10 August, 2018

2018

2019

Urine Treatment and Smart Irrigation System

Dr/ Mohamed El-Sayed

Ahmed Farghali Abdelrehim

Ahmedfarghly2002@gmail.com

High Efficiency

Lower Cost

Sustainable

Treatment of Urine

Key Words: Water treatment – Urine – Bulk Alum – Charcoal – Photocatalysis – Management system

Abstract:

In most recent years, Egypt has been suffering from some **grand challenges** that disrupt its march of progress. Amongst all these challenges, the dilemma concerning **water and agriculture** has become worse than before and requires immediate resolution. Egypt depends on conventional water resources that face many problems due to over-consumption and pollution. **The purpose of the study** is to implement a practical solution related to **treatment of wastewater and advanced irrigation water techniques**. Therefore, it was decided to conduct an extensive research to find a suitable solution. By taking into account the **prior solutions,** it was obvious that the **chosen solution,** which is a urine treatment system provided with an Arduino based irrigation system, will be an ideal solution for water crisis in Egypt. A prototype was constructed with specific **design requirements** such as the quality of water and the efficiency of irrigation system. By **testing** the prototype, the **results** were more preferable than expected as it confirmed that the project fulfilled its design requirements. **In conclusion,** these promising results gave us a clue that this project will be so powerful on large scales in the near future.

Introduction:

Egypt’s future is obstructed by dreadful **grand challenges.** Water scarcity and agricultural base depression are the most substantial and solving them is a delicate task. Egypt’s total available water resources is 58.88 billion m^3, whereas its total consumption is 79.5 billion m^3 (as shown in fig 1&2). The main reasons for these problems are the increased demands due to over-population and water pollution. This leads to several consequences related to our environment, economics and social life such as diseases spreading and lack of food supply.

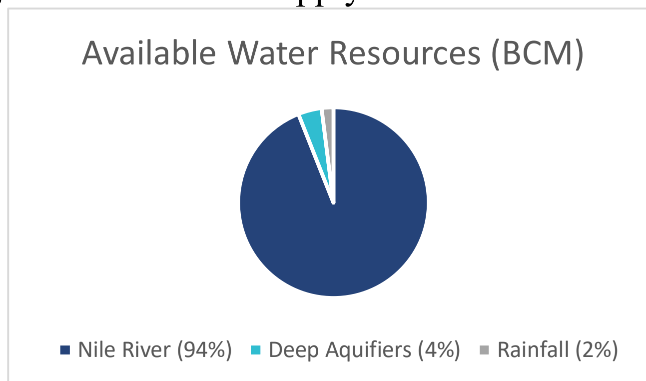


Figure 2- Available Water Resources (BCM)

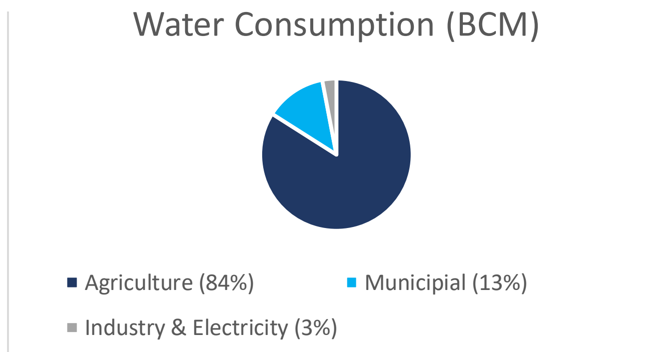


Figure 1 - Water Consumption

In order to overcome such tragedy, **prior solutions** were implemented, including the Aswan High Dam and New Cairo wastewater treatment plant. Although many of these attempts have **strengths,** they also have **weaknesses**. For example, New Cairo wastewater treatment plant has a capacity of 250,000 m3/day to treat domestic wastewater serving 1 million people within New Cairo City. Unfortunately, the unorganized administration led the treated water to be pumped into the Nile River, so that it is required to be treated again using chlorine before it is served to the community. After understanding the **merits** and **demerits** of these solutions, it was required to find an alternative source of water in order to get rid of this crisis. The **selected solution** to resolve this severe problem is composed of two systems. First, the treatment system, which treats wasted urine through considerable stages; coagulation, filtration, and disinfection. Each stage is done by a certain chemical in order to achieve a specific purpose. Second, the irrigation system, which controls the use of produced water with moisture sensor and temperature sensor. The **design requirements tested** on the **prototype** are water quality and irrigation system’s efficiency. The prototype was made, tested to measure the ratios of the undesirable materials in the treated water and their effect on the irrigated plant, also the water conserved determined the efficiency of the irrigation system and it was concluded from the test results that the project met these design requirements. The materials used in making the prototype are illustrated in the materials and methods section below.

- **Experimental:**
- **Materials:**

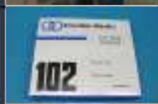
Dry Ice, Solid form of (Co_2)		Hydrated Potassium Aluminum Sulfate $(Al(SO_4)_2 \cdot 12H_2O)$		4 taps, 1cm in diameter	
Filter Paper 102		Drippers		Arduino Uno R3 V2.0, 1board	
Activated Carbon		Titanium Dioxide(TIO_2)		500 pin bread board, one	
Wood Stander		1K ohm resistors, 3		1 Soil Moisture Sensor	
2x16 Arduino LCD, one		LM35DZ temperature Sensor, one		1mm Jumpers of 20 cm length (male-male) (male-female) (female-female)	
JQX-32 21V 5pin-relay, one		Light emitting Diodes 3mm, two		Potentiometer (1K ohm)	
12volt water pump, one		Acrylic sheets with dimensions 30cm, 60cm, 3mm, 3 sheets $(C_5O_2H_8)$		Holder	

Table 1 - Materials

The materials listed in the previous table were all used according to the following steps to get the final configuration.

Figure 3 - 3D Design

For the treatment system:

1. A 3D pre-design for the prototype was designed using Sketch up program, shown in fig. (3)

2. Wood were cut and stuck together to form the shown shape in fig (4) to put the containers on.

Figure 4 - Wooden Stander

3. Four cubic container with dimensions 15cm, 15cm, 15cm were made from acrylic sheets as shown in fig (5) using the laser cutter in the FAB Lap. After that, 3 taps were connected to 3 of the 4 containers. Then, the containers were placed on their places on the wooden holder.

4. Firstly, the bulk alum (aluminum sulfate) was added to the urine, stirred, and kept for 15 minutes until the folks is formed, the tap was opened to allow the Urine pass to the next stage.

Figure 5 - Acrylic Containers

5. Secondly, the dry ice was added and kept for 1 hour.

6. Thirdly, the solution was allowed to pass through a filter paper.

7. Fourthly, the activated carbon was added and stirred until the color and the odor of urine disappear completely.

8. Finally, a disinfection process was done using titanium dioxide (TiO_2) to remove bacteria, viruses, and pathogens.

For the irrigation system:

Figure 6 - Final Prototype

1. Temperature sensor and soil moisture sensor were connected to a breadboard and then to Arduino pins using jumper wires, so that they can deliver signals.

2. Water pump was connected to the relay module and then to the Arduino, so that it can receive signals (ON/OFF).

3. An LCD was connected to bread board to Display readings from the sensors.

4. LEDs were connected to the breadboard to be able to test the circuit.

5. A code was written on Arduino IDE and uploaded to close/open the switch in the relay based on different conditions.

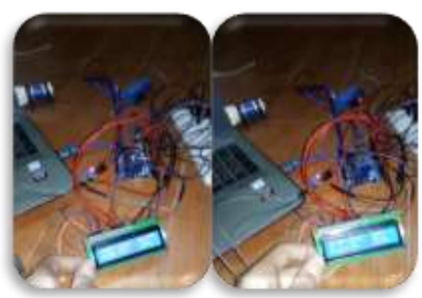


Figure 7 - Management System

After making the prototype, the test plans were conducted to it to assure that it achieved the design requirements. In fact, several tests have been carried out. These tests focused on the quality of water and the efficiency of the irrigation system and can be summed up as follows:

1. Quality of water:

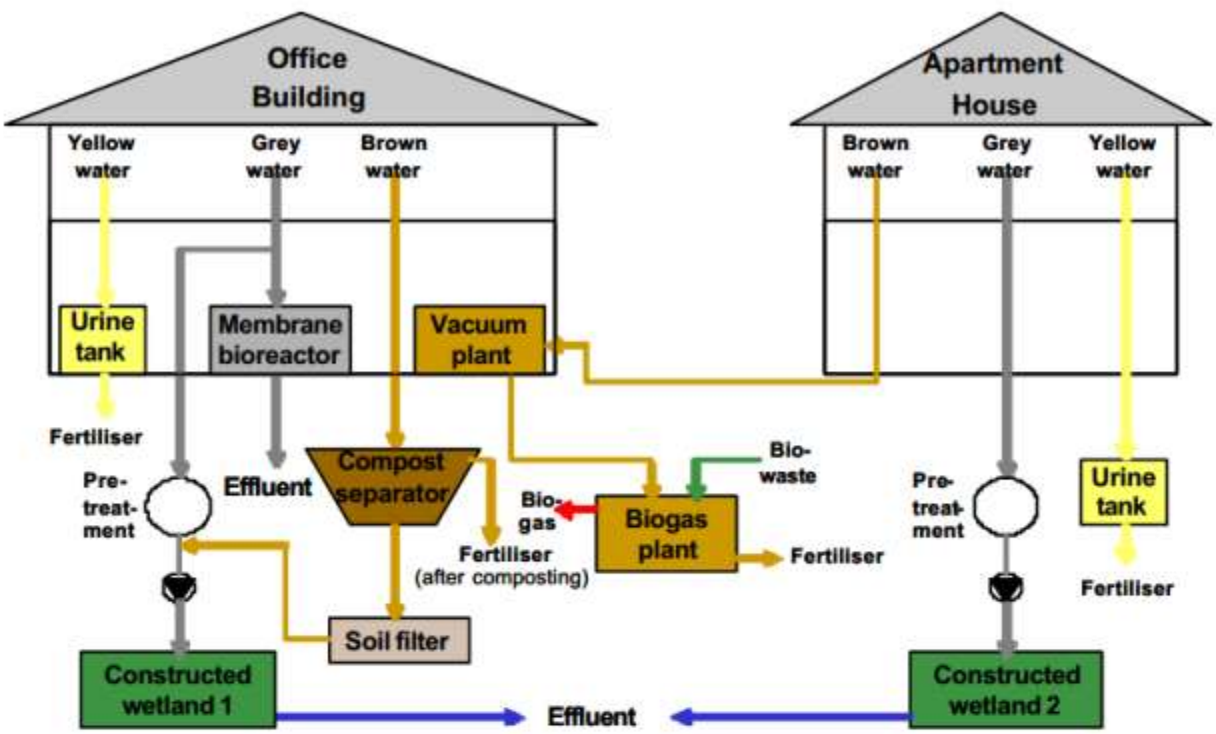
Many samples from various trials using different materials were collected and sent to the National Research Center in order to measure the parameters of treated water such as: pH, TDS, Conductivity, TSS, Turbidity and BOD using different devices including TDS & pH meter. Then, the results were compared to the suitable parameters of the chosen plant.

2. Efficiency of irrigation system:

The efficiency of the irrigation system was calculated by evaluating the difference in the water used to irrigate the chosen plant per day in traditional irrigation systems & the recommended system. After that, it will be easy to compare between different irrigation techniques depending on the estimated water used.

Figure 8 - Urine Before & After the Treatment

The small-scale prototype photos

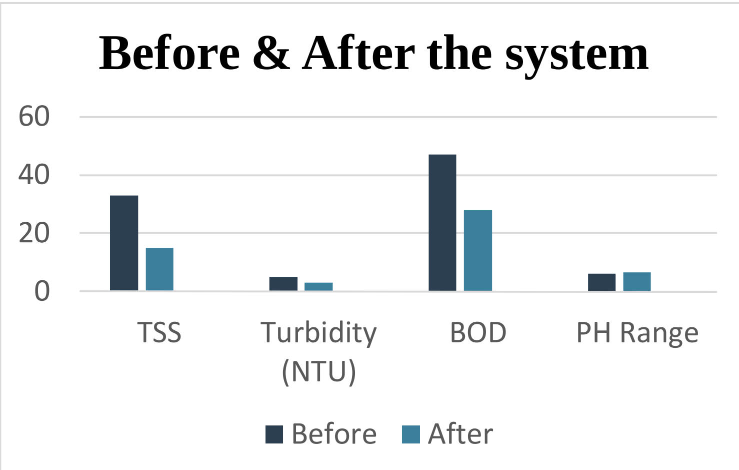


The new sewage system description

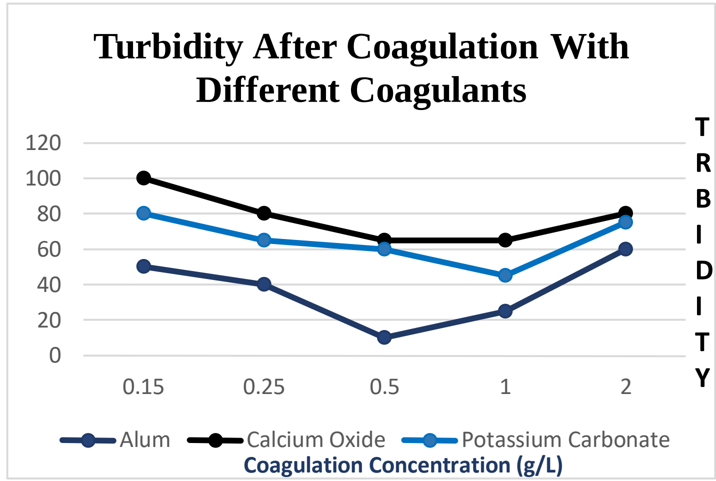
- **Discussion & Results:**

1. Water Quality:

More than one trial using different coagulants, performing the steps stated above, was carried out. Therefore, some of the results were negative as shown in graph (1), but the final results showed that our project will be so effective if applied to irrigate pea plant, radish, and lettuce. The following graph (2) & table (2) shown the final results.



Graph 2 - Urine Parameters After & Before the System



Graph 1 - Turbidity Using Different Coagulants

Before	Concept	After
6050 mg/L	Total Dissolved Solids (TDS)	700 mg/L
5	Turbidity (NTU)	3
9.4 dS/m	Conductivity	1.1 dS/m
320 mg/L	Total Suspended Solids (TSS)	160 mg/L
6.2	PH Range	6.8
47 mg/L	BOD (Biological Oxygen Demand)	16 mg/L
120 mg/L	COD (Chemical Oxygen Demand)	92 mg/L
1000	E. Coli (Number per 100 mL)	850

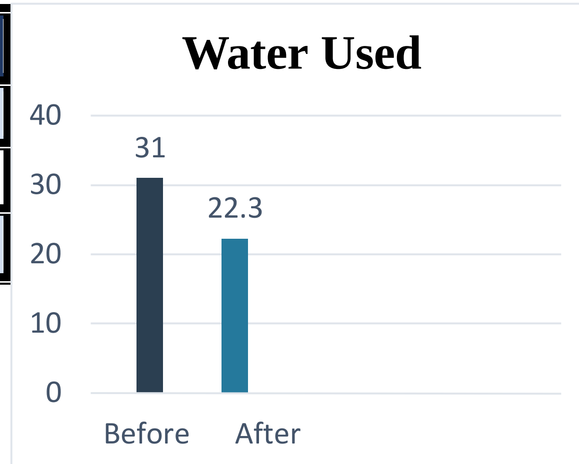
Table 2 - Water Quality Test Results

2. Efficiency of irrigation system:

When testing the different situations, the pump turned on only when the moisture in the soil was less than the suitable amount of water. The management system reduced the consumption of water from 31mm (L/m^2) per week by 28%, so about 8.68 L is reduced as shown in graph (2).

Trials	Before	After
Trial 1 (Pea)	31 mm	22.3 mm
Trial 2 (Bean)	28 mm	20.2 mm
Trial 3 (Citrus)	24 mm	17.2 mm

Table 3 - Irrigation System Test Results



Graph 3 - Water Consumed Before & After applying the System

According to the results, obviously, the project was able to meet its requirement and its readiness for centralization. The project went through deep analyzing that included scientific bases in order to obtain such results. Two minor sections will divide the Analysis section, which are treatment system and irrigation system.

Treatment System:

The idea of this system is all about using specific chemicals in each stage of the system. The following 3 stages discuss the system in details:

First stage: Coagulation

At this stage, the inorganic small floating particles that are not able to settle to the bottom by gravity like clay, silt, and mineral oxides are removed. These particles are referred to as colloids. Turbidity, the state of cloudiness in the water, is caused by these colloids and as it increases, the risk of being infected increases as well. As a matter of fact, this happens because the poisonous chemicals are more likely to stick to the surface of the suspended colloids. Most of the colloids have negatively charged surfaces that attracts other charged particles. A chemical compound called (Hydrated Potassium Aluminum Sulfate) ($KAl(SO_4)_2 \bullet 12H_2O$), is added to aid the settling process. The colloids gather forming larger clumps called flocs. Flocs settle relatively fast due to gravity. After performing its role, the Alum is filtered from water with the precipitated colloids in the next stages. The following equations represents alum's reaction with the urine:

$$\mathbf{KAl\,(SO_4)_2 \bullet 12H_2O(aq) \rightarrow K^{+}_{(aq)} + Al^{+}_{3(aq)} + 2SO^{-2}_{4(aq)} + 12H_2O}$$

$$\mathbf{KAl\,(SO_4)_2 \bullet 12H_2O(aq) + 2Bacl_2 \rightarrow KCl + AlCl_3 + 2BaSo_4 + 12H_2O}$$

The rate of this process is based on the power provided. This rate is measured by velocity gradient and to calculate it, the following mathematical equation is used:

$$G = \sqrt{\frac{W}{\mu}} = \sqrt{\frac{P}{\mu V}}$$

(G) = velocity gradient, sec-1 (W) = power imparted per unit volume of basin, N-m/s-m3
(P) = power imparted, N-m/s (V)= basin volume, m3 (μ) = absolute viscosity of urine.

Second Stage: Filtration

This stage is divided into 3 stages: First, using Dry ice, also known as "cardice", as a cooling agent to Cool the urine, then crystalizing the salts inside it to help the filter paper in the filtration process. This chemical is used due to its appropriate characteristics including lower temperature than that of water ice (-109.3 degrees Fahrenheit (-78.5 degrees C)) and not leaving any residue. In addition to its ability to remove the crystalized solids, it can lower the pH of a solution when dissolved in water, forming carbonic acid (H_2CO_3).
Second, using qualitative filter paper to remove the crystalized salts inside urine. There are different grades of qualitative filter paper according to different pore size. In this project, a grade 102 filter paper, with pores' size ranging from 15 to 20 μm, was used due to its special and suitable characteristics including medium flow rate, good retention, High capacity, and high absorption.
Third, using an activated carbon layer (As in Geology), also known as charcoal, to adsorb natural organic compounds, taste and odor compounds, and to reduce pollution parameters, including total SM (Suspended Matte), COD, and BOD. Activated carbon is part of a range of substances with a high porosity and a significant surface area of about 500 to 1500 m^2 per gram of coal. These qualities give the activated carbon a high adsorption capacity. The structure of pores can be classified into three different categories. According to table (4), the macro porous has no role in the process. The micro pores, representing up to 95% of the total surface of the coal, are the places of adsorption. The mathematical formula for calculating the balance between the adsorbate molecules fixed and those remained free in the liquid phase is $\frac{X}{m} = Q_e$
(x) is amount of adsorbate, (m) is mass, (Q_e) is amount of solute adsorbed per unit mass of coal.

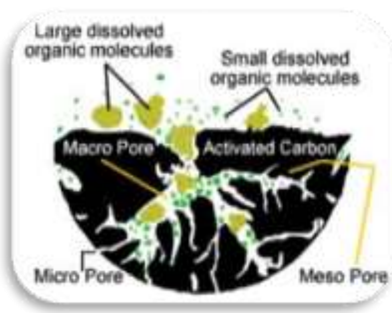


Figure 9 - Activated Carbon Structure

Ray	Macro pore	Mesopore	Microspore
Ray (nm)	50-100	1,8-50	<1,8
Volume (ml/g)	0,2-0,8	0,02-0,1	0,15-0,5
Area Mass (m²/g)	0,5-2	25-75	95% total Area

Table 4 - Activated Carbon Pores Size

Third stage: Disinfection

Disinfection is all about the killing or inactivation of microorganisms. While several metals are noted for their anti-microbial activity by being toxic, titanium dioxide is believed to be unique in that, it primarily acts as a photocatalyst using UV light and is not consumed in the reaction. Titanium dioxide can be used in many formulations that exhibit anti-microbial activity against all types of microorganisms. In the presence of water and light energy (photons), photocatalysis results in the formation of reactive oxygen species which react with organic molecules in microorganisms resulting in their death or inactivation (in the case of viruses). The process of photocatalysis begins when photon energy (hv) of greater than or equal to the bandgap energy of TiO_2 is illuminated onto its surface. The photo excitation (TiO_2+$hv \rightarrow e^- + h^+$) leaves behind an empty unfilled valance band, creating an electron–hole pair ($e^- h^+$) as the electron moves to a higher energy level. The interaction of the hole with water molecules or hydroxide ions produces very reactive hydroxyl radicals as in the following equation: H_2O+$h^+ \rightarrow H^+$+$OH^\bullet$. Eq. 2 depicts how the presence of oxygen allows for the formation of superoxide radicals ($O_2^{\bullet -}$).

Photoexcited: e^-scavenging:$(O_2)_{ads}$ +$e^-_{cb} \rightarrow O_2^{\bullet -}$ (eq.2)

This radical can be further pronated to form hydroperoxyl radical ($HO_2^\bullet$) and subsequently hydrogen peroxide (H_2O_2) as shown in Equations (3 & 4).

Protonation of superoxide: $O_2^\bullet$ +$OH^+ \rightarrow HOO^\bullet$ (eq.3)

Formation of H_2O_2: $HOO^\bullet$ + H $\rightarrow H_2O_2$ (eq.4)

It is important to recognize that for these processes to precede both dissolved oxygen and water molecules have to be present. Without the presence of water molecules, the highly reactive hydroxyl radicals ($OH^\bullet$) could not be formed. Thus, the availability of both moisture (in the air or on the surface of the treated surface) and oxygen are necessary for titanium dioxide to be an effective antimicrobial. Light intensity is one of the few parameters that greatly affect the degree of photocatalytic reaction on reaction with organic molecules.

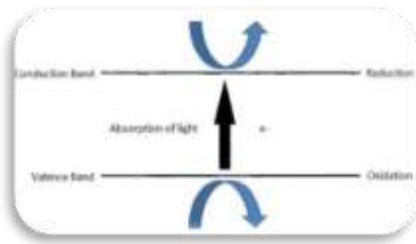


Figure 10 - Titanium Dioxide Mechanism

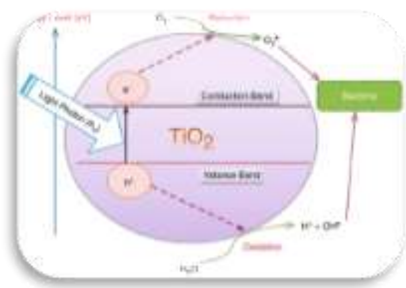


Figure 11 - TiO2 Reaction

IRRIGATION SYSTEM:

The drippers used in this project are specialized with a constant flow rate that
can be calculated using the following equation: $\mathbf{Q = 60 \frac{m}{\rho t}}$

(m) mass of collected water, (t) time of the test, (ρ) specific weight and (Q) is the flow rate.

The management system consists of temperature sensor, a soil moisture sensor, a water pump, a relay, and an LCD.

- Soil moisture sensor: A sensor that can read the amount of moisture present in the soil using its 2 probes to conduct a current through the soil, and then it reads that resistance to get the moisture level. More water makes the soil conduct electricity more easily (less resistance) and vice-versa.
- Temperature sensor: A temperature sensor is a device that detects and measures hotness and coolness and converts it into an electrical signal that can be send to the Arduino.

- Arduino LCD: It is used mainly to display the readings from the sensors and also the state of the soil being dry or wet and also the state of the water pump (ON / OFF).

- If/then statement (As studied in Technology) (Fig. 10): It is a code which integrates all signals from sensors together: If (temperature > 20), see if (moisture >700) that is equal to humidity of 58%, which is suitable for plant growth, and if so then turn the pump & light on but if else, then turn the pump & light off. Where moisture is the received signal from moisture sensor and temperature is the received signal from the temperature sensor.

- A relay is an electromechanical switch that has its contacts opened or closed by a magnetic force, conducted by the flow of small voltage current through a coil, as shown in (Fig 11). When a small voltage gets applied to the relay's coil, it results in a large voltage being switched by the contacts.

Figure 12 - If Statement Code

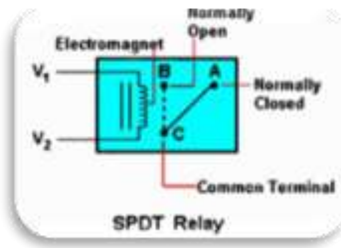


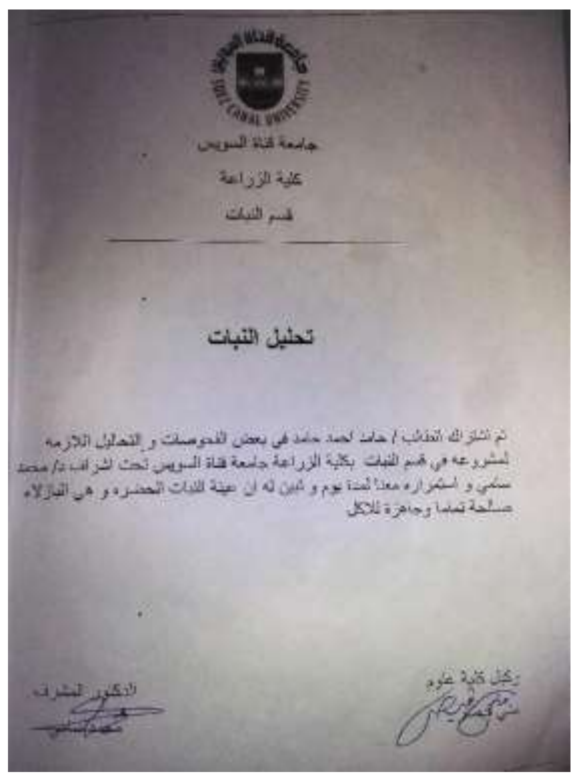
Figure 13 - Relay Mechanism

جامعة قناة السويس
كلية علوم
قسم الجيولوجيا

تحليل مياه

تم اشتراك الطالب / حامد احمد حامد في بعض الفحوصات و التحاليل اللازمه لمشروعه في قسم الجيولوجيا بكلية علوم جامعة قناة السويس تحت اشراف د/ كمال عودة و استمراره معنا لمدة ثلاث ايام متتالية و تبين تلك النتائج
نقاء الماء بنسبة ١٠٠%
و عينة المياه صالحة للشرب

الدكتور المشرف
وكيل كلية علوم



جامعة قناة السويس
كلية الزراعة
قسم النبات

تحليل النبات

تم اشتراك الطالب / حامد احمد حامد في بعض الفحوصات و التحاليل اللازمه لمشروعه في قسم النبات بكلية الزراعة جامعة قناة السويس تحت اشراف د/ محمد سامي و استمراره معنا لمدة يوم و تبين له ان عينة النبات الخضراء و هي البازلاء صالحة تماما وجاهزة للاكل

الدكتور المشرف
وكيل كلية علوم

Tests and Certificates

• Conclusion:

The problems that face Egypt in its water and agriculture sector came at a time of great uncertainty. In order to stabilize the country in the long run, the government will need to diversify its sources of water. So, using a urine treatment system based on analytic base with effective irrigation system that increases its efficiency and noticeably reduce the water losses. Using high efficient materials led the urine treatment system to meet its design requirements. The results proved that this project achieved its design requirements by providing suitable water for agricultural use, which will decrease the water consumption of traditional water resources by about 23%, if applied on a large scale at the Delta, and raising the efficiency of traditional irrigation methods by about 28%. This project is suitable to be applied in our real life and it will be a good source of water to Egypt and will save the water consumption effectively.

• Recommendations:

Nothing is completely perfect, and for so, some future modifications were recommended to be constructed in the future models. However, they were not applied due to some obstacles that will be discussed below.

- It's recommended to utilize the transpiration process in the plant. In this process, the moisture changes to vapor and is released to the atmosphere as it passes through plants from roots to leaves. The water produced from this process can be used as supply for drinkable water as it's a pure water.
- For the irrigation system, it is recommended to use a GSM module to create a communication between a computer and the irrigation system in order to make the owner able to identify the project state and to provide him with the readings of the system's sensors.
- For the centralized project, it is recommended to establish a sewage system and the toilet design that indicates small halls in the bottom of the toilet as shown in the figure that allows the urine flows through a series of pipes into the Urine Processing Room in the basement of the building. No solid waste (feces) reaches the Urine Room. The Urine will go through a series of processing steps that we have mentioned before and can be re-use as water for agriculture.

Figure 14 - GSM Module

Figure 15 - Sewage System

- ## References:

- Water Scarcity. Retrieved from http://www.fao.org/nr/water/aquastat/countries_regions/EGY/
- The Integrated Water Resources Management Plan For Egypt. Retrieved from http://documents.worldbank.org/curated/en/561611468234311417/pdf/341800EGY0whit11public10Action0Plan.pdf
- EarthComm: Project-based space and earth system science. (2012). Armonk, NY: Its About Time.
- Reddy, P. L., Kavitha, B., Reddy, P. A., & Kim, K. (2017). TiO 2 -based photocatalytic disinfection of microbes in aqueous media: A review. Environmental Research, 154, 296-303. doi:10.1016/j.envres.2017.01.018
- Reviews, C. T. (2013). Studyguide for chemistry by zumdahl, steven s., isbn 9781133611097. Place of publication not identified: Cram101 Incorporated
- Missing-Value, M. Activated Carbon. Activated Carbon Adsorption for Wastewater Treatment, 29-40. doi:10.1201/9781351069465-2

- ## Acknowledgment:

Thanks, first and foremost, to Allah who reconciles us in our capstone. And to Eng. Ahmed Towfek, Mrs Israa, Dr. Salah Mohamed (Official in the Ministry of Environment). Secondly; want to thank agricultural research center and their instructor (Dr. Mostafa El-Sheikh) and Suez Canal University for their help, Dr. Ahmed Elkhart, Dr. Ahmed Fathy, Mr. Adel Zidane and each person helped us one way or another and we forgot to mention him Great thanks for dr/ Kamal oda and doctor Mohamed samy.