Gentian Blossom

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ABSTRACT

For every destination, there is a road. The road to prosperity is industrial evolution. In Egypt, the grand challenges of the industrial base and alternative energy are the shackles of development. The story begins with traditional inefficient industrial methods and ends with suffocating with carbon dioxide. To achieve the desired industrial evolution, two aspects must be solved simultaneously. The first is the industrial method, and the latter is energy. Therefore, it is only reasonable to choose a solution addressing them both, so the solution will be to improve traditional industries using a feedback mechanism and alternative energy resources. Instead of working on new industries, the resurfacing of traditional industries will impact wider sectors from small to large-sized corporations. The chosen solution is the industry of gentian violet because of its wide use in various sectors. On large scale, this can increase industrial production and decrease the environmental impact. For the problem to be solved, the prototype must have the design requirements of being efficient with ideal pH products. After running various tests, the prototype proved to be highly effective in achieving its purpose. The major findings demonstrate that we can control the concentration through sensing the pH, solving the main challenge.

INTRODUCTION

Egypt encounters challenges that constrain its development. Being engulfed with arduous challenges, Egypt is a developing country, and these grand challenges have a very wide impact on the growth of the country. Among those numerous challenges, the deterioration of the industrial base of Egypt possesses a markable significance in the emergence of the rest of Egypt's grand challenges. Traditional industries in Egypt represent a notable sector of the industrial base. Traditional industries are facing many challenges: a lack of professional labour, the usage of polluting energy resources like fossil fuels, and the lack of advanced technological facilities. The CO_2 emissions from Egypt were around 330 million tons in 2018 making it the 10^{th} largest greenhouse gas emitter in the world **as shown in figure (1)**. Also, the limited applications of recycling and the scarce implementations of green sources of energy in industrial processes both are indicators of how inefficient is Egypt's industrial sector. Besides, the final products have lower quality than the ideal.

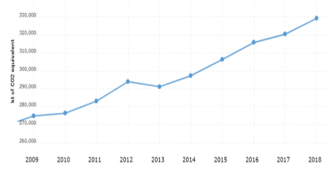


Figure (1): Carbon dioxide emissions in Egypt.

Thus, the main problem required to be solved is to improve a certain traditional manufacturing process by using a suitable feedback control system coupled with a green source of energy to adjust the quality of the output and minizine the harmful environmental effects. Gentian violet's production process was chosen as a traditional industry to be improved. The Gentian violet industry in Egypt is not efficient, is labour extensive, and yields unsatisfactory products.

Prior solutions involve a feedback control mechanism to monitor and manipulate the production process. Firstly, in the smart grids in solar energy production, which are implemented within USA's infrastructure, a feedback control mechanism monitors and adjusts the electricity derived from solar panels for home appliances **as shown in figure (2)**. Besides its clean environmental impact, the high efficiency that the smart grid delivers during the transmission of electrical power is regarded as an advantage for smart grids. The disadvantage of the smart grid system is that not all countries can embrace such an expensive energy system. The second prior solution is the smart Sulfur recovery unit (Claus's unit) **as shown in figure (3)**. Sulfur recovery is an important industry that works on extracting sulfur from acid gases and products. It involves a coalition of different chemical reactions. Its advantages are that it is an automated process and has a very huge production capacity. Nevertheless, it is difficult to be installed and operated.

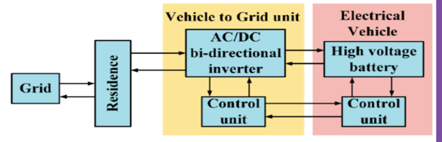


Figure (2): Feedback control system in smart grid

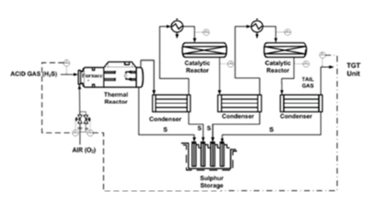


Figure (3): Feeback control system of the sulfure recovery unit.

After searching different industrial methods in Egypt, it was found that the production of gentian violet is very suitable. Gentian violet can be used in many sectors, and its production method is inefficient. Also, the product is far from ideal, so a feedback control mechanism coupled with solar energy would be an effective solution to produce an approximately ideal product with decreasing the environmental pollution. Two testable design requirements have been established to assess the success of the project. The first design requirement is the pH of gentian violet because pH plays a major role in the quality of the product. The second one is to measure the efficiency based on the power consumption relative to the actual amount entering the prototype.

After testing the project it was found that it was an efficient solution that successfully satisfies its design requirements. It yields approximately ideal products while using a green energy source. The success of the solution is a result of the chosen materials and how they were installed. Materials and methods will be discussed thoroughly in the next section.

MATERIALS

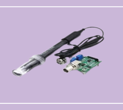
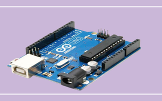
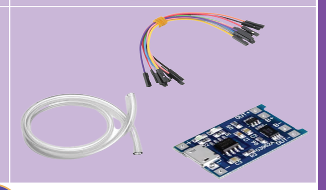
Name	Quantity	Description	Image
Gentian violet	22 grams	Main chemical compound ($C_{25}N_3H_{30}Cl$)	
pH sensor	1	calculating solutions' pH	
Pump	2 pumps	5-volt pump Transfers water to cup	
Arduino uno board	1	Micro-controller	
Solar panels	2 solar panels	5 watt, 5.5 volts solar panels	
Lithium-ion battery	1	3.7 volts, 5.5 ampere lithium-ion battery	
Transformer	1	Used to step up the volt up to 5 volts	
Stirring mug	1	A cup that stirrs solution	
Jumpers, hose, and charging module	10 jumpers 1 hose 1 charging module	1-meter-hose, male-male, male-female jumpers, charging module for lithium battery	

Table (1): Materials Table

METHODS

1.Three samples of gentian violet of concentrations 0.5%, 0.75%, and 1.0% were prepared in beakers in the chemistry laboratory to test the relation between pH and concentration **as shown in figure (4)**, and a linear relation between the concentration and the pH was deduced.


Figure (4): The three prepared GV samples

2.The pH sensor was calibrated to measure accurate pH results and connected to the A0 pin. After that, the Arduino UNO board was linked to the laptop **as shown in figure (5)**.

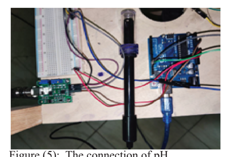


Figure (5): The connection of pH

3.The lithium-ion battery of 3.7V was connected to the charger module **as shown in figure (6)** charge the battery, and afterwards, they were connected to the solar panels of 5.5V and 5W and the solar panel was at an angle of 25 degrees.

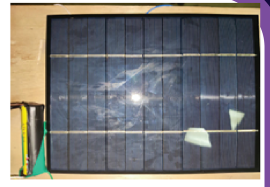


Figure (6): Connection of solar panel

4.A step-up transformer was connected to the battery **as shown in figure (7)** to increase the emf to 5 volts which is suitable for powering each of the two pumps.

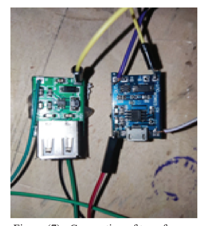


Figure (7): Connection of transformer

5.The pump was connected to the relay to control the intervals of opening and closing the pump **as shown in figure (8),** and the relay was connected to the Arduino UNO.

6.One pump was connected with distilled water for transferring the suitable amount of water to decrease the concentration of the solution in case of a pH was higher than 3.4. The other pump was connected with gentian to increase the concentration in case of the solution was diluted **as shown in figure (9).**

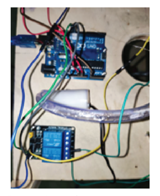


Figure (8): Connections of two pumps


Figure (9): Connections of two pumps withtheir solutions

7.The pH sensor was put in the stirring mug to measure the pH directly. The Arduino code was operated, and the feedback control system maintained the pH in the ideal range by controlling the concentration of the product **as shown in figure (10).**

Design requirements:

(1) pH measurement
(2) Efficiency

Safety Precautions:

Lots of safety precautions were taken in consideration: coats were worn to be protected from the chemical solutions. Masks and glasses were also worn.

Test plan:

1. Three solutions of gentian violet with different concentrations (diluted, ideal, and concentrated) were brought, and they were put in the stirring mug with the pH electrode. The code was run, and the feedback control system was tested according to these three solutions. The pH of the three products were measured and compared to the ideal pH. The pH values were recorded before and after the feedback.
2. The time taken to make each sample was recorded and the increase in efficiency was calculated by dividing the amount of saved time (the time taken by traditional industries – the amount of time taken by the prototype) by the time taken by traditional industries.

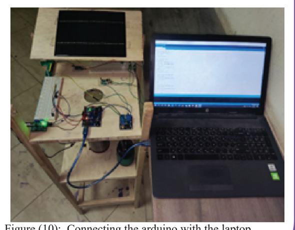


Figure (10): Connecting the arduino with the laptop.

RESULTS

While constructing the prototype, there were negative results. The Arduino UNO was burned due to the wrong connections of the wires as the positive and negative poles were reversed. Moreover, the pH sensor was not calibrated correctly which affected the results at the beginning. However, another Arduino UNO was brought, and a buffer solution was used to calibrate the pH sensor correctly, and positive results were obtained.

Results:

The results of the following table show that the prototype has adjusted the pH of the diluted and the concentrated gentian violet solutions efficiently, without affecting the pH of the ideal solution, and the time is taken (average of 3.50 ± 0.01 min) for the process has been reduced, which reveals that the prototype achieved the design requirements successfully.

	Diluted (Trial 1)	Ideal (Trial 2)	Concentrated (Trial 3)
Before trial 1	5 ± 0.01 pH	3.4 ± 0.01 pH	2.5 ± 0.01 pH
After trial 1	3.6 ± 0.01 pH	3.4 ± 0.01 pH	3.3 ± 0.01 pH
Before trial 2	5.5 ± 0.01 pH	3.4 ± 0.01 pH	2.2 ± 0.01 pH
After trial 2	3.62 ± 0.01 pH	3.4 ± 0.01 pH	3.28 ± 0.01 pH
Average for after trials	3.61 ± 0.01 pH	3.4 ± 0.01 pH	3.29 ± 0.01 pH

The efficiency of the prototype was measured by calculating the saved time by the project, which equals the time used by traditional industry – the time used in the prototype (6 – 3.5 = 2.5 minutes). The increase in efficiency was measured by dividing the saved time by the time taken by traditional industries and was found to be around 40%.

ANALYSIS

Chemistry of Gentian Violet

Gentian violet is an aniline-derived dye with antifungal and antibacterial properties. It is a triarylmethane dye that is synthesized with organic compounds containing triphenylmethane as a backbone. To synthesize crystal violet, Dimethyl aniline is condensed in the presence of Carbonyl chloride and Phosphoryl chloride, which yields Michler's ketone. The compound is then heated in the presence of the previous compounds, which results in the final product of crystal violet. It has the chemical formula of $C_{25}H_{30}N_3.Cl$ **as shown in figure (11)**. It is a monochloride salt of the crystal violet cation. The gentian violet salt is a green powder with blue-violet color in water. Gentian violet is used in many different sectors such as dyes, fungal infection treatment, ballpoint pens ink, and gram staining. Gram staining differentiates between gram-positive and gram-negative bacteria. Gentian Violet (GV) dissociates into positive GV^+ ions and negative Cl^- ions. The GV^+ ions interact with negatively charged components of the bacterial cell wall including peptidoglycan. Gram-positive bacteria are colored in violet and gram-negative are colored in red. This is because the thick layer of peptidoglycan in gram-positive bacteria retains crystal violet. The thin layer in gram-negative bacteria does not retain crystal violet and, hence, is not colored in violet. The solubility of Gentian Violet is 4g/L in water at 25°C. The color of Gentian violet changes according to pH, where it changes from yellow to violet at pH 1. Hence, it is sometimes used as a pH indicator.

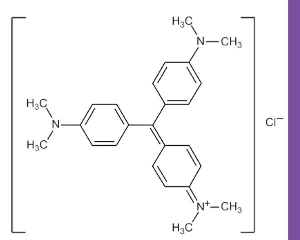


Figure (11): Structure of Gentian Violet.

Dependence of pH on gentian concentration:

Three samples of different concentrations were made. The concentrations were 1%, 0.75%, and 0.5%. The pH measured for the three samples was 3.4, 3.6, and 3.8, respectively. After carefully comparing the results and plotting them on **a figure (12),** a relation between the pH and the concentration of gentian violet was found. It was found that with increasing the concentration of gentian violet, the pH decreases and vice versa. The relation was defined by the equation y=-0.8x+4.2 **as shown in figure (13)**. This is the main idea behind the feedback mechanism. The ideal gentian violet product is of concentration 1% and pH 3.4. If the product value is larger, the feedback decreases the pH by adding gentian violet, and if the output value is smaller the feedback increases the pH by adding distilled water to decrease the gentian concentration.

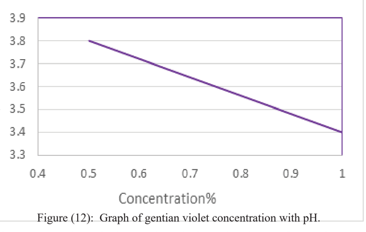


Figure (12): Graph of gentian violet concentration with pH.

$$y = -0.8x + 4.2$$

Figure (13): Equation of relation between pH and concentration.

pH Electrode:

The pH electrode is the main sensor of the feedback mechanism, giving the controller values of the gentian violet product. The electrode is a concentration cell. In the galvanic cell, the potential is dependent on the concentration of the two compartments. The pH electrode, **as shown in figure (14)**, has three main components: a standard electrode of known potential, a special glass electrode that changes potential according to concentration, and a potentiometer to measure the potential between the electrodes. There is also a reference solution inside the glass membrane of known pH value, so when the electrode is dipped in a solution, the potential changes according to the difference of [H+] concentration. This cell potential is automatically changed to a pH reading.

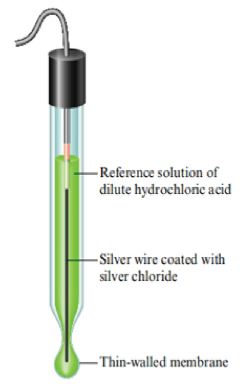


Figure (14): The structure of a pH electrode.

pH sensor calibration:

The calibration finds a relation between the measured pH and the voltage. When the sensor is first used, calibration is needed for accurate results. The electrode has a voltage of 0 to 5V. The calibration is done by using two solutions of known concentration. The solutions used were buffer solutions of pH 4 and 10. The pH electrode is dipped in both solutions, and the voltage is obtained. From these results, two points expressing the relation between voltage (read by the sensor) and pH are obtained. Then, by using these two points, a linear equation between the voltage and the pH is calculated. This equation is used in the code to get future pH results.

Feedback Control Mechanism:

A Control system is a collection of units, forming whole parts, that give orders to control itself or another system. A feedback control mechanism is a control system that gives orders after investigating its output. It consists of input, controller, process, output, and feedback. On operating the system, the controller takes input from the surrounding environment, processes them, and makes decisions. After the process produces output according to the orders of the controller, the feedback processes that output again, giving more orders. For example, if the output is fine (checking the output is done by comparing it to the ideal product), the controller won't give more orders. Otherwise, the controller will give orders. Actuators are the things that do an action according to the orders.

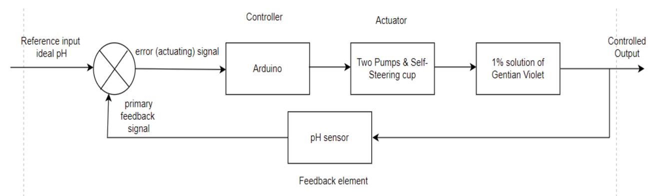


Figure (15): Diagram of the feedback control mechanism of the project

In our project's control system design, **as shown in figure (15)**, the Arduino is the controller and takes input via the pH sensor, and the pumps are the actuators. On operating the prototype, the Arduino orders the pump to transfer gentian violet and water and orders the steering cup to mix them. After mixing, the Arduino makes the pH sensor process the output solution and makes decisions according to the sensor's processing. If the pH is high, the solution should be concentrated, and if it is low, the solution is diluted. No action is made if the solution is in an ideal pH range.

Arduino Analysis:

Arduino boards consist of a microcontroller, analog (input) pins, digital pins, and a 5V pin. A microcontroller consists of memory and a CPU. There are 6 input pins, named A0 to A5, responsible for receiving data from sensors. There are 14 digital pins used for output and input, with an output current of 40 mA. A 5V pin is necessary for outputting the current with 5V for the pH sensor. The code, **as shown in figure (16)**, starts with making the two pumps release the amount of solution necessary for making a 1% gentian violet solution, where the Arduino gives an order for the self-steering mug to steer the solution for 3.5 minutes and gives orders the sensor to measure the pH of the solution after steering. If the pH was less than the ideal range, the solution is concentrated and should be diluted by operating the water pump. If the pH was more than the ideal, the solution is diluted and should be concentrated by using the gentian violet pump, so the result is a product of a gentian violet solution with ideal pH of 3.4.

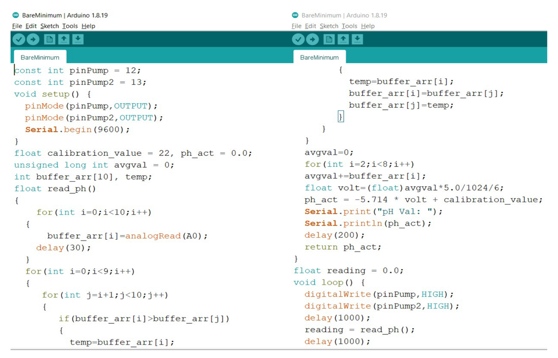


Figure (16): The code of the Arduino Project.

Photovoltaic cell:

Solar energy (**studied in PH 2.15**) was chosen to be the main energy resource for the prototype due to being green and efficient. Solar panels are composed of numerous solar cells connected in series, a schematic diagram, **shown in figure (17)**, to increase the output voltage. Each solar cell produces a small voltage ranging from 0.5 to 0.7 volt, but the series arrangement of those cells adds the voltage generated inside each cell. Solar cells, known as photovoltaic cells, convert solar energy into electrical energy through a stepwise process called "The photovoltaic effect''. A single photovoltaic cell consists of a P-type and an N-type semiconductor.

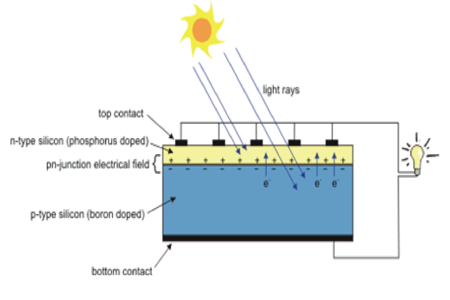


Figure (17): Schematic Diagram of a solar panel.

Most energy transfers in the boundary between the two semiconductors are called a P-N junction. The light photons strike the depletion region of the P-N junction, carrying free charge carriers (holes and electrons). Those new excess charges create an internal electric field inside the depletion region. Electrons start moving toward the N-semiconductor layer, and holes move toward the P-layer, destabilizing the thermal equilibrium of the whole P-N junction and promoting the diode to act as a small battery that produces an external current that can be implemented in operating the two pumps.

Lithium-ion battery:

Galvanic cells (**studied in CHEM.2.09**) are electrochemical cells that convert chemical energy into electric energy by harnessing electrons from the basic oxidation-reduction chemical reactions, happening in two separate compartments. Each of the compartments has an electrode, called anode and cathode respectively. Oxidation is the process of losing electrons of an atom, changing into a positive ion at the anode. Reduction is the process of gaining electrons of an atom, changing into a negative ion at the cathode, so electrons transfer from anode to cathode through the wire connecting the compartments. There is a salt bridge between the anode and the cathode to maintain the spontaneity of the reaction by neutralizing the charge of the two compartments and maintaining the potential difference between the compartments.

Lithium-ion batteries, **as shown in figure (18)**, are galvanic cells that consist of a me- over, encapsulating three sheets (anode-cathode-isolator), where they are dipped in the electrolyte. The electrolyte solution is lithium hexafluorophosphate. The anode is lithium graphite, and the cathode is lithium cobalt oxide.

Overall Reaction: LiC6(s) + CoO2(s) <-> C6(s) + LiCoO2 (s) Eo = 3V.

The battery can be recharged because the reaction is reversible. The lithium-ion battery is used in our project to collect the power, generated by the solar panels, to be stored.

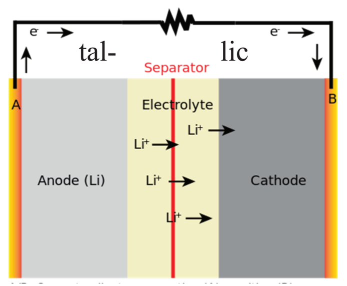


Figure (18): Illustration of a lithium-ion battery.

Micro Submersible water pump:

The Arduino-operated water pump (presented in figure number 18) transports both distilled water and Gentian Violet and adjusts their flow at a very efficient rate. The internal structure of a mini water pump consists of a Brushed DC-Motor (studied in **PH.2.10**) that converts electrical into mechanical energy. A brushed motor's main structure consists of a stator, armature, and brushes. It works on the principle of magnetic torque, one of the electromagnetic laws that state that the wound armature experiences two identical forces acting in opposite directions and have the same line of action, causing the coil to face a magnetic torque. By rotating the commutator, the armature rotates in two half-cycles, each starting from a different position, and interchange their positions. Thus, it continues rotating with constant rotational speed. The brushed DC motor diagram is illustrated in **figure number (19)**.

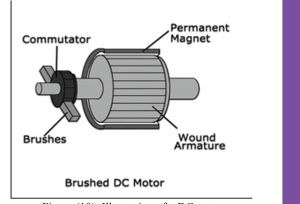


Figure (19): Illustration of a DC motor

After analyzing the results, it was found that the prototype achieved the design requirements of ideal products and efficiency. Deducing from this the project can be applied systemically in Egypt to improve the traditional industry of gentian violet. This will lead to improving the industrial base and solving the grand challenge of green energy sources and pollution.

CONCLUSION

After a thorough study of the problem of the industrial base and use of green energy in Egypt and searching for possible solutions that can be applied to solve the problem, it was concluded that using a feedback mechanism can improve the industry of gentian violet and yield more ideal products. This in return will improve the industrial base and decrease the pollution. A prototype for automated production of gentian violet and a feedback mechanism with a pH sensor was constructed. After running several tests, the prototype proved to be successful with ideal products. This means that the project can be implemented in real-life to solve the grand challenge.

RECOMMENDATION

Electronic pipette:

It is highly recommended to use the electronic pipette, **shown in figure (20)**, instead of the pumps as they are very accurate and precise because they work by dripping very small amounts and uses a motor to maintain the movement of the piston in the electric pipette. Therefore, they will dispense the volume programmed exactly which means that the error in the concentration of gentian will be near zero. However, it has a disadvantage which is the cost: the cost of the electronic pipette is high which resulted in the limitation of its usage.


Figure (20): Electronic Pipette Illustration.

Magnetic stirrer:

It is highly recommended to use the magnetic stirrer, **shown in figure (21)**, instead of the stirring mug as it is much faster than the stirring mug where its speed can reach 1500 rpm (rounds per minute) which means that the efficiency of the process of making gentian violet will increase, and hence the time, taken for the process of the feedback control system, will decrease. However, it has a disadvantage which is its cost. Also, it has a high capacity, which is not suitable for our project. However, it will be convenient for real-life applications.


Figure (21): Magnetic Stirrer Illustration

Real-life application:

The most important point when applying the prototype in real life is considering the source of energy and the use of the product. The prototype uses solar panels as an energy source, and on applying the prototype in real life, it is necessary to put it near Benban Solar Park, **shown in figure (22)**, in Aswan Governorate. Benban Solar Park is the world's 4^{th} largest photovoltaic power station, which is characterized by an annual production of 3,800 GWh. That amount of energy would be enough to produce massive amounts of Gentian Violet solution if the real-life application was done there. Gentian violet will be used as a dye, and it would be beneficial to use the produced solution in the textile factories in upper Egypt (the area where the Benban Solar Park is located). Taking Qena's textile factory as an illustrative example, it is important to know that the factory has a daily production of 2 textile tons. That production needs a minimum of 60,000 litres of Gentian Violet each day. If the prototype is enlarged at a scale of 30, it will give 1234 litres per day. To generate 60,000 litres per day a system of 49 units should be used. a single unit consisting of one prototype uses 5.4 KWh. Each year this will lead to power consumption of 2.9 GWh. The enlargement of the prototype can be done by using a magnetic steerer.

Figure (22): Benban Solar Park

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