respondents were male students and working staff in the university, whereas 35% of the respondent were female students.

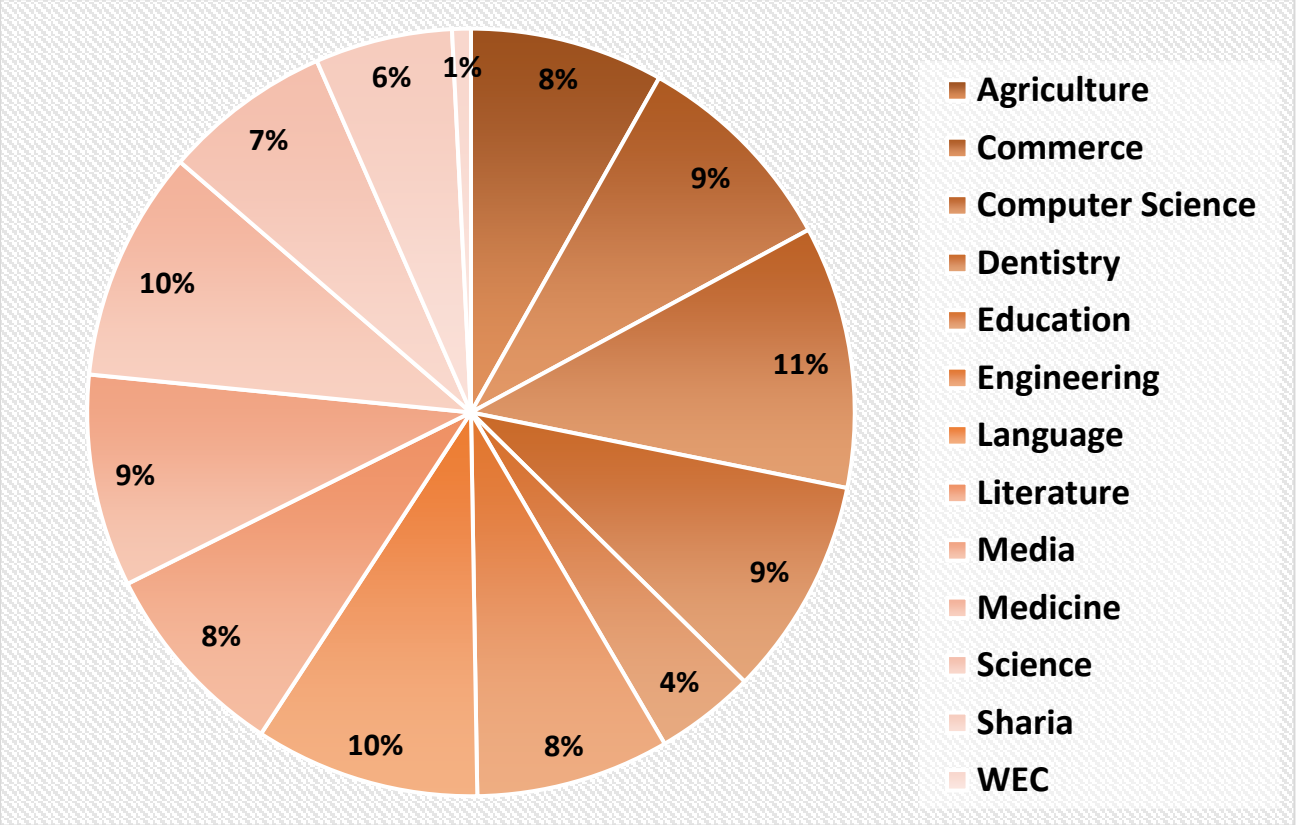


Figure (4-2): Distribution of the Respondents Over the University

From the (figure 4-2) we observe that the respondents were distributed over all the university faculties equally. There is some variance in coverage of some faculties due to the absence of the students when conducting the questionnaire due to their schedule.

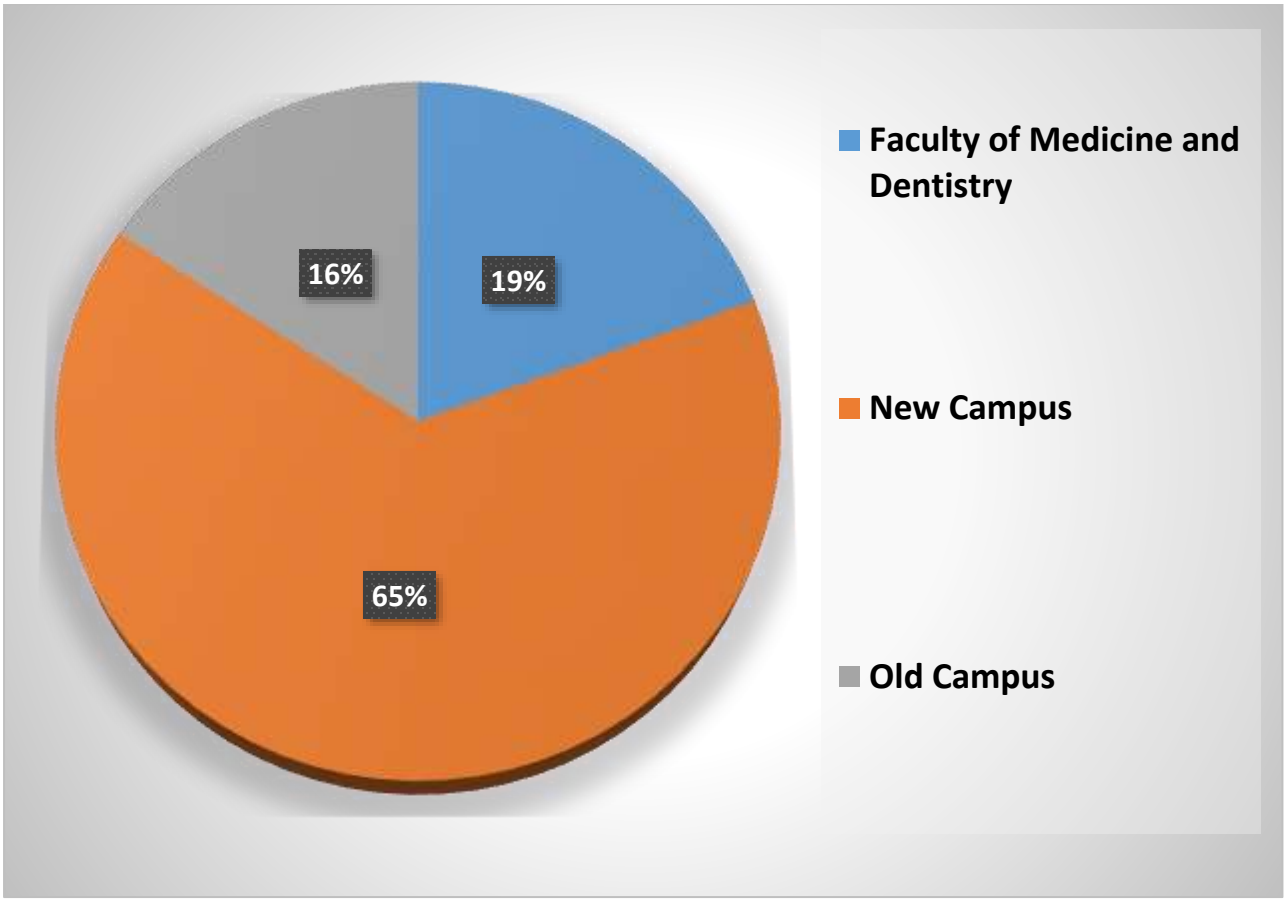


Figure (4-3): The Coverage of The University Campus

The (figure4-3) shows the coverage of the university campus and the respondents. The new campus has the majority of the responses with 65% because of the density of students and faculty staff there, whereas the old campus and the faculty of medicine campus are matching in coverage with 16% and 19%, respectively.

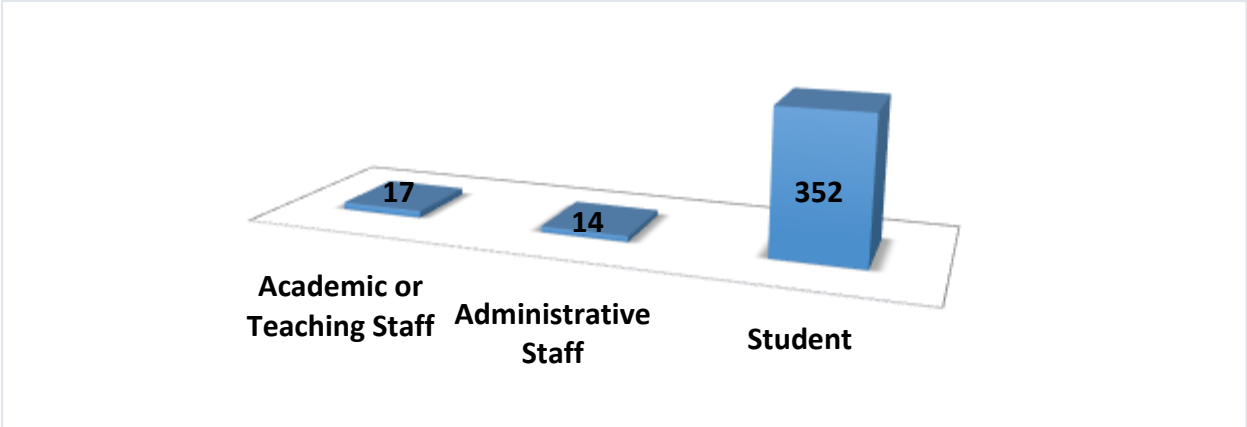


Figure (4-4): Respondents

The (figure 4-4) showed clearly that the majority of the responses came from the students (352 out of 383) because they are the main beneficiaries of the WASH services provided by the university. The academic and administrative working staff contributed 17 and 14 responses, respectively.

4-1 Water

In this section, all the finds related to the water are discussed in terms of water quality, quantity, and ease of access.

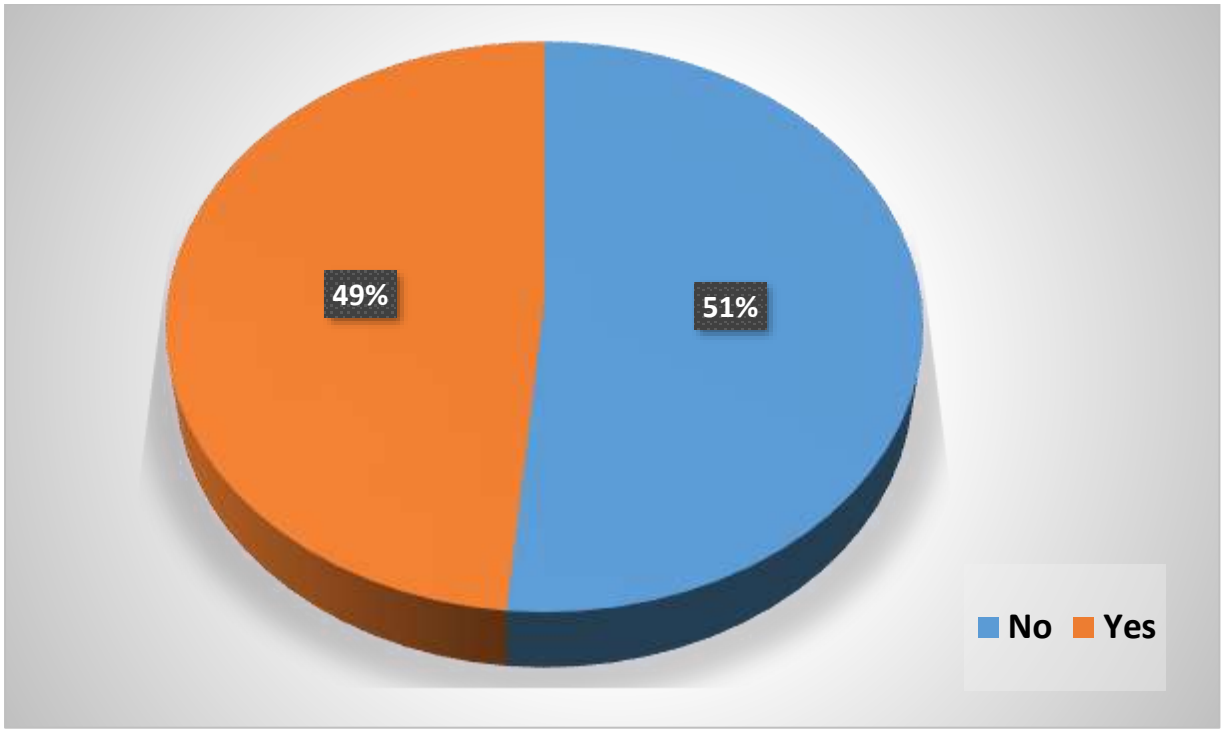


Figure (4-5): Are There Any Drinking Water Facilities?

The (figure 4-5) shows the responses to the question 'Are there any drinking water points or facilities available within the faculty?'. Most of the responses (51%) were 'no' indicating that the drinking water points are not present, whereas 49% of responses mentioned that there are water points available within the faculty. On average only 3 drinking points are available in each faulty that are used by all the students and working staff within the faculty. As per sphere standards, the quantity of drinking water that must be available per person per day is 3.0 liters which means the total quantity

of drinking water required to meet the drinking purpose must be 137,000 liters per day based on Sphere. Hence,there were shortage of the drinking water quantity within Sana'a University.

The water source for the university was found to be supplied by the private water tankers 3-4 with an average capacity of 5 m^3; water tankers on average for each faculty per week; however, the university owns five boreholes that are located within the university, only three of which are working. One of these wells is considered to be the main well that supplies the university water's needs, whereas the other two working wells supplying the university were shut down for maintenance, one of these wells was closed recently. The other remaining two boreholes are collapsed and required further deepening to work again, but due to the lack of financial resources is not possible now to fix them as stated by the general secretary, "we can said the working wells provide almost 200 m^3 /day of water for all uses that include agriculture and recreation" mentione by the department of project management of the university see annex 4 that show the location of the boreholes and their coverage for the university water needs within campuses.

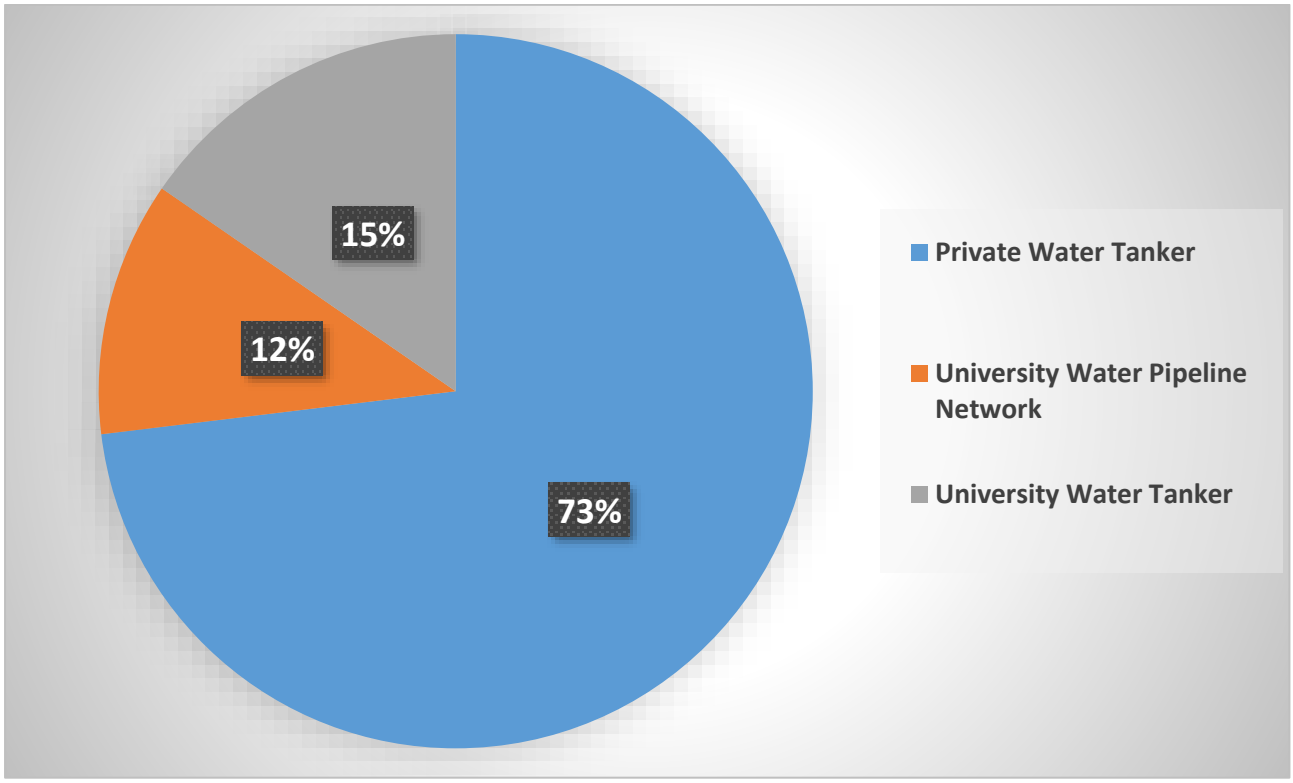


Figure (4-6): What Is The Water Source At University Faculties?

The (figure 4-6) shows the water resources of the university determined with the help of the checklist. It is shown that 73% of the water source in university was supplied by the private water tanker also as shown in photo (1) , whereas the university water pipe network supplied only 12% of the university's water requirement whereas, the water supply network of the university have a good infrastructure but unfortunately it's unusable due to some operation problems and unavailability of the fuel. In addition 15% of water required were provided by the university water tanker, so the total water needed provided by the university was 27% that include university water pipeline network and university tanker. The water supply network of the university was designed to meet the university water need as per its requirement by the researcher (see Annex 4).

Photo(1): Private Water Tanker Supplier – Source Own Representative

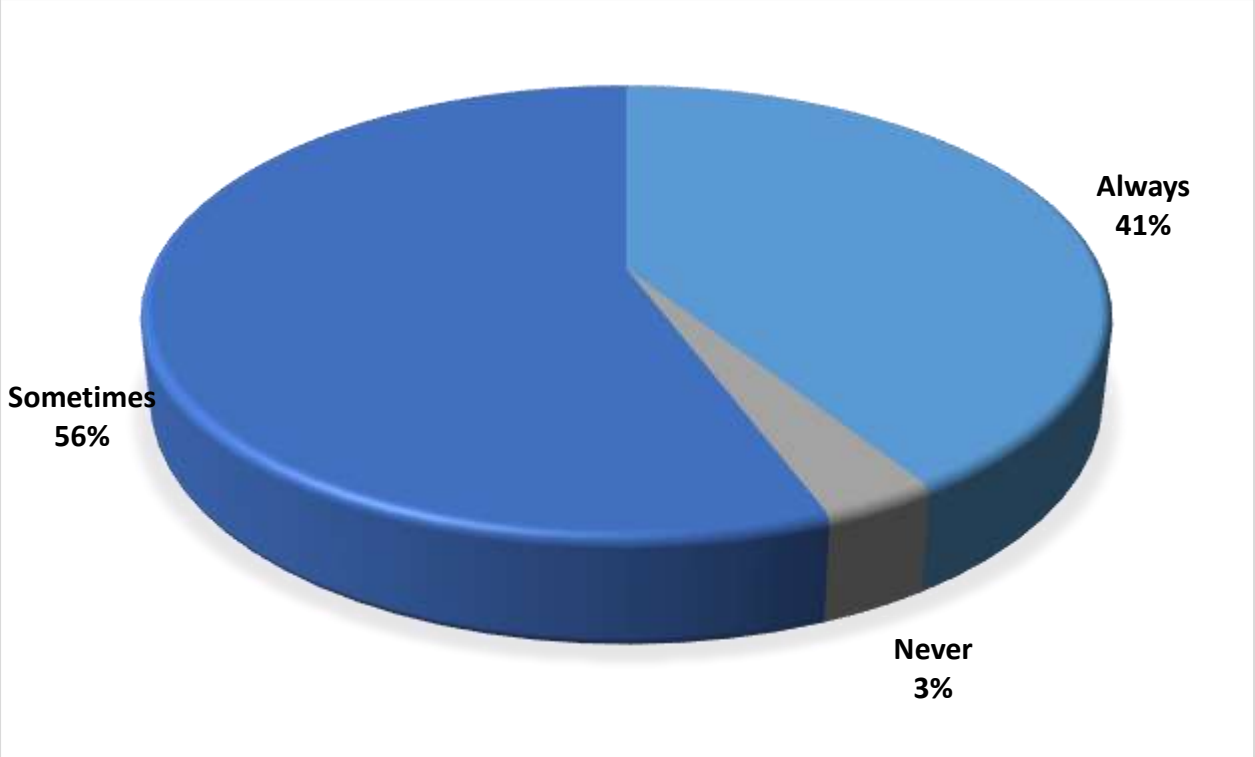


Figure (4-7): Drinking Water Availability At Drinking Points In The Faculties

The drinking water availability is not regular as demonstrated in (figure 4-7). It was only sometimes available as 56% of the responses mentioned, whereas 41% and 3% of the responses mentioned that it was always and never available respectively which mean that there is drinking water points shortage within the university campuses.

As demonstrated in (figure 4-8), almost all the facilities did not have adequate drinking water points available within them. Also during the fields visits to the facilities it was noted that the drinking water points were not available at all and if they were available only limited in their numbers. Only the computer science faculty had drinking water points present however it did not meet the faculty need of drinking water.

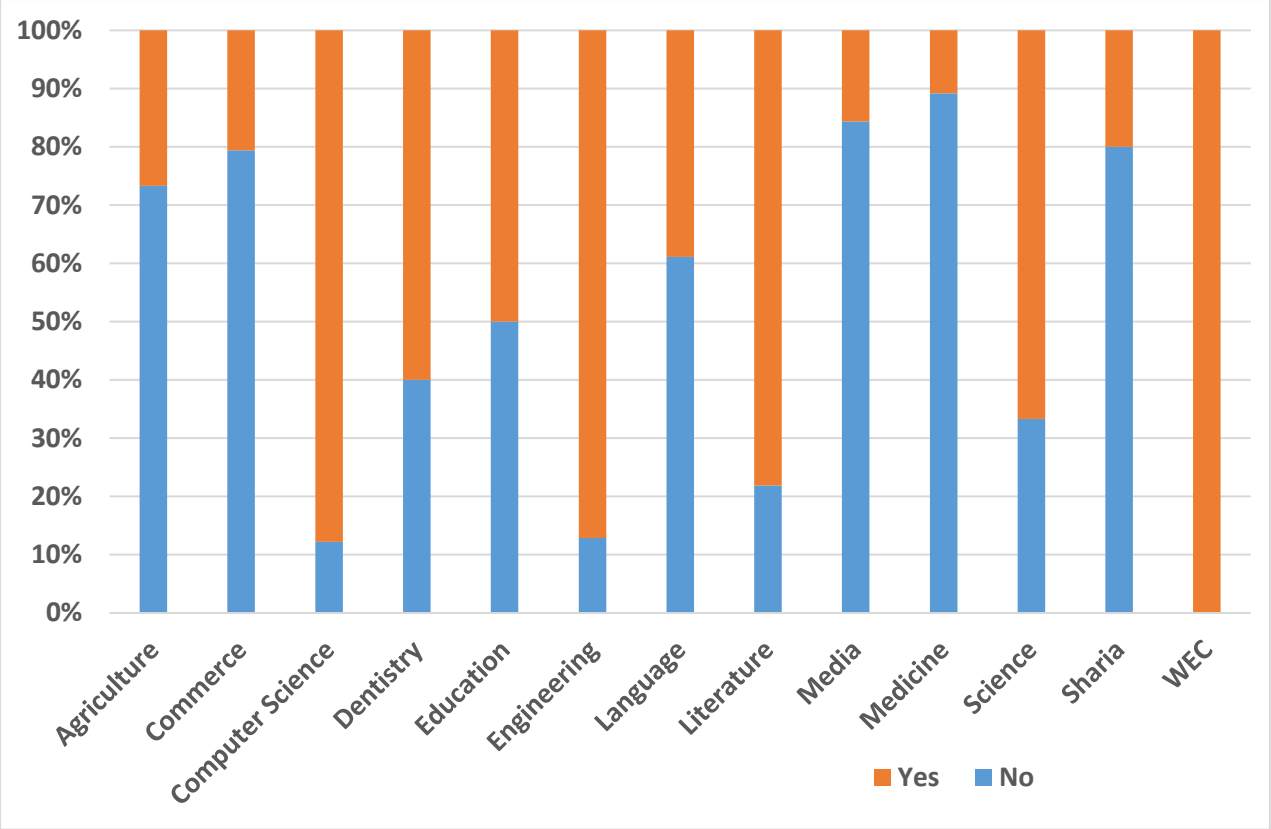


Figure (4-8): Drinking point availability at faculties

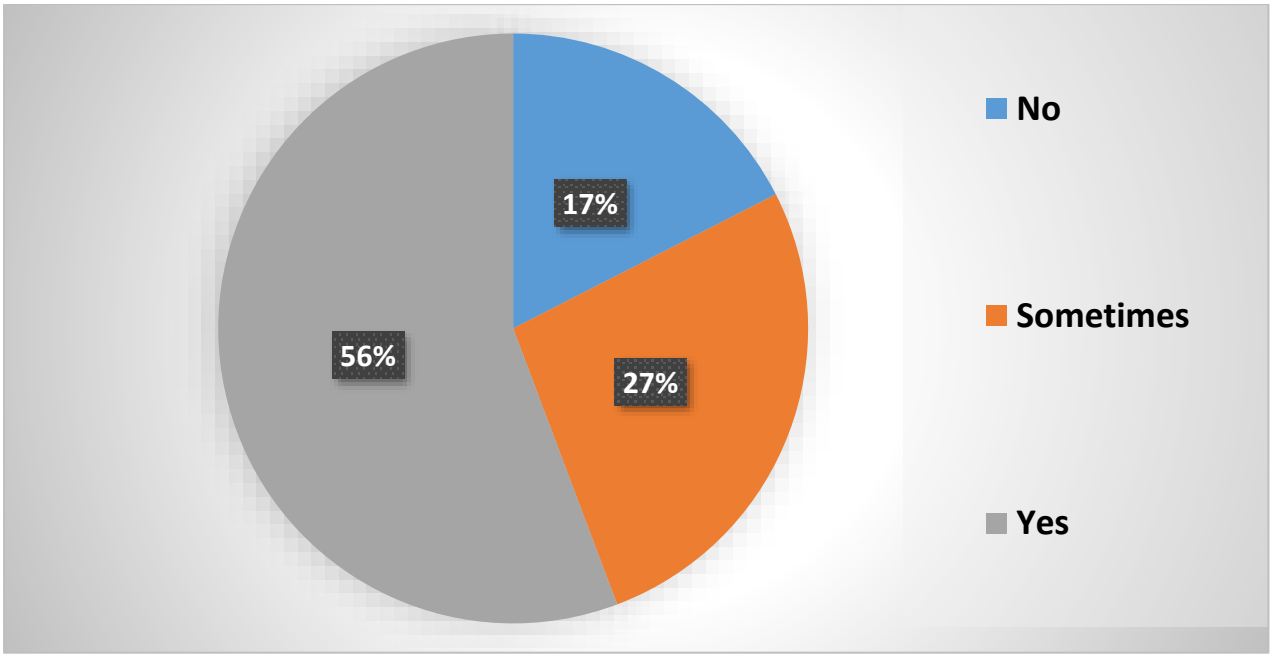


Figure (4-9): Are You Using Drinking Water From The Facility?

As shown in the (figure 4-9), almost half of the university people depend on these water facilities for drinking with 56% of respondents answering 'yes', whereas 17 % are not using these facilities for drinking.

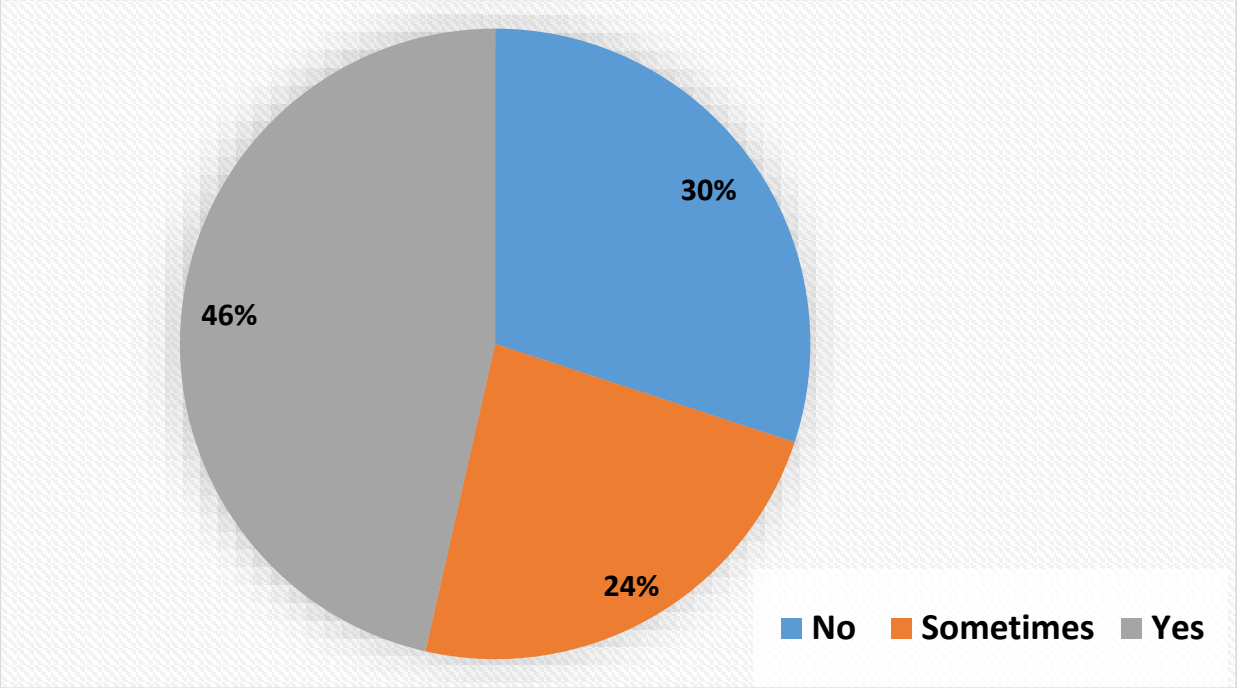


Figure (4-10): Are You Satisfied With The Drinking Water Quality?

The (figure 4-10) shows the satisfaction of the drinking water consumers with the quality of the drinking water available at the university faculties. It shows that only 46% were satisfied with the quality, whereas 30% and 24% mentioned that they were not and sometimes satisfied respectively. On the other hand, the researcher visited the supplier of the drinking water for university faculties. The drinking water quality met with Yemeni drinking water (1999) and WHO standards, as it was confirmed by the NWRA as there was regular monitoring for the water quality supplied by the National Water Resource Authority (NWRA), and it was confirmed by the checklist during the site observations. In addition, the laboratory results of the taken samples by the purifying company showed that the water quality of the university two well is good and within the Yemeni 1999 well water and WHO standards except for one well which was found to have a high concentration of total dissolved solid exceeding 1000 mg/l as well as having a high pH value this is may be the sample diluted or the geological Colum of that area. See the (table 2).

Table (3): Quality Test of the Boreholes

Parameter	Unit	Well No 1 Presidency Block	Well No 2 Faculty of Medicine(Madbah)	Yemeni 1999 drinking water and WHO standards
pH		8.5	8.7	6.5-8.5
TDS	Mg/l	270	1200	≤ 1000
Total Hardness as $CaCO_3$	Mg/l	150	230	≤ 300
Iron	Mg/l	0.15	Nil	≤ 0.7
Total Coliform	100No/ml	NIL		
Facial Coliform	100No/ml	NIL		

(Source Aqua Filtration test on August 2019)

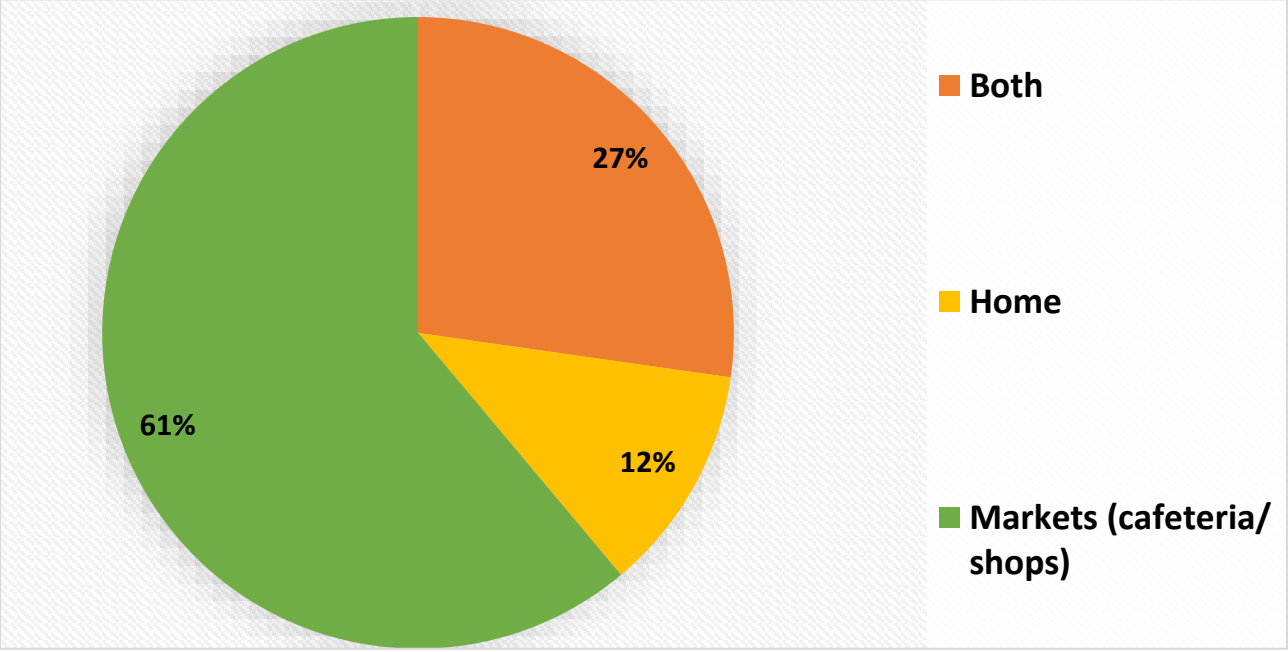


Figure (4-11): If There Are No Drinking Water Facilities Within The Faculty, From Where Do You Obtain Drinking Water?

The (figure 4-11) shows that the majority of the students and working staff (60%) bought the drinking water from the markets, including the university's cafeteria. 27% got drinking water either from their homes or the market, whereas only 12% brought the drinking water from their home. So we could

conclude that there were drinking water shortage at the university faculties.

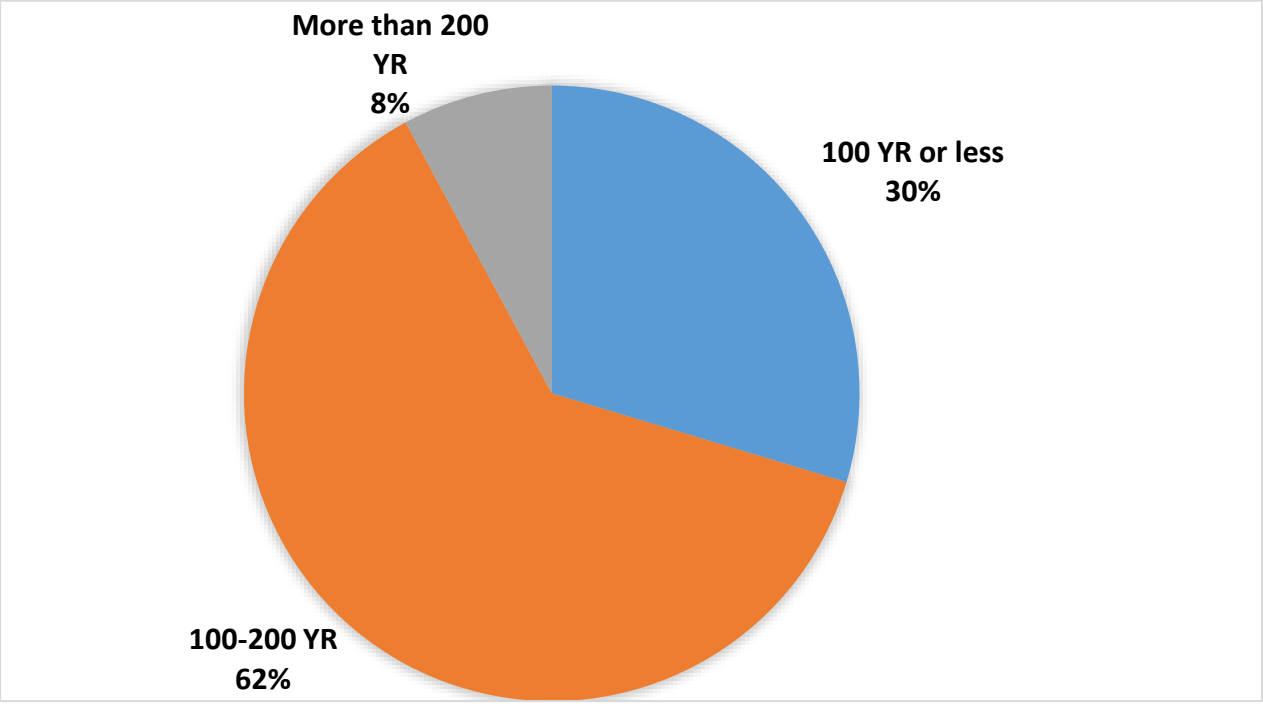


Figure (4-12): How Much Does Drinking Water Cost You During Your Presence At University?

Most of the respondents (62%) spend around 100-200 Yemeni Riyal for the drinking water as shown in the above figure (4-12). 30% spend less than 100 Yemeni Riyal and 8% spent more than 200 Yemeni Riyal. As we know that the bottle of one liter cost 100 Yemeni Riyal, the total amount spent on drinking water will be 7.5 million Yemeni Riyal per day therefore the researcher recommended to establish the water purifying plant within the university campus that will reduce the cost. This amount can be utilized to establish purification unit of the university water resource and to build a water treatment plant within the university campus, minimizing the expenditure on drinking purposes and meeting the drinking water quantity requirement of the university.

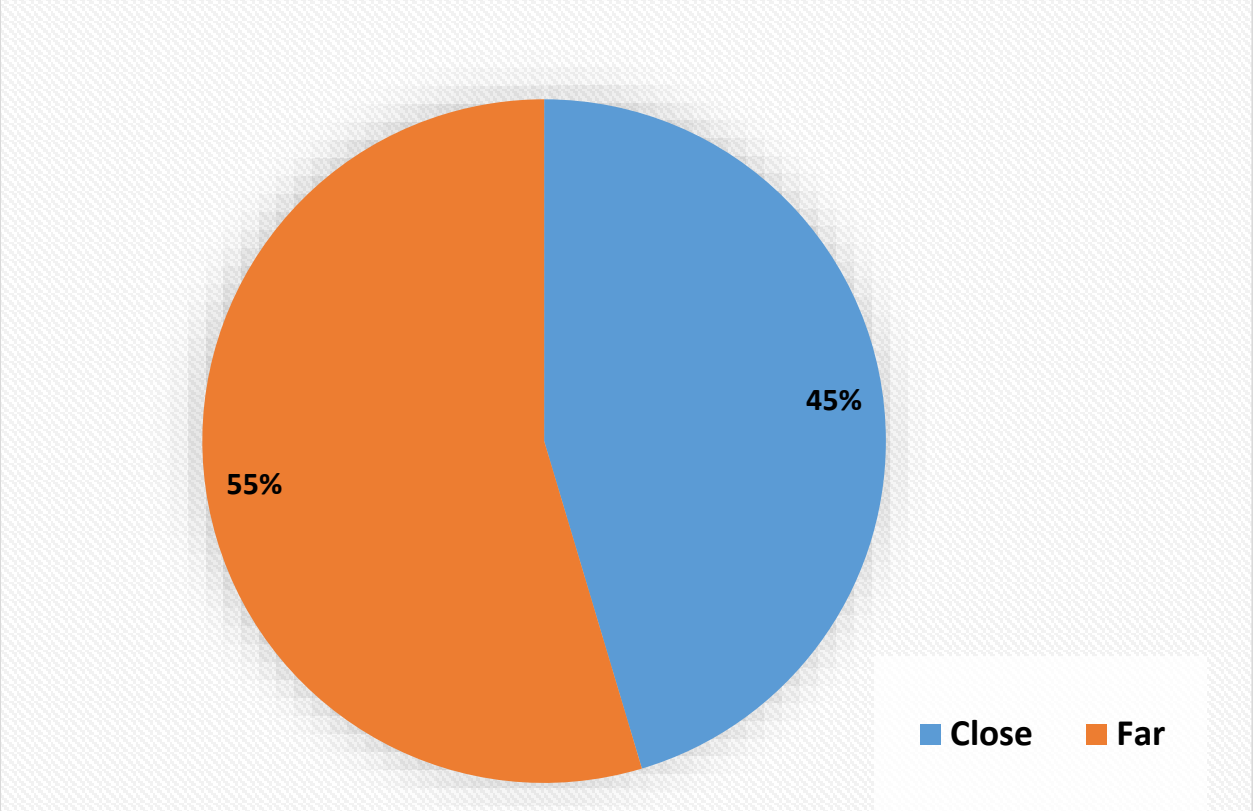


Figure (4-13): How Far Is The Drinking Water Facilities From Classrooms, Lobbies, and Workplaces?

"The drinking water was not only costly, but it was also located very far away" as mentioned by some of the students. The (figure 4-13) shows that 55% of responses stated that the drinking water points are far from the academic section with an average distance of 300 meters. Some of the students mentioned that they have to go outside of their faculties to drink the water, and sometimes they miss some of their class or enter the classroom late. As per WHO and Sphere standards concerning education institutions, the water drinking points should be close from the classrooms and lobbies (Sphere 2018), and according to the site observation there weren't any drinking water points available at the right places within the faculties; if available they were either not covered or protected from contamination or an insufficient quantity was available. As shown in (figure 4-14), 39% mentioned that the drinking water points of facilities were not protected sufficiently from contamination. The same was found within the Brazilian schools where there was a problem of the water contamination without any monitoring in the quality, insufficient toilets, accumulation of waste, and no hygiene practices were found (Borges-pedro et al. 2018).

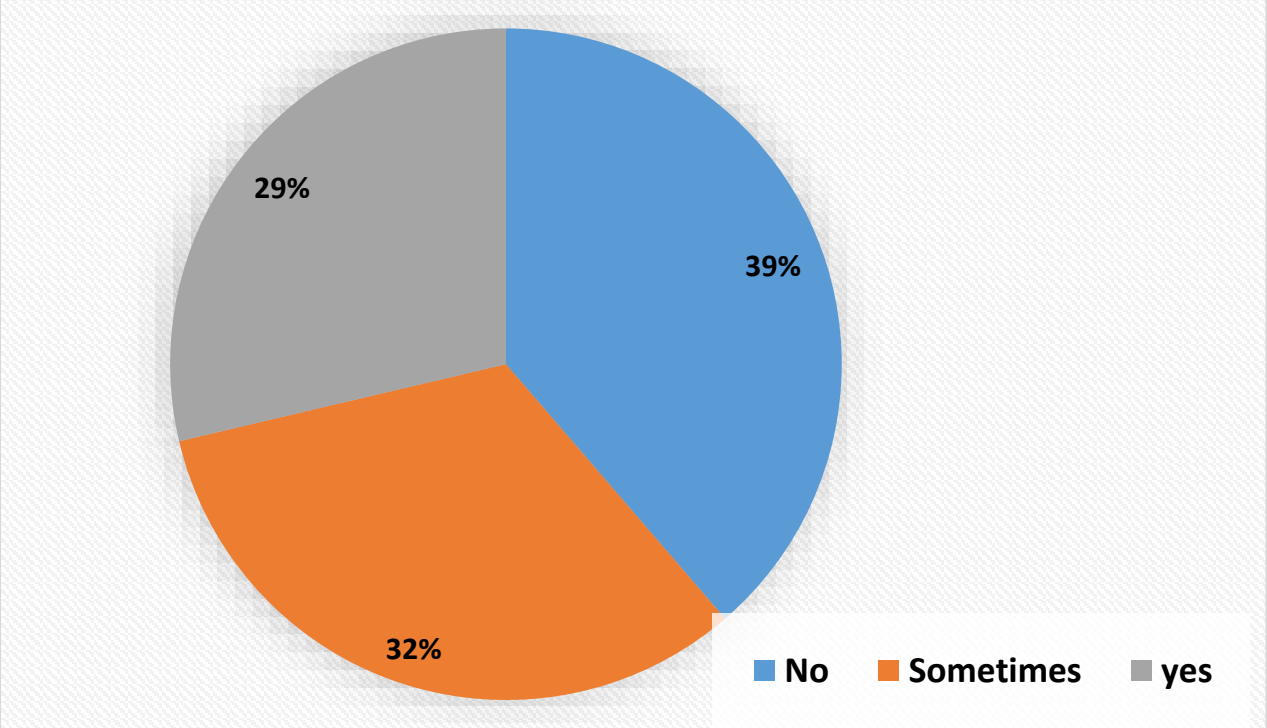


Figure (4-14): Is The Drinking Water Source Protected/Covered From Contamination?

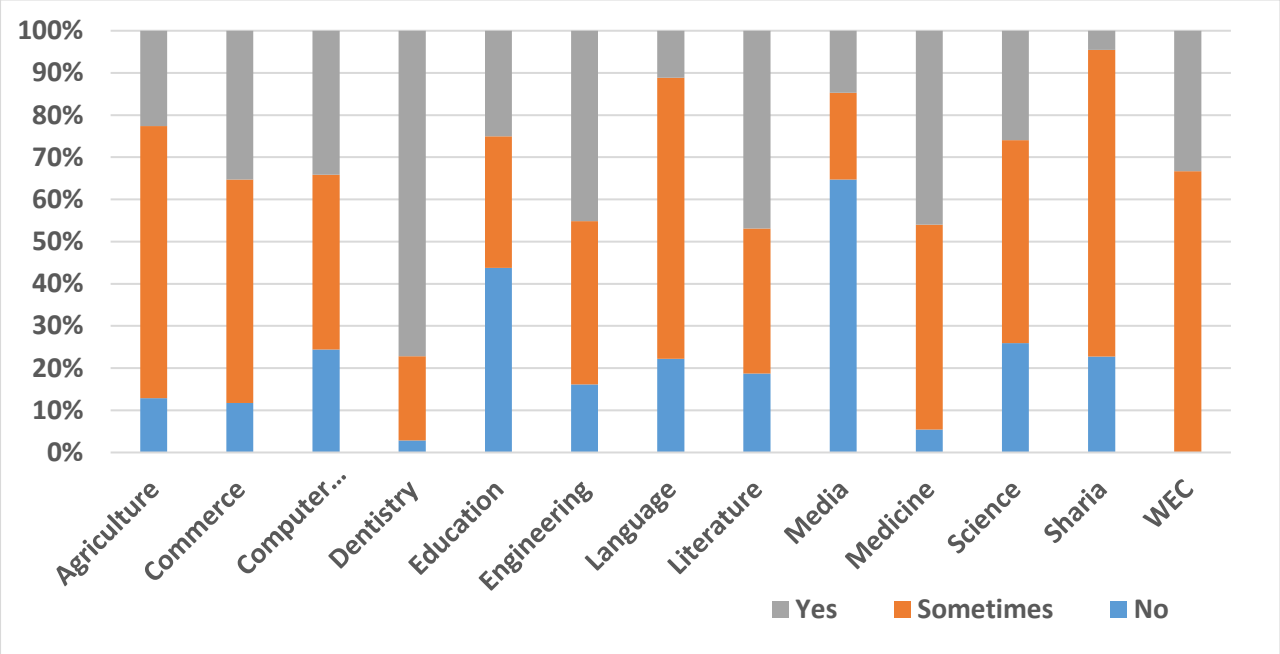


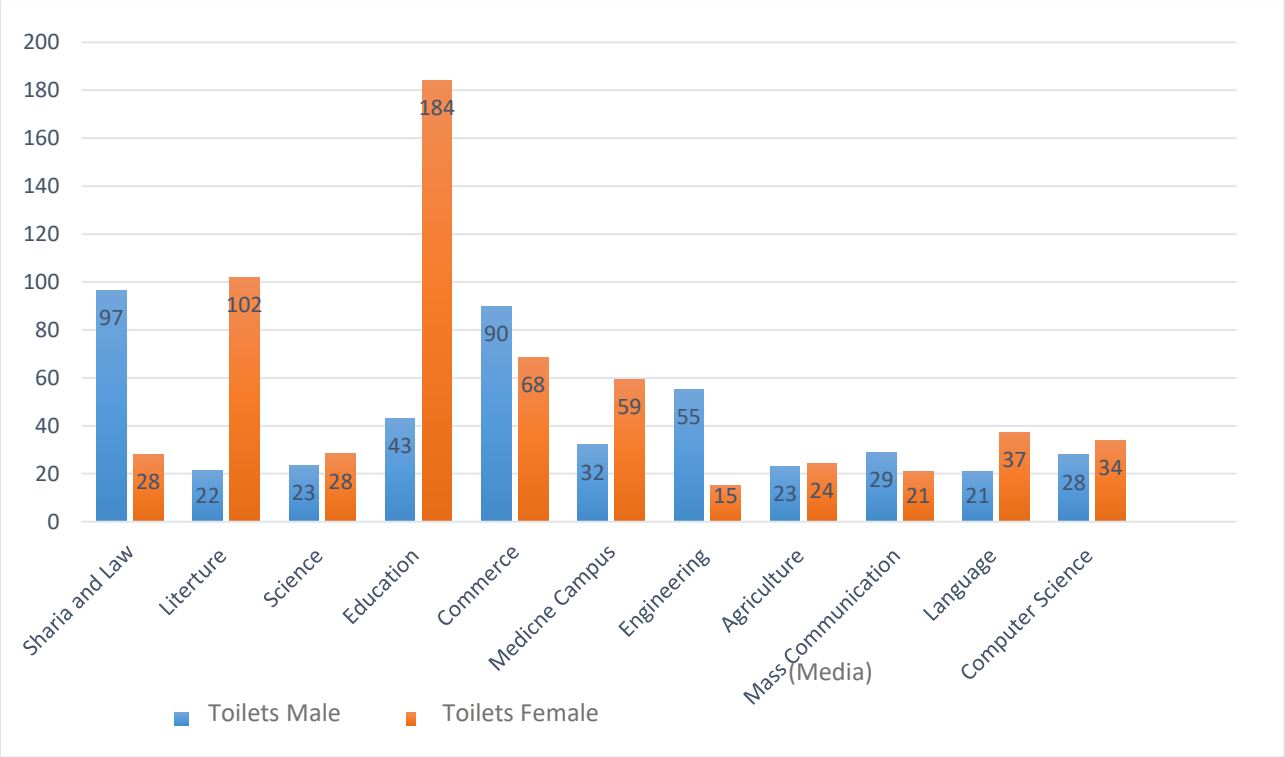
Figure (4-15): Is The Water Available For Other Uses and Purposes (Cleaning/Washing Hands, Faces, and Wado)?

The university did not meet the minimum requirement for the water for other purposes such as washing hands, cleaning, and ablution. The water was not available at all in some faculties sanitation facilities (toilets). In the (figures 4-15) it is shown that, most of responses mention that the water is

available sometimes in some of the sanitation facilities (toilets) and only few mentioned that the water was available for other uses. As per WHO and sphere standards for schools and educational institutions, the minimum water requirement are 5 and 15 liter per person per day respectively and, so the minimum water that the university must arrange is 687 cubic meters of water per day as per sphere whereas as per WHO it must be 229 cubic meters of water per day to meet the university's water demand see annex (6) (WHO 2007) (Sphere 2019).

4-2 Sanitation facilities (toilets/hand washing basins)

Although the sanitation facilities are available everywhere within the university faculties, only a few of them are suitable for use. Most of them are either closed due to lack of maintenance and repair or have been transformed into a warehouse for storing purposes; only one-third of the toilets are available for boys/girls therefore the researcher suggest to regular maintaining the existing toilets and construct a outside toilets block for each faculty. The (figure 4-16) shows that 93% of responses mentioned that the sanitation facilities (toilets/ handwashing basins) are present at their faculties and 7% mentioned they were not present due to the fact that most facilities are present but closed. On average, around 12 toilets were opened for students to use. However, as stated by most of the universal standards, a minimum of one toilets must be available for every 30 female students and one toilet for every 60 male students; therefore, at least 462 toilets have to be available for male students and 602 toilets for the female students as shown in figure (4-16A) see annex (6) . As for the working staff, there must be 88 toilets within the university campuses to meet the minimum requirement for sanitation services. The same case of inadequate maintenance and repairing of the water, sanitation and hygiene infrastructures was found in the village of Gouansoloo in Mali, West Africa (Telmo 2002) (Sphere 2018)



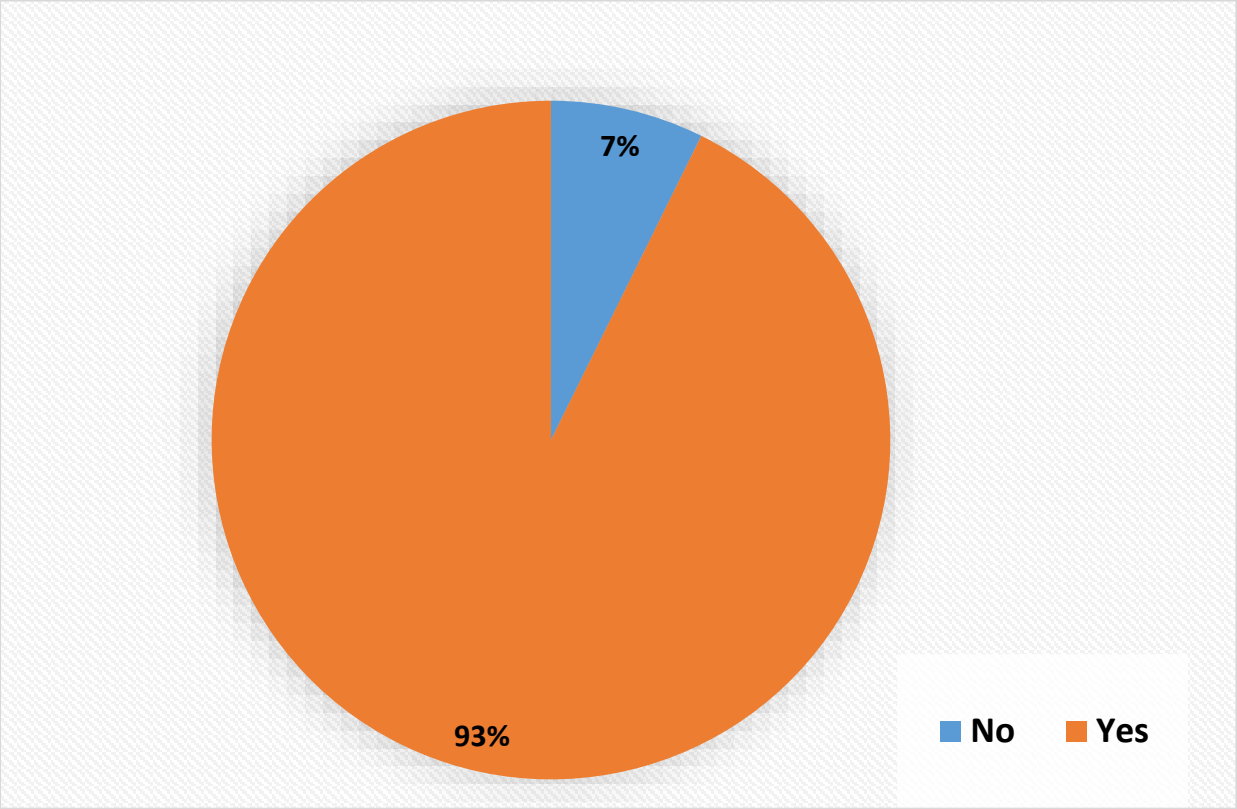


Figure (4-16 & 4-16A): Are There Sanitation Facilities (toilets) Within Your Faculty? And total Toilets needed

The other parameter that all the WASH standards refer to in regards to the sanitation and toilet is the cleanliness. During the site observation, the cleanliness status of the toilets, handwashing basins, and sanitation facilities within the university faculties did not meet the required cleanliness. Most of them were unclean, broken, and unsuitable for use, whereas some of them were closed due to lack of maintenance. The general secretary of the faculty was asked the reasons behind the terrible situation of the sanitation facilities. He stated that "the students did not know how to use the sanitation facilities as required; some of the water taps were stolen and the drainage network was blocked by adding garbage on the sinks, especially by the female students". According to the questionnaire, most of the responses (62%) mentioned that the sanitation facilities within the faculty were unclean, broken (37%), or closed (37%). Only 34% of respondents said they were clean and suitable to use, so the university did not meet the minimum requirement for the sanitation facilities in terms of cleanliness. Similar to Mpigi district, the cleanliness of the available sanitation facilities was not at its best and this forms part of the reasons why some of the students choose not to use the facilities and, instead, opt for use of bushes around the schools (NANSEREKO 2010) as shown in (figure 4-17).

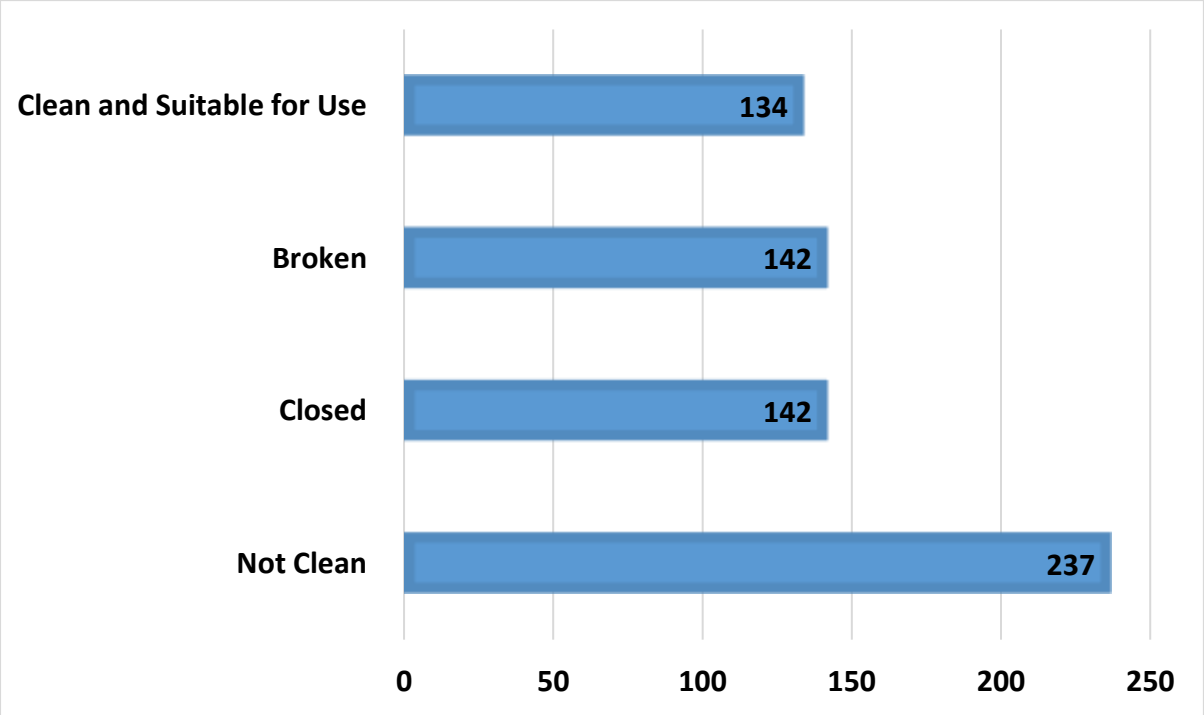


Figure (4-17): What Is The Status of The Sanitation Facilities (Toilets) At Your Faculty?

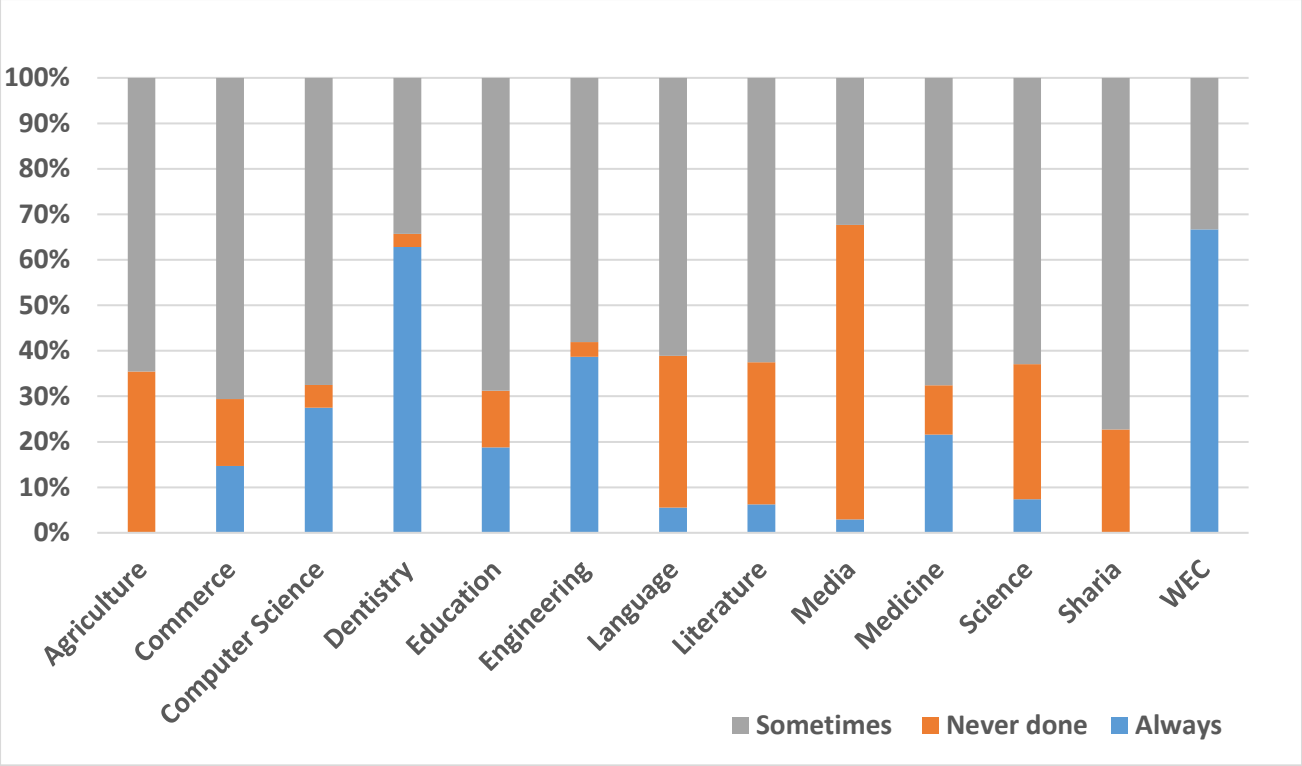


Figure (4-18): Cleanliness status and the sanitation facilities status within each faculty

As demonstrated in (figure 4-18) the cleanliness status and the sanitation facilities status within each faculty of the university most of the response were negative in term of the cleanliness , which mentioned unavailability of the regular cleanliness for the toilets which lead to stink and avoided to be used by the students. The faculties which need to give more attention for the cleanliness of their toilets are the agriculture, sharia, science and mass communication (Media) faculties. whereas the (figure 4-19) and (Photo 2) show the status of the sanitation facilities with each faculty which show that most of the sanitation facilities were not clean as needed and most of the faculty need to give more attention to its sanitation infrastructure is faculty of mass communication (Media) its noticed that all most of the toilets were broken and not in usable status. Whereas the others facilities their sanitation facilities were either broken or closed due to lack of the maintenance and financial resources that all the faculties complained about

Photo 2 The Cleanliness Status at One of University Toilets - Source Own Representative

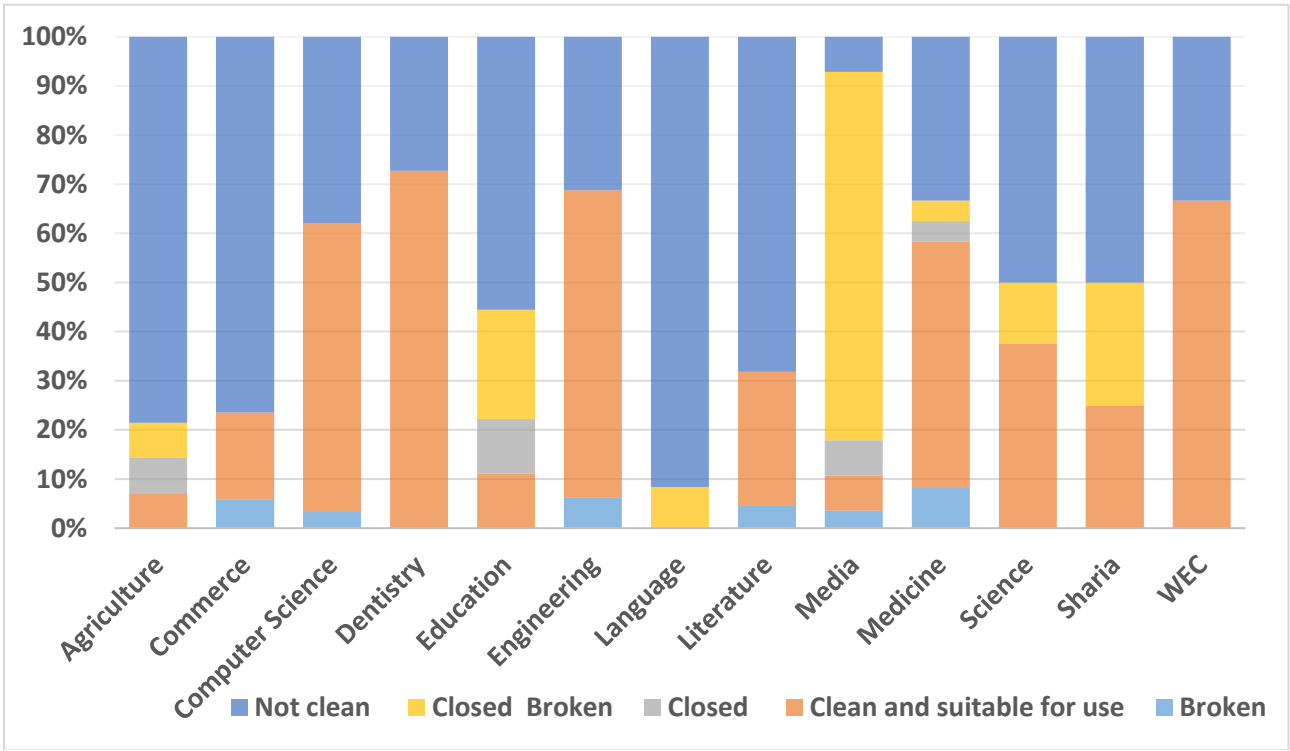


Figure (4-19): Status of the sanitation facilities with each faculty

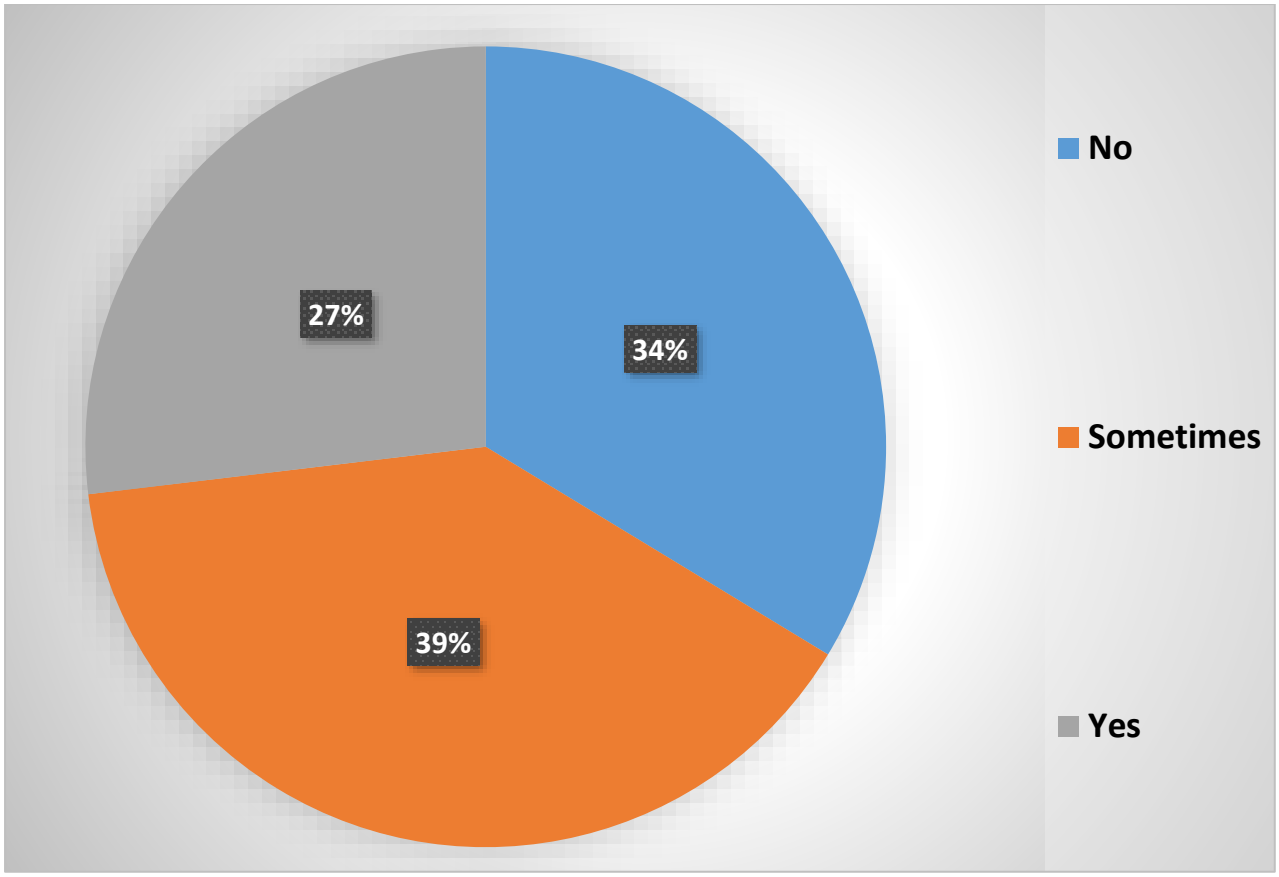


Figure (4-20): How Frequently Do You Use The Sanitation Facilities of Your Faculty?

The (figure 4-20) shows the frequency of use of the sanitation facilities by the students and the working staff of the university. The results were shocking as 39% and 34% of the respondents mentioned that they only used them in cases of necessity or never used, especially the female students.

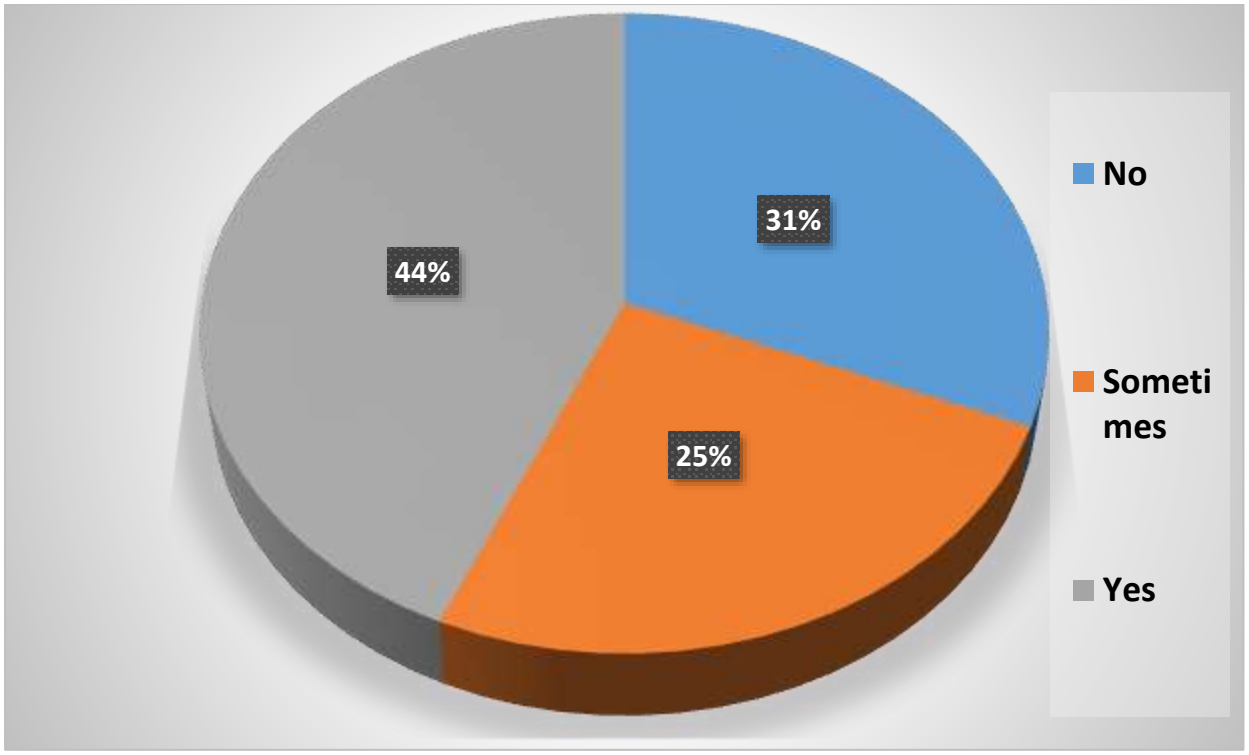


Figure (4-21): Are The Sanitation Facilities (toilets) Provide Privacy And Security?

The universal standards for sanitation facilities state that there must be privacy and security while going to or using these facilities, particularly for women and children. As shown in the (figure 4-21), most of the responses (44%) mentioned that the sanitation facilities ensure this parameter, while 31% mentioned that they did not ensure the privacy and security. Most of the negative responses came from female students. Some of them mentioned, "we cannot use the toilets and sanitation facilities in the afternoon as there is no security or privacy. Some of the toilets do not even have lighting and become dark. We have been absent a few days from the university because we can not use the toilets of our faculty." And as showed in (Photo 3)

Photo 3 The Main Door Status of the Male Students Toilets - Source Own Representative

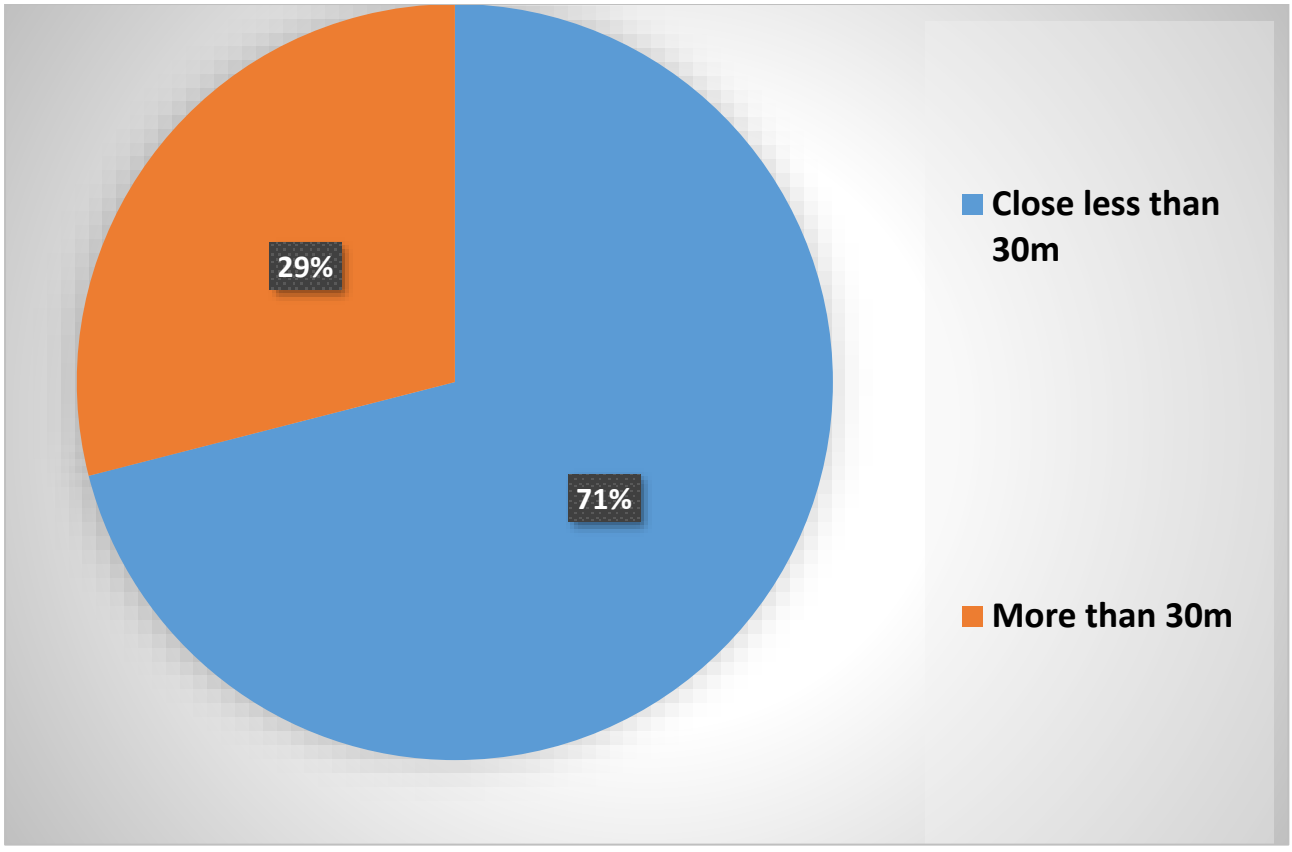


Figure (4-22): How Far Is Sanitation Facilities (toilets) From Classrooms, Lobbies, and Workplaces?

The most important measure for sanitation facilities is that they must be within 30 meters of classroom and lobbies as per WHO WASH standards (WHO 2007). The (figure 4-22) shows how far the sanitation facilities are from classrooms and lobbies. Most of the responses (71%) mentioned that they were close, whereas 29% of responses mentioned that they are far with an average distance of 230 meters. Some of the sanitation facilities were located not in a suitable location in some of the faculties. Unfortunately, more than half of toilets were either closed or broken down, some of the female students mentioned, “They could not find toilets to use at all.”

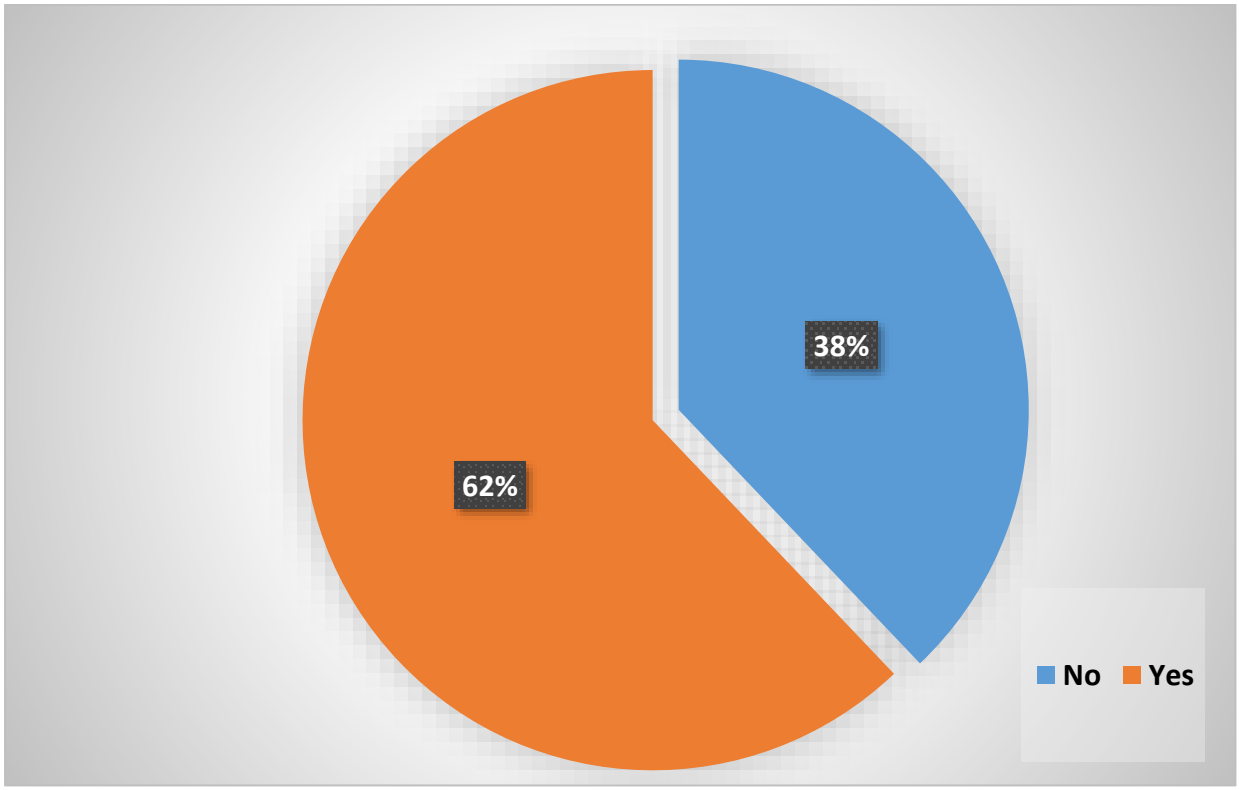


Figure (4-23): Are There Any Handwashing basin Facilities Close By?

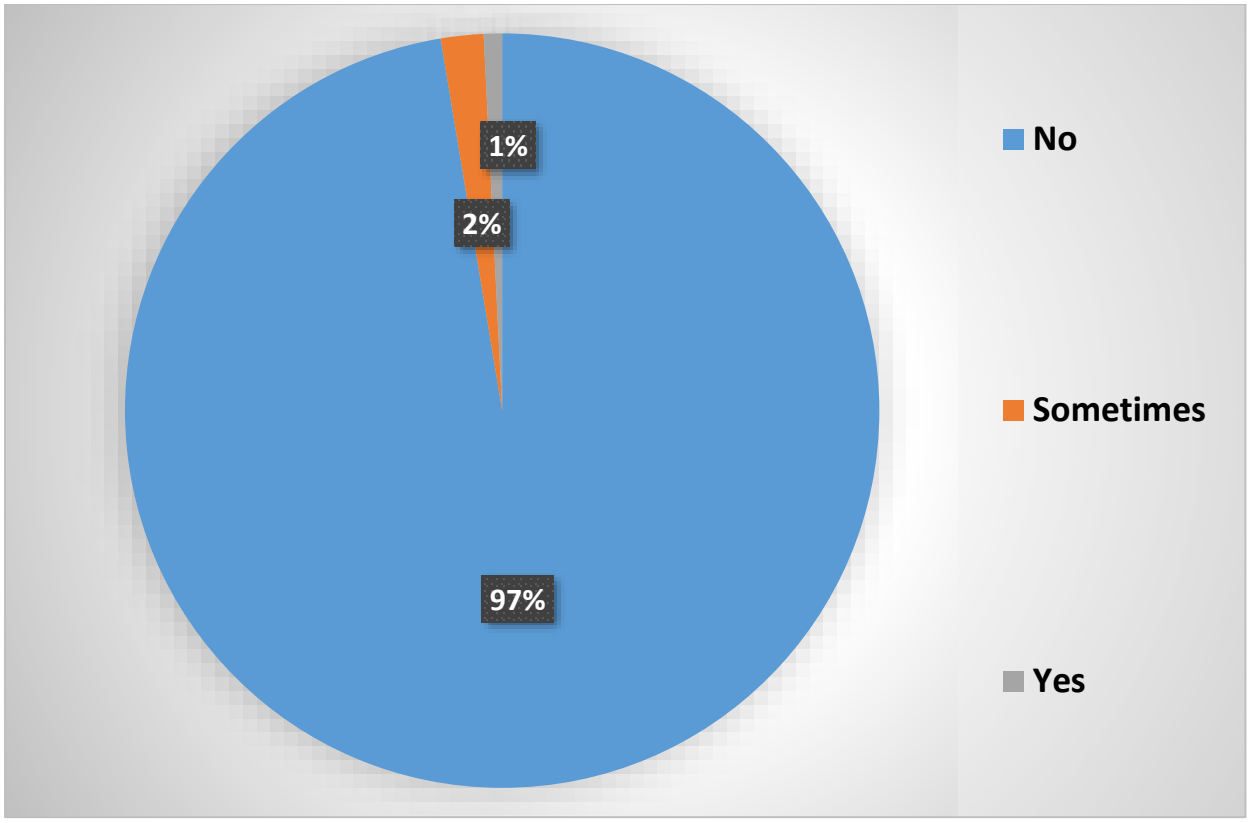


Figure (4-24): Are The Handwashing Facilities Provided With Soap?

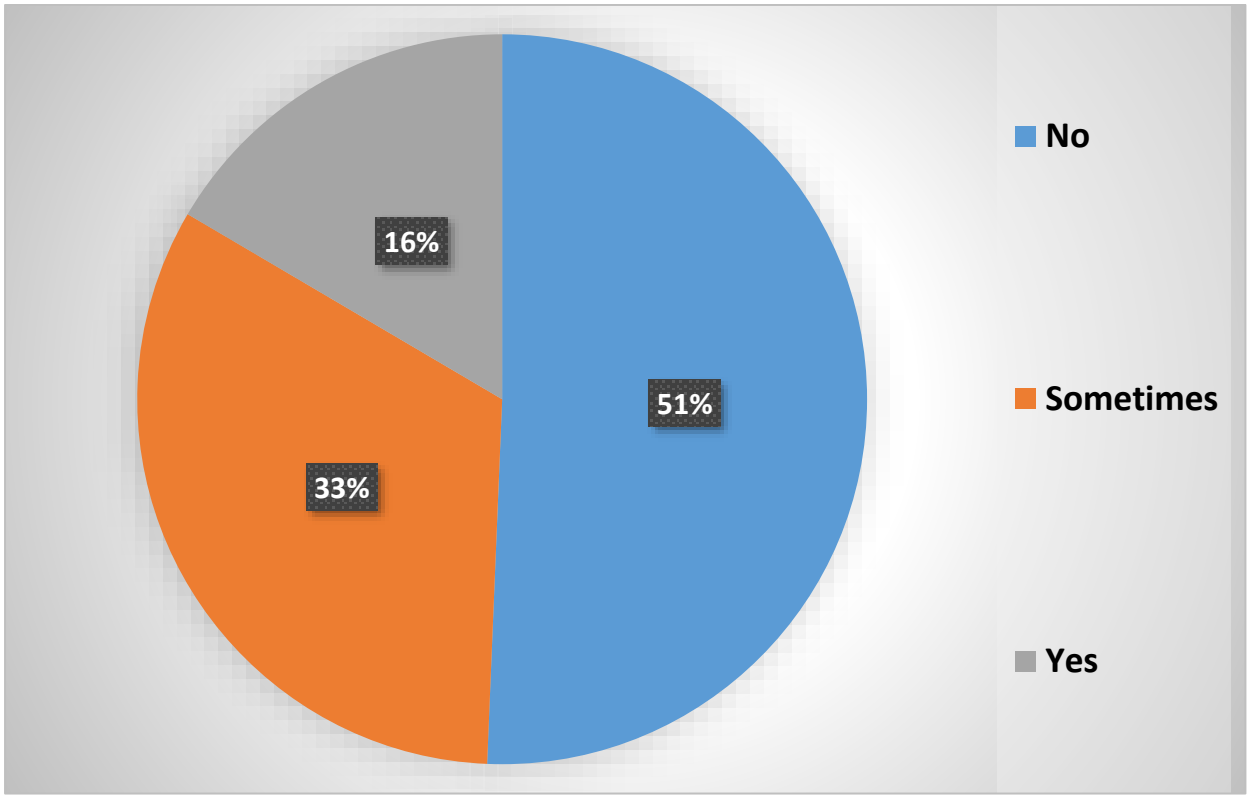


Figure (4-25): Is Water Available At Handwashing Facilities?

The most important parameter that is associated with the sanitation is the handwashing basins that ensure hygiene promotion and personal hygiene behavior among the students of the university, but as shown in (figures 4-23, 24, 25) and (Photo 4) the handwashing basins were present nearby the toilets with 62% responses while 38% mentioned that they were not present; however, although the handwashing basins were available, they were broken or in an unusable state due to poor maintenance. Another finding associated with the handwashing basins was the availability of soaps either in the form of bars or powder. Unfortunately, there was not any soap present, even in the staff toilets. As we can see from the responses, all the students agreed that soap was not available at all (figure 4-24). The water availability in the water taps of the handwashing basins is the main element that also was not available due to broken pipe networks, and some of the handwashing basins were completely broken as shown in the (figure 4-25). The same case was found in Nicaragua where the handwashing basins and soap were missing in the schools in low socio-economic regions in Nicaragua. It was concluded that their presence is essential and the WASH infrastructure was devastated (Cumming et al. 2014).

In case if we are going to talk about the sanitation infrastructure of the sewage network, the university own a very excellent sewage network that was implemented by the Sana'a water and sanitation local cooperation as a part of Sana'a city sewage coverage, sewage network was executed at new campus as it acquired a very huge area that include residential blocks and dense population figure A4-4 (see annex 4). Whereas the faculty of medicine and old university campuses was connect to the sewage network from the nearest main manholes that are located in the main street. The researcher asked the department of the maintenance and projects of the university if they face any problem with the executed sewage network, "the sewage network solved a very big problem for the university as the faculties where depending upon a cesspit system which were regularly over flowed resulting in a very big challenge for the university administration" said by the head of the department.

Photo 4 Handwashing Basin Status - Source Own Representative

4-3 Hygiene

The third parameter of WASH is hygiene. During the site observation of the university faculties, a lack of hygiene activities and promotion within the faculties and the surrounding area was observed. As shown in (figure 4-26) which displays the cleanliness status of the faculties lecture rooms, lobbies, halls, and surroundings there were Consensus within the response that the cleanliness status was conducted sometimes neither as per regular schedule nor daily basis and that was due to lack of the manpower who were responsible for the cleanliness of the facilities. Only two faculties were noticed to have proper cleanliness schedules during the field visit and they were the Engineering and Dentistry faculties.

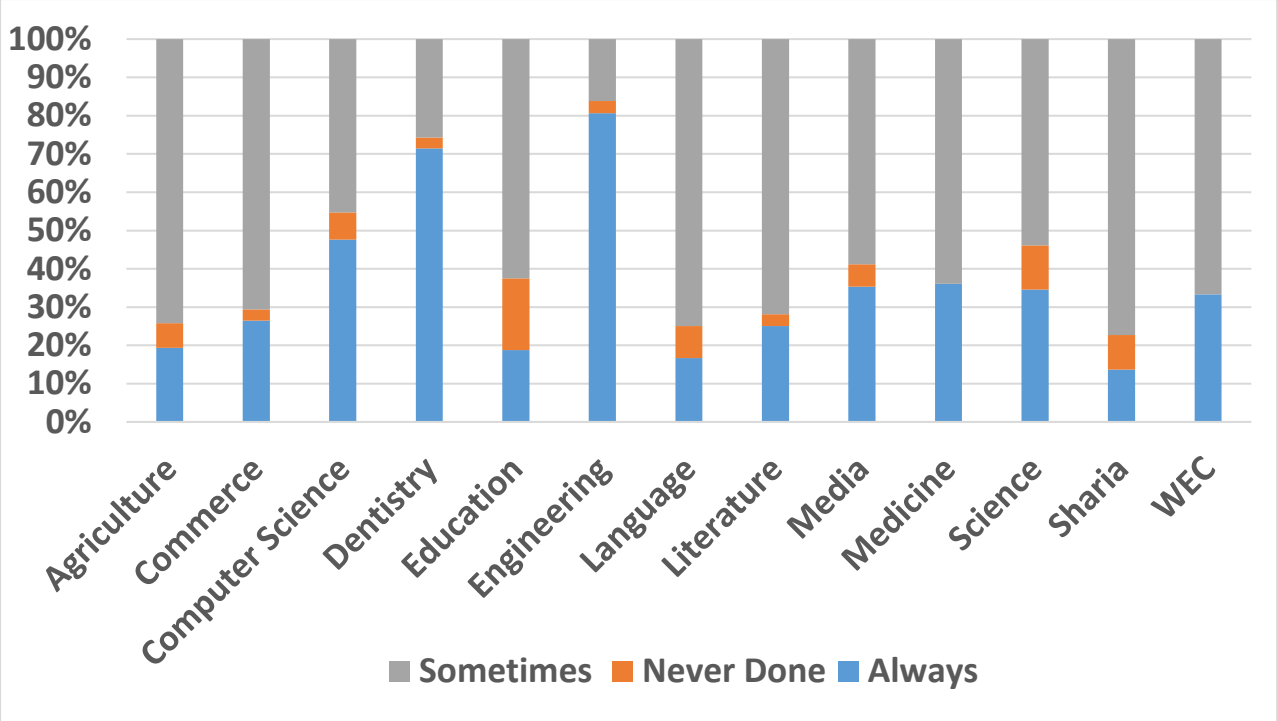


Figure (4-26): Cleanliness status at faculties

As shown in (figure 4-27) which indicates the presence of dustbins that aims for the solid waste management within the faculties most of the responses were consensual that the dustbins were available all the time at the right places, while conducting the checklist it was noticed that the dustbins were available but not as per the need and were distributed randomly all over the faculties and some of them were full of waste, all the dustbins were without covers.

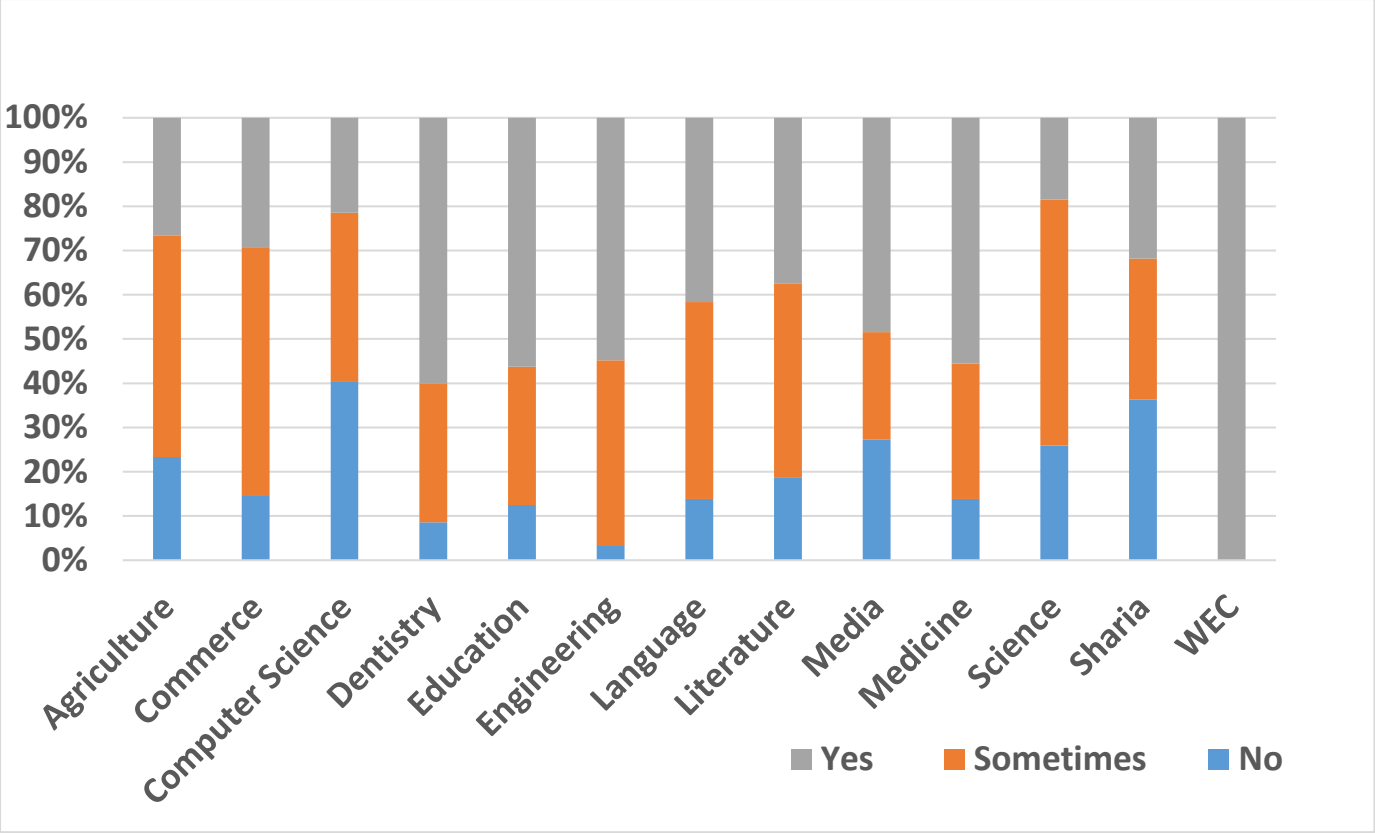


Figure (4-27): Dustbins Distribution at faculties

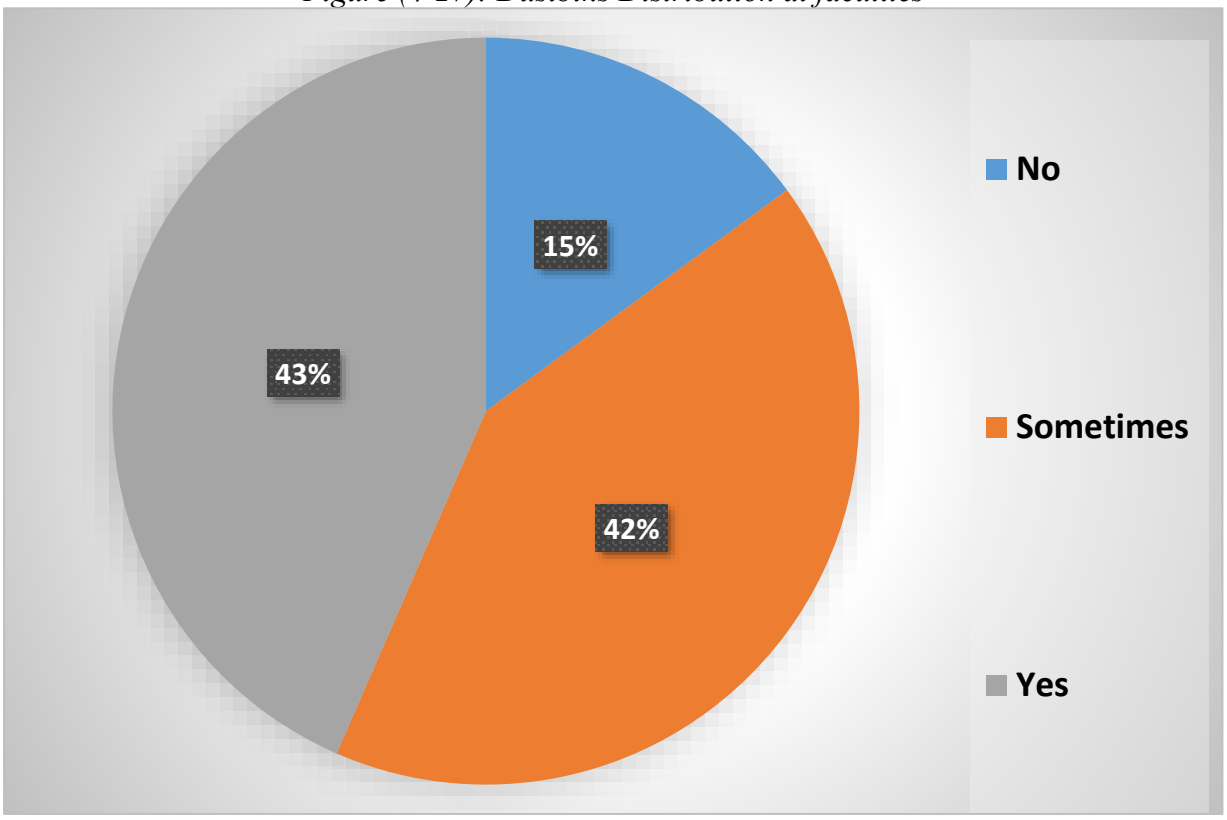


Figure (4-28): Are The Floors, Classrooms, Lobbies and faculty Surroundings Clean And Hygienic?

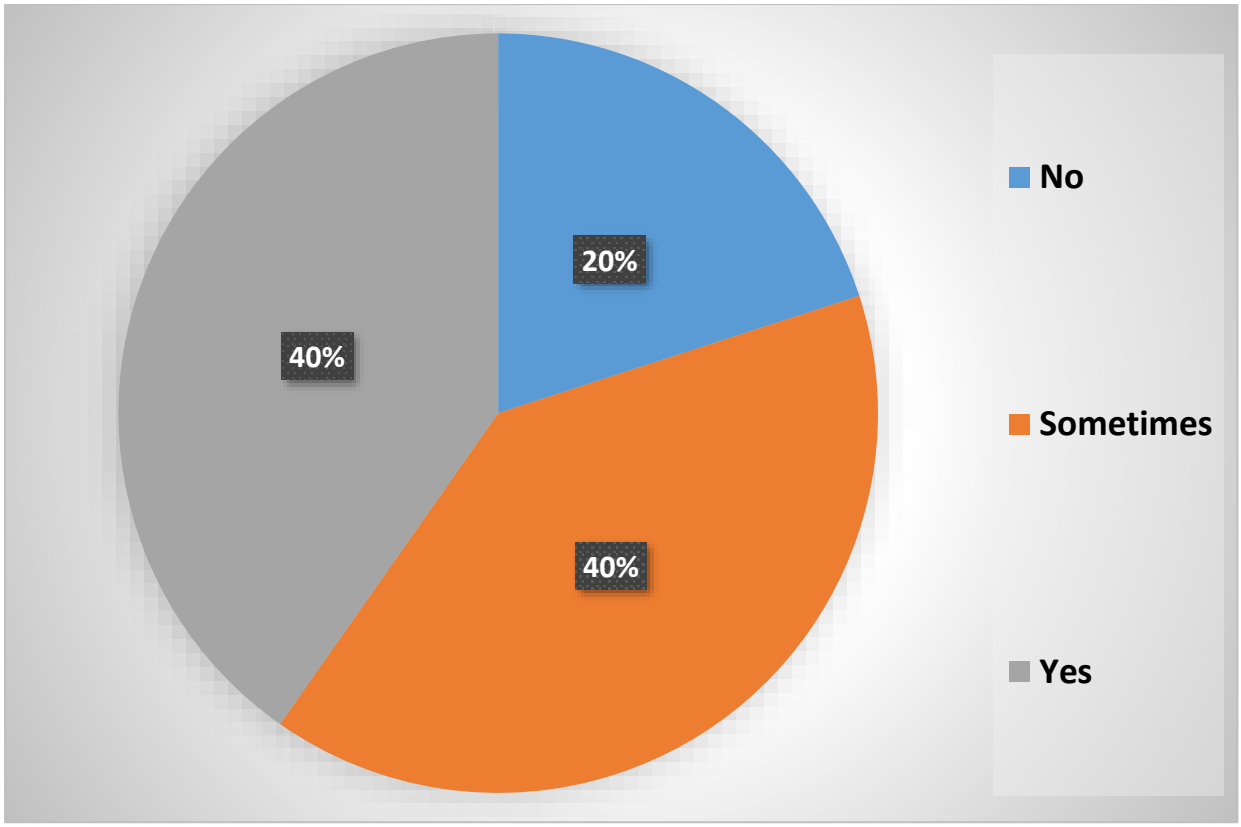


Figure (4-29): Are There Adequate Dustbins In The Classrooms, Lobbies, and Faculty Surroundings?

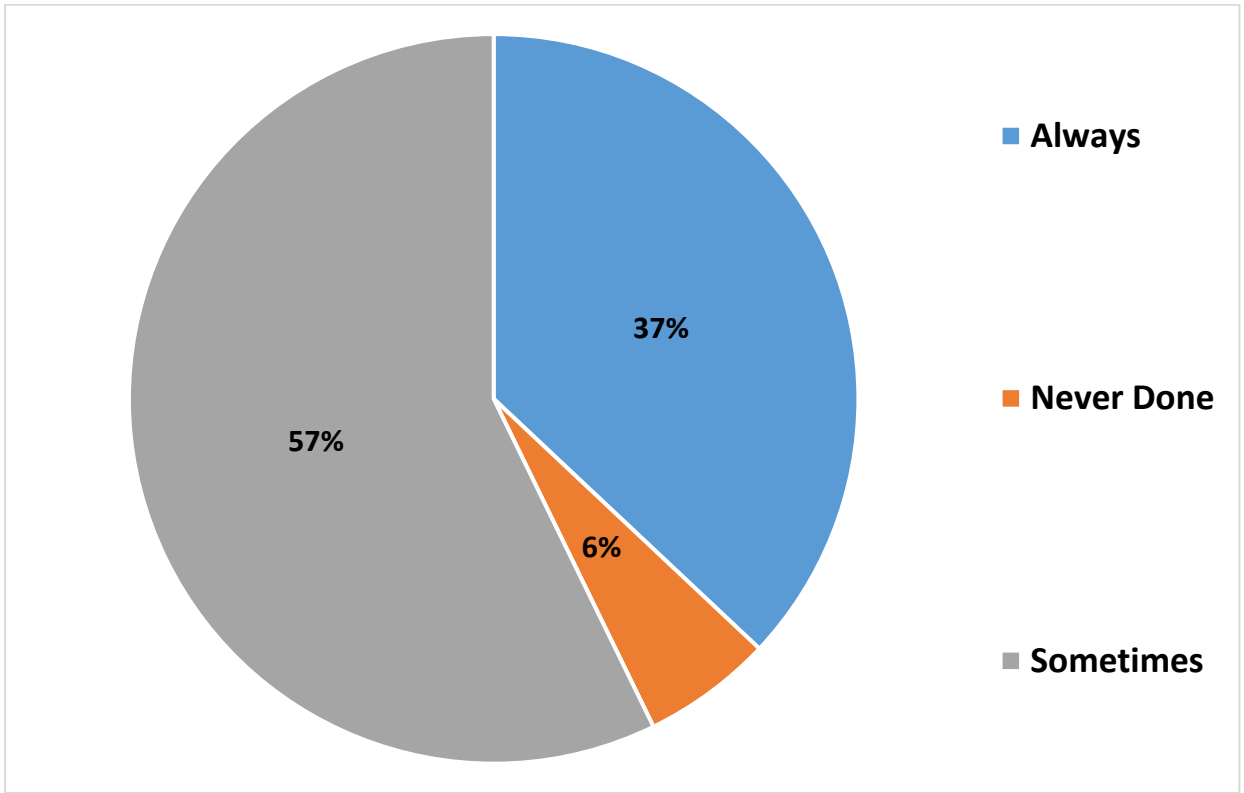


Figure (4-30): How Frequently Are The Classrooms, Lobbies, And Faculty Surroundings Cleaned?

As shown in the above figures (4-28,29,30), most responses mentioned that the cleanliness activity within the faculties was good with 43% and 42% saying the cleanliness was conducted regularly and sometimes, respectively. In regards to the presence of the necessary tools to collect the garbage and trash such as dustbins in suitable locations, 40% of responses mention that they were regularly and another 40% responded by sometimes. During the site visit, the cleanliness level was not as per required as some of the classrooms and lecture halls were full of trash and dust. While sitting with some of the cleaning staff, they discussed their problems such as insufficient payment and unavailability of necessary tools and materials supplied by the subcontractor. Additionally, they mentioned that the cleaning staff must be increased. Therefore, the cleanliness was not conducted regularly as mentioned by the respondents with 57% declaring the cleanliness was conducted sometimes.

As shown from the (figure 4-31) the response of the beneficiaries for the presence of the waste accumulation within their faculties surroundings went with almost negative responses, whereas some of them mentioned that there was waste accumulation such as Mass communication (Media), Education and Sharia faculties see (photo 5&6). During the field visit this issue was given more attention, and it was observed that there were some waste accumulation in the three mentioned faculties due to poor solid waste management.

Photo 5 Waste Accumulation within the University - Source Own Representative

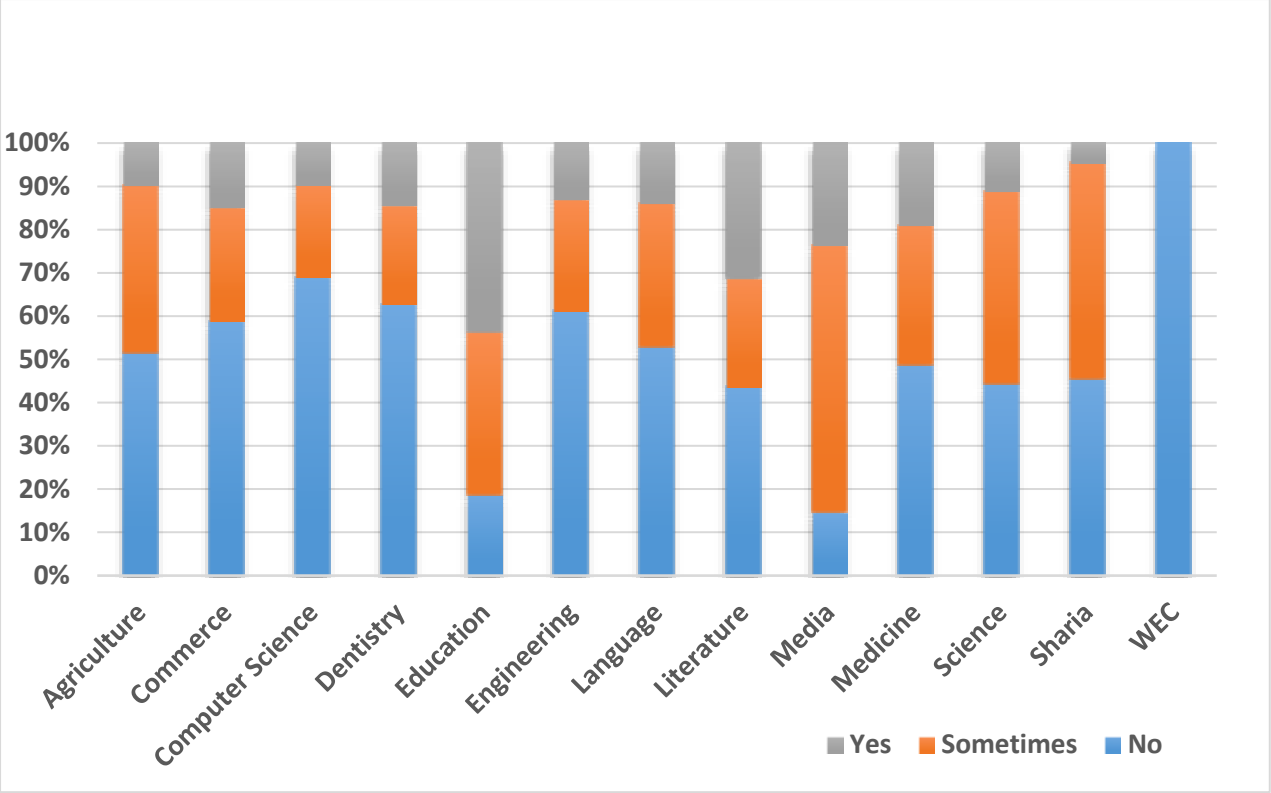


Figure (4-31): Waste Accumulation at faculties

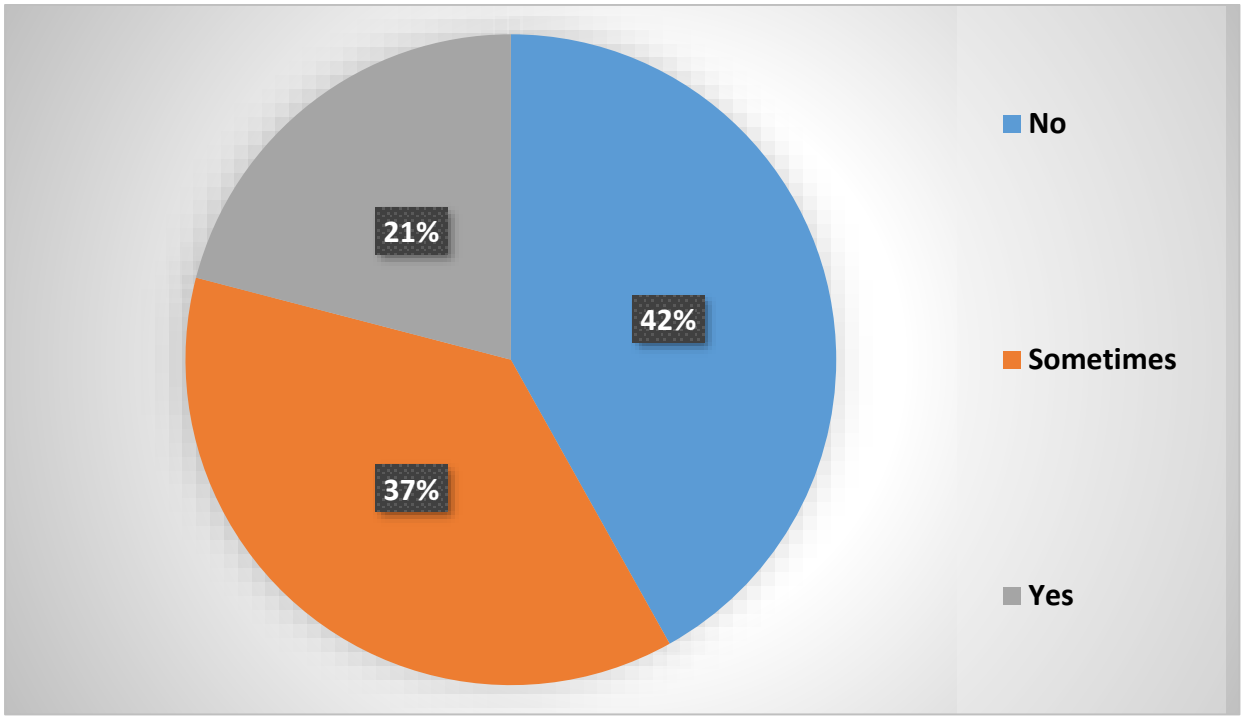


Figure (4-32): Is The Food Prepared In A Hygienic Way Inside The Faculty Cafeteria (cafeteria labors, gloves, kitchen cleanness, cleanness of used tools)?

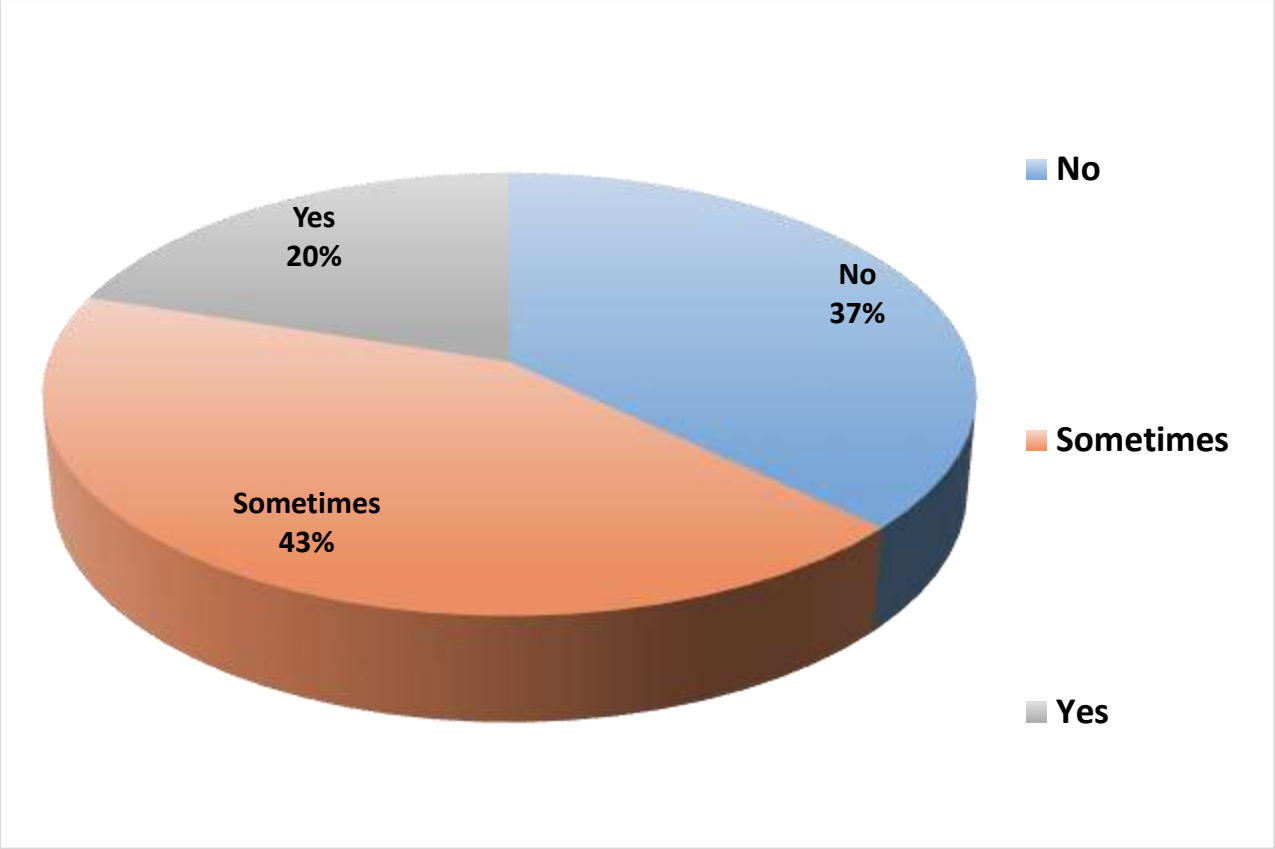


Figure (4-33): Is The Food Covered And Protected Well Inside The Faculty Cafeteria?

The preparation of food is one of the most important measures that have to be taken into account by most of the WASH universal standards, particularly in schools and educational institutions. The food must be prepared in a very hygienic way and protected from contamination from the surrounding environment. None of these measures was found within the university cafeteria as shown in the (figures 4-32,33). Most of the responses were completely negative in terms of preparation and protection of the food that was available at the university.

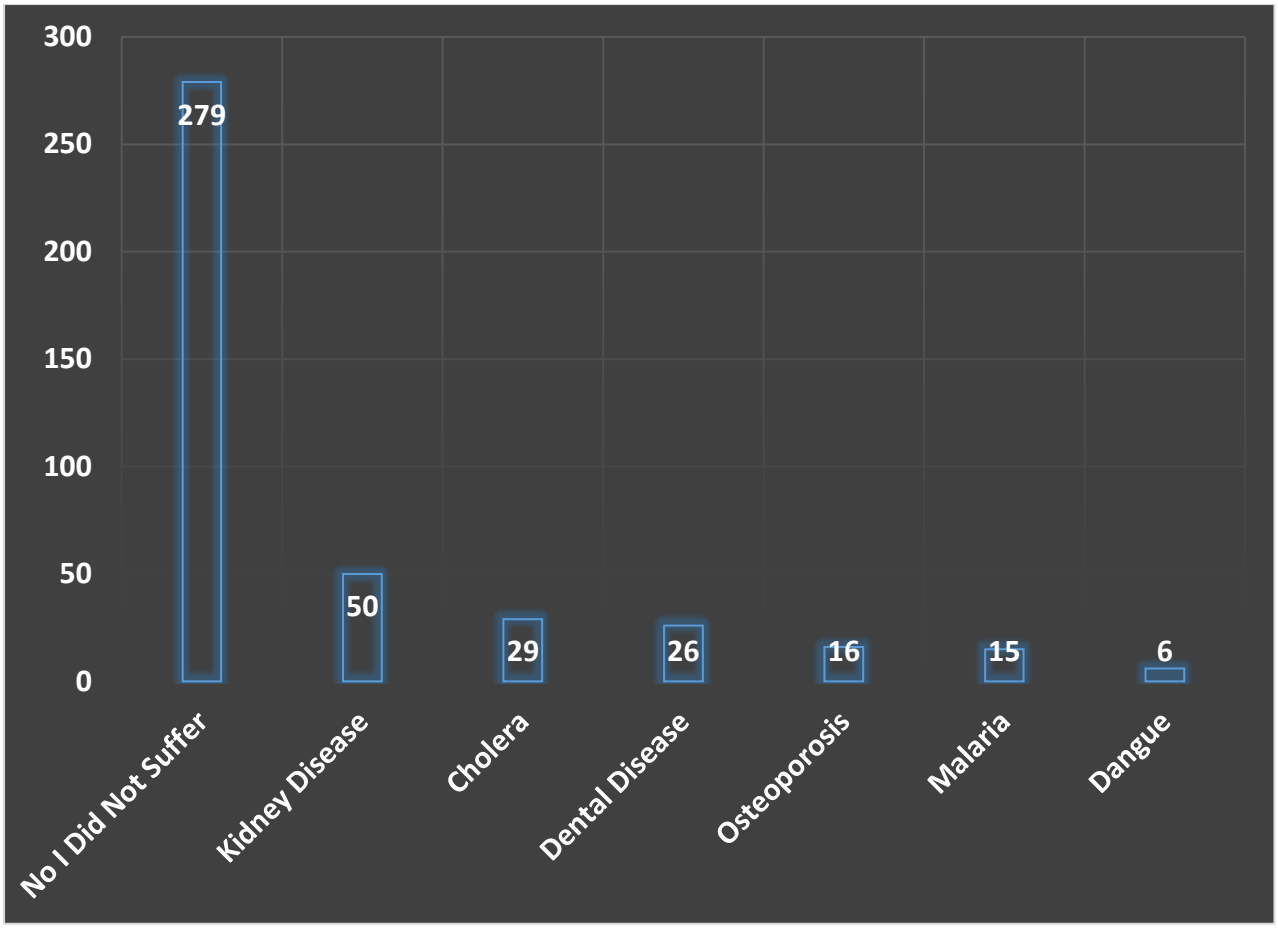


Figure (4-34): Did You Suffer From Any Waterborne Diseases During Your Studies And Working Period Within The University?

The (figure 4-34) demonstrates waterborne disease acquired within the university among the students and working staff during their study and working period. It's shown that 50 students suffered from kidney-related diseases, 29 students suffered from cholera which could be high-risk indicators, 26 students complained about dental issues, 16 students underwent osteoporosis, 16 students suffered from malaria, and 6 students suffered from dengue fever. These figures gave an alert indication of high-risk diseases that speared within the university population and must be taken into consideration.

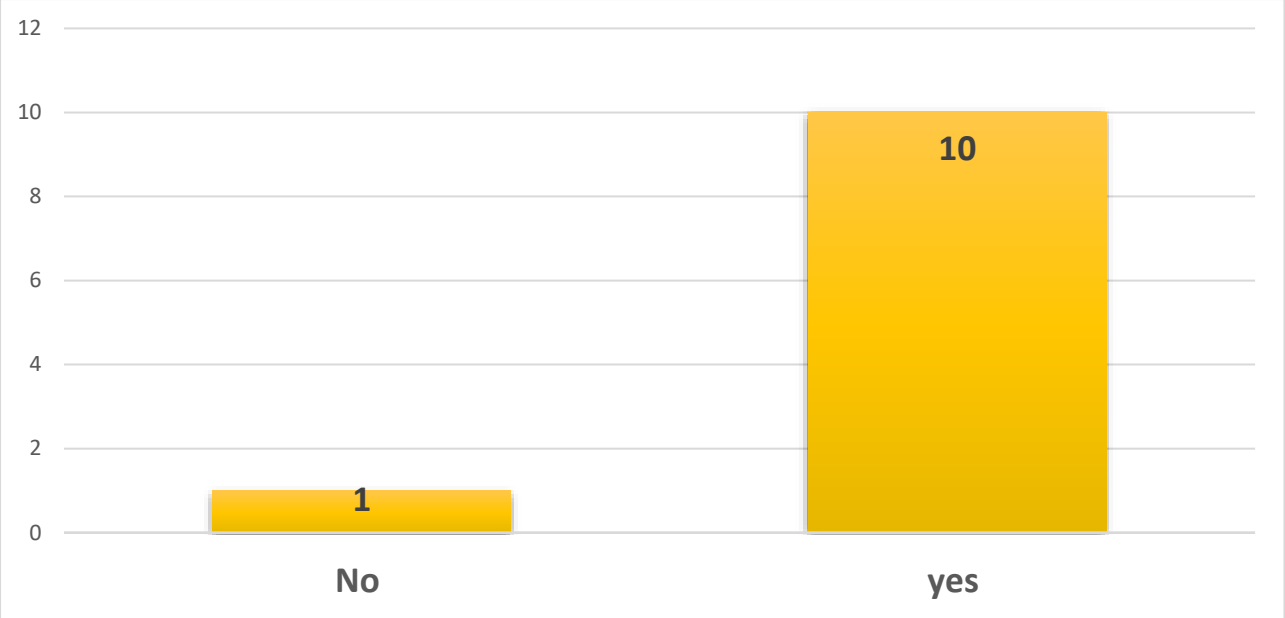


Figure (4-34A): Health Clinics Presence

(figure 4-34A) showed that the presence of the health clinic within the faculties of the university as shown all the faculties have the health clinic in their blocks except one but during the field visit to these clinics most of them were closed, the reasons behind their closing "was due unavailability of sufficient fund ,required equipment and medications as they used only for emergency situation only" as mentioned by the some of the facilities administration. In addition the student was asked how if they could get treatment from these clinics they mentioned" whenever we be there for treatment they do not have any medication to give us and most of the time they remain closed so, we have to go outside for buying the pharmaceutical from nearest pharmacy"

The (figure 4-35) exhibits the availability of the soap at the handwashing basins station at the facilities of the university. Unfortunately, soap was rarely available all the time and in all faculties. This could be due to the lack awareness of the importance of using soap or lack of financial resources. Also it was confirmed during the field visit that soap was missing at all the handwashing basin stations, therefore the university as general and the faculties administration are responsible for this issue that play a major role in the hygiene promotion activities and prevention of disease transmition among students.

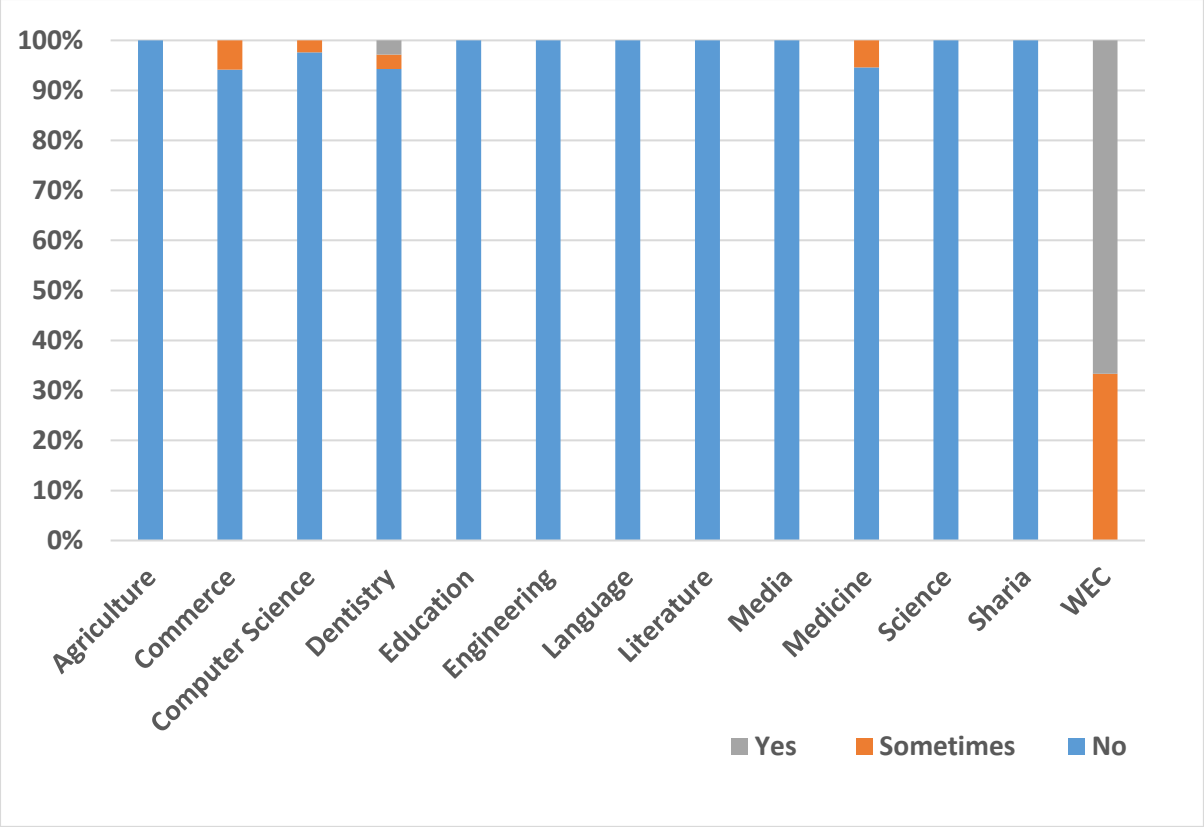


Figure (4-35) Soap Availability at each faculty

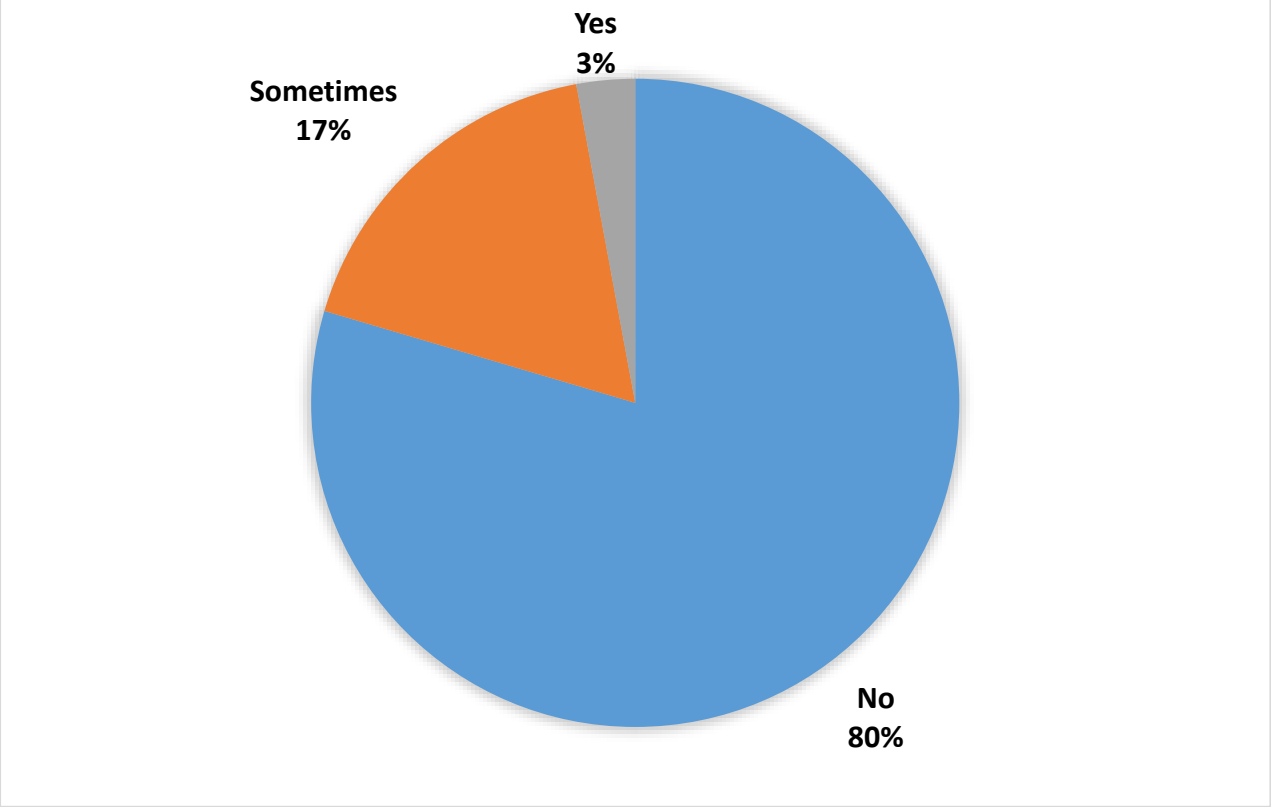


Figure (4-36): Is Awareness About The Water, Sanitation And Hygiene (WASH) Important Within The Faculty? Workshops, wall stickers, brochure...etc

From the (figure 4-36), it showed clearly that there was a lack of awareness activities with the university faculties as there were not any awareness campaigns anywhere. Not a single wall poster or sign spreads the awareness. Some of the faculties deans requested to include the awareness courses within the academic curriculum at the beginning of each academic year, especially in relation to hygiene promotion, proper use of the sanitation facilities, and the maintenance of the cleanliness of the surrounding environment. As per Sphere, hygiene promotion is very important for WASH intervention everywhere as it leads to change in the social behaviors of the targeted communities (Sphere 2018).

Chapter (5)

Conclusion and Recommendation

This chapter provides the conclusion and recommendation of the study. The conclusion provides the overall findings of the study. From the findings of the study, the researcher extracted recommendations that can be implemented to improve the water, sanitation, and hygiene (WASH) situation at Sana'a University as per IWRM perspectives.

The main objective of the study was to evaluate the WASH at Sana'a University as per IWRM perspectives whereas the sub-objectives were to assess the water supply, sanitation, and hygiene facilities and infrastructure at university faculties, to determine beneficiaries access to WASH facilities, and to recommend necessary solutions to improve the WASH sector as per the IWRM for students and staff.

5-1 Water resources

The university owns 5 boreholes that are located within the university campuses out of these only two boreholes were functioning regularly and supplied around 200 cubic meters per day which cover some of the university needs from water as an average, whereas the remaining boreholes were either under maintenance or shut down due to the lack of the financial resources required for deepening the wells. The university water requirement did not meet the minimum requirement as per Sphere and WHO emergency standards which is about 687m^3 and 229 m^3per day respectively. Each faculty is responsible for fulfilling its water needs either for drinking or other uses. These shortages were covered from private water suppliers. The water storage infrastructure of the university faculties need to be reconsidered in terms of replacement, maintenance, and cleanliness, Some of them have not been maintained since they were constructed which has led to waste accumulation, and a thick alga layer has grown inside.

The drinking water facilities or points could be counted with an average of 2-3 drinking points in each faculty that did not even meet the minimum sphere drinking water requirement of 137 cubic meters per day, as a much lower quantity of drinking water was available for drinking purposes.

As for the quality of the water resource of the university, unfortunately, there was no monitoring or controlling over the water quality. There was no department or section responsible to monitor the water quality for neither the university nor the faculty. The quality of the drinking water and water for other uses supplied by the private supplier was monitored by the National Water Resource Authority (NWRA) as mentioned by the NWRA representative during the site visit to their office.

It seems that the University is going to face big and serious challenges to meets its water requirements in the future. As the IWRM concept was not adopted by the university administration, which aims to deal with university campus as a mini watershed that moves with IWRM concept.

5-2 Sanitation facilities (Toilets and Hand washing basins)

The sanitation infrastructure of the university was retrograded with time, as there was no frequent repairing and maintenance. One-third of the sanitation facilities of the university were open and allowed to be used as seen during the site visit unfortunately most them were closed, whereas the other two-thirds were closed permanently or converted to storage as mentioned by the university administrative. As per sphere humanitarian standards, the university must have 462 toilets for boys students, 602 toilets for girls students, and 88 toilets for working staff and these toilets must be available all the times However the university sewer network is in a very good working condition that meets university needs. Although the wastewater that come out from the university must be utilized as per IWRM concept and reused for the recreation works within the university campus.

As shown from the analysis, most of the students do not use the sanitation facilities of the university regularly as there was no regular water availability, cleanliness, or privacy and, sometimes, they would have to go to another faculty within the same university campus.

The hand washing basins were accessible but not functional. All of them were either broken or not in operational conditions, so there were not any handwashing facilities nearby the toilets that let the students wash his/her hands after using the toilets as the soap and water were not available all the times.

The cleanliness of the available sanitation facilities is not at its best. This forms part of the reason why some of the students choose not to use the facilities and instead opt for the bushes around the faculties. This exposes the students to illnesses related to poor sanitation and hygiene as evidenced by the cases of students, especially female students who missed some lectures during the university term. There is a very real and imminent risk of major outbreaks of cholera and other diseases as shown in the analysis.

5-3 Hygiene

The few sanitation facilities are poorly used which is a result of many factors including student background and upbringing, lack of discipline regarding personal hygiene, and weakness in the implementation of sanitation and hygiene policies. For instance, the site observations revealed poor disposal of solid waste as dustbins were ignored and solid materials/waste were disposed just outside the bins even when the bins were not necessarily full, insufficient numbers of waste bins and poor solid waste management.

There was poor preparation of the foods inside the faculties cafeteria as there is no monitoring of cafeteria staff and kitchens that may lead to poor quality of food that the students consumed.

The awareness and hygiene promotion activities were missing at all the university faculties, which are very important to be conducted to maintain the university’s environment and students' health.

The findings of the research showed that the IWRM was degardaed technically due to water shortages and inadequate sanitation were systems that were not repaired and maintained regularly which lead systems to fall into disuse. There were no any water quality monitoring were that may cause

contamination of existing water sources physically, and institutionally due to lack of communication between university officials and unclear roles and responsibilities. Socioeconomically due to lack of human and financial resources, environmentally no attention was given to the surrounding environment of the university campuses, lack of personal hygiene awareness.

The university may meet the WASH requirement from water, sanitation and hygiene but, IWRM concept requirement will be missing therefore the university official shall work hand by hand to achieve the IWRM concept within the university.

5-4 Recommendations

5-4-1 Water institutions

There must be a department within the university that takes on the responsibility of the water resource management of the university in terms of the quality and quantity by documenting the water and sewer networks, monitoring the water quality and repairing and maintaining the sanitation infrastructure, in other word WASH Program department in each faculty to operate under the university projects and maintenance department which structured as below

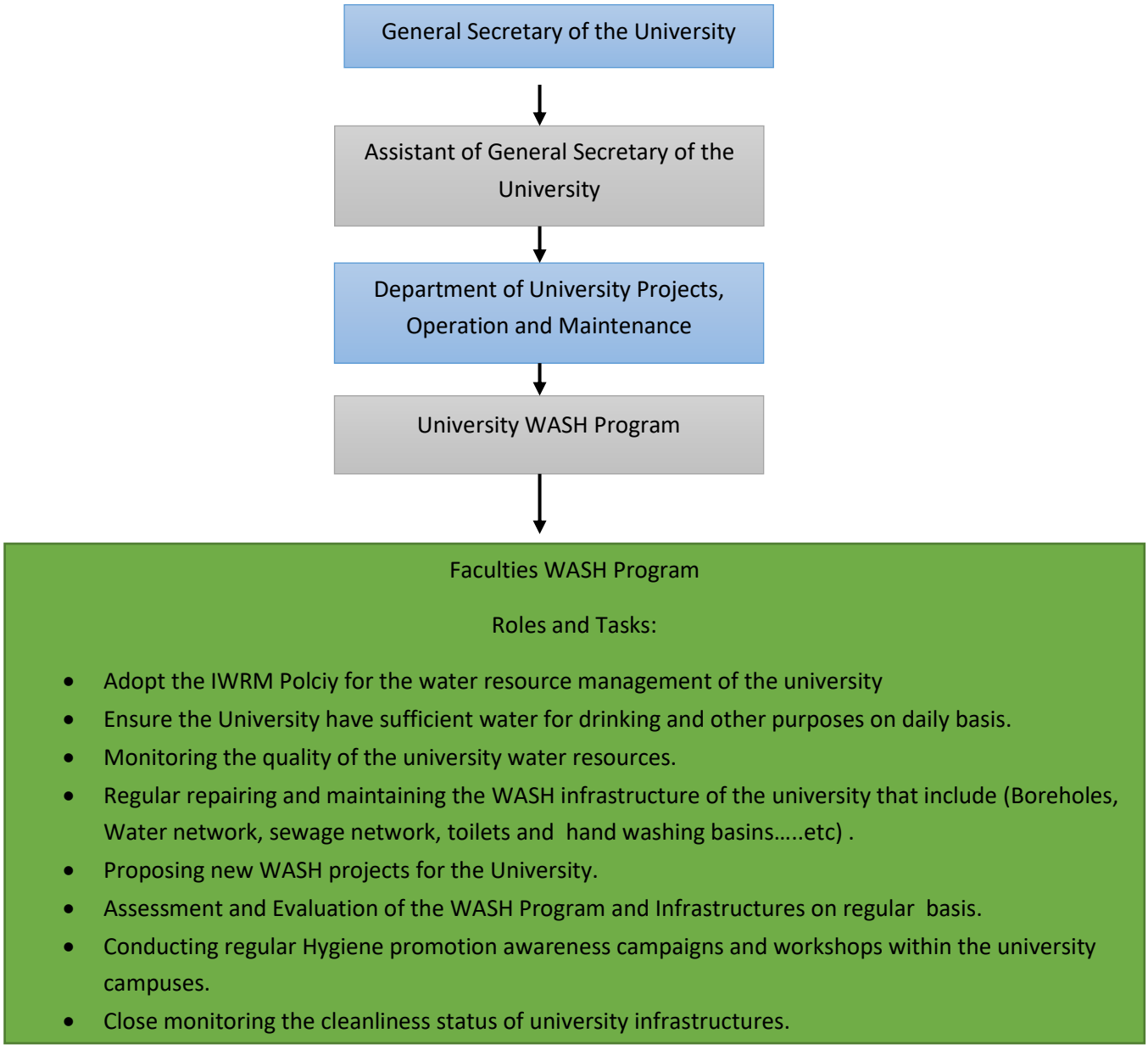


Figure (5-1) The Water Institution Framework

5-4-2 Water Resources

- The existing boreholes must be repaired and maintained so that the university can meet its water needs.
- The existing water pipe networks of the university must be repaired and documented.
- The water storage infrastructures must be taken into consideration in terms of replacing, cleaning and maintained.
- Drinking water must be available all the times and on supply/ demand basis.
- The researcher recommended the establishment of a water purification plant within the university campus as shown below in (Figure5-2) with a design capacity 250 m^3/day with a total cost less than 30,000 USD.
- The rainwater harvesting technique from the rooftop must be adopted with the existing infrastructure that requires maintenance. See annex (5) for the purposed design of the rainwater-harvesting tank with total capacity 100m^3 and their location. In addition, the utilization of the rainwater harvesting pond, which located behind the faculty of Agriculture and the proposed rainwater harvesting tank by the students of the BSc faculty of Engineering (Al-Nozaily Fadhl and BSc Students 2018).

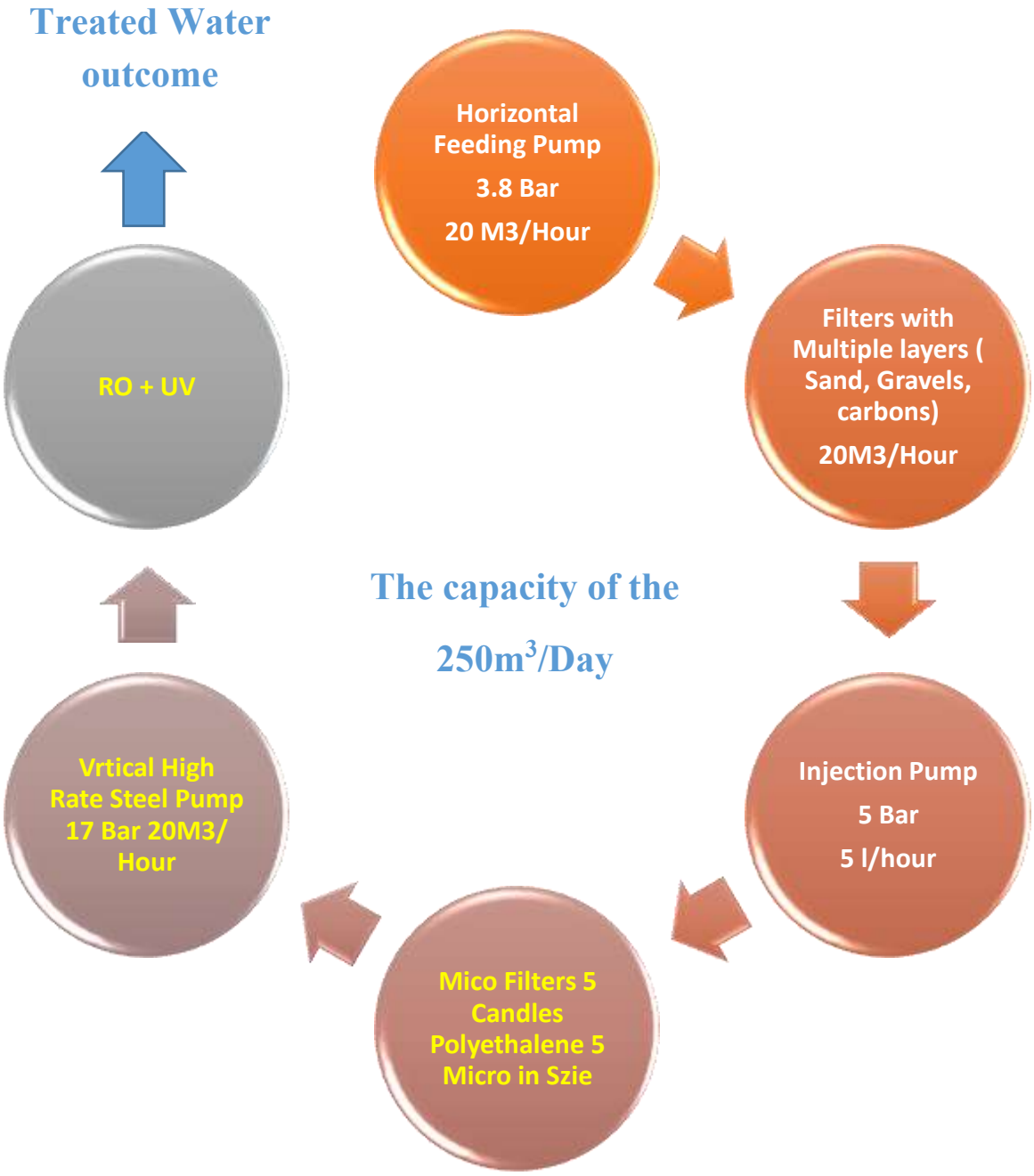


Figure (5-2) Proposed Drinking Water Purification Plant - Source Aqua Filtraion 2019

5-4-3 Sanitation

- Regular repairing the existing toilets that will meet the university's minimum requirement in terms of privacy, water availability, and handwashing basins.
- The researcher recommended establishing a Pilot wastewater treatment plant within the university campus such as the FAO-Yemen wastewater treatment plant for the faculty of engineering that can be utilized for educational and research purposes, see annex (7) the drawings and BoQs, so the treated water can be utilized for irrigation purposes and to save the groundwater quantity of the university from over-extraction.
- Construction of new toilets building outside each faculty that will meet the faculty toilets need see annex (6) the matrix, drawings and BoQs

5-4-4 Hygiene

- There should an awareness course in the curriculum of the first year of each academic course.
- There should be regular awareness campaigns in each faculty for male and female students.
- Soap must be available in each handwashing basins of each faculty all around the university.
- More attention must be given to cleanliness status of the university.
- There must be well-planned management of the solid waste within the university.
- Increase the awareness posters, brochures, campaigns and workshop.

5-4-5 Non-Government Organizations (NGOs)

It seems that improvements in university water supply, sanitation and hygiene can only be achieved with outside assistance from aid agencies. Types of aid include technical and financial assistance. There should be a shared responsibility between the aid agencies and the university.

5-4-6 Researchers:

The WASH studies in Yemen has to be taken with high intention and more research, studies and case studies must be conduct as there are a huge gap.

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Annexes

1- Questionnaire

الاستبيان لرسالة الماجستير

تقييم المياه و الإصحاح البيئي(WASH) في جامعة صنعاء من منظور الإدارة المتكاملة للموارد المائية

المقدمة:

الاخ/ الأخت المحترمة

تحية طيبة :-

أنا أسامة فردوس أحمد الجيلاني طالب ماجستير في مركز المياه و البيئة جامعة صنعاء أجري رسالة الماجستير بعنوان " تقييم المياه و الإصحاح البيئي(WASH) في جامعة صنعاء من منظور الإدارة المتكاملة للموارد المائية " هذه الرسالة سوف تساعد على تطوير الموارد المائية وخدمات الصرف الصحي و نظافة البيئة في الحرم و فناء الجامعة و يعتبر الحصول على المياه النظيفة الصالحة للشرب وللاستخدامات الأخرى وكذلك خدمات الصرف الصحي من حمامات و مغاسل نظيفة مع تأمين كامل الحماية والخصوصية وأيضا إلى جانب نظافة البيئة المحيطة بالكلية و مرافقها ويعتبر مشروع المياه والإصحاح البيئي أحد المقومات الأساسية التي تقوم عليها أي جامعة أو مؤسسة تعليميه و من الضروريات التي يحتاج إليها الطلاب و الطالبات و الكادر التدريسي و الاداري في الجامعة.

هذا الاستبيان هو أحد الطرق المستخدمة من قبل الباحث للحصول على المعلومات اللازمة من قبل المستفيد (الطلاب / العاملين) لذا أرجوا ملء هذا الاستبيان بما لديكم من معلومات لما فيه المصلحة العامة.

المعلومات التي سوف تدلي بها ستكون موثوقة و سرية لن يتطرق إليها أحد غير الباحث.

شاكراً تعاونكم سلفاً ,,,,

الباحث:

أسامة فردوس أحمد الجيلاني

الاستبيان:

الإرشادات : ضع علامة ☑ أمام الإجابة المختارة

الجنس او النوع الاجتماعي : رجل ☐ امرأة ☐

الكلية أو المركز:..... القسم :.....

هل أنت : طالب ☐ كادر إداري ☐ استاذ جامعي ☐

إذا أنت طالب ماهو مستواك.....

متى التحقت بالجامعة أو العمل (السنة) :.....

الحرم الجامعي الذي أنت فيه:

الجامعة القديمة ☐ الجامعة الجديدة ☐ حرم كلية الطب البشري و الأسنان ☐

المياه

1. هل هنالك أماكن/نقاط لمياه الشرب في الكلية
نعم ☐ لا ☐ إذا نعم كم عددهن تقريبا.....
2. هل مياه الشرب تتواجد في هذه الأماكن/ النقاط
دائما ☐ أحيانا ☐ لا يتواجد ☐
3. هل تستخدم هذه الأماكن/النقاط في الكلية لغرض الشرب
نعم ☐ لا ☐ أحيانا ☐
4. هل أنت راضي عن جودة مياه الشرب في الكلية
نعم ☐ لا ☐ أحيانا ☐
5. في حالة عدم وجود مياه للشرب داخل الكلية من أين تجلب مياه للشرب
السوق (الكفتيريا – البقالة) ☐ البيت ☐ كلاهما ☐
6. كم تكلفك مياه الشرب أثناء تواجدك في الجامعة
100 ريال او أقل ☐ 100-200 ريال ☐ اكثر من 200 ريال ☐
7. هل تعتبر أماكن/ نقاط مياه الشرب داخل الكلية من قاعات المحاضرات – الممرات – مكان العمل
قريبة ☐ بعيدة ☐ إذا بعيدة كم المسافة .....
8. هل أماكن/ نقاط مياه الشرب محمية أو مغطاة من مصادر التلوث
نعم ☐ لا ☐ أحيانا ☐
9. هل يتم توفير المياه للاستخدامات الأخرى مثل غسل اليدين و الوضوء و النظافة الشخصيه
نعم ☐ لا ☐ أحيانا ☐
10. ماهي المشاكل التي تواجه خدمات المياه من ناحية سهولة الحصول على مياه للشرب و للاستخدامات الأخرى في الكلية؟

.....

.....

.....

الإصحاح البيئي(الحمامات و الصرف الصحي)

1. هل توجد حمامات في الكلية
نعم ☐ لا ☐ إذا نعم كم عددهن تقريبا.....

2. ماهي حالة حمامات الكلية (اختار اكثر من اجابه)
نظيفة و صالحة للاستعمال ☐ غير نظيفة ☐ مغلقة ☐ مكسرة غير صالحة للاستعمال ☐

3. هل تستخدم حمامات الكلية
نعم ☐ لا ☐ أحيانا ☐

4. هل تؤمن حمامات الكلية الخصوصية
نعم ☐ لا ☐ أحيانا ☐

5. هل تتوفر المياه في حمامات الكلية
دائما ☐ أحيانا ☐ لا تتوفر ☐

6. هل يتم تنظيف الحمامات الكلية بشكل دوري
دائما ☐ أحيانا ☐ أبدا ☐

7. كم تبعد الحمامات بالكلية من قاعات المحاضرات – الممرات – مكان العمل
قريبة أقل من 30 متر ☐ أبعد من 30 متر ☐ إذا بعيدة كم المسافة .....

8. هل توجد مغاسل لغسل اليدين بالقرب من الحمامات
نعم ☐ لا ☐

9. هل يتواجد الصابون عند المغاسل
نعم ☐ لا ☐ أحيانا ☐

10. هل تتوفر المياه في حنفيات المغاسل
نعم ☐ لا ☐ أحيانا ☐

11. ماهي المشاكل التي تواجه حمامات و مغاسل غسل اليدين في الكلية؟ مثل مكسره - لا توفر الحماية و الخصوصية – لا تتوفر مياه – رائحة – غير نظيفة....الخ

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.....
.....

الاصحاح البيئي(النظافة)

1. هل تتواجد سلات قمامة و مخلفات في قاعة المحاضرات و ممرات و كفتيريا و فناء الكلية
نعم ☐ لا ☐ أحيانا ☐

2. هل قاعة المحاضرات و ممرات و فناء الكلية نظيفة بشكل لائق
نعم ☐ لا ☐ أحيانا ☐

3. هل يتم تنظيف قاعة المحاضرات و ممرات و كفتيريا و فناء الكلية بشكل منتظم
دائما ☐ أحيانا ☐ أبدا ☐

4. هل يوجد تراكم للمخلفات و القمامة في فناء الكلية
نعم ☐ لا ☐ أحيانا ☐

5. هل يتم اعداد الأكل بشكل لائق (نظيف) داخل كفيتريا الكليه (عامل الكفتيريا –قفازات- نظافة المطبخ-نظافة الادوات المستخدمه)
نعم ☐ لا ☐ أحيانا ☐

6. هل يتم حفظ الأكل بشكل لائق (نظيف) داخل كفيتريا الكليه
نعم ☐ لا ☐ أحيانا ☐

7. هل أصبت بأمراض متعلقة بالمياه و النظافة خلال فترة دراستك او عملك في الجامعه ؟

الملاريا ☐ الكوليرا ☐ حمى الضنك ☐ املاح الكلى ☐ هشاشة العظام ☐

امراض متعلقة بالاسنان ☐ لا لم اصب ☐

8. هل توجد توعية في مجال المياه و الاصحاح البيئي في الكلية مثلا ندوات – ملصقات – لافتات - بروشورات
نعم ☐ لا ☐ أحيانا ☐

9. مإذا تقترح من حلول لتطوير و تحسين خدمات المياه و الاصحاح البيئي في الكلية

i. مجال المياه مثل: تطوير جودة المياه – توفير مياه الشرب بالكميه الازمه و في الاماكن الملائمة ....الخ

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.....
.....

ii. مجال الاصحاح البيئي (الحمامات و المغاسل) مثل: توفير الإضاءه – المغالق- النظافه الدوريه ....الخ

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.....
.....

iii. مجال الاصحاح البيئي (النظافة) مثل: توفير الصابون – سلات القمامه.....الخ

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.....
.....

شكرا لك

2- WASH Evaluation Field Checklist

Date: **Faculty/Center:**

S No	Description	Yes	No	
Water المياه				
1.	What is the source of the Water & protected from contamination?			1. هل المياه من مصدر امن و محمي من التلوث؟
1.	Is there periodic monitoring of water quality?			2. هل يوجد فحص الدوري للمياه؟
2.	Is water source protected from contamination			3. هل مصدر المياه محمي من التلوث؟
3.	Are there any drinking water points? If yes, how many?			4. هل توجد اماكن او نقاط للمياه الشرب ؟ كم عددهن
4.	Does the drinking water quality meet the Yemeni General Drinking water 1999 and WHO2018 Standards			5. هل مياه الشرب ضمن المواصفات اليمنيه و منظمة الصحه العالميه؟
5.	Is water acceptable? Smell, taste, appearance			6. هل مياه الشرب مقبوله؟ الريحه, الطعم و الشكل
6.	Does the water meet the faculty requirements (needs)			7. هل كمية المياه تلبي احتياجات الكليه ؟
7.	Are there enough water points in the right places for drinking and/or other uses/cleaning/ washing			8. هل توجد نقاط او اماكن لمياه الشرب و/ أو للنظافه الشخصيه في الاماكن الملائمه؟
Toilets and Hand Washing Basin الحمامات و المغاسل				
8.	Are there sufficient sanitation facilities for men/women within the faculty? If yes, how many men/women?			9. هل توجد حمامات كافيه للرجال و النساء؟ إذا كانت الإجابة بنعم فكم عددهن للرجال و النساء
9.	Are the sanitation facilities located in the right places?			10. هل تقع الحمامات في الاماكن الملائمه؟
10.	Do the sanitation facilities provide privacy and security for men/women?			11. هل تؤمن الحمامات الخصوصيه للرجال و النساء؟
11.	Are the sanitation facilities hygienic and clean			12. هل الحمامات نظيفه بالشكل المطلوب؟
12.	Are there handwashing facilities close by?			13. هل توجد مغاسل للغسل اليدين بالقرب من الحمامات؟
13.	Are the handwashing facilities provided with soap?			14. هل يتواجد الصابون في مغاسل اليدين؟
14.	Is the water is available at the hand washing basin?			15. هل تتوفر المياه في حنفيات المغاسل؟
15.	Is there a schedule for cleaning the sanitation facilities?			16. هل هناك جدول دوري لتنظيف الحمامات و المغاسل
Hygiene النظافة				

16.	Are the floors, lobbies, classrooms, and surroundings clean?			17. هل قاعة المحاضرات و ممرات و فناء الكلية نظيفة بشكل لائق؟
17.	Is there adequate dustbins with covers and other tools for managing solid waste			18. هل تتواجد سلات قمامة أو سلات مخلفات في قاعة المحاضرات و ممرات و كفتيريا و فناء الكلية؟
18.	Is there any solid waste accumulation at the faculty			19. هل يوجد تراكم للمخلفات و القمامة في فناء الكلية؟
19.	Is the food prepared in a healthy way inside the faculty cafeteria?			20. هل يتم اعداد الأكل بشكل لائق داخل كفيتريا الكليه؟
20.	Is the food covered and protected inside the cafeteria?			21. هل يتم حفظ الاكل بشكل أمن داخل كفيتريا الكليه؟
21.	Is there any maintenance and cleaning plan?			22. هل توجد خطه للصيانه الحمامات و المغاسل؟
22.	Is there any hygiene promotion activity within the faculty?			23. هل توجد توعية في مجال المياه و الاصحاح البيئي في الكلية مثلا ندوات – ملصقات – لافتات – بروشورات؟
23.	Is there any health clinic within the campus?			24. هل يوجد مرفق عيادة صحيه داخل الكليه؟
24.	Are there any WASH facilities for the disabilities students?			25. هل يوجد مرافق المياه و الاصحاح البيئي لطلاب ذوي الاحتياجات الخاصه؟
25.	Who is responsible for providing the service of WASH Maintenance/ Cleanness/ Water?	من المسؤول عن تقديم خدمات المياه و الاصحاح البيئي في الكليه مع الالتزام بالخدمه (نعم –لا- احيانا)		
		الصيانه	النظافه	المياه

3- Evaluation of FAO Mini Wastewater Treatment Plant

Bait Hanthal, Bani Al-Hareth District Sana'a – Yemen.

Prepared By: Osama Al-Jailani

Supervised by: Prof. Fadhl Ali Al-Nozaily

Introduction and Background

The Mini wastewater treatment plant constructed by Ahdaq water user association and funded by the Food and Agricultural Organization - United Nations (FAO) at Bait Hanthal, Bani Al-Hareth district Sana'a – Yemen. This region is famoused by growing the variety of vegetable that supplied to the most of the Sana'a city markets, whereas most of these vegetables are irrigated directly by treated and untreated wastewater from wastewater plant that come from the Sana'a city where through an open channel passing the area where wastewater treatment plant effluent is discharged. Moreover, to counteract the Cholera epidemic that, spread rapidly in the Sana'a city since the cholera outbreak as per the Yemeni WASH cluster report where around 9000-suspected cases out of which 2000 cases are confirmed. Based on that and to mitigate the Cholera epidemic, the Food and Agricultural Organization United Nation (FAO) thought to establish a Mini Wastewater Treatment Plant that will help to reduce the concentration on the wastewater pollutants to be suitable for reuse it in irrigation of the vegetables at bani Al-Harith district as shown in Figure (1)

The Objective of the Project:

Evaluate the FAO mini-WWTP at Bani Al-Harith to treat further the treated wastewater effluent from the existing SWWTP which would mitigate the Cholera epidemic that speared rapidly in Sana'a city and reduce the health risk from vegetables that grown from wastewater.

The project Area:

The project was located in northern part of the Sana'a city in Bani Al-Harith district within the coordinates 15.5103174N 44.2234614E downstream the Sana'a wastewater treatment plant

Figure (A3-1): FAO WWTP Location Sana'a (15.5103174N 44.2234614E)

Design criteria:

- Design flow: 500 m^3/day
- BOD in 1200 mg/l
- BOD out should be less as much as possible to meet the irrigation requirement as FAO standards
- SS in 2000 mg/l
- SS out should be less as much as possible to meet the irrigation requirement as FAO standards for the crop irrigation that use for agriculture purposes.

<u>Components of the FAO Mini Wastewater Treatment Plant:</u>

Construction area: 32m*30 m

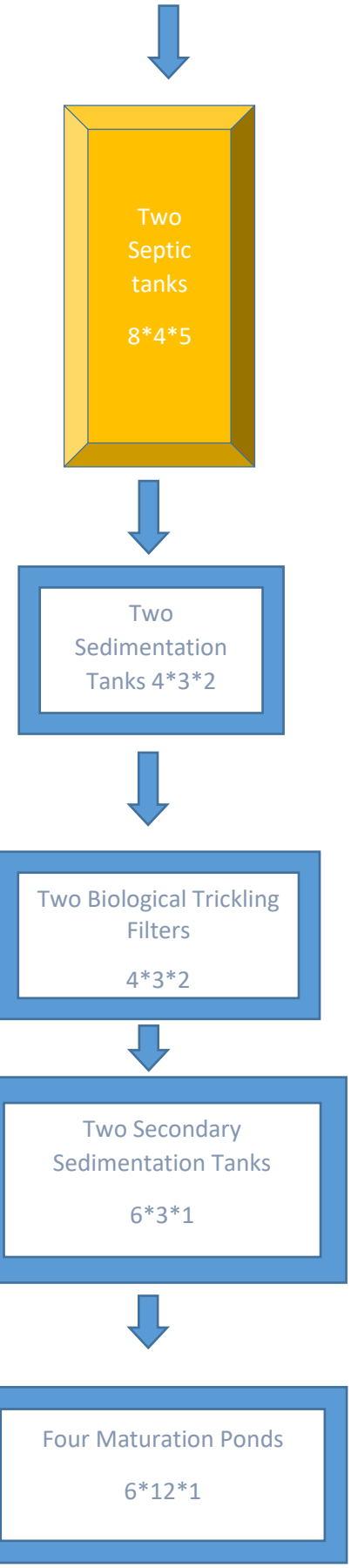
Two Septic tanks 4*8*5 (W x L x H (m))

Two Sedimentation tanks 4*3*2 (WxLxH (m))

Two Trickling filters 4*3*2 (WxLxH (m))

Two Secondary Sedimentation tanks 6*3*1 (WxLxH (m))

Four Maturation ponds 6*12*1 (WxLxH (m))



Figure(A3-2): The Existing Wastewater Treatment Process within the Plant

❖ Inlet:

The inlet of the flow was controlled by pipe with 10 cm (4") diameter without providing any screening for the removing of the Solid waste, while observation it shown that the inlet pipe was surrounded with some solid waste, which may result in blockage of the inlet pipe

Recommendation: to control the inlet with channel with 0.1*0.1 (w*h) with providing coarse and fine screening

❖ Septic Tank:

The design Criteria for Septic Tank are summarized as below:

- The difference between the inlet and the outlet must be at least 15cm.
- The difference between the roof of the tank and the water level must be at least 60cm.
- While using multi compartment the inlet compartment should utilized 2/3 of area of the tank.
- The length must be 2-3 times of the width.
- The detention time (t_d) must be more than 48 hours.

- The flow rate to the septic tanks from the sewage channel was 500m^3/day whereas the deigned volume of the tanks was 320 m^3/day, which is less than assumed volume.
- As per the designed volume, the detention time (t_d) will be 14 hours, which is less than the required as per the design criteria.
- The length to the width was 2 : 1 which is acceptable.
- The compartment of the inlet and the outlet was divided equally.

  Recommendation: the volume of the septic tanks has to be more than the assumed flow 500m^3/day it could be assumed with depth 5 m with surface area 100m^2 , therefore the detention time will be increased, as well as the septic tanks can be divided in to more than two compartments.

❖ Sedimentation Tanks:

The design Criteria for the sedimentation tanks are summarized as in the table :

Table (A3-1): Design Criteria of Sedementation Tanks

Type	detention time (t_d) (hr)	Side Depth h(m)	Surface Loading SL ($m^3/m^2.day$)	Weir Loading WL($m^3/m.day$)	% BOD Removal
Primary	1-2	2-2.5	16-33	Q<4000m^3/day: WL<120 Q>4000m^3/day: WL<250	30-40%
Secondary	2-3	Not less than 2.1	Not more than 33		Depend on the Biological Treatment

Source (Al-Nozaily F, Haidera M 2013)

Two sedimentation tanks before the biological trickling filters with the details as below:

- Area of the two sedimentation tanks 24 $m^{2.}$
- Volume of the two sedimentation 48 $m^{3.}$
- The purposed of these tanks was unknown but they were considered to be sedimentation tanks.
- The assumed volume was 500m^3/day, whereas the deigned volume is 48 m^3 .
- Therefore the detention time (t_d) as per the deigned volume will be 2.3 hours.
- The depth of the tanks as per the designed volume and area will be 4m, but it was considered to be 2m.
- The surface loading accordingly to the to the Maximum flow and designed area will 20.8 m^3/m^2.day, for each tank.
- The weir loading was not taken into the account .

Recommendation: the sedimentation should be designed for long retention time and the area and volume of these tanks should be designed as per the assumed flow 500 m^3/day.

There were two sedimentation tank after the biological trickling filters with the details as below

- Area of the two tanks 72m^2 (6*3) (W*L).
- Volume two tanks 72m^3 (6*3*1) (W*L*H).
- So the detention time (t_d) as per the designed volume will be 3.5 hours which is out of the range as per design criteria.
- The surface loading accordingly to the maximum flow and designed area will 6.9 m^3/m^2.day.
- The weir loading was not taken into the account.

Recommendation: the area and volume of these tanks should be designed as per the assumed flow 500 m^3/day with depth up to 3 m as the area will be 170m^2 and depth 3m

❖ The Biological Trickling Filters:

The design criteria for the low rate biological filters are summarized as below:

- BOD load 60-180g/ $m^{3.}$ day.
- Surface loading 2-4.5 m^3/m^2.day.
- Depth 1.5-2.4m.
- Velocity of out flow 0.9m/sec.
- The bottom slope should be 3-5% .

There were two low rate biological filters after the sedminataion tanks with given details below:

- The size of the gravel was three layers of 3 mm, 0.5 inch and 1 inch from top to the bottom respectively.
- The depth of the gravel layers was varying from top to the bottom 0.8m, 0.4m and 0.4m respectively as per design while implementation there were only one layer of the gravels with one meter depth of 18 mm in size.
- Area of the two low rate biological filters 24 m^2 (4*3) (W*L).
- Volume two low rate biological filters 48 m^3 (4*3*2) (W*L*H).
- Therefore the detention time (t_d) as per the deigned volume will be 2.3 hours and it will depend upon the filters medium used but it should be as long as.
- The surface loading accordingly to the maximum flow and designed area will 41.6 M^3/M^2.day, which out of the range as per design criteria. However, as per the designed volume was 4 m^3/m^2 .day.
- The depth as per the designed area and volume will be 4m but it was considered 2 m.
- Only on medium of coarse aggregate has been used.
- The bottom slope of the was considered to be 6%.
- The inlets pipes are holed with small holes, which going to be blocked with the time.

Recommendation: the law rate trickling filter must be designed for the assumed flow 500 m^3/day

and the filter medium should contain three different layers of coarse aggregate as designed. also the bottom slope of the filters must be within the design criteria.

❖ The Maturation Ponds:

The design criteria for the maturation pond are summarized as below:

- BOD load 1-2g/ m^3. day.
- Depth 0.5-1.0 m.
- The detention time (td) must be more than 5-15 days.
- The length must be 2-3 times of the width.

The treatment plant based of four maturation pond with dimensions (6*12*1) (W*L*H) and given details as below:

- The area of the four maturation ponds 288 m^2 (6*12) (W*L) each
- The volume the four maturation ponds 288 m^3 has the dimensions (6*12*1) (W*L*H) each.
- The detention time (t_d) as per the deigned volume will be 14 hours, which is out of the criteria.

Recommendation:

- Its preferable to have small depth to allow more subjection to the sunlight.
- The area of the maturation ponds must be as large as possible.
- The weir loading should be not neglected.

Observations:

- The design criteria were missing while designing and implementation of the plants.
- The treatment process will be based on gravitational flow with no pumping, whereas the plant level adjacent the canal, without any protection against heavy storm or water flood during the monsoon period which flows to the canal.
- From the field visit, the people complains about the lack of environmental and social studies. Hence, this may lead to some environmental and social issues in the future.
- The treatment quality should be expected to achieve BOD and COD suitable for the irrigated plants which are according to FAO standards for irrigation.

Conclusion:

This FAO mini WWTP is considered as a good effort was made by FAO to mitigate the Cholera epidemic that speared rapidly in Sana'a city. However, the treatment plant should be modified as per the requirement and standards. Accordingly, the effluent values of each BOD and COD should matched with WHO and FAO standards for safe reusing the treated water for irrigation.

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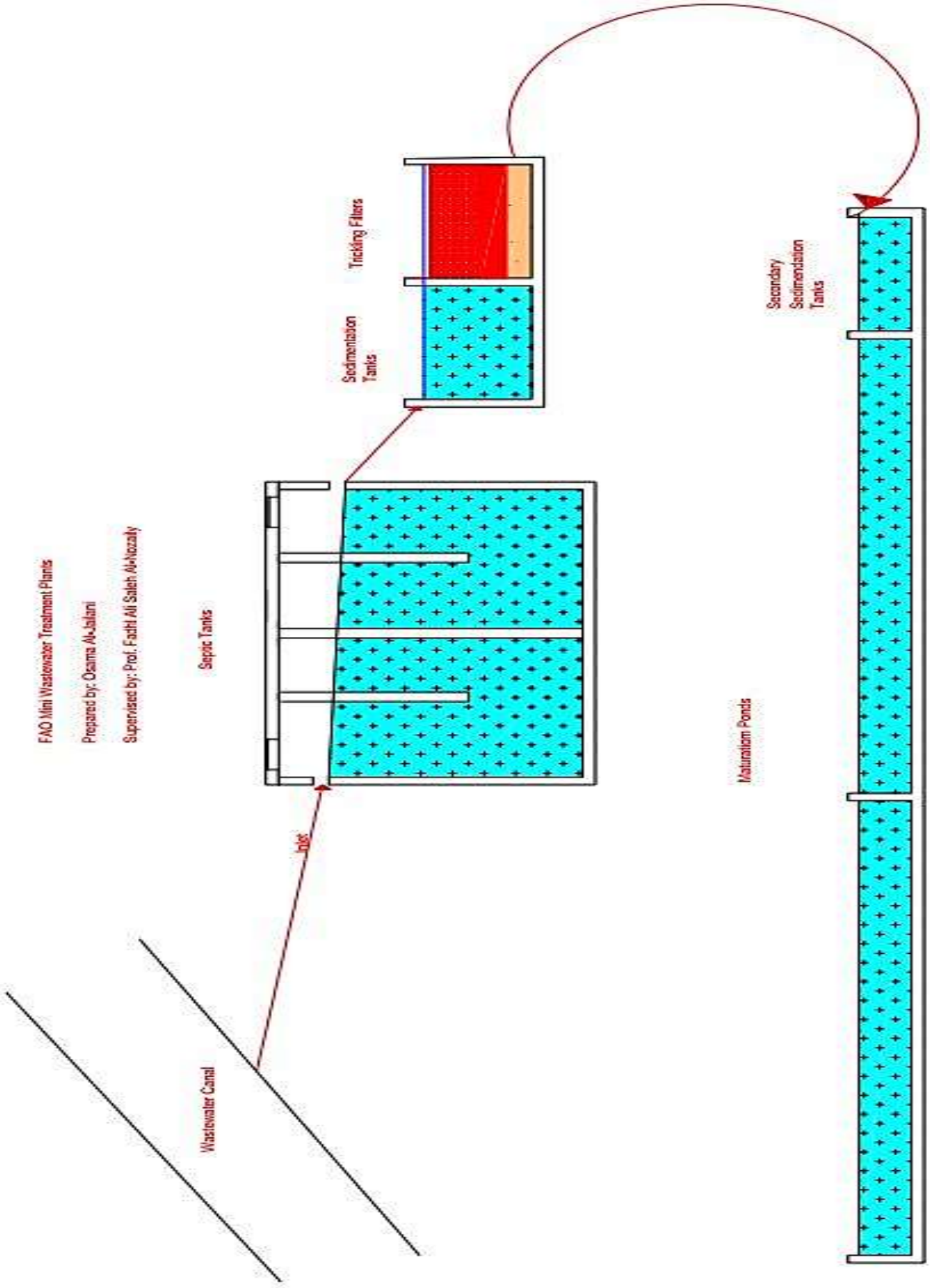


Figure (A3-1) Vertical Cross section of FAO WWTP - Source Own Representative

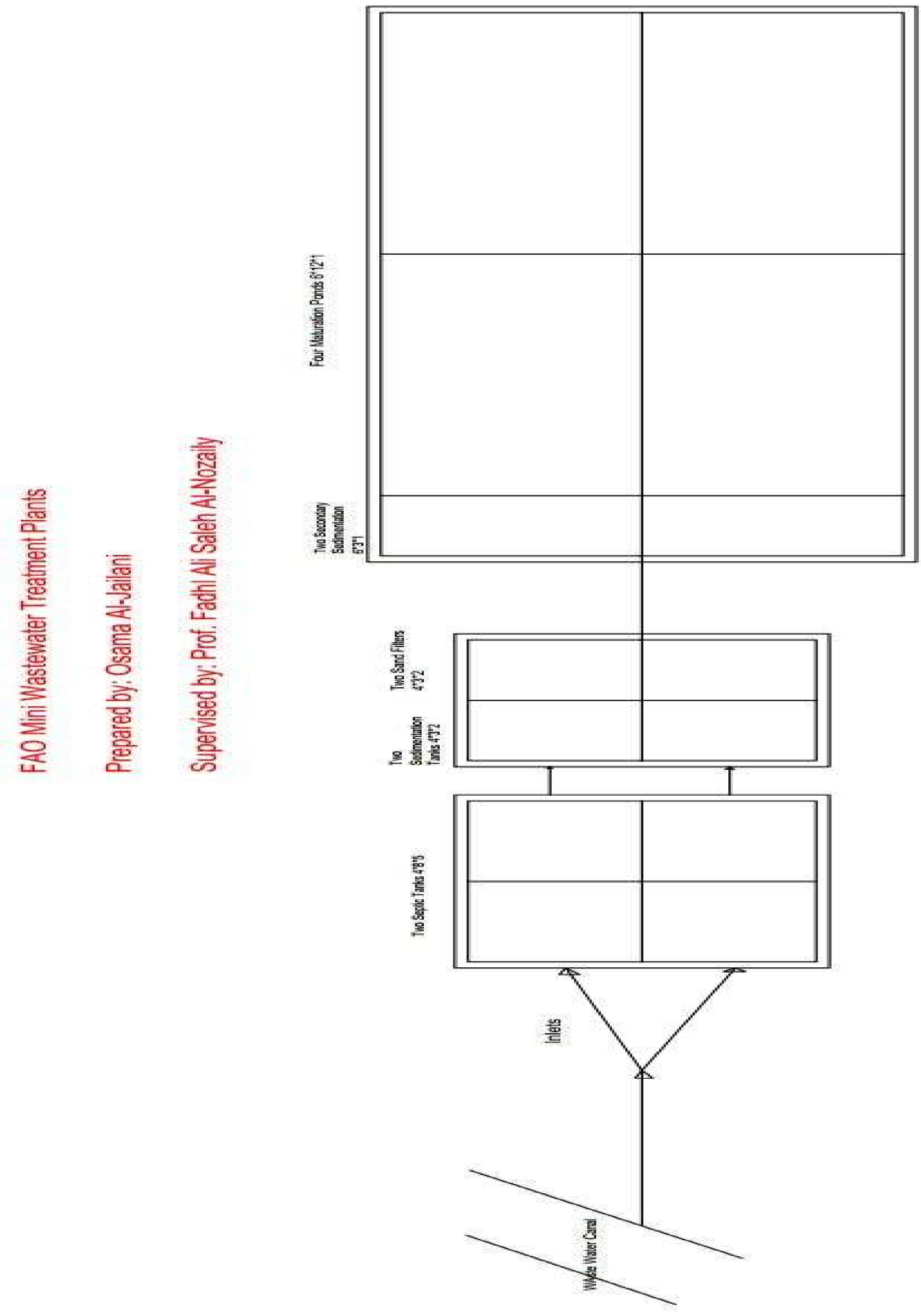


Figure (A3-2): Horizontal Cross section FAO WWTP - Source Own Representative

Photos No (1- The Project sign Board) (2- The Wastewater Canal) (3- The wastewater directly used for irrigation) (4- Septic Tanks) - Source Own Representative

Photoes No (5&6 Sedimentation Tanks and Biological Filters) (7- The maturation ponds) (8- The WWTP whole view) - Source Own Representative

Photo (9): The waste accumulation at the inlet pipe - Source Own Representative

4- University Water Supply and Sewer Network

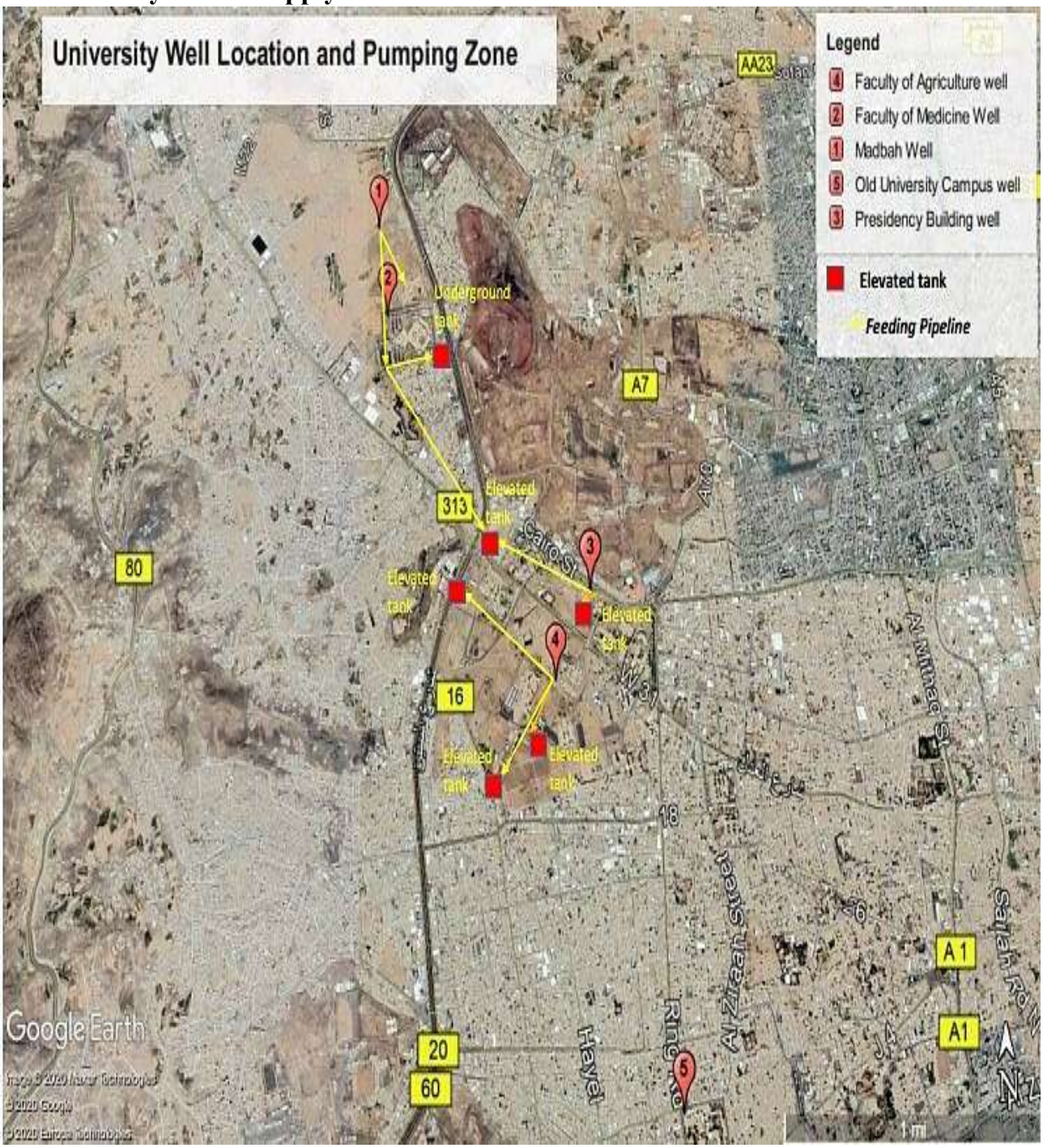


Figure (A4-1) University Well Loaction and Pumping Zone – Source Google Earth

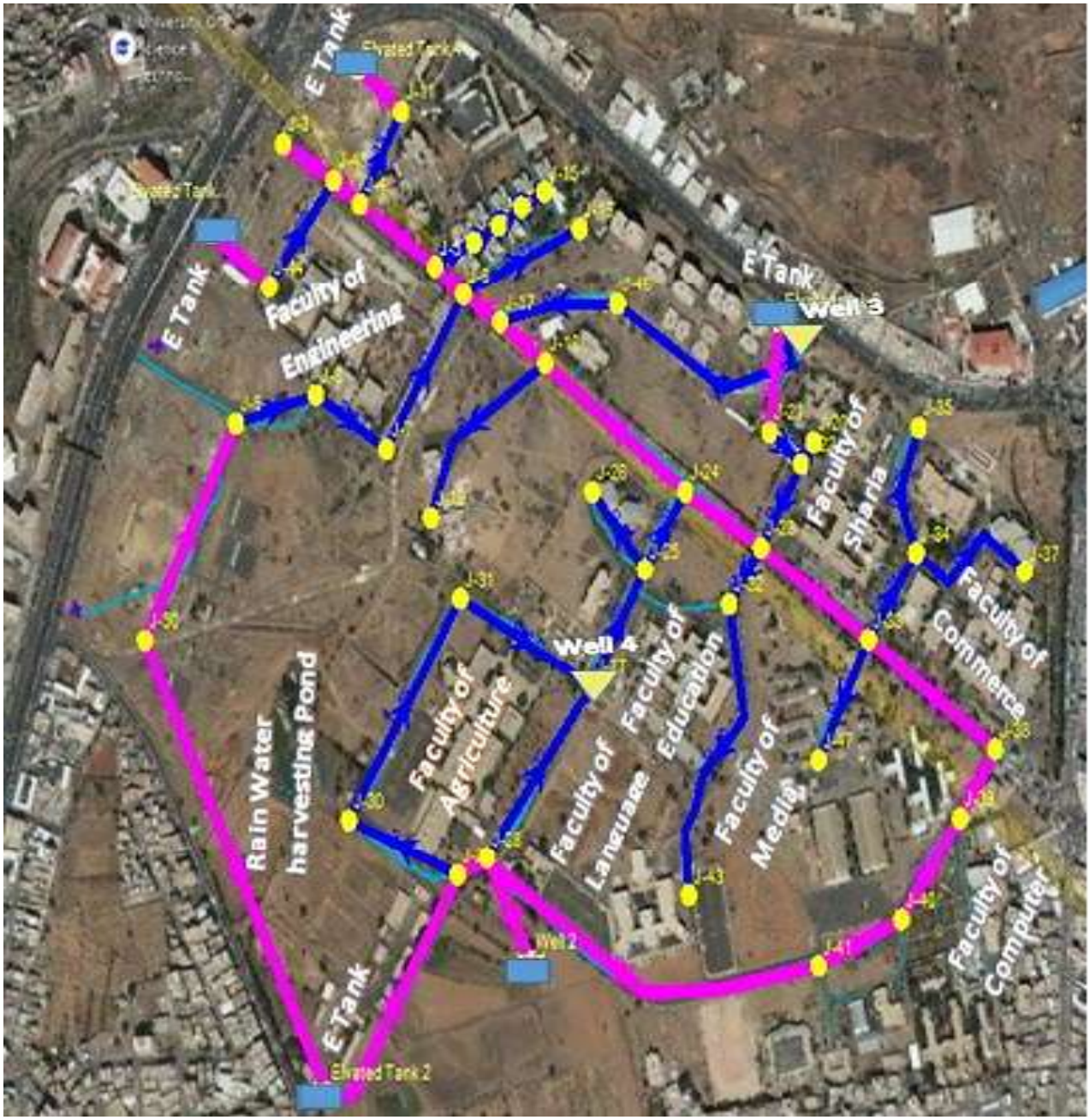
Faculty of Medicine Campus

Well or Elevated Tank' Junction Point

------ Main Water Pipeline from well to tank -------- Main Water pipeline with 4”

----- Branch water pipeline 3”

Figure (A4-2) Faculty of Medicine Water pipeline Network



New University Campus

Well

Junction Point

-------- Main Water pipeline with 4”

------- Branch water pipeline 3”

Elavated Tank

Figure (A4-3) New University Campus Water pipeline Network

Figure (A4-3) Old University Campus Water pipeline Network

Figure (A4-4) New University Campus Sewer pipeline Network

5- Proposed Rainwater Harvesting Tank, Calculations and Their Locations

Table No (A5-1) Summary of Rain Water Harvesting Tanks, Calculation and Their Location

S.No	Faculty	Roof Top Area m^2	Average Quantity Rainfall in Sana'a 2019 (m^3) = Area of roof Top*Avg Rainfall*Coff	Harvesting Capacity	Recommendation	Coordinates
1	Sharia and Law	6780	403	4	4 Tanks of 100 m^3	15.222N/44.119E 15.222N/44.118E 15.223N/44.112E 15.222N/44.111E
2	Literature	2920	174	2	2 Tanks of 100 m^3	15.2055N/44.1129E 15.2052N/44.1129E
3	Science	2720	162	2	2 Tanks of 100 m^3	15.2055N/44.1123E 15.2052N/44.1126E
4	Education	3704	220	2	2 Tanks of 100 m^3	15.2158N/44.1140E 15.2159N/44.110E
5	Commerce	5250	312	3	3 Tanks of 100 m^3	15.2159N/44.1115E 15.2159N/44.1117E 15.2208N/44.1118E
6	Medicine +Dentistry	There is no need for the Rainwater harvesting as there were already RWH Pond Infront of the faculty gate				
7	Engineering	4215	251	3	3 Tanks of 100 m^3	15.2210N/44.1044E 15.2214N/44.1042E 15.2211N/44.1042E
8	Agriculture	24000	1428	14	Utilized the Rain water Harvesting Pond Behind the faculty	15.2152N/44.1039E
9	Mass Communication (Media)	980	58	1	Tanks of 100 m^3	15.2156N/44.117.6E
10	Language	4485	267	3	3 Tanks of 100 m^3	15.2149N/44.1058E 15.2148N/44.1100E 15.2150N/44.1176E
11	Computer Science	1080	64	1	Tanks of 100 m^3	15.2150N/44.1118E

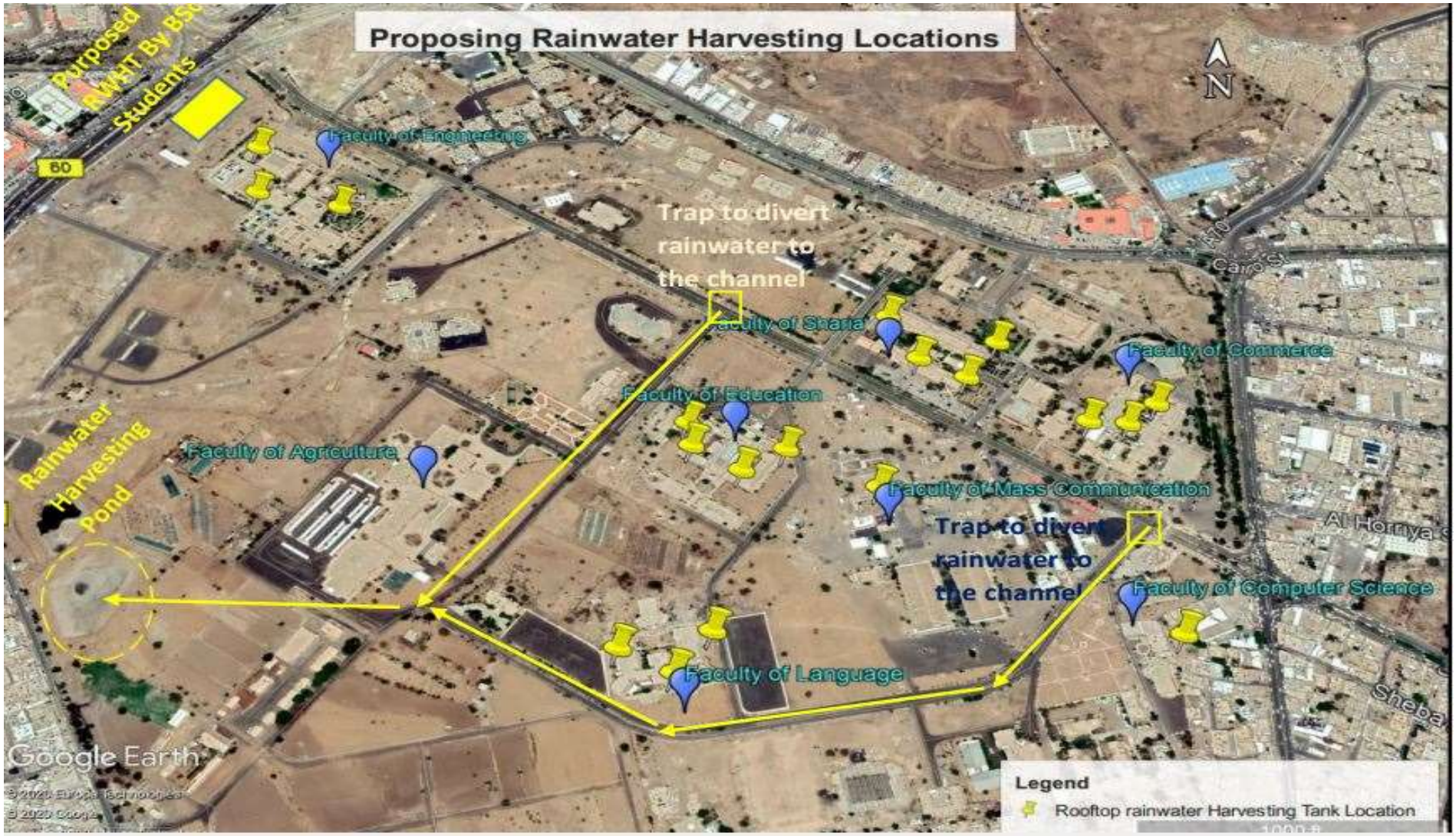


Figure (A5-1): Proposing Rainwater Harvesting Tanks and Pond Locations and Diversion Channel- Source Google Earth

New University Campus

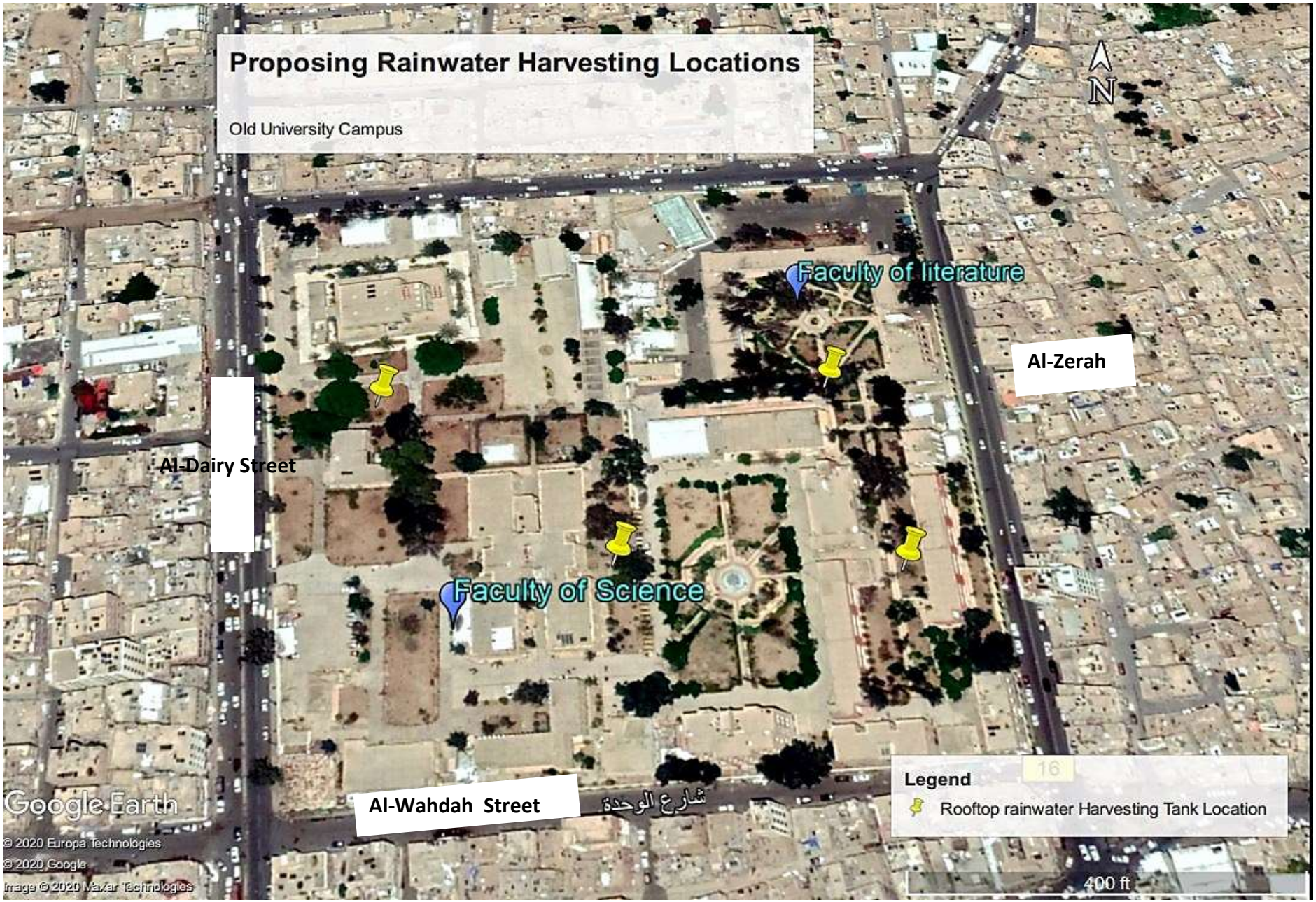


Figure (A5-2) Proposing Rainwater Harvesting Tanks Old University Campus- Source Google Earth

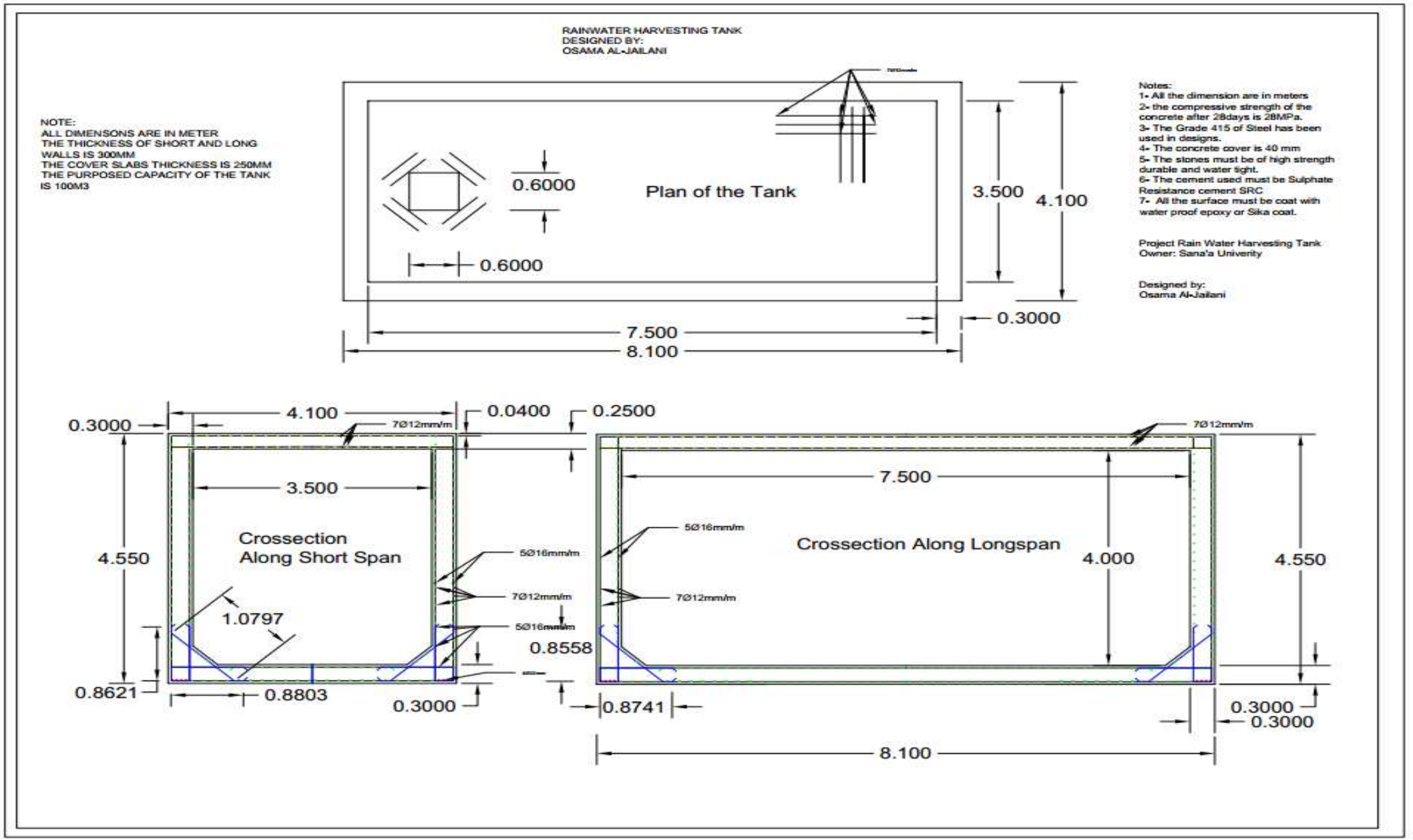


Figure (A5-3): Rainwater Harvesting Tank Detailing - Source Own Representative

6- University WASH Needs (Matrix, Calculation and Drawing)

Table (A6-1) Summary of University Water and Toilets Need as per each faculty

S.No	Faculty	No of student male	No of student female	Total	Minimum Water Quantity need M^3/ Day (15liters/person) Sphere Household Emergencies	Mnimum Water Quantity need M^3/ Day (5 liters/Student) WHO Educational Institute Emergencies	Total Drinking Water Quantity need M^3/ Day (3.0 liters/person) as per Sphere	*Toilet* Male (one toilet /60 boy students) as per Sphere	*Toilet* Female (one toilet /30 girl students) as per Sphere
1	Sharia and Law	5797	840	6637	100	33	20	97	28
2	Literature	1291	3055	4346	65	22	13	22	102
3	Science	1404	850	2254	34	11	7	23	28
4	Education	2588	5525	8113	122	41	24	43	184
5	Commerce	5383	2054	7437	112	37	22	90	68
6	Medicine & Dentistry	1924	1780	3704	56	19	11	32	59
7	Engineering	3313	452	3765	56	19	11	55	15
8	Agriculture	1390	729	2119	32	11	6	23	24
9	Mass Communication (Media)	1731	630	2361	35	12	7	29	21
10	Language	1250	1122	2372	36	12	7	21	37
11	Computer Science	1670	1020	2690	40	13	7	28	34
**Total		27741	18057	45798	687*	229*	137	462	602

* Including Drinking Water

** There are some fraction while calculation of the total has been taken into the account.

Table (A6-2) WASH Needs Matrix of the University (Water as per Sphere)

S.No	Faculty	No of student male	No of student female	Total	Quantity Of Water Provided by The University 200m^3/day	Minimum Water Quantity need m^3/ day (15liters/person) As per Sphere	Excess Quantity	Sufficiency	Deficiency m^3/day
1	Sharia and Law	5797	840	6637	29	100	-	-	71
2	Literature	1291	3055	4346	19	65	-	-	46
3	Science	1404	850	2254	10	34	-	-	24
4	Education	2588	5525	8113	35	122	-	-	86
5	Commerce	5383	2054	7437	32	112	-	-	79
6	Medicine & Dentistry	1924	1780	3704	16	56	-	-	39
7	Engineering	3313	452	3765	16	56	-	-	40
8	Agriculture	1390	729	2119	9	32	-	-	23
9	Mass Communication (Media)	1731	630	2361	10	35	-	-	25
10	Language	1250	1122	2372	10	36	-	-	25
11	Computer Science	1670	1020	2690	12	40	-	-	29
*Total		27741	18057	45798	200	687			487

* There are some fraction while calculation of the total has been taken into the account.

Table (A6-3) WASH Needs Matrix of the University (Water as per WHO)

S.No	Faculty	No of student male	No of student female	Total	Quantity Of Water Provided by The University 200 m^3/day	Minimum Water Quantity need m^3/day (5liters/Student) As per WHO	Excess Quantity	Sufficiency	Deficiency m^3/day
1	Sharia and Law	5797	840	6637	29	33	-	-	4
2	Literature	1291	3055	4346	19	22	-	-	3
3	Science	1404	850	2254	10	11	-	-	1
4	Education	2588	5525	8113	35	41	-	-	5
5	Commerce	5383	2054	7437	32	37	-	-	5
6	Medicine & Dentistry	1924	1780	3704	16	19	-	-	2
7	Engineering	3313	452	3765	16	19	-	-	2
8	Agriculture	1390	729	2119	9	11	-	-	1
9	Mass Communication (Media)	1731	630	2361	10	12	-	-	1
10	Language	1250	1122	2372	10	12	-	-	2
11	Computer Science	1670	1020	2690	12	13	-	-	2
*Total		27741	18057	45798	200	229			29

* There are some fraction while calculation of the total has been taken into the account.

Table (A6-4) WASH Needs Matrix of the University (Hand washing Basins and Toilets as per Sphere)

	Faculty	No of student male	No of student female	Total	Toilets Male (one Toilets /60 boy students) as per Sphere	Toilets Female (one Toilets /30 girl students)as per Sphere	Required Toilets	Toilets Available Approximately	Excess Quantity	Sufficiency	Deficiency
1	Sharia and Law	5797	840	6637	97	28	125	50	-	-	75
2	Literature	1291	3055	4346	22	102	123	70	-	-	53
3	Science	1404	850	2254	23	28	52	55	3	Applicable	-
4	Education	2588	5525	8113	43	184	227	27	-	-	200
5	Commerce	5383	2054	7437	90	68	158	50	-	-	108
6	Med & Dentistry	1924	1780	3704	32	59	91	120	23	Applicable	-
7	Engineering	3313	452	3765	55	15	70	42	-	-	28
8	Agriculture	1390	729	2119	23	24	47	48	1	Applicable	-
9	Mass Communication (Media)	1731	630	2361	29	21	50	18	-	-	32
10	Language	1250	1122	2372	21	37	58	46	-	-	12
11	Computer Science	1670	1020	2690	28	34	62	48	-	-	14

Note: One third of the toilets were open to be used
*** Repairing and Maintenance of all Existing Toilets and Hand Washing Basins Should include all required items of water taps , drainage, tiles , and piping**
Each Toilets Should attach with Hand washing basin

Table (A6-5) WASH Needs Matrix of the University (Soap as per Sphere)

	Faculty	No of student male	No of student female	Total	Quantity Of Soap Provided by The University Kg/Month	Minimum Soap Quantity need Kg/ Month (250gram/person/Month) As per Sphere	Excess Quantity	Sufficiency	Deficiency Kg/Month
1	Sharia and Law	5797	840	6637	0	1659	-	-	1659
2	Literature	1291	3055	4346	0	1087	-	-	1087
3	Science	1404	850	2254	0	564	-	-	564
4	Education	2588	5525	8113	0	2028	-	-	2028
5	Commerce	5383	2054	7437	0	1859	-	-	1859
6	Med & Dentistry	1924	1780	3704	0	926	-	-	926
7	Engineering	3313	452	3765	0	941	-	-	941
8	Agriculture	1390	729	2119	0	530	-	-	530
9	Mass Communication (Media)	1731	630	2361	0	590	-	-	590
10	Language	1250	1122	2372	0	593	-	-	593
11	Computer Science	1670	1020	2690	0	673	-	-	673
*Total		27741	18057	45798	0	11450			11450

* There are some fraction while calculation of the total has been taken into the account.

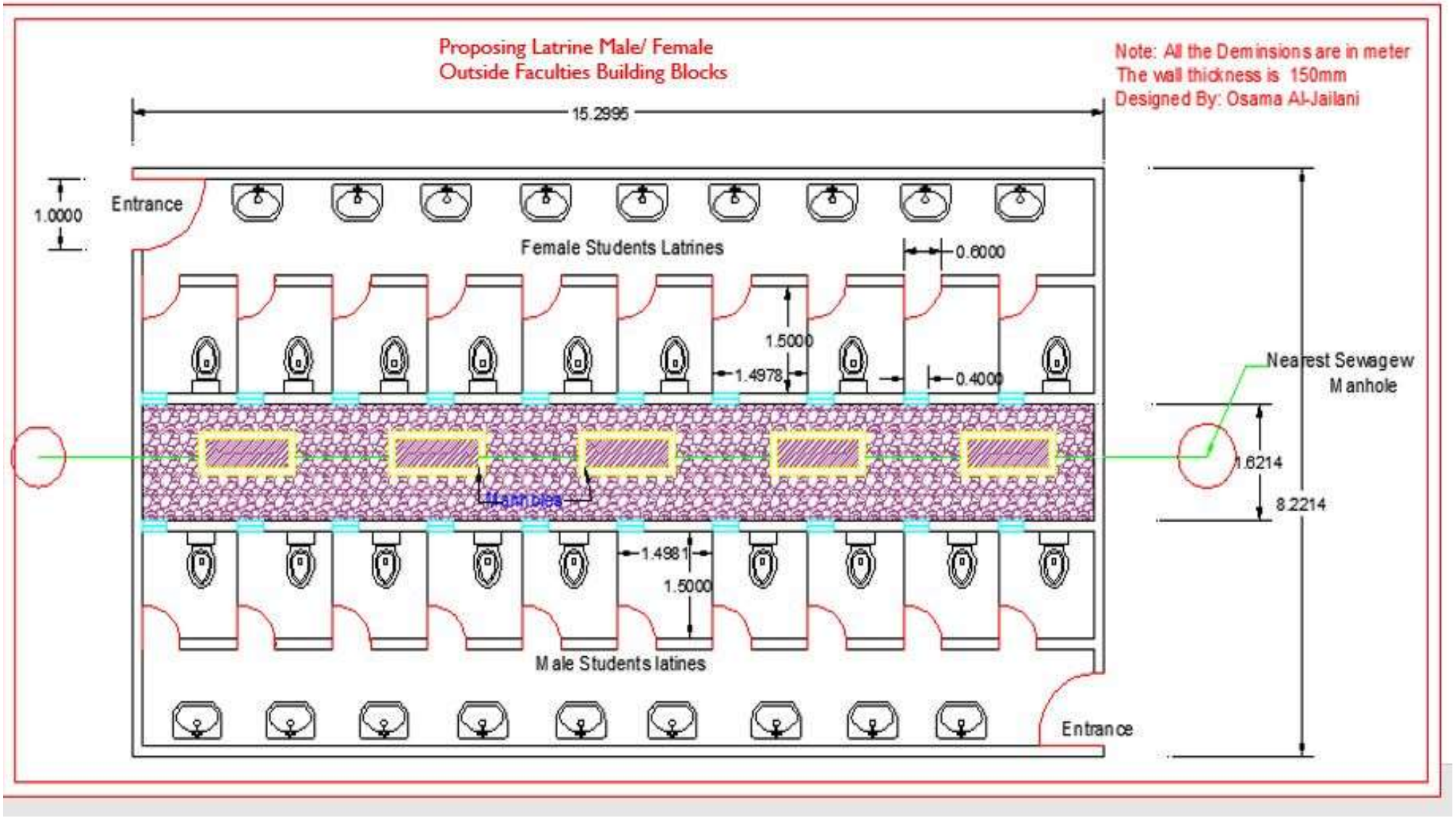


Figure (A6-1) Proposing Toilets for Male/Female outside the Faculties Blocks - Source Own Representative

7- Proposed Pilot Wastewater Treatment Plant (Faculty of Engineering), Design Criteria and Drawings.

Table (A7-1): Design Criteria for Wastewater Treatment Plant and Proposed Designed Values

Design Criteria for WWTP Q=500m^3 BOD=200mg/l			
S.No	**Description**	**Range**	**Designed values**
Design Criteria for Sedimentation Tanks			
1.	detention time (t_d)	1-2	1.8
2.	Side Depth h(m)	2-2.5	2
3.	Surface Loading SL (m^3/m^2.day)	16-33	26.6
4.	Weir Loading WL(m^3/m.day)	Q<4000m^3/day: WL<120 Q>4000m^3/day: WL<250	66.6
Design Criteria for Low Rate Biological Filters			
1.	BOD load g/m^3. day	60-180	180 assume
2.	Surface Loading SL (m^3/m^2.day)	2-4.5	3.4
3.	Side Depth h(m)	1.5-2.4	2.44
4.	Velocity of out flow m/sec	0.9	-
5.	The bottom slope	3-5%	3
Design Criteria for Maturation Pond			
1.	BOD load g/m^3. day	1-2	2 assume

2.	**Side Depth h(m)**	**0.8-1**	**1**
3.	**detention time (t_d)**	**5-15**	**5**
4.	**Length (m)**	**2-3 width**	**3 width**
Design Criteria for Channel			
1.	**Diameters of bar(mm)**	**10-15**	**15**
2.	**The inclination of the bar(degree)**	**30-60**	**45**
3.	**The velocity of flow (m/sec)**	**0.9-1.2**	**1.2**
4.	**The bar spacing (mm)**	**Up to 25**	**25**

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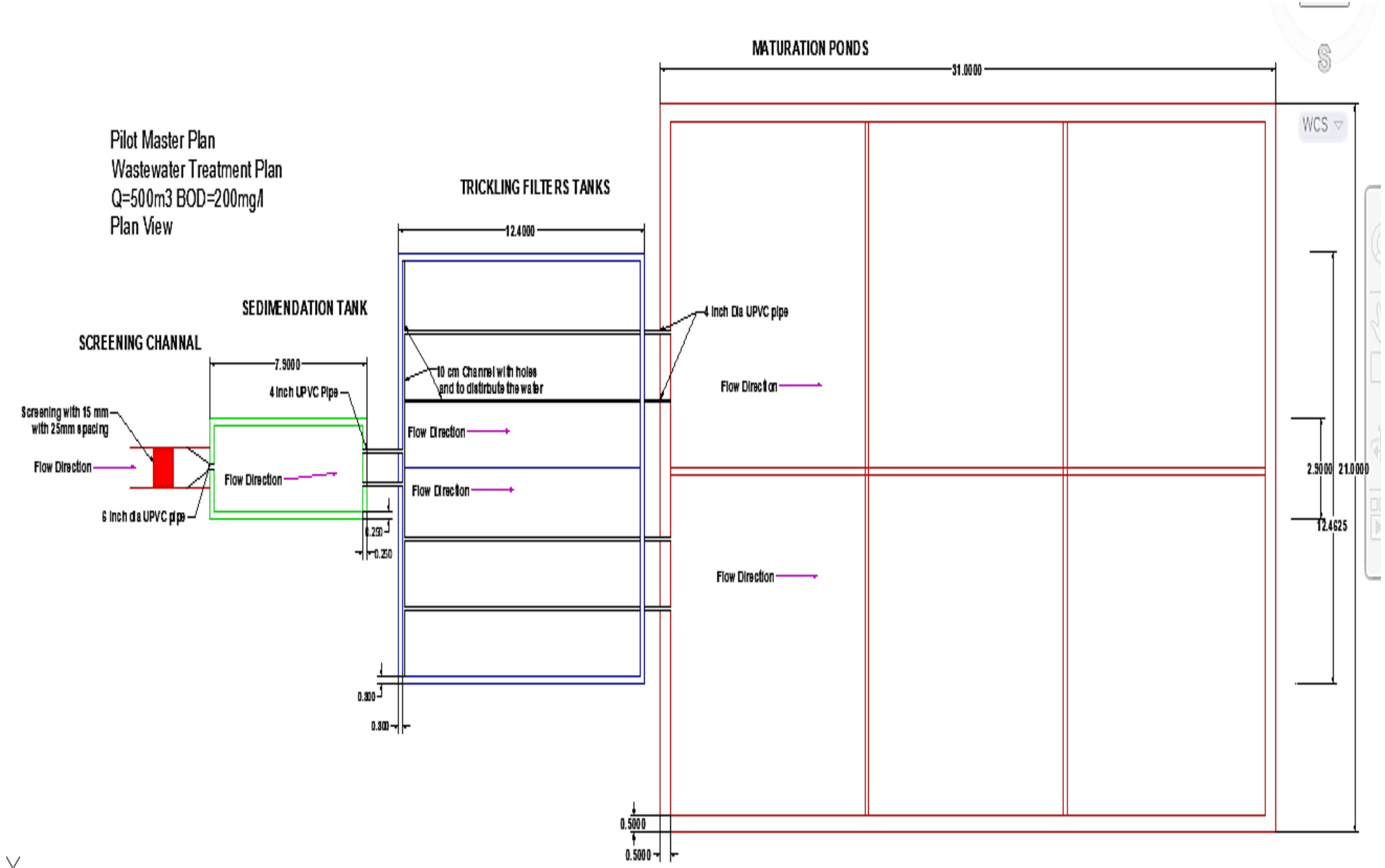


Figure (A7-1) Plan View of Pilot Master Plan for the Proposed WWTP outside the Faculty of Engineering - Source Own Representative

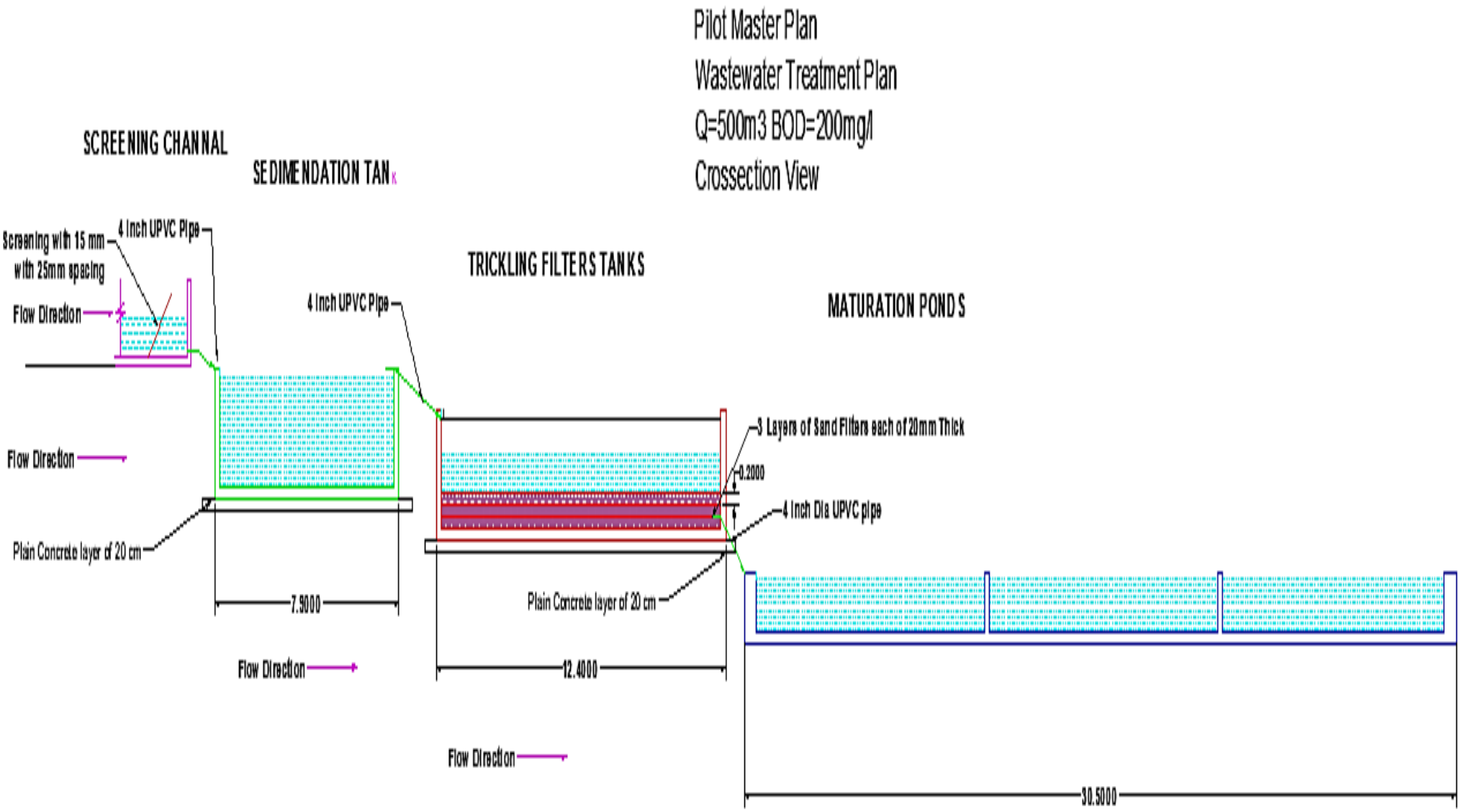


Figure (A7-2) Side View of Pilot Master Plan for the Proposed WWTP outside the Faculty of Engineering - Source Own Representative

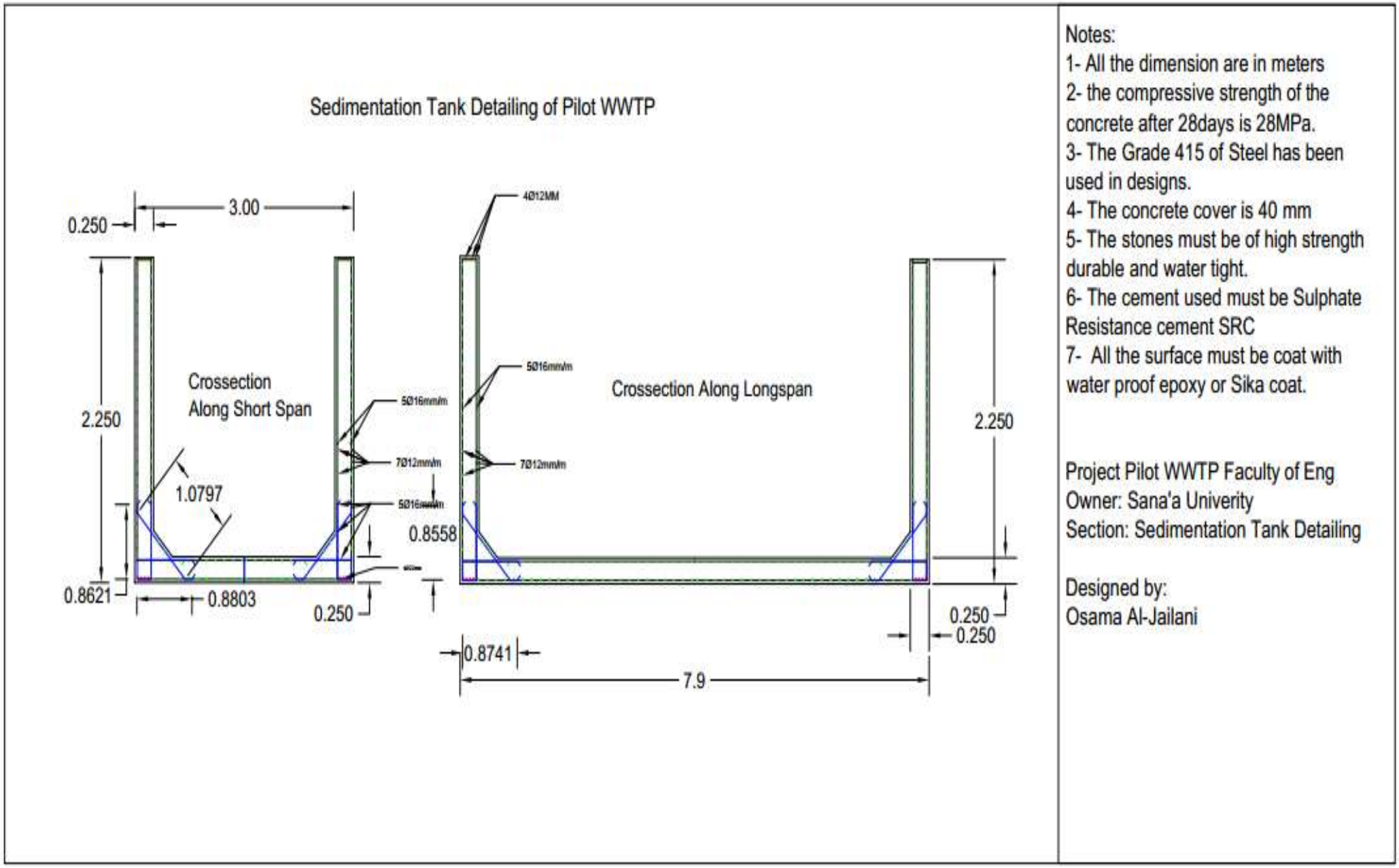
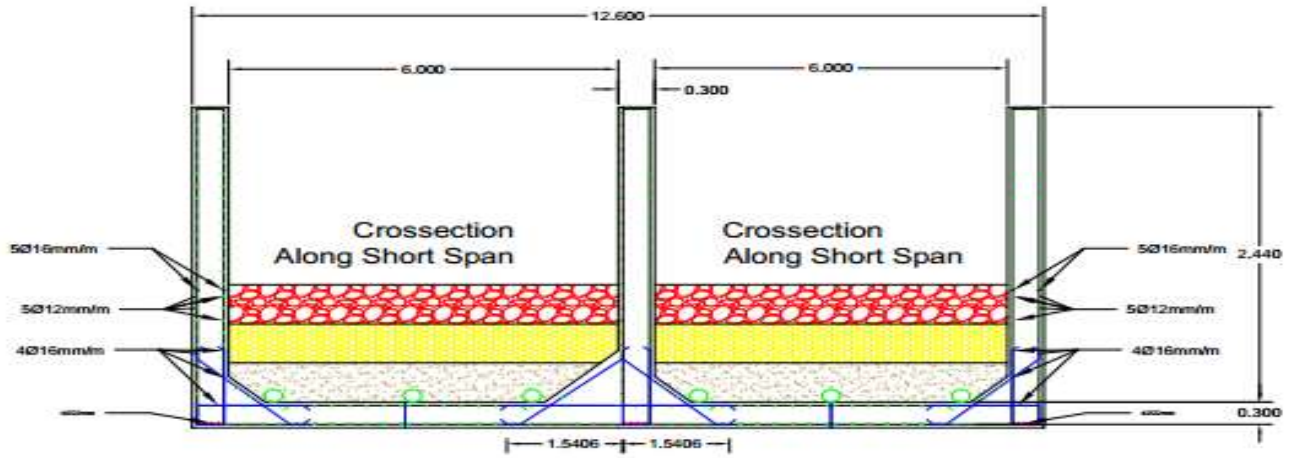
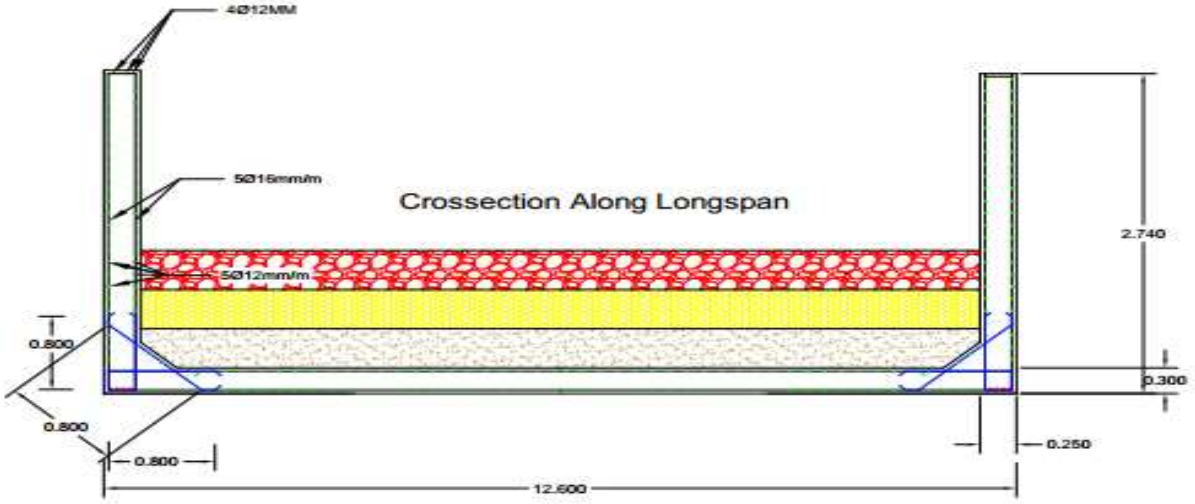


Figure (A7-3) Reinforced Detailing of Sedimentation Tank for the Proposed WWTP outside the Faculty of Engineering - Source Own Representative

Trickling Filter Detailing





Notes:

1- All the dimension are in meters
2- the compressive strength of the concrete after 28days is 28MPa.
3- The Grade 415 of Steel has been used in designs.
4- The concrete cover is 40 mm
5- The stones must be of high strength durable and water tight.
6- The cement used must be Sulphate Resistance cement SRC
7- All the surface must be coat with water proof epoxy or Sika coat.

Project Pilot WWTP Faculty of Eng
Owner: Sana'a Univerity
Section: Sedimentation Tank Detailing

Designed by:
Osama Al-Jailani

Figure (A7-4) Reinforced Detailing of Trickling Filters Tank for the Proposed WWTP outside the Faculty of Engineering - Source Own Representative

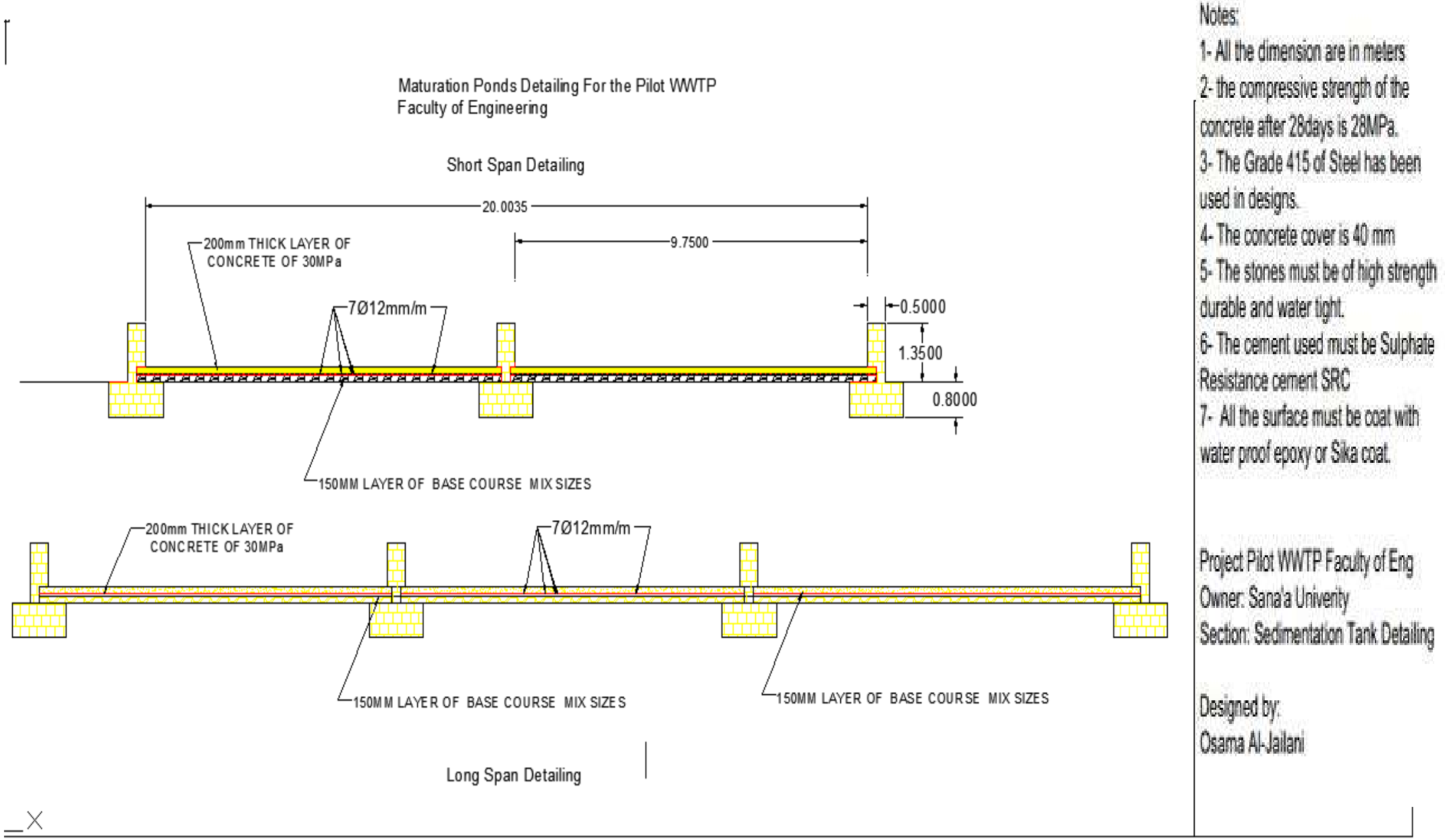


Figure (A7-5) Reinforced Detailing of Maturation Ponds for the Proposed WWTP outside the Faculty of Engineering - Source Own Representative

8- BoQs for the Suggested Projects

Table (A8-1) BoQ for Construction Outside Toilets Blocks (Emergency)

No.	Descriptions	Unit	Quantity	Unit Price USD	Total Price USD
1.	**Leveling, Excavation and backfilling works:** Leveling and removal any obstacles exist in the implementation site, the Price includes Cleaning the site from all dirt or any unrequired topsoil up to 25cm and leveling the site, and excavation in all types of soil for foundations and, shift all remaining to landfill as approved by engineer, and all needed to finish the work according to drawings, specifications, the technical asset & workmanship, general & specific conditions and instructions of the supervisor engineer or his representative.	**m^3**	**101**	7	707
2.	**Excavation up to the required levels for the wall foundation (1m*1m*1m)** :in any type of soil, dimenations as follow : (1 m depth). also includes backfilling and carry out the waste soil from the site , according to the drawings and specification and the engineer requirements	**m^3**	77.8	10	778
3.	**Crushed stones works for wall foundation :** Supply and putting crushed stones "basaltic stones" below the Block Wall with dimension (1*1) m and depth of 1 m under the ground level, and below the bathroom slab with thickens of 15 cm , the "basaltic stones" should be clean form dust, mud and any substances, mortar mixing ratio should be (1:3) cement to fine aggregate and ratio 40% stone and 60% morter.and all needed to finish the work according to drawings, specifications, the technical asset & workmanship, general & specific conditions and instructions of the supervisor engineer or his representative..	**m^3**	77.8	15	1244
4.	**Supply and concreting plain concrete for Toilets floor** , 10.0cm thickness ,225 kg/m3 ,(1:3:6) Plain concrete and make Breaking Stones (solange),15.0 cm depth . according to drawings, specification and the engineer instructions	**m^3**	135	40	5400

5.	**Blocks Works:** Supply and installation of concrete hollow block for the external wall, dimension of block (0.15 * 0.20 * 0.40) meters sample of hollow block must be approved by engineer, the mortar mixing ratio (1: 3) cement to fine aggregate .all works must be done accordance to attached drawings and specifications height of wall 2.5m.	**m^2**	200	15	3000
6.	**Supply and installation Roof works.** The item includes supply & install Malaysian wooden plate with thickness of 10 mm and red wooden beam with dimensions (5m * 10cm * 7.5cm) , Supply and installation of ordinary concrete with depth 10 cm and with ratio (1: 2: 4) according to the specifications and instructions of the engineer	**m^2**	127	20	2540
7.	**Supply and Installation** of the inspection rooms of size (0.5*1.5)m upto 1 m depth by hollow blocks of (15*20*40)cm size, the mortar mixing ratio (1: 3) cement to fine aggregate. with steel cover of 2mm thick all works must be done accordance to attached drawings and specifications	**No**	5	100	500
8.	**Supply and Installation** of Ceramic Tiles for the *toilet*s floors and wall (up to 1.5m) height the mortar mixing ratio (1: 3) cement to fine aggregate. with steel cover of 2mm thick all works must be done accordance to attached drawings and specifications	**m^2**	244	25	6100
9.	**Supply and installation** of steel door size (0.6*1.6)m thickness 2 mm and the price includes: the supply of materials and implementation and installation of side angle thickness of 4 mm and the installation of the hendrab from two side and locks and cleaning and polishing the door and painting works with antirust paint two layers and all necessary to complete the work on the full face of the drawings attached and technical specifications and instructions of supervisor engineer.	**No**	20	50	1000
10.	**Supply and installation** of steel door for main entrance size (1*2)m thickness 2 mm and the price includes: the supply of materials and implementation and installation of side angle thickness of 4 mm and the installation of the hendrab from two side and locks and cleaning and polishing the door and painting works with antirust paint two layers and all necessary to	**No**	2	100	200

	complete the work on the full face of the drawings attached and technical specifications and instructions of supervisor engineer.				
11.	**Supply and installation** of a window (0.4*0.5)m size from glass thickness 6 mm, the price include doing and accessories needed to complete items and all necessary to complete the work on the full face of the drawings attached and technical specifications and instructions of supervisor engineer.	**No**	20	70	1400
12.	**Supply and installation** of one Arabic lavatory and one western lavatory ,each lavatory install with: ventilation elbow +upvc high pressure (pipe) 4 " , length=3m + flush box + Chrome faucet and pipe 0.5 inches + major stopcock 0.5-inch extensions pipping for each bath + all internal pipes cpvc (0.50") + connect of drainage pipes to inspection chamber pipes,hight pressure plastic (UPVC) diameter (4 inch) and with all the necessary, according to the drawings , specifications and the engineer requirements.	**No**	20	120	2400
13.	**Supply and installation** of wash basin size at least (40*60 cm)with tap chrome (0.5 inches) + Harab + Internal pipes for water pipes metal Gelovnez (0.5 ") and discharges into manholes pipes (UPVC) diameter (2 inches) and with all the necessary according to the specifications The instructions of the supervising engineer.	**No**	18	120	2160
14.	**Supply and installation** of floor drain colander with ventilation elbow 20 * 20cm and all that is needed to finish the work as required, in accordance with the specifications, drawings and instructions of the supervising engineer.	**No**	40	7	280
15.	**Installation of water network** for bathroom with high-pressure pipes according on British standard DIN-8062 ،ISO 161-size 0.5 inch and connected the network to upper tank and doing all the working needed as per the site engineer directions.	**m**	150	5	750

16.	**Supply and installation of pipes**, plastic 4-inch diameter (UPVC) High pressure for the drainage of sewage from manholes even pit includes excavation 70 cm depth at least and backfilling by sand , according to the specifications, drawings and instructions of the supervising engineer	**m**	30	5	150
17.	**Plastering works** for the concrete walls outside with cement ratio of 1: 4 on two layers to prevent leakage of water from the walls according to specifications and instructions of the engineering supervisor	**m^2**	195	4	780
18.	**Supply and installation** of electricity socket (13 amp -220 volts with the key installed inside the wall with all the requirements of piping and wiring size 3 × 2.5 mm, according to instructions of the supervising engineer.	**No**	25	10	250
19.	**Supply, installation** of normal lighting unit ,price includes the keys and plastic pipes, wire size 3 × 2.5 mm and connected from the point to the distribution panel, according to instructions of the supervising engineer.	**No**	25	10	250
	Total for Construction Outside Toilets Blocks (Emergency)				29,889
Notes					
1)	**The prices include all things. All materials to be installed on site need to be supervised, checked and verified by the engineer before installation.**				
2)	**The potential contractor is expected to visit the site and get clarity on what is expected with this works before completing the BOQ**				

Table (A8-2) BoQ for Construction Rain Water Harvesting Tank size 100 M3					
No.	**Descriptions**	**Unit**	**Quanti ty**	**Unit Price USD**	**Total Price USD**
1	**Excavation up to the required levels** :in any type of soil, dimenations as follow : (4.45 m depth) under tank's base. also includes backfilling and carry out the waste soil from the site , according to the drawings and specification and the engineer requirements	**m³**	118	10	1180
2	**Supply and concreting plain concrete** under tank's base , 10.0cm thickness ,225 kg/m3 ,(1:3:6) Plain concrete and make Breaking Stones (solange),15.0 cm depth . according to drawings, specification and the engineer instructions	**m³**	26.5	50	1325
3	**Supply and concreting reinforced concrete** for Tank roof,floor,beams and walls using Portland cement 325 kg/ m3,(1: 1.5 : 3) and addition cika or Equivalent material 1kg/100kg cement , according to the drawings, specifications and the engineer approval.	**m³**	40	300	12000
4	**Supply and implementation of plaster coat:** for internal surfaces base and wall, using cement mortar 1:3 and addition cika or Equivalent material 1kg/100kg cement including watering 2times a day for 7days. Price includes providing steel screen in places of places of connecting different surfaces or materials to avoid cracking . According to the drawings, specifications and the engineer requirements.	**m²**	176	10	1760
5	**Supply and install Galvanized Iron Pipes** and Fitting, medium pressure .pipes specification according to British standard B.S-1387 or equivalent specifications, B.S-21 ,work pressure 25 kg/cm2 , fitting specification according to British standard B.S-1470, with insted it with concrete structure , work includes any materials or activities necessary to installation or to operation ,From roof	**Lump Sum**		**2000**	**2000**

	top to tank and connection from tank to nearest WS network , specifications and the engineer requirements.				
6	**Supply and install cover for tank's roof** opening of iron sheets 2 mm 60 * 60 cm with lock , according to the drawings, specifications and the engineer requirements.	**No**	1	100	100
7	**Supply and build control room :**build control room by square stone with 30 cm thickness ,beside Ground tank (alongside) ,internal size (80X80X80) cm with a base footing(1.5*1.6)m of plain concrete 10cm thickness and broken stone (solange) 15cm,work includes excavation and implementation plaster coat for internal surfaces, also includes supply and install cover of iron sheets 2 mm 80 * 80 cm with lock , according to the drawings , specifications and the engineer requirements.	**No**	1	150	150
8	**Supply and insall Aluminum ladder:** supply and install Aluminum ladder high quality with length=2.9 m,width=50 cm, installed on a slant and well proven on the concrete beam, according to the drawings , specifications and the engineer requirements.	**No**	1	200	200
	Total for Construct Rain Water Harvesting Tank size 100 m^3				18,715
Notes					
1)	**The prices include all things. All materials to be installed on site need to be supervised, checked and verified by the engineer before installation.**				
2)	**The potential contractor is expected to visit the site and get clarity on what is expected with this works before completing the BOQ**				

Table (A8-3) BoQ for Construction Sedimentation Tank for the Pilot WWTP Faculty of Engineering					
No.	**Descriptions**	**Unit**	**Quantity**	**Unit Price USD**	**Total Price USD**
	<u>WWTP Site Leveling, Excavation and Backfilling works size (20*60)m with an average depth of 2.5m :</u> Leveling and removal any obstacles exist in the implementation site, the Price includes Cleaning the site from all dirt or any unrequired topsoil up to 25cm and leveling the site, and excavation in all types of soil for foundations of each section with suitable depth as the flow will be by the gravity and, shift all remaining to landfill as approved by engineer, and all needed to finish the work according to drawings, specifications, the technical asset & workmanship, general & specific conditions and instructions of the supervisor engineer or his representative	**M^3**	3000	10	30,000
1	**<u>Leveling, Excavation and Backfilling works:</u>** Leveling and removal any obstacles exist in the implementation site, the Price includes Cleaning the site from all dirt or any unrequired topsoil up to 25cm and leveling the site, and excavation in all types of soil for foundations and, shift all remaining to landfill as approved by engineer, and all needed to finish the work according to drawings, specifications, the technical asset & workmanship, general & specific conditions and instructions of the supervisor engineer or his representative	**m^2**	18.7	7	131
2	**<u>Supply and concreting plain concrete</u>** under tank's base , 20.0cm thickness ,225 kg/m3 ,(1:3:6) Plain concrete and make Breaking Stones (solange),15.0 cm depth . according to drawings, specification and the engineer instructions	**m^3**	3.75	50	188

3	**Supply and concreting reinforced concrete** for Tank roof,floor,beams and walls using Portland cement 325 kg/ m3,(1: 1.5 : 3) and addition cika or Equivalent material 1kg/100kg cement , according to the drawings, specifications and the engineer approval.	**m^3**	20	300	6000
4	**The work of a waterproof work** seal between the walls and beams under the walls according to specifications and instructions of the engineering supervisor	**m^2**	40	10	400
5	**check from plumbing work** from the surface of sedimentation tank from the channel and to the trickling filters tank by pipe with diameter 4 inch with installation of required valves, elbows, joints, connection, … etc installation of valves for inlet and out and filter Pipes according to the drawings and specifications or instructions engineering supervisor	**Lump Sum**	**1000**	**1000**	**1000**
6	**installation sika material** (insulating layer prevent leakage) Two layers of the walls from the inside with roof and ground slap according to specifications and instructions of the engineering supervisor	**m^2**	**69**	**3**	**207**
	Total for Construction Sedimentation Tank for the Pilot WWTP Faculty of Engineering				37,926
Notes					
1)	**The prices include all things. All materials to be installed on site need to be supervised, checked and verified by the engineer before installation.**				
2)	**The potential contractor is expected to visit the site and get clarity on what is expected with this works before completing the BOQ**				

Table (A8-4) BoQ for Construction Trickling Filters Tank for the Pilot WWTP Faculty of Engineering					
No.	**Descriptions**	**Unit**	**Quantity**	**Unit Price USD**	**Total Price USD**
1	**Leveling, Excavation and Backfilling works:** Leveling and removal any obstacles exist in the implementation site, the Price includes Cleaning the site from all dirt or any unrequired topsoil up to 25cm and leveling the site, and excavation in all types of soil for foundations and, shift all remaining to landfill as approved by engineer, and all needed to finish the work according to drawings, specifications, the technical asset & workmanship, general & specific conditions and instructions of the supervisor engineer or his representative	**m^2**	169	7	1183
2	**Supply and concreting plain concrete** under tank's base , 20.0cm thickness ,225 kg/m3 ,(1:3:6) Plain concrete and make Breaking Stones (solange),15.0 cm depth . according to drawings, specification and the engineer instructions	**m^3**	34	50	680
3	**Supply and concreting reinforced concrete** for Tank roof,floor,beams and walls using Portland cement 325 kg/ m3,(1: 1.5 : 3) and addition cika or Equivalent material 1kg/100kg cement , according to the drawings, specifications and the engineer approval.	**m^3**	95	300	28500
4	**The work of a waterproof work** seal between the walls and beams under the walls according to specifications and instructions of the engineering supervisor	**m^2**	40	10	400

5	**check from plumbing work** from the surface of filters tank from the sedimentation tanks and to the maturation ponds by pipe with diameter 4 inch with installation of required valves, elbows, joints, connection, … etc installation of valves for inlet and out and filter Pipes according to the drawings and specifications or instructions engineering supervisor	**Lump Sum**	**3000**	**3000**	**3000**
6	**installation sika material** (insulating layer prevent leakage) Two layers of the walls from the inside with ground slap according to specifications and instructions of the engineering supervisor	**m^2**	**147**	**3**	**441**
7	**Supply three layers** of the filters of sand of different size each layer of 20cm	**m^3**	**86**	**20**	**1720**
	Total for Construction Trickling Filters Tank for the Pilot WWTP Faculty of Engineering				35,924
Notes					
1)	**The prices include all things. All materials to be installed on site need to be supervised, checked and verified by the engineer before installation.**				
2)	**The potential contractor is expected to visit the site and get clarity on what is expected with this works before completing the BOQ**				

Table (A8-5) BoQ for Construction the inlet channel size (1.25*1)m and 50 m length for the Pilot WWTP Faculty of Engineering					
No.	**Descriptions**	**Unit**	**Quantity**	**Unit Price USD**	**Total Price USD**
1	**Leveling, Excavation and Backfilling works:** Leveling and removal any obstacles exist in the implementation site, the Price includes Cleaning the site from all dirt or any unrequired topsoil up to 25cm and leveling the site, and excavation in all types of soil shift all remaining to landfill as approved by engineer, and all needed to finish the work according to drawings, specifications, the technical asset & workmanship, general & specific conditions and instructions of the supervisor engineer or his representative	**m^2**	62.5	7	437.5
2	**Channel Blocks Works**: Supply and installation of concrete solid block for the external wall, dimension of block (0.15 * 0.20 * 0.40) meters sample of hollow block must be approved by engineer, the mortar mixing ratio (1: 3) cement to fine aggregate .all works must be done accordance to attached drawings and specifications height of wall 1m.	**m^2**	162.5	15	2437.5
3	**Supply and implementation of plaster coat:** for internal surfaces base and wall, using cement mortar 1:3 and addition cika or Equivalent material 1kg/100kg cement including watering 2times a day for 7days. Price includes providing steel screen in places of places of connecting different surfaces or materials to avoid cracking . According to the drawings , specifications and the engineer requirements.	**m^2**	162.5	20	3250

4	**installation sika material** (insulating layer prevent leakage) Two layers of the walls from the inside with ground slap according to specifications and instructions of the engineering supervisor	**m²**	162.5	3	487.5
5	**check from plumbing work** from the surface of manholes of the faculty to the channel and to the channel inlet by pipe with diameter 4 inch with installation of required valves, elbows, joints, connection, … etc installation of valves for inlet and out Pipes according to the drawings and specifications or instructions engineering supervisor	**Lump Sum**	**1000**	**1000**	**1000**
6	**Supply and installation** of the Mesh with 15mm diameter bars with 25mm spacing C/c along the width of the channel and before inlet of the sedimentation tank about 2m. the work should include all the necessary work to be done under the supervision of the engineer	**Lump Sum**		**200**	**200**
	Total for Construction the inlet channel size (1.25*1)m and 50 m length for the Pilot WWTP Faculty of Engineering				**7,812.5**
Notes					
1)	**The prices include all things. All materials to be installed on site need to be supervised, checked and verified by the engineer before installation.**				
2)	**The potential contractor is expected to visit the site and get clarity on what is expected with this works before completing the BOQ**				

Table (A8-6) BoQ for Construction the two Maturation ponds size (10*30)m each for the Pilot WWTP Faculty of Engineering					
No.	**Descriptions**	**Unit**	**Quantity**	**Unit Price USD**	**Total Price USD**
1	**Leveling, Excavation and Backfilling works:** Leveling and removal any obstacles exist in the implementation site, the Price includes Cleaning the site from all dirt or any unrequired topsoil up to 25cm and leveling the site, and excavation in all types of soil shift all remaining to landfill as approved by engineer, and all needed to finish the work according to drawings, specifications, the technical asset & workmanship, general & specific conditions and instructions of the supervisor engineer or his representative	**m^2**	704	7	4928
2	**Filling Works of thickness 20cm** on layer with a ditch and water spray to get to the required thickness between the walls stonewalls to reach the level according to the instructions of the engineering supervisor.	**m^2**	704	5	3520
3	**Construction works of basalt stone** walls and the foundation of the ponds wall with the dimensions shown in the drawings with the work of the tendencies shown in the drawings and concrete cement 1: 4 or according to the instructions of the engineering supervisor.	**m^3**	210	30	6300
4	**Supply and concreting reinforced concrete** for floor of ponds Portland cement 250 kg/ m3,(1: 1.5 : 3) and addition cika or Equivalent material 1kg/100kg cement , according to the drawings, specifications and the engineer approval.	**m^3**	140	200	28000
5	**Supply and implementation of plaster coat:** for internal surfaces base and wall, using cement mortar 1:3 and addition cika or Equivalent material 1kg/100kg cement including watering 2times a day for 7days. Price includes	**m^2**	172	20	3440

	providing steel screen in places of places of connecting different surfaces or materials to avoid cracking . According to the drawings, specifications and the engineer requirements.				
6	**<u>installation sika material</u>** (insulating layer prevent leakage) Two layers of the walls from the inside with ground slap according to specifications and instructions of the engineering supervisor	**m²**	172	3	516
7	**<u>check from plumbing work</u>** from the surface and underground plumping work for the maturation pond inlet by pipe with diameter 4 inch with installation of required valves, elbows, joints, connection, … etc installation of valves for inlet and out Pipes according to the drawings and specifications or instructions engineering supervisor	**Lump Sum**	**2000**	**2000**	**2000**
	Total for Construction the two Maturation ponds size (10*30)m each for the Pilot WWTP Faculty of Engineering				**48,704**
<u>Notes</u>					
1)	**The prices include all things. All materials to be installed on site need to be supervised, checked and verified by the engineer before installation.**				
2)	**The potential contractor is expected to visit the site and get clarity on what is expected with this works before completing the BOQ**				

Table (A8-7) Summary Cost of the proposed Projects:

S. No	Required Project Work Description	Estimated Cost in USD
1	Pumping Test for the five Wells of the university to prepared them for the required maintenance	10,000
2	Pumping Test for water pipe network of the university to prepared them for the required maintenance	5,000
3	Proposed Water Purifying Plant	30,000
4	Rain Water Harvesting Tank of 100m3 Capacity	18,715 each
5	Proposed Additional outside toilets blocks	29,889 each
6	Proposed Waste Water Treatment Plant for the faculty of Engineering	130,366
7	The Proposed Diversion Channels to the rainwater harvesting pond behind the Agriculture Faculty with an average length of 1,200m	48,000

9- Photos of Field Visits

Figuers (1- Private Tanker Inside one of the faulties, 2&3- Status of the Students *toilet*s, 4- Hand washing Basin status, 5&6- Solid Waste Status) - Source Own Representative