

## Using a Developing Approach to Improve the Performance of an Industrial Water System

Mohammed Hasan Mustafa

Ministry of Science and Technology/ Environment and Water Directorate

Baghdad-Iraq

E-mail:mhmustafa\_mm&qec@yahoo.com

### Abstract

The present work involves a field application case in a one of the industrial sector companies for a reverse osmosis (RO)– industrial water system with a capacity of 80 m<sup>3</sup>/hr. Microfiltration equipment and their parts in the pretreatment subsystem had been dealt with via pursuing a reliability oriented developing approach deduced from matching between an improved recent qualitative approach which is (Site Applications of Quality Characteristics Evaluating and Activating Design Standardization (SAQCEADS<sup>+</sup>)) approach and qualitative considerations inspired by process based approach in project engineering quality management : qualitative enhancing , rehabilitating , and executing. In that context replacing of microfiltration equipment had been conducted to be as 75 m<sup>3</sup>/hr flow rate for each equipment instead of 60 m<sup>3</sup>/hr in order to solve the increase occurred in pressure drop between the inlet and outlet of the micro (cartridge) filter equipment. Also, induced vibrations in the system had been reduced via utilizing flexible joints and metal supports for the plastic pipes subsystem in the pretreatment system. Conducting of the developing approach adopted by the present work resulted in an improvement in turbidity value of the treated water. Also , it encompasses some of what can contribute in system quality boosting, its performance upgrading, and reliability enhancing in an endeavor to approach horizons of continual improvement and future development in that field .

**Key words :** Micro filter, Industrial Water System, Reverse Osmosis, Quality and Turbidity

### استعمال أسلوب تطويري لتحسين أداء منظومة مياه صناعية

محمد حسن مصطفى

وزارة العلوم والتكنولوجيا / دائرة البيئة والمياه

بغداد- العراق

### الخلاصة

يتضمن البحث الحالي دراسة حالة تطبيقية في إحدى شركات القطاع الصناعي لمنظومة مياه صناعية ذات سعة 80 م<sup>3</sup> / ساعة تعمل بطريقة التناضح العكسي. جرى التعاطي مع معدات الترشيح الدقيق وأجزائها في منظومة المعالجة الأولية عبر انتهاج مقارنة تطويرية ذات توجه معوّلي مستنبطة من مواشجة مقارنة نوعية محسنة حديثة وهي مقارنة (التطبيقات الحقلية لتقييم خصائص الجودة وتفعيل تقييس التصاميم) مع اعتبارات نوعية مستوحاة من نهج أسلوب العملية في إدارة جودة هندسة المشاريع : ترصيناً نوعياً وتأهيلاً وتنفيذاً. وفي ذلك الإطار تم استبدال معدات منظومة المرشحات الدقيقة لتكون ذات معدل جريان 75 م<sup>3</sup> / ساعة لكل معدة منها بدلاً من 60 م<sup>3</sup> / ساعة ، وذلك من أجل معالجة الزيادة الحاصلة في مقدار تغير هبوط الضغط بين مدخل ومخرج معدة المرشح (الخرطوشي) الدقيق . كما تمّ التقليل من الاهتزازات الحاصلة في المنظومة عبر الاستعانة بوصلات مرنة ومساند معدنية في منظومة الأنابيب البلاستيكية لمنظومة المعالجة الأولية . أثمر تطبيق الأسلوب التطويري الذي تبناه البحث الحالي عن تحسن في قيمة كدورة المياه المعالجة، كما تضمن بعض ما يمكن أن يرفد في تعزيز جودة المنظومة والإرتقاء بأدائها وترصين معوّليتها وبمسعى استشراف آفاق التحسين المستمر والتطوير المستقبلي في ذلك الإطار .

**الكلمات المفتاحية :** مرشح دقيق ، منظومة مياه صناعية ، تناضح عكسي و الجودة والكفاءة .

## Introduction

In the face of rising quality engineering , reliability and operating requirements for water treatment systems and their technologies with increasing and versatile affairs , specialized scientific and research centers are devoted to performing forward – looking research with creative ideas to tackle pressing quality, maintenance , and operation problems and brace for future challenges .The target is to promote proper application of water systems engineered upgrades , and to gain extended life of the elements , parts , and components in that systems .

Specialized engineering researches and studies attempt to an active pursuing of developing approaches, methods , and techniques for quality enhancing in the units and components of industrial water systems for the sake of performance improving to be reliable. Reliability is one of the important and considerable quality characteristics in the design criteria of water treatment system (Davis , 2011) . Continual improvement of quality (ISO 9004, 2000) requires corrective actions that must be conducted because of the malfunction of the system parts (Elements ) due to lack of fulfillment of reliable quality standards or mismatch between detailed designs with process requirements .

The present work calls for adopting such a developing approach it pursued that is deduced from matching between an improved recent qualitative approach which is (Site applications of Quality characteristics Evaluating and Activating Design Standardization (SAQCEADS<sup>+</sup>)) approach (Mustafa , 2009) and qualitative considerations inspired by process based approach in project quality management for engineering of major components in the system dealt with in it (ISO 10006 , 2003) . To the extent of our available knowledge the present research paper might be the first one in Iraq which undertakes such an advanced approach in its attempt for pursuing and

implementing in industrial and utilities sectors .

Reverse osmosis (RO) is a process on which most water engineers would seek advice from specialist manufacturers. The efficiency and life of a reverse osmosis (RO) system depends on the effective pretreatment of the input (feed) water. The pretreatment includes processes that can minimize fouling , scaling and membrane degradation in order to optimize product flow , salt rejection , product recovery and operating costs . Cartridge filters are commonly used as secondary or another step of filtration pretreatment and as a precautionary measure . They help in reducing the suspended solids quantity in order to protect the membrane not to get damaged.

## Materials and Methods

Technical specification of the system concerned with in the present work are : input water flow rate (Nominal) 120m<sup>3</sup>/hr(120000 l/hr) ; Product water flow rate : 80 m<sup>3</sup>/hr ; Reject water flow rate 40 m<sup>3</sup>/hr . Fig.(1) shows the flow block diagram of the system .

Input (Feed) water is pumped by two centrifugal pumps ( P-101 and P-102 ) (One in Duty and the Second as Stand-by) to filtration unit ( sand filter and Multimedia Filter (two lines )) at flow rate 120m<sup>3</sup>/hr . Prechlorination is done through that flow via controlled dosing pumps . The function of unit 200 is preparing and addition of chemical solution by the dosing subsystem for RO unit operation . In unit 300 the filtered water will be passed through cartridge filters of 5 micron nominal rating (three micro filters F-301 , F- 302 and F-303 ; two in Duty, one Stand-by ) before entering the RO system . The micro filters are considered to prevent the membranes from choking . Sensing elements of pH ( for Acidity Function ), TDS ( total dissolved solids), turbidity and ORP (Oxidation-reduction Potential) were installed in the outlet water line and

connected to the control panel . Chemical cleaning dosing to RO membranes is done by unit 400 .

In unit 500 the filtered water is pumped to RO membranes by high pressure multistage pumps P-501 and P-502 (One in Duty and One Stand-by) . The pump is operated under PLC control . The flow is controlled at 120m<sup>3</sup>/hr during normal operation . RO membranes were arranged in two stages in series. Those membranes are (FILMTEC<sup>TM</sup> Reverse Osmosis membranes from DOW water and Process Solution Products : FILMTEC BW30-400 element Polyamide Thin-film composite ) . Filtered water enters first stage (60 membranes at 10 pressure vessels(type: Codeline<sup>TM</sup>)) and outlet concentrate water is fed to second stage

(30 Membranes at 5 Pressure Vessels). The outlet concentrate water goes out to drainage system while the permeate water of two stages is collected to storage tank . Fig.(2) shows RO skid in the RO System. The recovery of the RO system is about 70% .

The chlorinated water may oxidize the membranes . To avoid such an event , SMBS (Sodium Meta Bisulfate ) dosing is applied . Hardness salts of calcium and magnesium are likely to be precipitated if concentration exceeds its solubility limit and they may fault the membranes resulting into scaling which ultimately leads to poor treated water quality from Ro system. To prevent such a case, anti scalant (Scale Inhibitor) dosing is provided in prior to micro filters F-301 , F-302 and F-303.

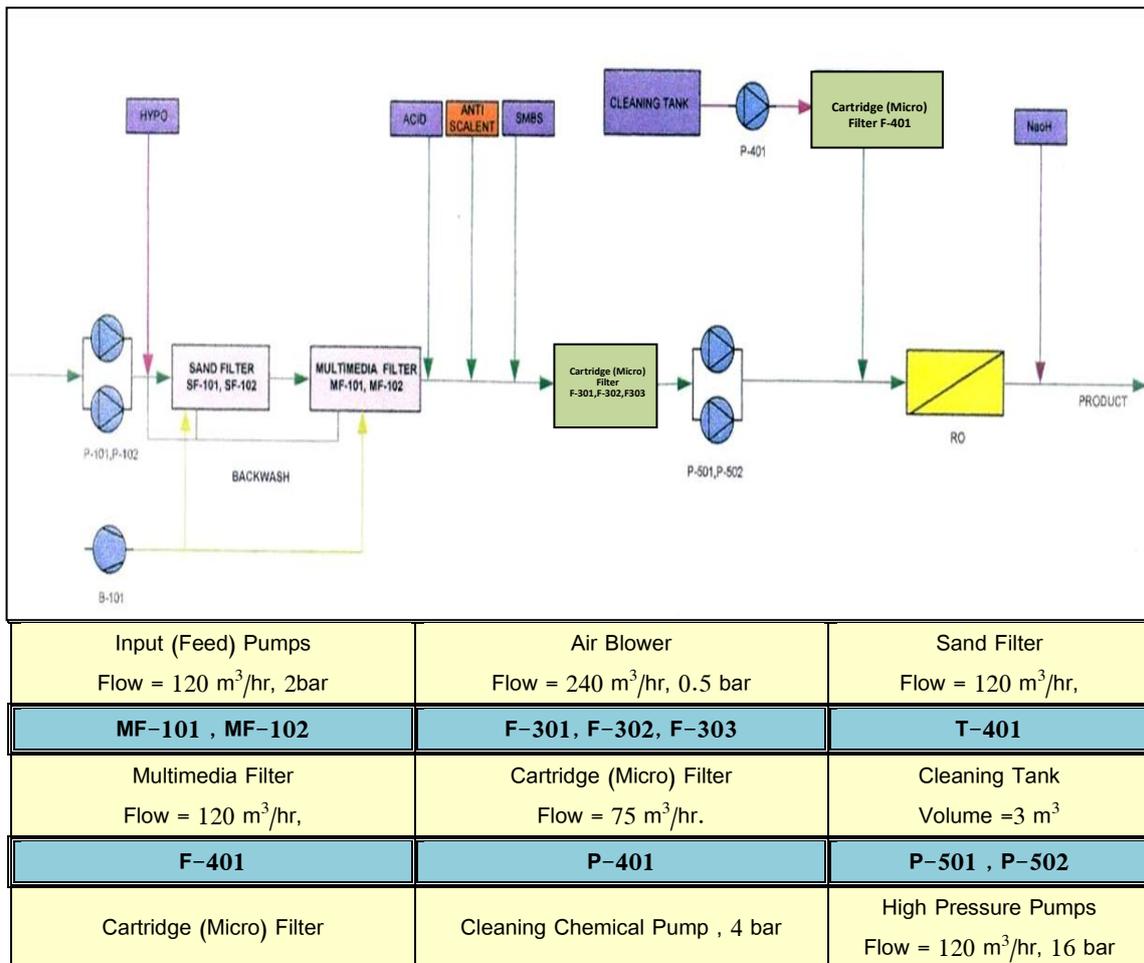


Fig.(1) Flow Block Diagram for RO Plant ( 80 m<sup>3</sup> / hr )



Fig.(2) RO System Concerned with in the Present Work

To raise pH to required level ,NaOH dosing system is applied. Also Sulfuric acid dosing is used to prevent Calcium Carbonate scale.

### Results and Discussion

Symptoms of faults and troubles occurred several times in the pretreatment subsystem of the system dealt with , such as low pressure reading on post cartridge filter gauge less than the design recommended value . Cleaning for blocked or dirty cartridges and replacing them ( see Fig.(3)) had been conducted . The occurrence of that trouble was repeated even after checking for cleaning and pressure drop across the inlet and outlet of any of the micro filter equipment in unit -300 after condition monitoring of feed pump pressure . An active pursuing of[SAQCEADS<sup>+</sup> ] (Site Applications of Quality Characteristics Evaluating and Activating Design Standardization ) approach ( Mustafa , 2009 ) had been performed in the implementing of the developing approach adopted in the present work . That approach indicates the necessity as a must to replace the unit-300 equipment by its careful consideration of process design and performance required of them in the system for quality upgrading and enhancing .

It is advisable and essential to wash or replace the cartridges when the Differential pressure (Manometric difference between the upper and lower Gauges of the Cartridge Filter ) exceeds 1 bar [( there is an increase in pressure Drop to the Permitted Limit ) because of cartridge fouling ( An Increase in the differential pressure between the inlet and Outlet of the Micro Filter)] . Cartridge filters need to be changed regularly ( Based On operation Time and according to the manufacturer recommendation) . Replacing cartridges depends on the quantity of suspended solids in the water .Most of Cartridge filters are replaced when head loss reaches excessive levels.Using cartridges other than the ones recommended by the manufacturer may lead to sand and solids passage to the membrane which will results in blocking them and that in turn will affect the system reliability and void the plant warrantee .

For a better performance , new cartridge (micro) filter equipment and cartridge filter elements that combine quality and cost effectiveness to provide better filtration value had been installed , tested , and operated instead of the previous equipment (see Fig.(3)) . The pore size ( micron rating ) of the cartridges is 5 $\mu$ . Polypropylene (pp)

replacement cartridge filter element were used for removal of sand, silt, dirt and rust particles. Installation and housing design can affect performance. That type of cartridge will not remove cysts, bacteria or viruses. They are characterized by their manufacturing material which meets reliable standard specification and were carefully constructed to avoid potential contaminants. The governing and significant characteristics of the new cartridge (micro) filter for each of unit -300 equipment (F-301, F-302, and F-303) in addition to their specific design feature and internal components are: 75 m<sup>3</sup>/hr flow rate and 30 cartridge filter elements (candles) which replaced the 60 m<sup>3</sup>/hr flow rate and 18 candles of the previous equipment.

Turbidity is another guideline as an indicator for the rate of RO membrane fouling (fouling Potential). Turbidimeters (also called nephelometers) measure the scattering & light caused by various suspended solids in the water sample. Water samples having turbidity reading greater than (1 NTU) will tend to foul the membranes. Those readings are typically given in nephelometric turbidity units (NTU).

According to process design wise considerations, in the normal operation two filters in unit 100 are in duty. In backwash sand filter and multimedia filter are in duty to remove residual chlorine and dissolved organic compounds from water which may foul RO membranes and to reduce the suspended solids to less than 3 to 1 NTU.

Fig.(4) shows turbidity measuring devices for the system in the present work. Checking available record of final inspection and calibration of WTW Turb 550 IR laboratory turbid meter had been conducted.

Fig.(5) shows turbidity measurements of the system after the previous cartridge filter in the commissioning phase. Fig.(6) shows turbidity measurements of the system after implementing the present work

approach. In Fig.(6) there is some increase in turbidity value in few readings of turbidity measurements caused by a failure case occurrence in the filtering system of the filtration unit in the pretreatment system.

Reviewing process system design of the system dealt with in the present work had been done by ROSA Membrane Design Software Version 8.0.1 from the DOW Chemical Company for Water and Process Solutions for FILMTEC™ Membranes from Filmtec Corporation and no design warning for that system had been shown (ROSA,2010).

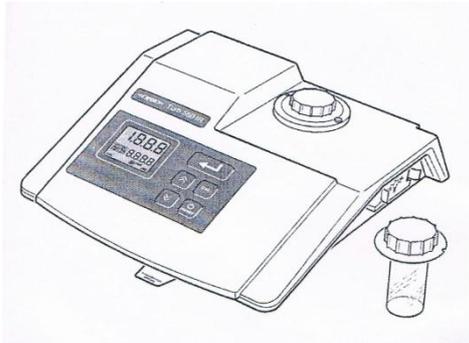
In addition to the characteristics shown before the following specifications for the product water from the concerned RO system under the specified operating conditions were (as average measured values): pH = 6.98 ; TDS = 21 mg/L.

Input water temperature less than 20°C will result in less product water flow rate than the designed output and with lower TDS value of product water. On the other hand, higher input water temperatures will result in higher product flow rate than the designed output with higher TDS value.

Fig.(7)(a and b) shows remedy of vibrations encountered in the system and that involved Preparing and installing flexible connections and appropriate subsystem to minimize and eliminate other possible water hammering and induced vibrations.



Fig.(3) The Replacing Micro Filter Equipment



a



b

Fig.(4)Turbidity Measuring

a. Laboratory Turbidity Meter

b. Online Turbidity Measuring Device

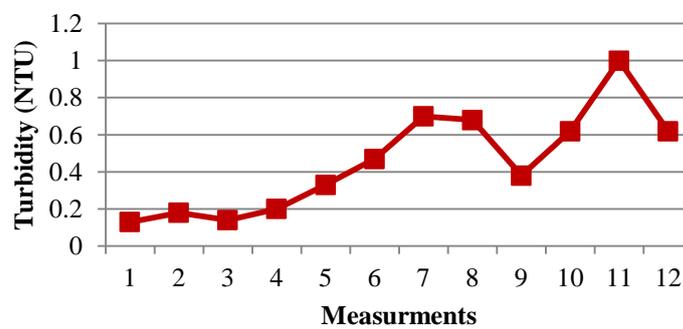


Fig.(5) Turbidity Measurements of the System after the Previous Cartridge Filter in the Commissioning Phase

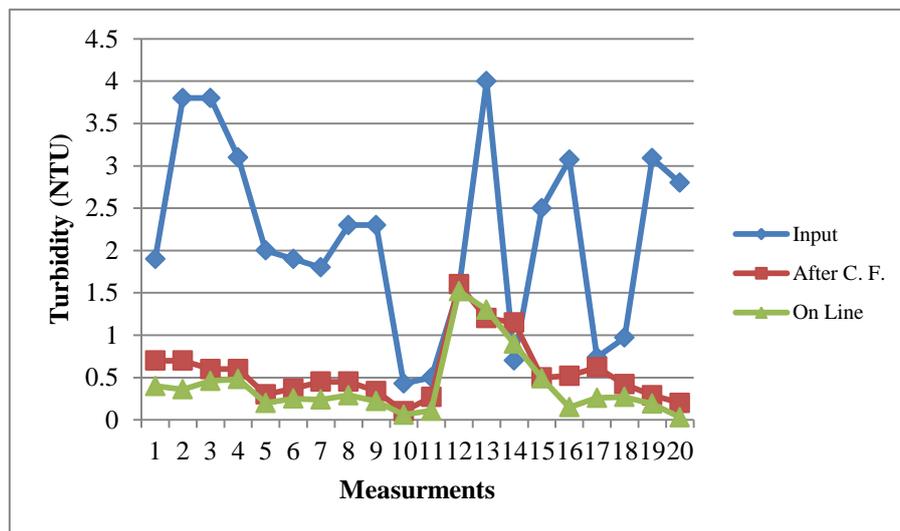


Fig.(6) Turbidity Measurements of the System after Implementing the Present Work Approach



a

**Fig.(7) Remedy of Vibration Encountered in the System**

**a. Rubber Ties and Steel Supports**



b

**b. Flexible Connections**

The vibratory actions are induced from (Equipment ,Machinery , and Piping ) in the system . Additional remediation for those vibration effects were also conducted by applying of rubber ties(Connecting Parts ) between steel supports and pipes , considering pipes leveling.Safety precautions were emphasized for assuring that pressure vessels are suitably anchored .

### Conclusions and Recommendations

1. The design of the pretreatment system must lead to provide the required quality for feed water to RO membrane sections. All the equipment, components, and parts should be operated and maintained properly to achieve the required quality . The requirements of the quality standards provide the

2. controls necessary to achieve the best possible quality standards for the components of the system dealt with
3. . That considerations hadbeen pointedout and confirmed by SAQCEADS+approach implementation in the present work.
4. Installing unit SDI (Silt Density Index) online meter in the outlet water line from unit – 300 is important .
5. Each cartridge filter might have its own differential pressure switch , and if that switch is energized , then it will give alarm and operator has to switch manually to thestand – by line.
6. It is considerable to make use of test method for turbidity of water according to the reference ( ASTM D 1889 – 2006) for a better compliance and more recent standards as a guiding reference .
7. Proper operation and maintenance of RO system are key factors in obtaining successful performance . For that sake , start-up report , record keeping of RO operating data , record keeping of pretreatment operating data , and a maintenance log must be available (ASTM D 4472 , 2008). The present work approach had pointed out a lack of such accurate and dependable records.

The present work hopes to make a valuable contribution in an endeavor that

could revolutionize quality engineering as a vital and important field dealt with. Some developing considerations for the implemented approach in the present work and suggestions for future research directions and improvements in the followings appear to be worthy for future study concerning the scope of the present work:

- a- Optimization of flow rate calculation and micro filter detailed design will be worthy to contribute for enriching the considerations and actions adopted and conducted in the present work .
- b- Long – term , in situ continuous monitoring of the slightest changes in the system is important . It is worthy to take advantage of recent optical sensor design and anti – fouling wiper control to avoid fouling growth on the sensor for improved reliability during extended deployments. Wiped fouling protection by self – cleaning optical sensors with integrated wipers remove bio-fouling and maintain high data accuracy . It is necessary that the sensor performance is verified by the EPA (Environmental Protection Agency , USA) environmental technology verification program (YSI , 2009).
- c- The pretreatment might involve back washable microfiltration and ultrafiltration membrane units .Such a facility can work reliably and with high recovery rate and low feed pressure that capillary feed filtration could provide a better quality of product water . The cost of such equipment is still high compared with RO unit cost(2010، (الدسوقي و أيتوني ،

المصادر

الدسوقي ، هشام ؛ أيتوني ، هشام (2010) ، المرجع في أسس تحلية المياه المالحة، منشورات جامعة دمشق ، كلية الهندسة المدنية ، 602 .

ASTM D 1889 (2006)

ASTM D 4472 (2008)

Davis, M. L. , (2011) Water and Wastewater Engineering : Design Principles and Practice , McGraw -Hill International Edition .

ISO 9004 , (2000)

ISO 10006 , (2003)

Mustafa , M. H. , (2009) , Quality Upgrading and Performance Reliability Enhancing of Mechanical System by Boosting Action of Pursuing Site Applications Approach for Its parts Quality Characteristics Evaluation and Design Standardization , the Second Scientific Conference of the College of Engineering – University of Al-Qadissiyah, 19 -20 Oct. .

ROSA Membrane Design Software Version 8.0.1,(2010) The DOW Chemical Company for Water and Process Solutions , and Filmtec Corporation ,USA .

YSI ,( 2009) , Environment Monitoring Solutions , YSI Inc. , USA.