DYE Disassembler: How to make the water that is used to color the cloths with fabric dye reusable without treatment power plants.

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Abstract- Water is one of the essentials needed to live on Earth. From animals to plants, all living things depend on water to continue life. Unfortunately, water now faces many threats and crises that will affect its supply in the future. One of these most prominent challenges facing Egypt is a water shortage, a significant problem. However, every issue has a solution regardless of its difficulty, and there are different ways to solve this problem. One of the most effective and least expensive methods is "water reuse", which relies on changing the process itself or its main components so that the resulting water becomes reusable without any treatment. We have chosen to apply this idea to the textile industry's dyeing process because it produces large amounts of wastewater. In Almost dye factories, NaOH, a strong base, is used after finishing the dying process, cleaning the container from the dye, and then discharge the colored wastewater, which causes many environmental disasters. So, we decided to replace NaOH with NaOCL, which cleans the container and removes the color of the dye from the water faster. This obviously will decrease the pH of the water compared to NaOH, and that's why we choose pH as a design requirement. After we tested our prototype, we found that the produced water contains HOCL, which has beneficial uses like killing most viruses. Subsequently, our idea succeeds in performing the "water reuse" as the produced water is reusable.

Keywords: Dying Process, Fabric Dye, Sodium Hydroxide, Sodium Hypochlorite.

I. Introduction

Egypt faces many problems in various aspects. These problems are called "Egypt's 11 grand challenges," and unfortunately, these problems are devastating. We were supposed to solve two of these problems, Water pollution and lack of clean water supplies. Egypt has been suffering from pollution for hundreds of years as many of the factories' beneficial substances contain pollutants that are often discharged into clean water. As a result, clean water sources have been polluted. Several solutions have been shown to solve this serious problem. One of these solutions is the application of reverse osmosis in which water passes through it and particles such as salt ions, bacteria, and others are excreted. However, this solution was not very useful because the water contains many ions and other contaminants that are very small and can pass through the semi-permeable membrane's pores. Therefore, we decided to solve the problem differently and effectively. First, we decided to work on the textile industry's dying process as it produces large quantities of wastewater that is discharged into the sewage and causes many environmental disasters. This wastewater is so disastrous that after the dying process, they put NaOH to clean the container from the dye. This process increases the pH of water, as sodium hydroxide is a strong base, reaching about 12 and aquatic organisms live in the pH range from 6.5 to 9. A white precipitate also forms in the water, affecting the respiratory system of organisms. We decided to replace NaOH with NaOCl as we discovered that it was the best chemical to use. It can clean the container efficiently and remove the dye's color in just 12 hours. The resulting water contains hypochlorous acid with a pH of 6.3, which can be used as a hand sanitizer. The hydrochloric acid can kill germs and bacteria in just 5 minutes, including SARS-cov2 that causes the covid-19 virus. Besides, there will be a white residue in water, sodium hydroxide, which can be used in various industries such as soap making or glass making. Therefore, by using NaClO instead of NaOH, we lowered the process's cost because NaOCl is cheaper than NaOH and lowered the pH. Finally, we saved time as we reduced the process cycle from 24 hours to 12 hours.

II. Literature Review and Hypothesis

Obviously, Egypt faces many problems regards to water. Water shortage, for instance, is one of the most critical problems facing Egypt. The main reason behind this problem is that Egyptians use large amounts of water in their homes, factories, and agriculture. Undoubtedly, all this usage results in water that is unusable for other purposes. In other words, there is a large amount of produced wastewater that leads to water shortage. If we take the textile factories as an example, we will see that the dyeing process makes a large amount of sewage. Unfortunately, this is not the only problem; this produced wastewater discharge into the water bodies, which certainly increases water pollution. Subsequently, there must be solutions to this problem, water pollution. There are indeed many different solutions that exist, such as water reduction, recycle, and reuse. All of them are ways to deal with this problem. So, what is the difference between them? And what is the best one?

Firstly, water reduction. Instead of using a large amount of water in a specific process, which leads to also a large amount of wastewater, this way focusing on reducing the amount of needed water to reduce the wastewater. We can do so by modifying the process to reduce the amount of water we need to accomplish the same task, whether preparing food, raising crops, running a business office building, or an industrial process. For example, in agriculture, we can use an efficient way of irrigation that uses less water than the traditional way and does the same function. The problem with water reduction is that it is not efficient in all processes because there are processes that required a specific amount of water that cannot be reduced or replaced.

The second way is water recycle. We can recycle the water that is output from a specific process by treating the water byproducts of these processes by removing contaminants to re-enter local water systems for use in homes and businesses. Water recycle requires many treatment processes to be conducted. There may be unit operations, and methods are combined to provide primary, secondary, and tertiary treatment. They include different steps like Coagulation and Flocculation, Filtration, sedimentation, disinfection, and many other vital steps. Each of them responsible for dealing with a specific type of contaminants. Subsequently, all these steps could convert the wastewater into good quality water that can be used for a different purpose; that is why water recycle is very efficient. However, it obviously has disadvantages, specifically in the economic aspect, as it requires significant financial assistance to apply the treatment processes or construct the necessary applications for these processes.

The third way that is related to but different from recycling and reducing is water reuse. Recycling and water reuse may be confusing a little bit, so here is the difference between them. Recycling is about treating the wastewater after it is indeed produced as a byproduct from a specific process. While reuse is about changing processes resulting in polluted water, the resulting water is reusable directly without any treatment. In other words, we can define water reuse as the way of studying the process to know the reason that makes the water polluted and try to solve it directly. We can apply this way by changing a specific raw material that is the leading cause of pollution, modifying a piece of existing equipment used in the primary process, or creating an improvement in the process itself. For instance, we might change a chemical reaction that results in the same product but reduces the number of chemical products that pollute a water byproduct.

Hypothesis

The textile industry has been producing massive amounts of pollutant water. After they finish weaving the fabric in the weaving factory, they take all these fabrics into big containers to dye. These containers consist of base solution, water, and the color required for dyeing. After the dyeing process finishes, they take the clothes out of the container, and the container is left with colored wastewater, and the container becomes contaminated. So, to clean the container, they use sodium hydroxide (NaOH) in 24 hours. Finally, they discharge the colored wastewater with a pH of 8-12 and a white precipitate (NaOH) that causes environmental disasters.

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This discharged solution causes many environmental disturbances as the white precipitate causes many chest disorders such as asthma and lung failures. Also, the high pH of the discharged solution can disturb the aquatic life as the marine organisms live at a pH between 6.5-8; since sodium hydroxide is a strong base, aquatic organisms cannot survive.

Finding the chemical that substitutes sodium hydroxide and gives the same the efficiency of cleaning the container and decolorizes the fabric dye was a bit tough. We have made many test plans to find out this chemical. In our first test plan, we used algae formed in the sewage to decolorize the dyed wastewater. Unfortunately, it did not do its primary function, which is cleaning the container. Therefore, we worked on figuring out another solution, and we came up with replacing NaOH with H_2O_2. This solution worked well theoretically, but when we tried to test it, it cleaned the container in 36 hours and did not decolorize the wastewater completely. However, we succeeded in our third test plan as we replaced sodium hydroxide (NaOH) with sodium hypochlorite (NaOCl).

We used NaOCl as it decolorizes the dyed wastewater completely and cleans the container in just 12 hours instead of 24 as the NaOH method or 36 hours of algae method. We produced reusable water as the resulted water contains HClO and a pH of 6.3, according to the equation: “$NaClO + H_2o \longrightarrow HClO + NaOH\downarrow$.” and this solution could be used as a hand sanitizer as the HClO kill all the germs, including SARS Cov-2, which causes Covid-19 in just 5 minutes. The NaOH white precipitate could also be used in many industrial fields such as the soup industry or glass industry.

III. Materials & Methods

We have constructed a similar prototype to the container in which the dying process is done. We tried to make our prototype independent without anything annual as we applied a 12volt DC to the prototype using an adaptor. Figure 1 shows the materials that we have used.

Figure 1

In the beginning, we made a glass container in the form of a cuboid with dimensions of 50 cm high, 30 cm long, and 30 cm wide. Also, we made two 20 cm plastic pipes and put into them two solenoid valves, in which we stacked plastic bottles that were cut from the bottom. The solenoid valve's function is that it only passes the liquid through it when it takes 12 volts DC. Then we made three holes in the container: two in the top of the container to stick the two pipes and one in the bottom of the container to attach the faucet to it as it acts as a drain for water. Finally, we brought sodium hypochlorite from a chemical shop to use in both cleaning the container and decolorizing the fabric dye used instead of NaOH.

TEST PLAN:

In agreement with the textile factory, we brought in some Fabric Dye to conduct our test plan. We put the Fabric dye and NaOCl in the other bottle in one bottle. Then we applied 12 volts from the adaptor to one of the two solenoid valves to pass 100ml fabric dye into the container. Then we used another 12 volts to the other solenoid valve to give about 300 mL NaOCl. After about 12 hours, the container was cleaned, and the fabric dye was removed entirely. The resulting water contains hypochlorous acid plus sodium hydroxide as a white residue. Finally, we turned on the tap to pass the water into a plastic bottle.

IV. Results

Finding the chemical that substitutes sodium hydroxide and gives the same efficiency of cleaning the container and also decolorizes the fabric dye was very hard. We have made many test plans to find out this chemical. We made 2 test plans one, we used a type of algae formed in the sewage to adsorb the color, and the other, we used hydrogen peroxide instead of sodium hydroxide.

The negative results of these two test plans:

1) The algae didn’t clean the container at all.
2) Hydrogen peroxide cleaned the container in about 36 hours.
3) Both of them decolorize the dye, but in a small percentage.

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However, we learned a lot from these two test plans until we finally succeed in our third test plan as we used sodium hypochlorite (NaOCl) instead of Sodium Hydroxide (NaOH).

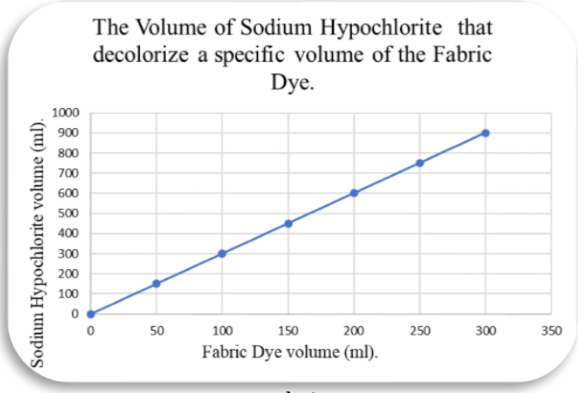
The positive results of these two test plans:
1) We got the idea to use solenoid valves to make our prototype use electricity as in the idea of algae, it needed to be stirred well to adsorb the fabric dye color, so we decided to use a water pump that uses electricity. After this idea failed, we decided not to abandon the idea of using electricity in our prototype.
2) To take into account the time taken for the chemical to decolorize the fabric dye and clean the container.

As we learned from our mistakes, we finally succeed in our final test plan as:
1) We succeed in decolorizing the fabric dye producing water that contains HClO with pH 6.3 that could be used as a hand sanitizer as it could kill all the viruses and germs in only 5min. Including SARS Cov-2 which causes Covid-19.
2) We didn't make any kind of treatment in the process.
3) The TDS of the water increased as it was about 36096ppm and in the water that we produced was about 41984ppm.
4) We decreased the time taken of one cycle from 24 hours to only 12 hours as shown in Graph 2.

Table 1

Fabric Dye (ml.)	50	100	150
NaClO (ml.)	150	300	450

Therefore, we conclude from graph 1 that the Ratio between the NaClO and fabric dye is 3:1 as "*150/50 = 300/100 = 450/150 = 3*". Graph 3 shows the trails we have made to make sure from this ratio.



graph 1

V. Decolorizing of water Steps

The colored water that is contained the fabric dye has been decolorized in approximately 12 hours which is half the actual time in the real industry which is 24 hours. The table below shows the how the color of the water has been decolorized using NaClO.

Table 2 The time and the color throughout 12 hours after adding the NaClO on the Fabric dye.

Time	**Color**	**Photo**
0 Hours	Dark Purple	
2 hours	Pink	

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4 hours	Light pink	
6 hours	Yellow	
8 hours	off-white	
10 hours	White	
12 hours	Clear water	

VI. Analysis

Finding a chemical to replace sodium hydroxide in the dying process wasn't easy, but the results of solving such a problem were worth a try. The results of the idea were perfect. However, there are some stuffs we need to take care of in order not to get other bad results.

Positive results:

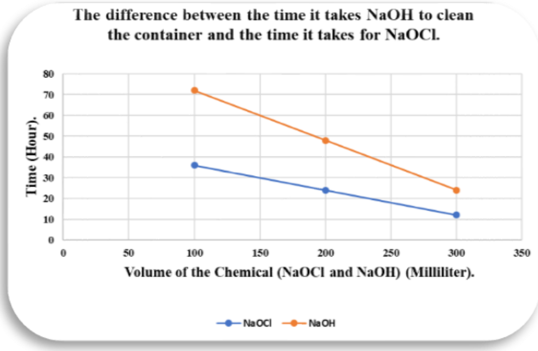
1) We produced reusable water as the resulted water contain HOCl, according to Equation *"*$NaClO + H_2o \longrightarrow HClO + NaOH\downarrow$*"*, and this water could be used as hand sanitizer to kill germs and bacteria.

2) We also produced with water NaOH that could be used in industrial fields such as soap industry or glass industry.

3) We reduced the time taken of one cycle of dying process from 24 hours to 12 hours only as shown in Graph 2.

4) We decreased the cost of this process as NaClO is cheaper than NaOH.

5) We didn't make any kind of treatment to water to make it reusable.



graph 2

Negative result:

The color of the water may become yellow If we increased the amount of NaClO poured. However, this problem has been solved as we calculated a ratio between the amount of NaClO could decolorize the fabric dye and the ratio is for every 1ml of the fabric dye, it needs 3ml of NaClO to decolorize it. Graph 3 shows 3 trails we have done to calculate this ratio.

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TEST PLAN:

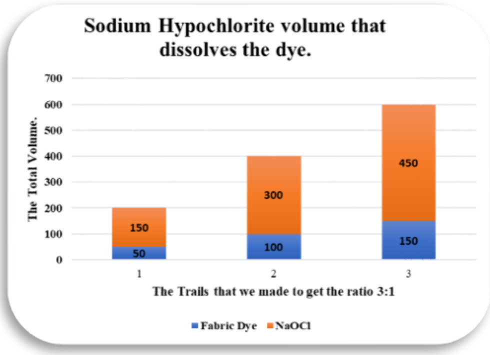
We have tested our prototype from different aspects to make sure that our prototype is efficient and achieve the design requirements.

Test Project:

Before we started building our prototype, we designed a virtual prototype, as shown in Figure 2 to make it easier for us to identify the materials we would need. After building it, we tested our prototype to make sure it was testable and that it would produce the required water and fortunately our prototype succeeded in producing reusable water without any kind of treatment.

Test Cost:

We were so careful about the cost as we tried to achieve the biggest result at the lowest cost. We were recording anything we bought. We spent about 450 pounds on our prototype; however, we decreased the cost of the process itself as NaOH cost is 100L.E while NaOCL is 17L.E.



graph 3

Test Result:

After finishing constructing our porotype, we tested it and waited for 12 hours until decolorization done. Then we measured the pH of the water which is 6.3 and compared it with the real discharged water that has a pH of 12. Also, we measured the TDS using the electric conductivity method and then we multiplied the resulting number by 0.64 to find the TDS in ppm unit. The TDS increased compared to the real discharged water as it is 41984ppm while the real discharged water is 36096ppm.

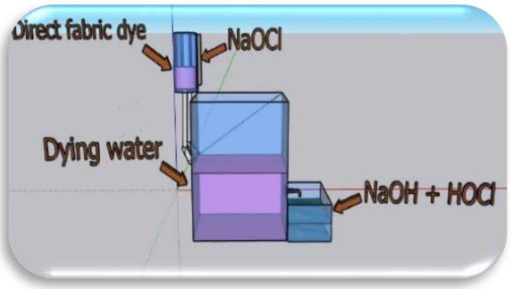


Figure 2

VII. Important learning transfers and scientific laws

In any project, there are some scientific basis that your ides have to be constructed on them. Table 3 shows the learning outcomes that we have used in order to success in our idea.

Table 3

Concept	Subject	Connection
Polynomial function.	Math.	The relation between Volume of NaClO and Fabric dye could be determined by the equation "$Y = mX$, where m = 0.34" to calculate the amount of NaClO needed to calculate a specific amount of Fabric dye.
Direct Current.	Physics.	The valves need 12 volts DC Current to pass the liquid.
Magnetic Field due to a Solenoid.	Physics.	We used a solenoid valve that use this mechanism to pass the fabric dye or the NaOCl when we give it 12-volt DC.
TDS.	Chemistry.	This is the water parameter that we have measured with pH.
Electric conductivity.	Chemistry.	We used this method to measure the TDS as we got the result in EC unit then multiplied it by 0.64 to convert it to ppm.
pH.	Chemistry.	This is the main design requirement that we have measured before and after making our solution.

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pH meter.	Chemistry.	We used this method to measure the pH of the water we have produced.
pH Scale.	Chemistry.	We use the pH scale in order to know the basicity and acidity of water.
Aqueous solution.	Chemistry.	In our chemical equation, NaOCl reacts with H2o, producing HClO and NaOH in aqueous form.
Double displacement Reaction.	Chemistry.	This is the reaction that our idea depends on.
Water Supplies.	Geology.	This concept provided us with the information that we have needed to know the type of water supply was affected before conducting our solution.

VIII. Conclusion

After we got our results, we concluded that we could remove the color of fabric dyes with sodium hypochlorite in just 12 hours; Instead of using sodium hydroxide that removes the color of fabric dye in 24 hours. The resulting water, which has a pH of 6.3 and TDS of 41984ppm, can be used as a hand sanitizer since this water contains hypochlorous acid, HCLO, that could kill germs in 5min. Without any effect on the skin. Also, the white residue, NaOH, could be used in industrial fields such as the soap industry or glass industry.

IX. Recommendation

Despite all the limitations we faced, our prototype succeeded in reaching our goal of reusing wastewater discharged from the dye factory. We encountered some limitations that unfortunately we could not overcome such problems, so we recommend you to:

1) Make a device with Arduino that can calculate the volume of dye and according to the ratio of the equation calculated, 3:1, this device pours the required amount of Sodium Hypochlorite.
2) Find out if sodium hypochlorite will decolorize other types of dye rather than Fabric dye. For example, Reactive dyes.
3) Find a more efficient way to extract the NaOH from the water.

X. Acknowledgment

This project consumed a lot of effort, attempts, and research. Implementation would not have been possible if we did not have the support of many individuals and organizations. Therefore, we would like to extend our gratitude to all of them. After Allah, we are thankful to Mrs. Shimaa Sophy, Dr. Dalia Fawzy as well as Chemistry Doctors at the Research Center El-Dokki. As all of them have helped us a lot.

XI. Literature Cited

1) Block, M. S., & Rowan, B. G. (2020). Hypochlorous Acid: A Review. *Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons*, *78*(9), 1461–1466. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7315945/.

2) Centers for Disease Control and Prevention, National Center for Emerging and Zoonotic Infectious Diseases (NCEZID), Division of Foodborne, Waterborne, and Environmental Diseases (DFWED). (2015, January 15). Water Treatment. https://www.cdc.gov/healthywater/drinking/public/water_treatment.html

3) Gómez, N., Sierra, M. V., Cortelezzi, A., & Capítulo, A. R. (2008). Effects of discharges from the textile industry on the biotic integrity of benthic assemblages. *Ecotoxicology and environmental safety*, *69*(3), 472–479 https://pubmed.ncbi.nlm.nih.gov/17490744/.

4) Gupta, V., K., Ali, I., Saleh, T., A., Nayak, A. & Agarwai, S. (2012, April 4). Chemical treatment technologies for waste-water recycling—an overview. *RSC Advances.* (16). 6380-6388. https://pubs.rsc.org/en/content/articlelanding/2012/RA/c2ra20340e#!divAbstract

http://dx.doi.org/10.31364/SCIRJ/v9.i04.2021.P0421854

5) Khattab, T. A., Abdelrahman, M. S., & Rehan, M. (2020). Textile dyeing industry: environmental impacts and remediation. *Environmental science and pollution research international*, *27*(4), 3803–3818. https://pubmed.ncbi.nlm.nih.gov/31838699/.

6) National Center for Biotechnology Information. "PubChem Compound Summary for CID 14798, Sodium hydroxide" *PubChem* https://pubchem.ncbi.nlm.nih.gov/compound/Sodium-hydroxide.

7) National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 23665760, Sodium hypochlorite https://pubchem.ncbi.nlm.nih.gov/compound/Sodium-hypochlorite.

8) Pettit, M. (2018, March). Save Water: Reduce Your Water Footprint. *RESET*. https://en.reset.org/act/save-water-reduce-your-water-footprint.

http://dx.doi.org/10.31364/SCIRJ/v9.i04.2021.P0421854