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Application of Ultra-Filtration Technique as a Water Purification Technology in Egypt-Case Study

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Abstract— *As known, traditional purification works for surface freshwater needs a large footprint area, on the other hand, ultrafiltration technique is a purification technique that needs a smaller area in comparison with traditional one. The objective of this study is to assess a small capacity water treatment plant that has been working in Egypt since 2019 using Ultra-filtration technique. The production capacity of the plant is 60 l/sec, and the plant is located in Genifa village, Suez Governorate, Egypt. According to the results, it can be deduced that the main advantage of ultra-filtration technique in water purification is that the filtrate water has a consistent value of turbidity (0.01 NTU) regardless the value of raw water turbidity. The Ultrafiltration is a highly recommended technology in line with the concept of green technology.*

Keywords— *Surface freshwater purification, water filtration, membrane filtration, ultra-filtration process.*

I. INTRODUCTION

In Egypt, the main potable water supply source is the River Nile science Ancient Egypt. Now adays, and due the increasing in population count, agricultural expansion, and urbanization, it was very important to use a water purification technique that produced a potable water in small footprint area.

Filtration technique is the removal of suspended solids from water by moving the water through a porous, inactive, and clean material. This porous material can be naturally made, such as sand, gravel, crashed stone, and clay, or it can be a membrane synthetically made of various materials. (1) Sometimes, large particles are settled before filtration in sedimentation basins; this process is called as a sedimentation process. The size of materials that can be removed during filtration depends upon the size of the pores of the filter media. Figure 1 below summarizes the various separation processes relative to common materials that would be filtered out through each process. (2)

The ultrafiltration removes the particles of size bigger than 0.001 micron and removes some portion of the viruses and bacteria. The ultrafiltration can't remove dissolved substances unless they are first adsorbed (with activated carbon) or coagulated (with alum or iron salts). (3)

Ultrafiltration technique has major advantage in compared to traditional one that the effluent water quality is stable and reliable (the water quality index changes little). (4) In the removal process of turbidity and particulate matter, the UF process has a higher removal rate than the conventional process, the effluent turbidity is stable below 0.1 NTU, and the removal rate of particulate matter is up to 99.9%. (5) It can effectively remove pathogenic microorganisms. The UF technology also effectively in the removing of the pathogenic microorganisms and pathogenic viruses such as Giardia, Cryptosporidium and bacteria in water (6). In fact, UF membranes can achieve values of 7 log in reduction of total coliform bacteria, 4.4–7 log removal for Cryptosporidium, 4.7–7 log removal for Giardia lambia and 6 log or higher for some viruses as MS_2 bacteriophage (7).

The main disadvantages of the ultrafiltration technique is that the dissolved matters and the odor will not be removed. (8)

UF modules are commercially available in tubular, hollow-fiber, plate and frame, and spiral wound configurations. Ultrafiltration (UF) technology is considered an efficient water treatment method. In recent years, researchers have been committed to enhancing the treatment efficiency of UF and alleviating membrane fouling. (9)

Research Significance

Small scale ultrafiltration (UF) systems have been increasingly used in rural areas for drinking water supply, but their effectiveness in guarantying microbiological water safety at household level has rarely been assessed.

Therefore, the objective of this study sis to assess a small capacity water treatment plant that has been working in Egypt since 2019 using Ultra-filtration technique. The production capacity of the plant is 60 l/sec, and the plant is located in Genifa village, Suez Governorate, Egypt.

II. MATERIALS AND METHODS

This paper will present the results of the raw water and filtered water analysis of Genifa WTP. The production capacity of the plant is 200 l/sec, with average daily production of 17000 m^3. The plant dimensions are (20 * 70 m) with footprint area of 1400 m^2. The raw water source is Ismailia Canal, this canal is a freshwater canal branched from the River Nile north of Cairo City.

The process flow line diagram of the plant is shown in figure 2 below. The raw water is screened at the inlet of intake pipe through (2 cm) strainers followed by (3 mm) mesh screen, then the raw water is collected into a raw water sump. The raw water is pumped from the raw water sump to the ultra-filtration skids. The raw water passes through automatic micro-strainer (150 microns) before filtration. The main purpose of the micro-strainer is the protection of the ultrafiltration membrane from blocking, this in return helps in increasing the operation period of ultra-filtration without the need of backwashing. The plant consists of (2) containers each of [12.19 m (L), 2.49 m (W), 2.90 m (H)], the first container consists of the micro-strainer and ultra-filtration skids, the second container consists of the electro-mechanical equipment of the ultra-filtration skids, such as, backwash pumps and air blowers souring, clean in place (CIP) pumps, and chemical solution tanks. The filtrate water is collected in the filtrate ground tank (volume 12000 m^3) after disinfected by chlorine gas, then the water is pumped to distribution network by filtrate pumps (60 l/sec @ 6 bars).

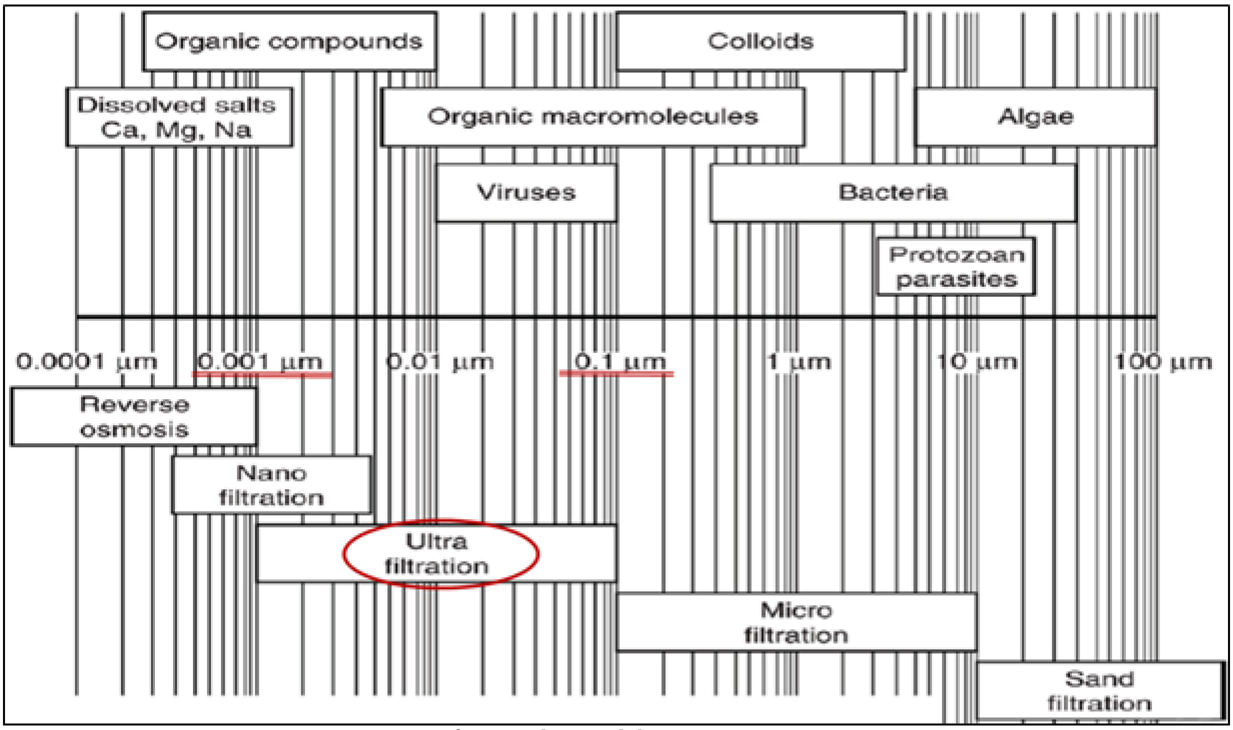

Figure 1. Size of Removed Materials by Various Separation Processes

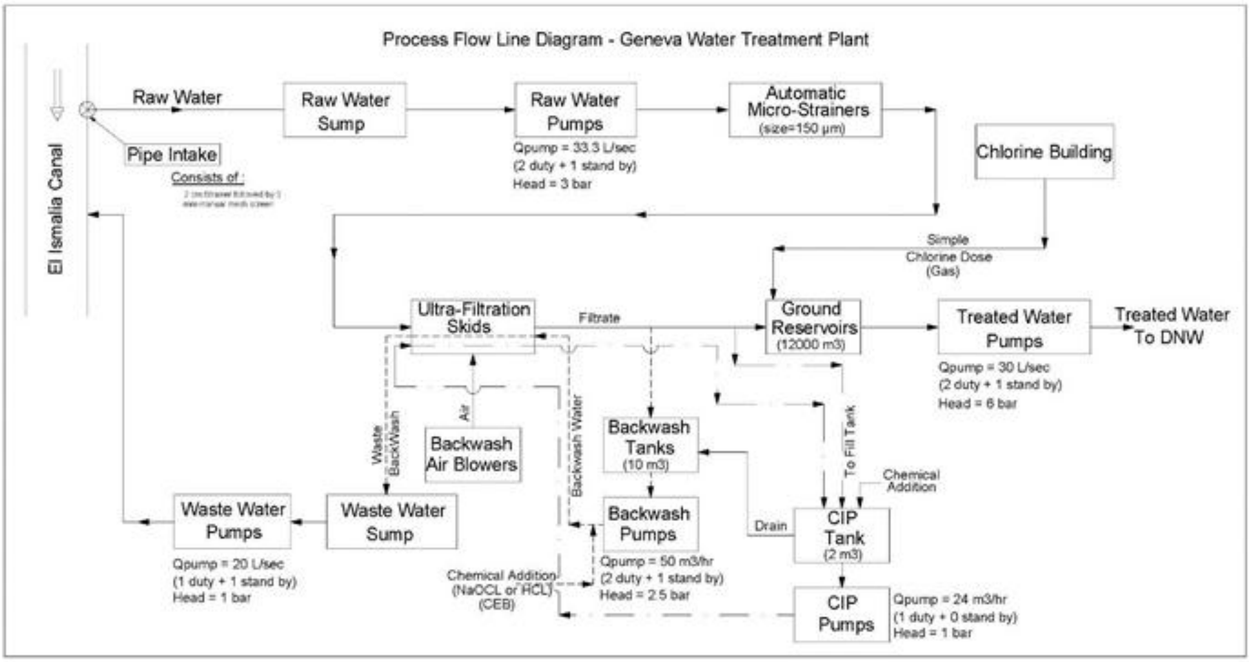

Figure 2. Process Flow Line Diagram in the Plant.

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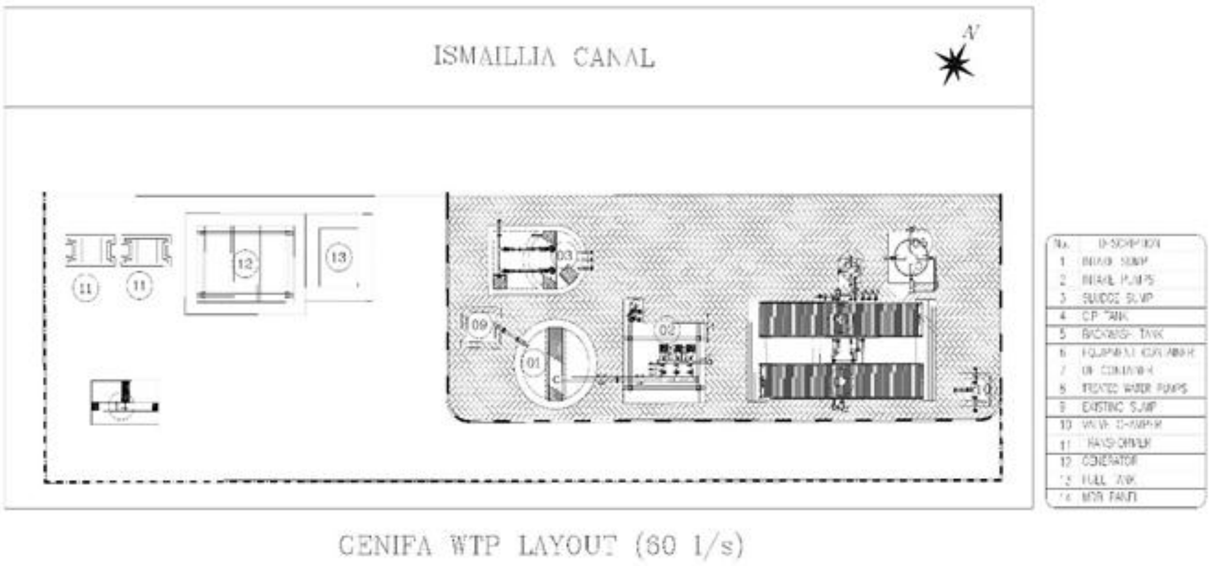

Figure 3. General Layout of the Plant.

The backwash water is collected in the wastewater sump to be pumped by wastewater pumped to Ismailia Canal downstream the location of intake conduits. Figure 3 shows the general layout of Genifa WTP.

The electro-mechanical equipment of the plant (production capacity 60 l/sec) can be summarized as follows in table 1:

Items	Number
• ultra-filtration trains	• 4 trains
• skids per train	• 1 skids/train
• modules per skid • Type of module (DOW company production)	• 16 modules/skid • InteraPac-IP-5J.XP
• Configuration of membrane	• Pressurized Hollow Fiber
• Nominal pore size of membrane • Material of membrane is PVDF	• 0.03 micron • Polyvinylidene Difluoride
• Area of module	• 51 m^2
• Flow path	• Outside to inside
• Intake/UF feed pumps	• 3 pumps (2 duty + 1 standby) • each of 33.3 l/sec @ 3 bar
• Backwash pumps	• 3 pumps (2 duty + 1 standby) • each of 50 m^3/hr @ 2.5 bar
• Backwash tank	• 10 m^3
• Clean in place (CIP) pumps	• 1 pump (1 duty + 0 standby) • each of 24 m^3/hr @ 1.0 bar
• CIP tank	• 2000 liters
• Backwash air blowers	• 1 blower (1 duty + 0 standby) • each of 200 m^3/hr @ 0.75 bar
• Air compressors	• 1 comp. (1 duty + 0 standby) • each of 254 liter/hr @ 10 bar
• Oxidizer dosing pumps	• 2 pumps (1 duty + 1 standby) • each of 125.7 l/hr
• Hydrochloric acid dosing pumps	• 2 pumps (1 duty + 1 standby) • each of 72.5 l/hr

III. Results

To evaluate the performance of the plant, many parameters were monitored, such as, raw water flow rate and turbidity, trans-membrane pressure (TMP) through ultra-filtration skids, filtrate turbidity, and waste backwash flow rate.

Figure 4 below show the raw water turbidity (NTU) were monitored versus the value of trans-membrane pressure (bar), the raw water turbidity was varied from 5.9 NTU to 12.65 NTU, and the corresponding trans-membrane pressure was varied from 1.13 to 1.35 bar. This result means that the TMP was increasing with the increase of feed water turbidity.

Figure 5 below show the raw water turbidity (NTU) were monitored versus the value of inlet raw water flow rate to ultra-filtration skids (m^3/hr), the raw water turbidity was varied from 5.9 NTU to 12.65 NTU, and the corresponding inlet flow rate varied from 230 to 217.5 m^3/hr. This result means that the inlet flow rate decreases with the increase of feed water turbidity.

Figure (6) below show the raw water turbidity (NTU) were monitored versus the value of % wash water and filtrate turbidity (NTU), the raw water turbidity was varied from 5.9 NTU to 12.65 NTU, and the corresponding % wash water was varied from 7.43 to 7.85 %, with constant value of filtrate turbidity 0.01 (NTU). This result means that % wash water increasing with the increasing in feed water turbidity.

IV. Conclusion

Ultrafiltration technology is widely used in various fields of water treatment around the world. Since physical screening is the main retention mechanism of ultrafiltration membranes, this technology is in line with the concept of green technology and can improve the utilization of energy and resources. Although membrane life and membrane fouling are still important constraints, with the continuous improvement of membrane assembly processes, membrane materials, membrane modules, system design, and operation and maintenance technologies, ultrafiltration technology will surely become more widespread in the field of water treatment applications.

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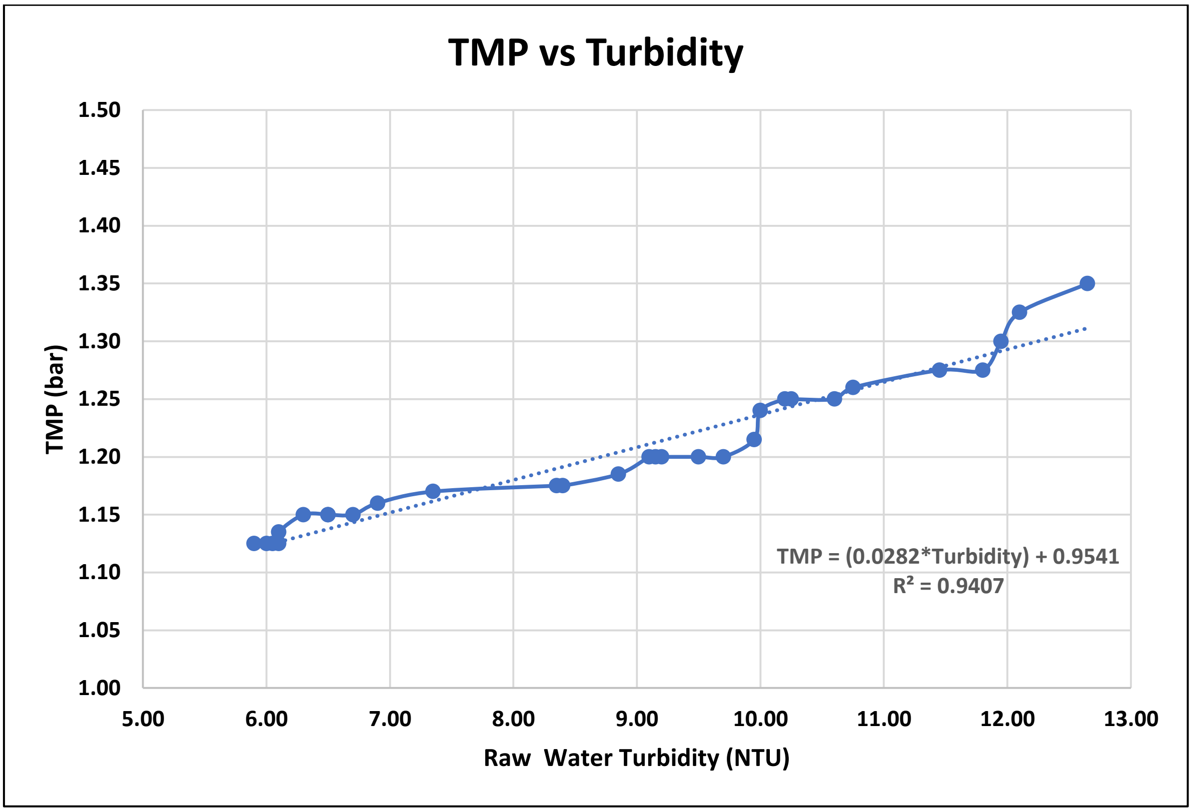

Figure 4. Trans-Membrane Pressure (TMP) versus Raw Water Turbidity.

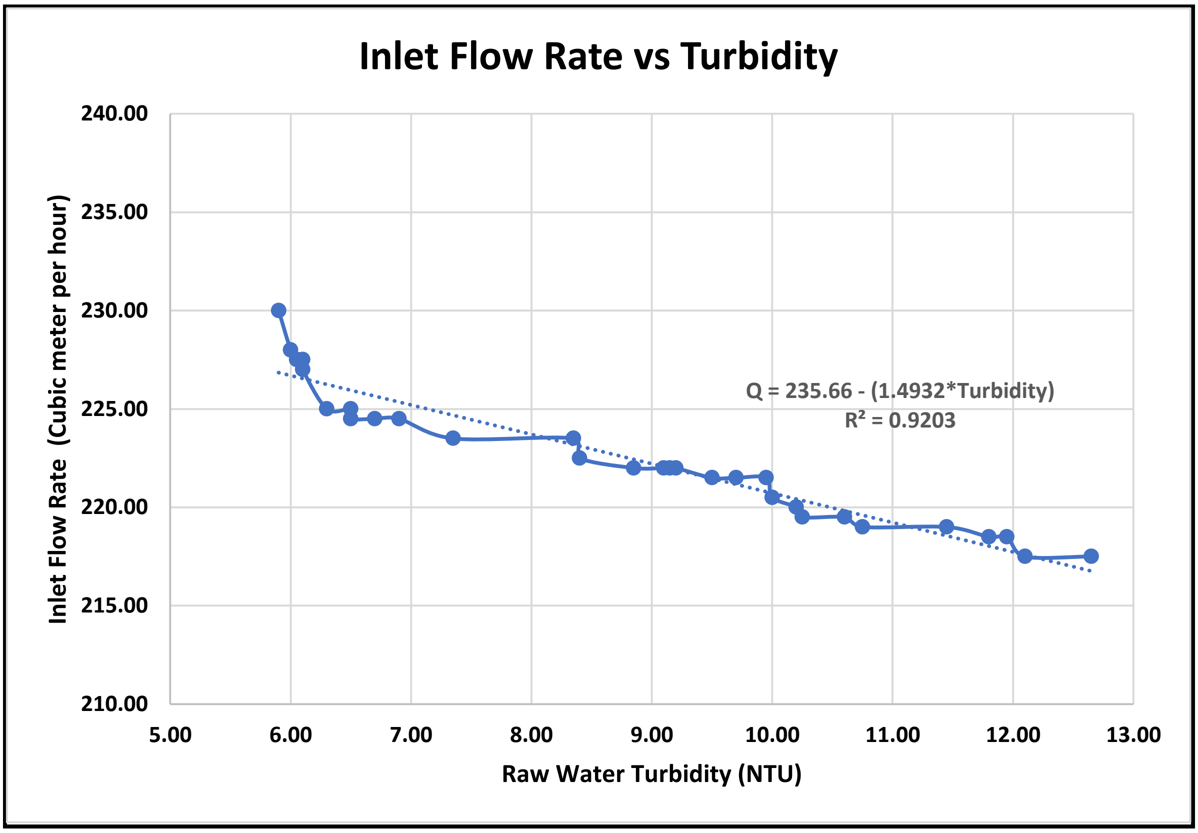

Figure 5. Inlet Flow Rate to Skids versus Raw Water Turbidity.

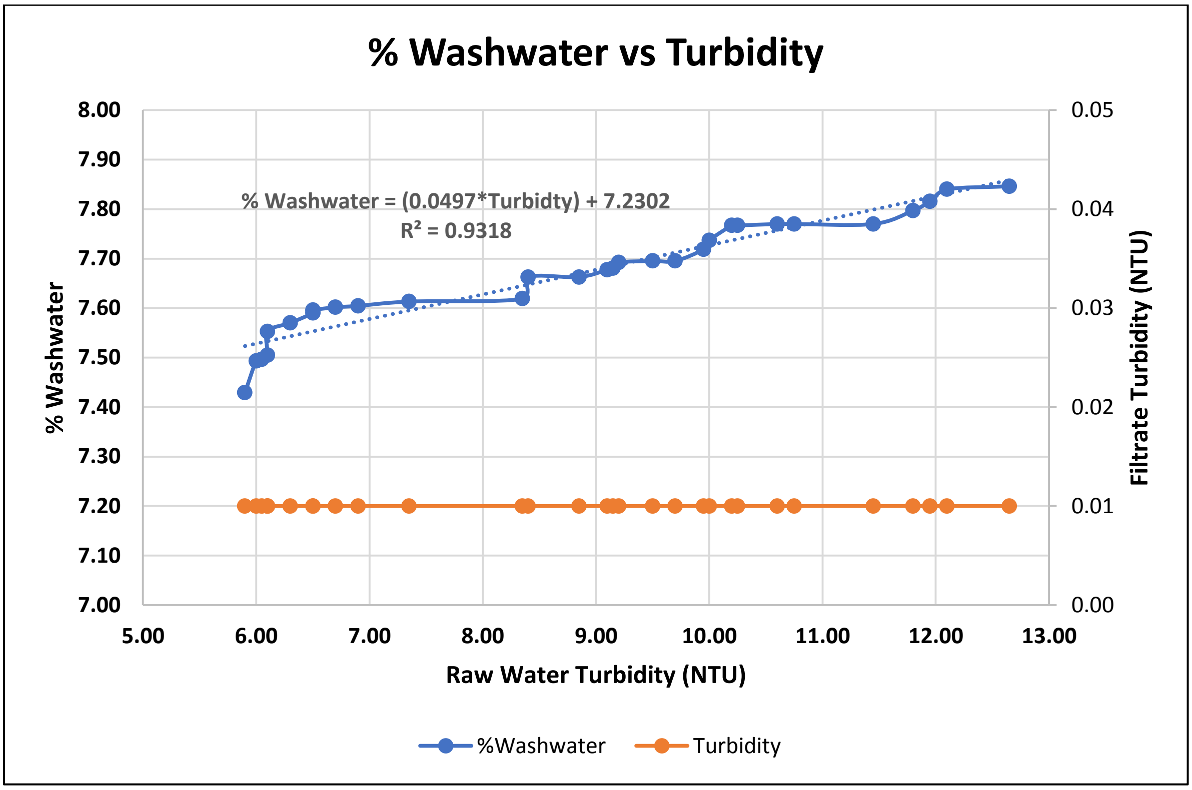

Figure 6. % Wash water versus Raw Water and Filtrate Turbidity

According to the results shown above, it can be deduced that the main advantage of ultra-filtration technique in water purification is the filtrate water has a consistent value of turbidity (0.01 NTU) regardless the value of raw water turbidity. The change of raw water turbidity effects in the required volume of wash water and the trans-membrane pressure. The increasing in raw water turbidity increases the rate of ultra-filtration membrane clogging, that increases the trans-membrane pressure in the modules. And the increasing in trans-membrane pressure causes the need of membrane back wash that increases the amount of required wash water. Increasing in amount of required wash water decreases the amount of product filtrate water or needs increase in the amount of raw water flow rate to produce constant rate of filtrate water.

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