Study the Changes in (pH, Turbidity, Hardness, and Total Organic Carbon) Levels of Water using Plant Membrane (Palm Leaves Powder) and Aquatic Plant System (Vine Stems)

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***Abstract*– Due to the increasing industrialization and urbanization, the requirement of clean water has been growing quite fast and it has the potential to keep increasing. There are many regions facing water crisis even some countries with a rich water source. In this study, three types of water (tap, ground, and light sewage) have been collected from different places in Ibrahim Ahmad site in Sulaymaniyah city/Kurdistan region – Iraq. The research studies the effects of plant membrane method, and aquatic plant system on the improvement of pH, turbidity, hardness, and total organic carbon (TOC) of water samples. In the plant membrane, palm leaves were crushed and used as a powder in filter bags; whereas in the aquatic plant system, vine stems were used by growing up the vines. The experimental results showed that the pH, hardness, turbidity, and TOC of water samples after using palm leaves powder and vine stems have been changed significantly with slight variation in some test results. The results of turbidity showed that using palm leaves powder as plant membrane was more effective than the vine stems in an aquatic plant system. On the other hand, the results of hardness and TOC tests of all water samples after using both methods proved that the vine stems method was more reliable than the palm leaves method. Finally, the pH results of all water samples after using both methods have been decreased to the normal range with a slight variation between the vine stems and palm leaves methods.**

***Index Terms*—Ground water, Light sewage water, Palm leaves, Tap water, Vine stems, Water improvement.**

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I. Introduction

The global demand for clean water increases rapidly (Adewumi et al., 2010; Bixio et al., 2006), the major environmental concerns made and membrane filtration technology are chosen by the industry to reuse their wastewater and reduce their wastewater footprint on the environment. The membrane filtration will help increase plant efficiency by choosing the specific membrane system for the chosen wastewater, while reducing operating costs, and complying with increasingly stringent discharge regulations.

The term "wastewater" can be defined as the end-product or by-product liquids from municipal, industrial, and agricultural activities (Timothy, 2004: Tchobanoglous, 2003; Galan and Grossmann, 1998). In other words, liquid waste or wastewater is the water supply to the society after it has been used in several (Tchobanoglous, 2003). Fig. 1 demonstrates the general sources of wastewater in society.

II. Problems with Wastewater

There are several problems associated with discharging of wastewater into a water body (Kurniawan, et al., 2006). Foul gases are one of the main serious public concerns. Foul gases are generated as a result of decomposition of the organic matter of untreated wastewater when it is accumulated. Furthermore, untreated wastewater can affect human health through various kinds of harmful pathogenic microorganisms that can be found in the wastewater (Kalra, et al., 2011; Liberatore, et al., 2012; Wang et al., 2011). These microorganisms have the ability to live in the human intestinal tract. In addition, untreated wastewater is found to contain harmful compounds, such as toxic, mutagenic, or carcinogenic compounds; as well as a nutrient (Tchounwou, et al., 2012). The latter compounds can increase the growing rate of the aquatic plants. Therefore, to protect the environment and human from the diverse effects of

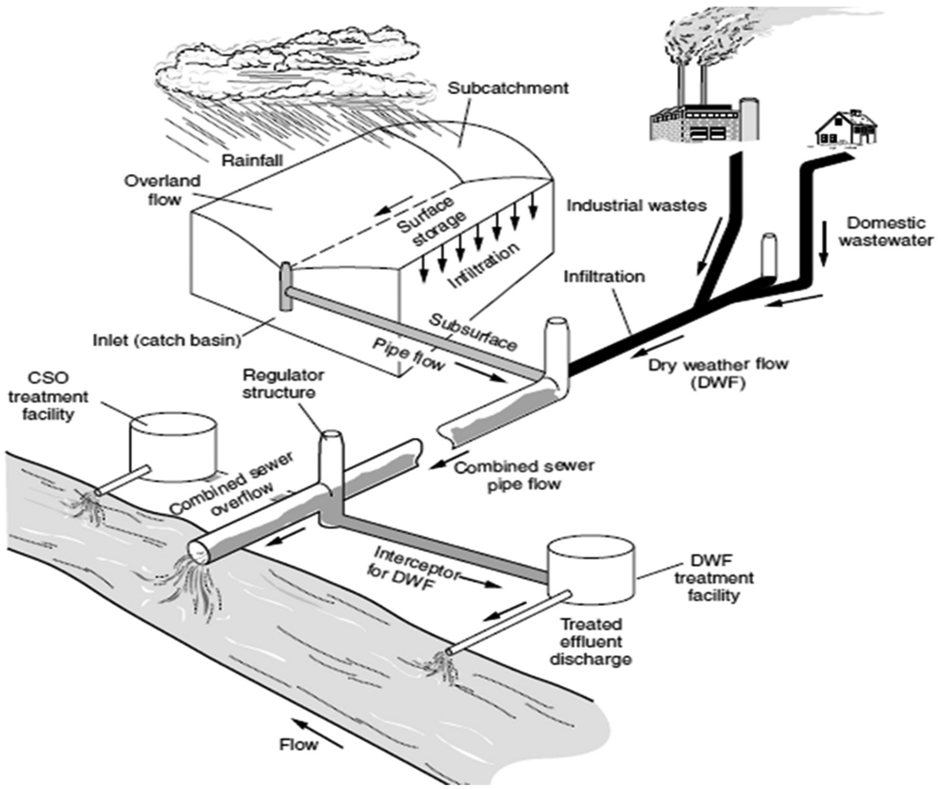

Fig. 1. A diagram of wastewater infrastructure (Timothy, 2004).

wastewater immediate and serious measures must be taken (Tchobanoglous et al., 2003; Salgot, et al., 2006).).

III. Wastewater Composition

Compositions of the most wastewater (both municipal and industrial) can be divided into three main categories according to its content: Physical, chemical, and biological characteristics. According to Muttamara (1996), actual quantities of chemical, physical, and biological characteristics present in wastewater refers to its compositions.

A. Physical Characteristics

The major physical characteristics of wastewater are solids (such as: Suspended and settled solids), color, odor, and temperature. Table I summarizes the main physical characteristics of wastewater and its sources.

B. Chemical Characteristics

The chemical compositions of wastewater can be divided into three groups: Organic compounds, inorganic compounds, and gases. Table II shows the sources of chemical composition found in wastewater and its sources.

C. Biological Characteristics

The biological constituents in the domestic and industrial wastewater (light and heavy wastewater) can be: Viruses, bacteria, plants, and animals (Dobson and Burgess, 2007). Table III summarizes all the biological constituents that can be found in the domestic and industrial wastewater with its possible sources.

TABLE I
Physical Characterizes of Wastewater (Metcalf and Eddy, 2003).

Physical properties	Source
Color	Domestic and industrial wastes, natural decay of organic materials
Odor	Decomposing wastewater, industrial wastes
Temperature	Domestic and industrial wastes
Solid	Domestic water supply, domestic and industrial wastes, soil erosion, inflow/infiltration

IV. Membrane Technology

Membrane technology can be defined as a physical treatment process in which the membrane is acting as a filter used for separating solid particles from water or wastewater (Pinnekamp and Friedrich, 2006: Pokhrel and Viraraghavan, 2004). This method cannot change the thermal, chemical, and biological properties of the separated materials (filtered liquid). The membrane technology can be used along with other purification and treatment methods such as biological treatment process. Globally, membrane technology application is becoming more and more broad. This technology was used for the first time in the field of water purification in the desalination of the brackish and sea in the arid zones, where its used for a long time in separating the valuable materials from small water volumes (e.g., in chemical and pharmaceutical industry, in biotechnology, and in food industry) (Pinnekamp and Friedrich, 2006).

TABLE II
Chemical Compositions of Wastewater (Metcalf and Eddy, 2003).

Chemical compounds	Source
Organic constituents	
Fats, oil, and grease	Domestic, commercial, and industrial wastes
Pesticides	Agriculture wastes
Carbohydrates	Domestic, commercial, and industrial wastes
Proteins	Domestic, commercial, and industrial wastes
Phenols	Industrial wastes
Priority pollutants	Domestic, commercial, and industrial wastes
Surfactants	Domestic, commercial, and industrial wastes
Others	Natural decay of organic materials
Inorganic constituents	
Chlorides	Domestic wastes, domestic water supply, and groundwater infiltration
Alkalinity	Domestic water supply, domestic wastes, and groundwater infiltration
Nitrogen	Domestic and agriculture
Heavy metals	Industrial wastes
pH	Commercial, domestic, and industrial wastes
Phosphorus	Natural runoff, domestic, commercial, and industrial wastes
Priority pollutants	Industrial, commercial, and domestic wastes
Sulfur	Domestic, commercial, and industrial wastes
Gases industrial waste	
Methane	Decomposition of domestic wastes
Hydrogen sulfide	Decomposition of domestic wastes
Oxygen	Surface water infiltration

TABLE III
Biological Compounds in Wastewater (Metcalf and Eddy, 2003).

Biological constituents	Sources
Plants and animals	Treatment plants and open watercourse
Viruses	Domestic wastes
Bacteria	Surface water infiltration, treatment plants, and domestic wastes

In fact, the operating principle of a membrane can be described in the wider sense like that of a filter. During the filtration, a substance mixture (feed of raw solution of water) is separated by the membrane. Permeate or filtrate is called on the part that passes through the membrane. The permeate represents the treated phase in the wastewater purification. The part of the wastewater that retained by the membrane is called brine or concentrate. Figure 2 illustrates the operational principles of membrane technology. The membrane technology is used in municipal and industrial wastewater treatment to satisfy the following; retention (e.g., solid matter including biomass and dissolved matter by reverse osmosis), purification (e.g., industrial water treatment and disinfection by retention of bacteria), concentration (e.g., recycling valuable substance), and finally fractionation (e.g., separation into two or more compounds) (Pinnekamp and Friedrich, 2006).

V. Aquatic Plant System

Aquatic plant system can be used for wastewater recovery and recycling by stabilizing the waste and removing the nutrient. The principal removal mechanisms of such a system are relaying on physical sedimentation and bacterial metabolic activity as in the conventional activated sludge and trickling filter (U.S. Environmental Protection Agency, 1991). In fact, plant assimilation of nutrients and its subsequent harvesting is another mechanisms for pollutant removal. The advantages of this system are low cost and easy maintenance compared to other treatment methods that, in turn, make it attractive to use. Recently, constructed ponds with aquatic plants are being applied widely as an effective way of treating municipal wastewater (Kanabkaew, and Puetpaiboon, 2004).

Pond with floating aquatic plants has been used for treating wastewater and/or improving water quality. For instance, the plant of the water chestnuts, water lettuce, heartleaf, hydrilla, duckweed and liverwort families, water hyacinths, and azollas have proven effective for water treatment. The duckweed family of plants provides for a biomass producing system wherein unwanted nutrients are harvested from aquatic systems by means of bioaccumulation to treat wastewater and/or improve water quality, and the plants are harvested as a cash crop (Ngo et al., 1993).

VI. Materials and Methods

The method used in this study was a simple direct way for water improvement by plant membrane and aquatic plant system. In this study, the samples were collected from three different places; homes (tap water), wells (groundwater), and drainages (light sewage water). The collected samples have been used to investigate the effects of two types of plants on improving the (pH, turbidity, hardness, and TOC) of water.

A. Experiments

In this study, all samples have been collected from Ibrahim Ahmad site in Sulaymaniyah city/Kurdistan region – Iraq. The following tests, turbidity, pH, hardness, and TOC, have been performed on the samples before and after applying the two methods. Usually, it takes up to 4 months to get good results, but generally, after 2 months of treatment process changes have been achieved.

Turbidity

Turbidity is the cloudiness or haziness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye, similar to smoke in the air (EPA, 2018). The measurement of turbidity is a key test of water quality. TN100 turbidimeter device was used in this study to measure the turbidity of the wastewater samples before and after treatment. This device uses an infrared light-emitting diode light source and delivers unprecedented laboratory repeatability and accuracy with a resolution of 0.01 nephelometric turbidity units (NTU) across an extended range of up to 20 NTU.

pH

pH is a measure of how acidic/basic water is. The range goes from 0 to 14, with seven being neutral. pH of <7 indicates acidity, whereas a pH of >7 indicates a base. pH is a measure of the relative amount of free hydrogen and hydroxyl ions in the water. The pH meter is a scientific instrument that measures the hydrogen ion concentration (or

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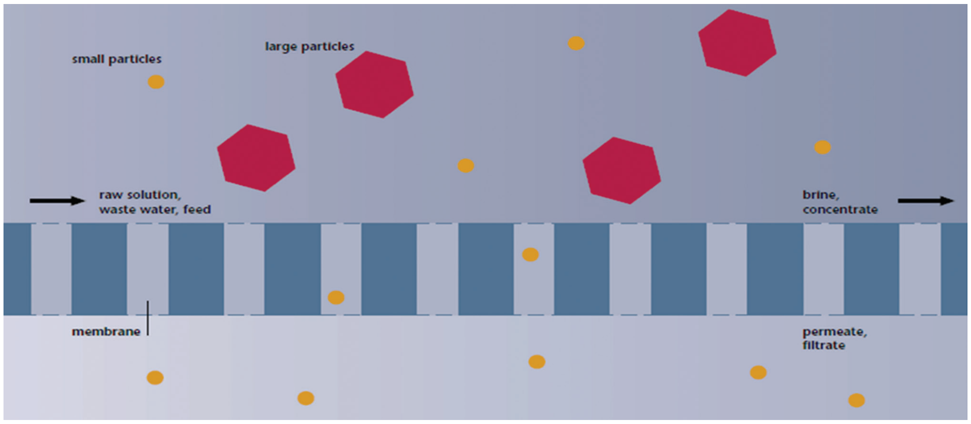

Fig. 2. Operation principle of the membrane (Pinnekamp and Friedrich, 2006).

pH) in a solution, indicating its acidity or alkalinity. The pH meter measures the difference in electrical potential between a pH electrode and a reference electrode. In this study, A Mettler Toledo pH meter was used to measure the pH of the wastewater samples before and after treatment.

Hardness

Hard water is water that has high mineral content (as opposed to "soft water"). Calcium is the most common mineral associated with water hardness. In general, hardness is not a health hazard; however, it can pose serious problems in industrial settings, where water hardness is monitored to avoid costly breakdowns in boilers, cooling towers, and other equipment. In domestic settings, hard water is often indicated by a lack of suds formation when soap is agitated in water, and by the formation of limescale in kettles and water heaters. In this study, ethylenediaminetetraacetic acid titration method was used to measure the permanent hardness of water samples before and after using membrane and aquatic plant system methods.

Total organic carbon (TOC)

An organic compound is any member of a large class of gaseous, liquid, or solid chemical compounds whose molecules contain carbon atoms. In this study, the TOC in the wastewater samples was measured by TOC analyzer (TOC fusion) Teledyne – Tekmar: Fusion – TOC analyzer. The fusion TOC analyzer utilizes powerful ultraviolet per-sulfate oxidation allowing superior carbon liberation from even the most challenging matrixes. The fusion TOC analyzer is able to achieve unprecedented low-end sensitivity from a non-dispersive infrared detector. TOC analyzer is built on the latest technology and is designed to offer productivity for a wide variety of applications.

B. Treatment Methods

Membrane filter bag method

In this method, palm leaves have been used to treat the wastewater samples. The leaves were first transformed from large solid pieces to soft powder through grinding using electric blade powder grinder "Silver Crest." The palm powder in size of few micrometer (100–200 µm approximately) was kept in closed fabric bags to avoid leakage to the water when it used as a filter. In this method, two filter bags of grinded palm leaves were used to increase the efficiency of the process. Each bag weighted approximately 250 g, with a size of 20 cm length and 20 cm width. 5 l of each sample were used in this method separately passed through the filters. The bags were fixed in the middle of a transparent glass container (70 cm height and 22 cm width), whereas the water samples were added from the top and the clean water settled in the bottom, with a flow rate of 0.0166 mL/s approximately using stopwatch and measured cylinder. The filter bags were used mainly as a filtration step to remove any solid particles in water samples. The turbidity of water can be decreased using this method as the size of the palm leaves powder was very narrow, so the spaces available for water to move through in the bags are very small. Fig. 3 shows the palm leaves after grinding it in an open filter bag. In addition, the figure shows the lab scale glass container that was used in this method. Fig. 4 shows the schematic diagram of plant membrane system setup with the dimensions of the container and filter bags.

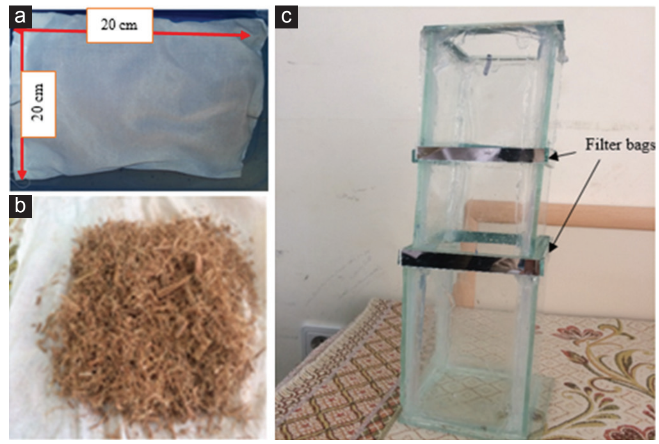

Fig. 3. *A* snapshot of membrane filter bags method: (a) Closed filter bag contain grinded palm leaves, (b) grinded palm leaves in open filter bag, (c) lab scale transparent glass container.

Vine stem method

The second treatment method was carried out using stems of vine tree by putting one head of a stem in the water horizontally. The organic pollution in the water can be removed as a result of vine growing. About 20 vine stems were fixed in a layer made of cork (30 cm length, 15 cm width, and 4 cm thick). In this method, 5 l of each water samples were added to a separate container, and the vine stems then added to the container. After 2 months, the vines started to grow, and as a result, the water started to become cleaner. After 4 months, samples from each container were taken and tested as the changes in the pH and other properties stopped to appear. As the palm leaves are growing, TOC and hardness levels in water samples will reduce as the plant will use the organic matter and salt in the water to grow. Fig. 5 shows the vines in the plastic container.

VII. Results and Discussion

The following tables demonstrate the results of treating the three types of collected water samples (sewage, ground, and tap water) using both methods (palm leaves and vine stems). In each table, the result of three tests (pH, turbidity, TOC, and hardness) was included to evaluate the effects of the treating methods.

From the test results of groundwater sample in Table IV, it can be clearly seen that the palm leaves method was remarkably reduced the turbidity of wastewater sample from 6.07 NTU to 1.8 NTU after using palm leaves, unlike of the vine stem method that just reduced the turbidity by few NTU from 6.07 NTU to 5.97 NTU. Furthermore, the results obtained showed that the palm leaves method reduced the TOC levels in the groundwater sample from 84 ppm to just 74 ppm; whereas, the vine stem method reduced it from 84 ppm to 26 ppm after the treatment.

Based on sewage sample treatment results in Table V, its clear that the TOC and hardness were reduced by roughly 50% after using vine stem, whereas the pH was slightly reduced from 8.63 to the normal range of 7.44 and 7.7 after using both methods. However, the yurbidity was considerably decreased from 8.09 NTU to 2.14 NTU after using vine stem and to 1.91 NTU after applying palm leaves.

Regarding the test results of a tap water sample that is shown in Table VI, the turbidity and pH of the sample were slightly reduced after using both methods. However, the hardness of the sample was significantly reduced from 175 mg/L to 93 mg/L after using vine stem; unlike, the palm leaves method where it was slightly decreased the hardness from 175 mg/L to 110 mg/L. According to the results obtained, the TOC of the sample was remarkably reduced from 86.16 ppm to 11.5 ppm after using the vine stem and to 75 ppm after using the palm leaves.

In the following figures, the effects of the treating methods on the property of wastewater (pH, Hardness, TOC, and turbidity) were compared and demonstrated separately.

By comparing Figs. 6 and 7, it can be clearly seen that the pH of all wastewater samples was reduced to the normal range after applying both methods. However, there is a slight variation between the vine stem and palm leaves methods' results. Although there is a variation between the two methods' results, its not quite insignificant and can be ignored.

Figs. 8 and 9 show the changes in the turbidity levels after applying both methods on all water samples. The primary results of turbidity before treatment showed that the

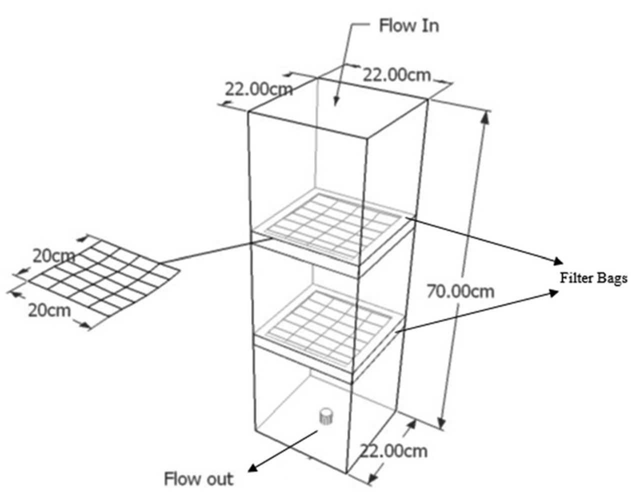

Fig. 4. Schematic diagram of plant membrane system setup.

Fig. 5. Vines in lab scale container.

TABLE IV
Test Results of Groundwater Sample (Before and After Treatment).

Test	Before treatment	After treatment	
		Vine stems method	Palm leaves method
Turbidity (NTU)	6.07	5.97	1.8
pH	8.72	7.66	7.53
Hardness (mg/L)	210	95	110
TOC (ppm)	84	26	74

TABLE V
Test Results of Light Sewage Water Sample (Before and After Treatment).

Test	Before treatment	After treatment	
		Vine stems method	Palm leaves method
Turbidity (NTU)	8.09	2.14	1.91
pH	8.63	7.44	7.7
Hardness (mg/L)	320	153	282
TOC (ppm)	87.35	37.9	65.12

TABLE VI
Test Results of Tap Water Sample (Before and After Treatment).

Test	Before treatment	After treatment	
		Vine stems method	Palm leaves method
Turbidity (NTU)	2.4	1.63	1.56
pH	8.63	7.91	7.39
Hardness (mg/L)	175	93	110
TOC (ppm)	86.16	11.5	75

higher and lower turbidity levels were measured in sewage water and tap water samples with 8.09 NTU and 2.4 NTU, respectively. This is because the tap water sample may be treated before being supplied to households. Although both treatment methods had the same effect on sewage and tap water samples, the turbidity of sewage water was considerably reduced compared to tap water sample. From the results, its obvious that the treatment for the light sewage water sample has a higher efficiency than for the tap water sample which can be due to the tap water being clean before treating.

Moreover, the results obtained from treating the groundwater sample showed that the turbidity was considerably reduced from 6.07 NTU to 1.8 NTU when palm leaves used as treatment medium, whereas the turbidity was slightly reduced from 6.07 NTU to 5.97 NTU after treating the groundwater sample with vine stems. This prove that the palm method is more efficient than vine stem for treating groundwater.

From Figs. 10 and 11, the higher levels of hardness were measured in sewage water sample, whereas the lower levels were found in tap water. According to the figures, there is variation in the results of the treatment of sewage and groundwater using vine stem and palm leaves. The vine stem method has significantly reduced the hardness of sewage water from 320 mg/L to 153 mg/L and from 210 mg/L to 95 mg/L for the groundwater. However, the palm leaves method has slightly decreased the hardness of the sewage water from 320 mg/L to 282 mg/L and 210 mg/L to 110 mg/L for the groundwater. Furthermore, both methods have decreased the hardness of tap water from 175 mg/L to 110 mg/L using palm leaves method and to 93 mg/L using vine stem method. This vaiation in results prove that vine stem method is more reliable for a reduction in the hardness of wastewater samples.

By comparing Figs. 12 and 13, the TOC levels before treatment in the three wastewater samples were measured with slightly over 80 ppm. From Figs. 12 and 13, it can be clearly seen that the TOC levels were considerably decreased after using vine stem method; whereas, the TOC levels were slightly reduced after using palm leaves method. The most significant differences between vine stem and palm leave methods results can be noticed in the tap water sample. The vine stem was remarkably reduced the TOC in tap water from 86.16 ppm to 11.5 ppm, whereas the palm leaves were slightly decreased the TOC levels from 86.16 ppm to 75 ppm in the same sample. Furthermore, the TOC levels in the groundwater have considerably decreased after treatment with vine stem in comparison to treatment with palm leaves; whereas, the TOC in groundwater was dropped from 84 ppm to 26 ppm after using vine

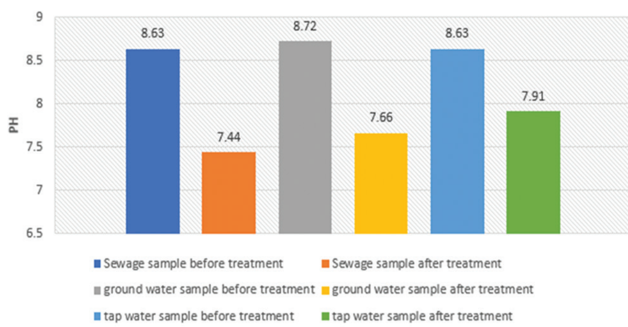

Fig. 6. Change in pH of water samples using vine method.

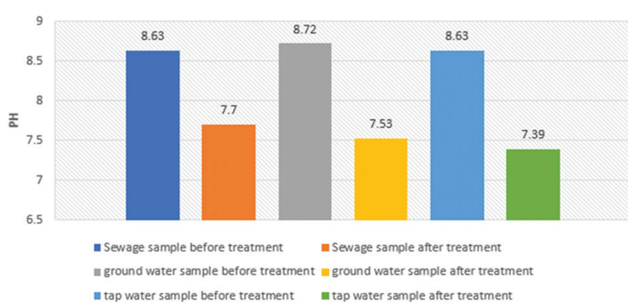

Fig. 7. Change in pH of water samples using palm leaves method.

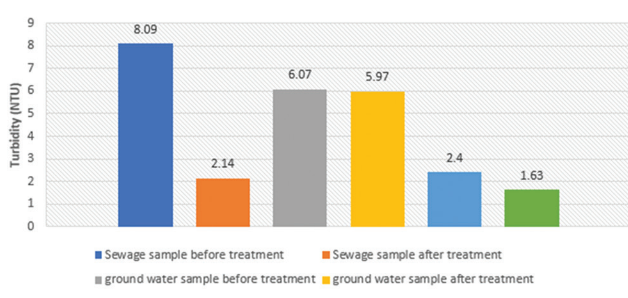

Fig. 8. Change in turbidity of water samples using vine stems method.

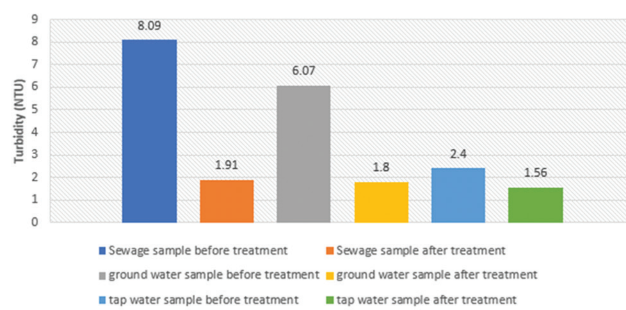

Fig. 9. Change in turbidity of water samples using palm leaves method.

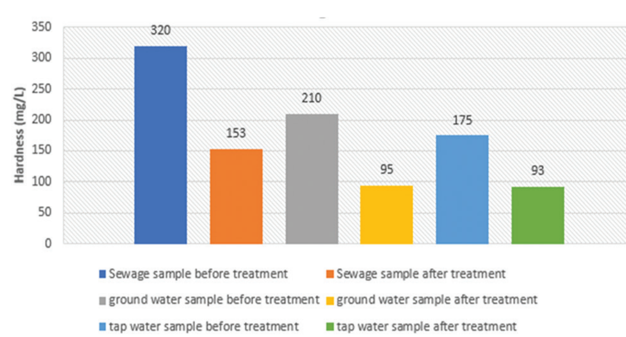

Fig. 10. Change in hardness of wastewater samples using vine stems method.

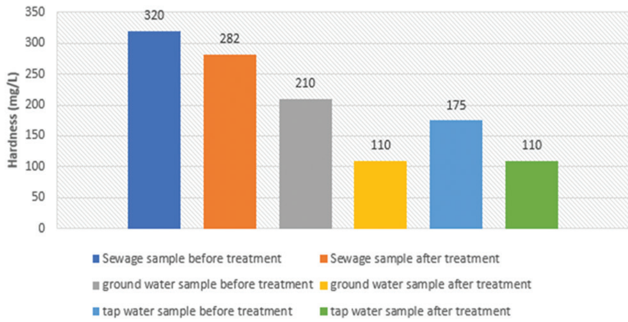

Fig. 11. Change in hardness of wastewater samples using palm leaves method.

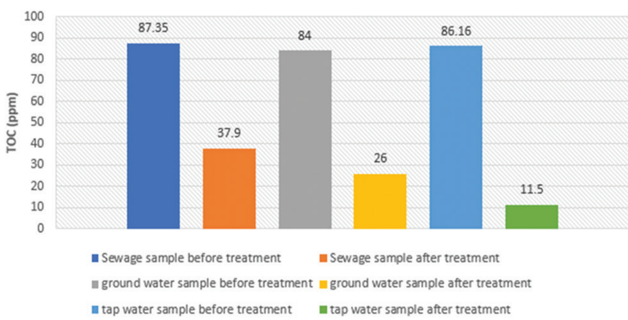

Fig. 12. Change in TOC of wastewater samples using vine stems method.

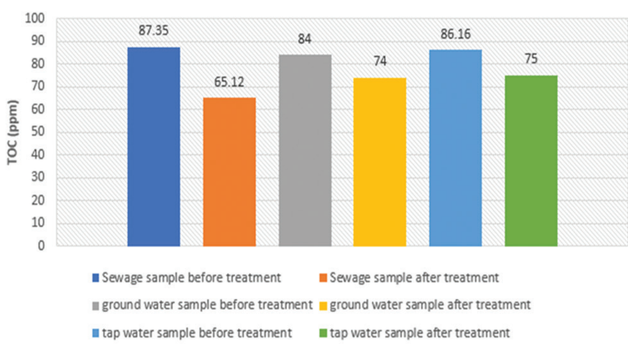

Fig. 13. Change in TOC of wastewater samples using palm leaves method.

stems method and to just 74 ppm after using palm leaves method. Although the TOC levels in sewage water were less decreased after using both methods in comparison to other water samples, the trend still shows that the vine stem method was more effective than palm leaves method. In general, the results proved that the vine stem method was more reliable, unlike the palm leaves method.

VIII. Conclusion

The research was carried out to study the effectiveness of two treatment methods on water samples' pH, turbidity, hardness, and TOC levels. Three different types of water (tap, ground, and light sewage) were used in this study. The first method (plant membrane) involved using two filter bags of palm leaves that showed a great effect on reducing water samples' turbidity. The second method (aquatic plant) includes using vine stems to improve water quality, whereas it showed a reduction in pH, hardness, and TOC levels for all samples.

Before applying the two methods, the highest and lowest levels of TOC, hardness, and turbidity are measured in sewage and tap water samples, respectively. The changes in these levels were measured after 3 days in palm leaves methods (plant membrane) and 4 months in vine stems methods (aquatic method). The results obtained showed that the pH levels were neutralized for all water samples. Furthermore, the turbidly of sewage and tap water was reduced to almost the same levels after applying both methods, except in groundwater where the membrane method was more effective than aquatic plant method. Moreover, the hardness of tap and groundwater samples was noticeably decreased to the same levels after using both methods, except in sewage water sample where the vine stem was more efficient than the other method. The TOC results of all samples after using both methods show that vine stem was very effective compared to the palm leaves method because the TOC levels results were sharply dropped after using vine stems, unlike to the palm leaves.

In general, using palm leaves powder as a membrane was a good method to reduce the turbidity of water as it includes an only physical process to separate the material mixture. However, an aquatic system using vine stem can be used as an effective way to reduce pH, hardness, and TOC levels, as the main purposes of such a system is waste stabilization and nutrient removal.

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