نجربة تلميذ مبدع

Nitrogen fixation rule in water purification

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ملخص:

تعد ندرة المياه من أخطر المشكلات التي تواجه مصر بداية من القرن الماضي. ندرة المياه هي عندما لا تتمكن الموارد المائية من تلبية الطلب على المياه كنتيجة بعيدة للتلوث. تعتبر مصر دولة تعاني من ندرة المياه منذ عام (٢٠٠٥) ، وبالتالي ، فالأولوية العظمى لتوفير أكبر قدر ممكن من المياه. يهدف هذا المشروع إلى تغيير العملية برمتها لتمكين إعادة استخدام المياه الأقل تلوثًا. تم استهداف القطاع الزراعي؛ لأنه يستهلك حوالي ٦٢.٤ × ١٠٩ م٣، أي أكثر من ٨٠٪ من إجمالي استخدام المياه. كما هو متوقع، تنتج الزراعة معظم مياه الصرف في مصر. استغللت آلية تثبيت النيتروجين عن طريق زراعة نباتات الفول (بقوليات) مع محصول الخس (نبات ورقي). تقوم البكتيريا العقدية (rhizobia) بتثبيت النيتروجين واستبعاد الأكسجين من الجذور إلى التربة، وبالتالي، يتم تقليل مستوى النيتروجين عند عمليه غسيل التربة وزياده مستوى الأكسجين الذي يقل بعد ذلك نتيجة وجود الـ COD. تم عمل نموذجين: أحدهما مع نبات تثبيت النيتروجين، والآخر مع الخس بشكل فردي. بعد قياس صفات مياه الصرف الزراعي لكل نموذج أولي، وجدت أن معاملات مياه الصرف الزراعي، خاصة النيتروجين، والأكسجين المذاب، و COD يتم تقليلها لتلائم عملية تبريد الفولاذ المقاوم للصدأ.

Abstract:

Water scarcity is one of the most dangerous problems that Egypt faces during the last century. Water scarcity is when the water resources cannot meet the water demands as a farther remote result of pollution. Egypt is considered a water-scarce country since 2005. Thus, it is crucial to saving as much water as possible. This project is to change the entire process to enable less polluted water to be further reused. I worked in the agricultural sector because it exhausts about 62.4×10^9 m^3, which is more than 80% of total water usage. As expected, agriculture produces the most wastewater in Egypt. The solution must meet the design requirements, which are: COD (chemical oxygen demand) decrement, nitrogen's quantification, efficiency, not to change in the product, and the low cost. In this solution, I exploited

the nitrogen-fixation mechanism by planting bean plants with the lettuce crop. In nitrogen fixation, the nodular bacteria fix the nitrogen and exclude the oxygen to the soil. Thus, the nitrogen level of the wastewater is reduced. Two prototypes were made, one with the nitrogen-fixing plant and the other with the lettuce individually. After measuring each prototype's wastewater qualities, I found that the wastewater parameters, especially nitrogen, DO (dissolved oxygen), and COD, are reduced to suit the stainless steel's cooling process.

Key words: Cooling stage, nitrogen fixation, nodular bacteria, and roof planting.

Introduction:

Egypt faces a set of problems called Egypt's grand challenge, mainly sub-categorized into pollution and water scarcity. These challenges are considered the most dangerous Egypt's grand challenges. Water scarcity is when the water resources do not meet the water demands. According to CAPMAS, in 2017, Egypt has a freshwater share per year per capita of 628.4 m^3 and decreased to 570 m^3 in 2018, which is about half of the water poverty line (1000 m^3). Egypt also is considered a water-scarce since 2005. This semester's capstone project is to change a process in industry or agriculture to reduce wastewater pollutants and then reuse this water.

Prior solutions' strengths and weaknesses must be considered before developing a new solution. Many prior solutions are done to solve the problem of the water crisis. One of these prior solutions is changing products. For example, the industry of non-rechargeable batteries pollutes the environment with heavy metals such as lead and mercury; The solution is either transforming into batteries having less toxic materials or rechargeable batteries, which can be used for years. This way reduces the pollutants of water, but it has significant disadvantages such as the output is changed, and the solution is not sufficient. Another prior solution is to make a change in the input materials. Such as reducing phosphate-containing chemicals in the textile industry. Nevertheless, this solution also will affect the product and is not sufficient. So, I searched for a solution that meets the design requirements; the solution must be testable and efficient, not to change in the product and the low cost.

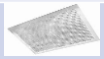
First, I searched about the most wastewater producing sector, and then I found that it is the agriculture sector. So, I decided that the solution will work on agricultural wastewater to reuse as much sewage as possible to be

most effective because lack of efficiency is the main disadvantage in most prior solutions. Then, I searched for a method to reduce the wastewater pollutants, which is nitrogen fixation by bean plants.

In this solution, I exploited the nitrogen fixation mechanism to reduce the wastewater pollutants. In nitrogen fixation, the nitrogen-fixing plant, most of the time legumes, fix the nitrogen and evict oxygen to the soil's pores. Thus, the nitrogen in the wastewater will be reduced while the DO level will increase simultaneously. However, the dissolved oxygen will be consumed in COD fragmenting. As a result, DO and COD will decrease. Water samples were tested in each phase in many trials every period to reach the desired results. I built two prototypes, one with lettuce and bean plants with its active nodular bacteria and the other with only lettuce plants; This is made to compare the water qualities of the wastewater before and after applying our solution.

Material and methods:

Table 1

Items	Cost	Picture
2 Plastic containers	105 L.E.	
Celtic soil	11 L.E.	
Pored-aluminum sheet	4 L.E.	
Bean's seeds	2.6 L.E.	
Lettuce	5 L.E.	
Wooden frame	35 L.E.	
Plastic bottles	6 L.E.	
Fertilizers	35 L.E.	

The methods for the construction of the project (test plan) are illustrated below to fulfill the design requirements which are:

1-COD decrement. 2-Nitrogen's quantification. 3-Efficiency. 4-Cost.

A- Initially, I have to buy the required materials for constructing our prototype, which matches with the standard expected solution requirements; I started by making some pores in the container using a hot cutter with an upper pored-aluminum sheet on the container's base, also forming an inclined plane under the container to slope the water in a particular position to be easily collected.

B- In the configuration stage, I put the soil in the container, inject the lettuce and bean seeds, and watered it frequently in its irrigation schedule after installing the container in the wooden frame.

C- In the stage of taking out the results, the plastic bottles at the end of the inclined plane are used to collect the water, which is measured according to the determined parameters on different periods to pursue the nodular bacteria activity.

Total cost: 203.6 L.E.

Literature review:

Water is the driving force of all nature; we forget that the water cycle and the life cycle are one, and for today's time, water is the primary reason behind life. Tomorrow, it might become the primary reason behind deaths. Sometimes we do not face what is going on in the world, but we had to intervene when it comes to water. There have been many ways in which water is treated, whether by treatment plants or chemicals, but the matter is slightly different for us; we have to amend the entire process at the lowest cost, effective materials with environmentally considerate and less polluted water to be reused, facing Egypt's grand challenges of cheeseparing of water sources and air, water and soil pollution.

Design requirements are considered to be eye-opening while constructing the prototype based on the selected solution leading to the desired solution requirements; First, I determined the four design requirements, which we demonstrated in our idea selection:

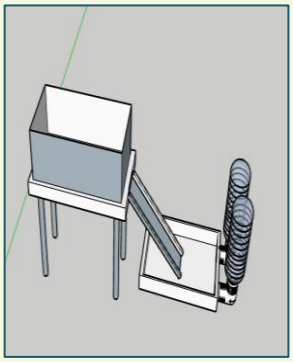
water quality adjustment and measuring

- Chemical oxygen demand (COD) amendment is our main desired goal, depending mainly on the concentration variety of dissolved oxygen (DO). COD relies on oxygen to be fragmented generates a direct relation between the two qualities.
- Quantification of Nitrogen (N) concentration at the beginning and end of the project timeline based on three trials. Its measurement is the most important because its change in concentration due to the nodular bacteria's fixation leads to differences in the other water parameters.

Figure 1

My desired design requirements

- My idea helps solve the water crisis, increasing the soil's efficiency and supplying the leafy plants with nitrogen, so the efficiency is achieved; Nitrogen is the major component of chlorophyll, the element by which plants use sunlight energy to produce sugar from water and CO2. It is also the main component of amino acid, which is the building block of protein. without protein, plants wither and die.
- Reducing the cost, as the huge expenses of transporting water from the agricultural land to the factory were solved by investing in the factory's administration building roof by making a roof planting connected with a pipe system to reach the containers.



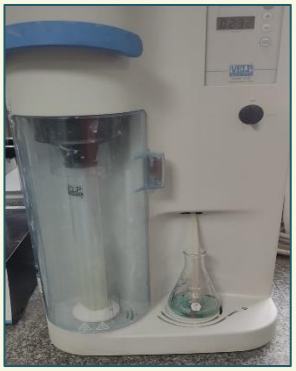
Fiaure 2

I have started by making a 3D design for our prototype, as shown in fig. (1), which consists of two sections:

The upper section

Entering beans planting in the cultivation of lettuces. Nitrogen fixation happens by the nodular bacteria in the plants' roots, which evict the Oxygen and decrease the soil's nitrogen concentration.

In washing the soil, the water will contain a small amount of total nitrogen, measured by Kjeldahl in ammonia and adding Devarda's alloy to determine the amount of Nitrate, as show in fig. (2), then making a titration process to be finally calculated in the formula of:



Fiaure 3

N, ppm (NH3, NO3) = [(V-B) × normality of H2SO4 × 14 × 1000]/ ml sample

and a large amount of dissolved Oxygen. Equilibrium will not happen until after irrigation because each plant performs the same process in a row.

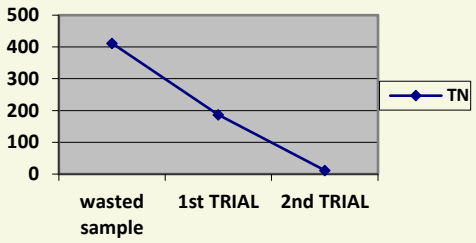
The increment of DO is useful in COD fragmenting, so the COD decreases, and Oxygen decreases as being used up. Therefore, the resulting water is suitable for the stainless-steel industry's cooling stage because it requires water with less dissolved oxygen concentration, not to form an oxide.

The TDS decrement is generated due to the variety of essential minerals for both plant types.

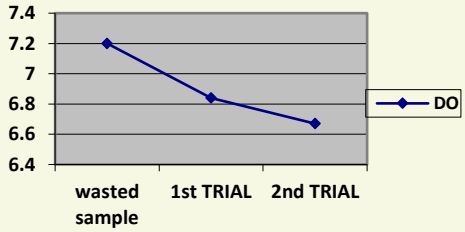
The lower section

An inclined layer to helps the water slope for the tanks, similar to a piping system.

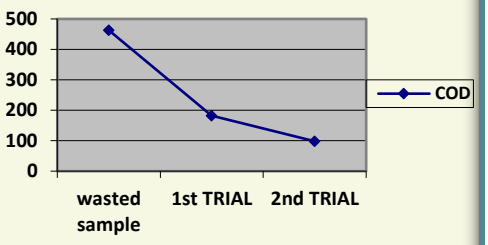
Test plan: I have done two test trials and other two quantifications of the reference pure water and the wasted sample to show our idea's efficiency, as shown in table (1) and graph (1), (2), (3).



graph 1



graph 2



graph 3

Test cost: we tried to minimize the cost of the real solution as well as we could. The whole solution in the large scale will cost 3540 L.E.

Test time: we tried hard to investigate our time in a perfect way to come up with the best product in a short period considering study time with two test trials to get the best result.

Samples	Measuring unit	Wasted sample	1st Trial	2nd trial	Pure water reference
TN	Mg/L	411.2	186.2	11.76	5.88
DO	Mg/L	7.20	6.84	6.67	8.26
COD	Mg/L	462.84	182.1	98.24	19.4

Results:

I have worked on this project as the best way to solve the water crisis, but nothing is completed as perfect as it begins; any project has its negative sides that must be overcome and also its positive sides.

Negative sides:

Firstly, the time of the lettuce plant's growing and the time of nodular bacteria in beans roots growing; nodular bacteria start its effect after four weeks so, I needn't start with lettuce's cultivation. Secondly, lots of lettuce plants died initially, and I have to put beans first in the soil before lettuce plants to affect well, so it turns into a positive side.

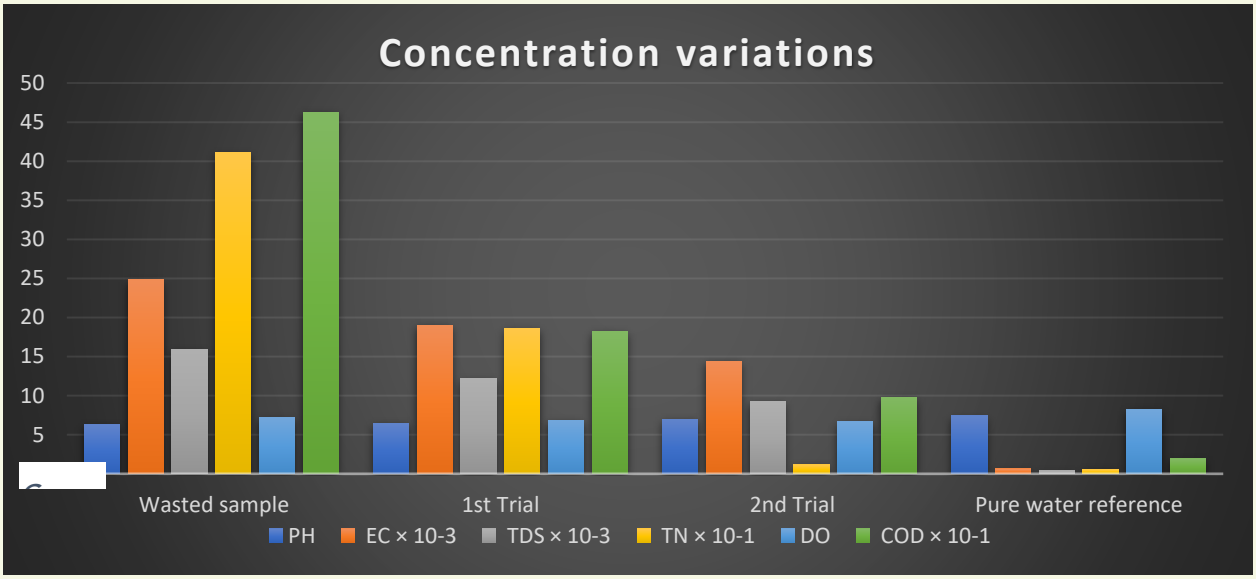
Positive sides:

The lettuce plant's searching time gives the bean's plant its advantage, so the Nodular bacteria become more active, giving us more effective fixation. The Celtic soil is the best selection as its good porosity allows fast drainage.

I tested our samples three times along different timelines. The first one was the wasted sample to know the degree of our progress.

After two weeks, Nodular bacteria started its effect, so I tested our sample for the second time, and I found a new variety of concentrations but not as I desired.

Then I tested our sample for the third time after another the third week, as shown in graph (4); I found a significant difference in desired results for reusing it in cooling stainless steel.



The wasted sample TN test refers to its toxicity; I have found a significant difference in the other two test results due to the nodular bacteria of the bean's roots. The lettuce plant needs nitrogen so, when I put the beans, its roots made a nitrogen fixation in the soil and plant so, I found that the lettuce plants look good and grow fast because as farther as the nitrogen fixation.

I had built two prototypes, the first with lettuce plants only and the other with the addition of beans; I get the wasted sample from the first prototype, and the trial one and two samples were from the second prototype.

Conclusion:

The solution met the design requirements as it reduced wastewater pollutants, and it's a low-cost solution. It is also effective as it will reclaim more than 16×10^6 m^3 of the wastewater.

Reducing agricultural wastewater pollutants using the nitrogen fixation method has many economic benefits, including alleviating freshwater scarcity, providing a drought-resistant water source, and increasing water productivity by cultivating multiple crops throughout the year. It also has many environmental benefits, such as improving the soil quality. However, variability in the composition of wastewater causes risks to the industry. Monitoring wastewater quality regularly and coming up with maximized benefits while minimizing the negatives impacts make reusing the wastewater sustainable.

After applying the solution, the nitrogen, DO, and COD will be reduced. The decrement of DO and COD will make the water reusable in water cooling systems. Water cooling is one of the most water-consuming steps in any industry.

Recommendation:

- **In the large-scale roof planting, the roof will be designed to be shed, as shown in figure (4), not a flat one, to accelerate the path of forced drainage in the vertical glass direction, which acts as a barrier connected with a pipe system to allow the water to reach the container via this system.**
- **Connect the Dissolved Oxygen Meter to the system to measure the DO concentration in the water; to ensure its suitability for use in the cooling stage in the stainless-steel industry.**

Fiaure 4

- **Plant the beans four weeks before the lettuce to allow time for nodular bacteria to be sufficient for nitrogen fixation and complete the process of water reuse.**
- **Standardization of irrigation hours and agriculture in Celtic soil.**
- **Using in-situ submerged biofilters and self-RBC, which accelerate the biodegradation rate of organic contaminant resulting in stream self-purification capacity improvement and enhanced water quality.**

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