Sudan University of Science & Technology

College of Graduate Studies

Assessment of Water Quality for Hemodialysis In Khartoum State

تقييم جودة المياة المستخدمة للاستصفاء الدموي في ولاية الخرطوم

A thesis Submitted in fulfillment of the Requirements for the Master Degree in Biomedical Engineering,

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الآيــة

بسم الله الرحمن الرحيم

قال الله تعالى:

اقْرَأْبِاسْمِ رَبِّكَ الَّذِي خَلَقَ (1) خَلَقَ الْإِنسَانَ مِنْ عَلَقٍ (2)
اقْرَأْ وَرَبُّكَ الْأَكْرَمُ (3) الَّذِي عَلَّمَ بِالْقَلَمِ (4) عَلَّمَ الْإِنسَانَ
مَا لَمْ يَعْلَمْ (5).

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Dedication

I would like to dedicate my dissertation to:

my mother,

my Father,

my husband,

my sons,

my brothers and sisters,

for their love, patience, and support.

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ABSTRACT

Hemodialysis (HD) is replacing kidney function by using a semi -permeable membrane in dialysis machine to filter wastes and water from the blood to dialysis fluid**.** Water treatment plays a vital role in the delivery of safe and effective hem dialysis (HD**).**

To assess of Water quality of dialysis two methods are used the first method is questionnaire targeted the medical engineers working in 10 of dialysis centers in state, the second method is monitoring chemical contamination in five dialysis centers using chemical analysis for treated water. The questionnaire included the types of tests carried out to monitor system efficiency and control of microbial and chemical contamination, as well as questions to identify the most important problems facing dialysis centers and prevent the application of quality control .As result of following the recommendations of American Association for the Advancement of Medical Instrumentation (AAMI) in monitoring and maintenance of the work of water treatment system the purity of treated water will increase and this reduces the risk of exposure to chemical and microbiological related to water, thus providing good health care. By analyzing the result of questionnaire found that 38% of dialysis centers are following the recommendations of (AAMI)because the tests conducted to monitor the work of water treatment unit were insufficient and were not done in some centers on regular basis, there is no monitoring to chemical contamination ,but on the other hand there are monitoring to microbiological contamination in all dialysis centers. Also by using statistical analysis program SPSS for the results of chemical analysis for treated water of five samples found that 80% of samples aren't pure and that meet the research problem statement there is lack of purity of treated water for hemodialysis.

المستخلص

الاستصفاء الدموي هو استبدال وظيفة الكلي باستخدام غشاء شبة منفذ في ماكينة الغسيل لتصفية النفايات والماء من الدم الي سائل الغسيل الكلوي.

لتقييم الجودة للمياة في الاستصفاء الدموي استخدمت طريقتيين، الطريقة الاولي : استبيان استهدف المهندسيين الطبيين العامليين في عشرة من مراكز الاستصفاء الدموي بالولاية، الطريقة الثانية مراقبة التلوث الكيميائي في خمس من مراكز الاستصفاء الدموي باستخدام التحليل الكيميائي للمياة المعالجة.اسئلة الاستبيان شملت انواع الاختبارات التي تجري لمراقبة كفاءة النظام و مراقبة التلوث الميكروبي والكيميائي،وايضا للتعرف علي اهم المشاكل التي تواجة مراكز الاستصفاء الدموي وتحول دون تطبيق برامج ضبط الجودة.

كنتيجة لاتباع توصيات الجمعية الامريكية للأجهزة الطبية (AAMI) في مراقبة وصيانة وحدة معالجة المياة، نقاوة المياة المعالجة ستذيد وهذا يؤدي الي تقليل المخاطر الناتجة من التعرض للتلوث الكيميائي اوالميكروبي المتعلق بالمياة وبالتالي تقديم رعاية صحية جيدة.

بتحليل نتائج الاستبيان وجد ان 38% من مراكز الاستصفاء الدموي بالولاية تتبع توصيات الجمعية الامريكية للاجهزة الطبية(AAMI). وذلك لان الاختبارات التي تجري لمراقبة عمل وحدة معالجة المياة غير كافية ولاتتم في بعض المراكز بصورة منتظمة، وايضا وجد ان اغلب مراكز الاستصفاء الدموي ليس هنالك اهتمام بعمل تحليل كيميائي ،لكن من جانب اخر وجد ان هنالك مراقبة للتلوث الميكروبي في كل المراكز.

وايضا باستخدام برنامج التحليل الاحصائي SPSS لنتائج التحليل الكيميائى لخمس من عينات المياة المعالجة، وجد ان80% من العينات ليست نقية وهذا يقابل فرضية البحث ان هنالك انعدام لنقاوة المياة المعالجة للاستصفاء الدموي.

CHAPTER ONE: INTRODUCTION

1.1 General Review

Hemodialysis is considered a modern health burden as a result of increasing case, multiple spores and complication, in addition to economic and social effects, so the interesting to improve the quality control programs in dialysis centers to meet world quality standard is very important to produce a good health care. The quality control for hem dialysis involves Physical facilities ,water treatment, infection control, patient and clinical staff.

If know that in hemodialysis (HD), more than90% of the dial sate delivered to the dialyzer is water. The more pure the water, the more accurate the dial sate prescription that is delivered. Water contamination can lead to anemia, alterations in blood pressure and acid-base balance, neurological issues, bone disease, and more, and patients may suffer acute or chronic problems from exposure to substandard daily sate.

1.2 Problems Statement

The important problems that prevent the water treatment plays a vital role in delivery of safe and effective dialysis are lack of purity of water, and quality control programs in testing, monitoring and maintained of the water treatment system aren't enough to meet standards for quality (set by the Association for the Advancement of Medical Instrumentation (AAMI) that lead To reduce the risk of chemical and microbiological contamination) .

1.3 Objective

1.3.1 General Objective

To know the important of uses treated water in dialysis unit to provide good health care, and the requirements of dialysis water purification.

1.3.2 **Specific objective**

To check the technical description of water treatment system, Study the tests that should follow to monitoring the quality of treated water and component function of water treatment system, Check the application for quality control programs, and Assessment of Water Quality for Hemodialysis.

1.4 Methodology

Firstly collection the data that related with the water that use in hemodialysis department, and how can the biomedical engineers contribute to getting treated water in high quality by well monitor and maintained of water treatment system. Also visit some hemodailysis centers to know about the quality control program that use. Secondly making a questionnaire task the biomedical engineers that work in hemodialysis unit to know what are the important problems that prevent to have effective quality control program. Finally evaluate the quality of treated water by making chemical analysis, and results of the questionnaire and chemical analysis will be displayed and analysis by SPSS.

1.5 Thesis Layout

This thesis consists of six chapter's chapter one is an introduction, chapter two is speak about theoretical fundamental, , chapter three is consists of back ground studies ,chapter four consists of Methodology, chapter five is analysis ,results and discussion, Finally conclusion and recommendation in chapter six.

CHAPTER TWO: THEORETICAL FUNDAMENTAL

2.1 Water Supply

The first step to understanding water treatment is to understand water sources. There are two sources of water that municipal water suppliers use: ground water and surface water. Ground water comes from underground

Chambers such as wells and springs and is generally lower in organic materials but higher in inorganic ions such as iron, calcium, magnesium, and sulfate. Surface water comes from lakes, ponds, rivers, and other surface type reservoirs. It is generally more contaminated with organisms and microbes, industrial wastes, fertilizers, pesticides and sewage. Municipalities or public water suppliers process both types of water and, depending on the quality of the supply water, they may add chemicals[1].

2.2 The Importance of water purity During Hemodialysis (HD)

The average person consumes approximately 2 liters of water a day in different forms (juice, coffee, etc.), whereas a patient on hemodialysis is exposed to anywhere from 90-192 liters of water (in the dialysate) per treatment. In healthy individuals, the contaminants in water are mainly

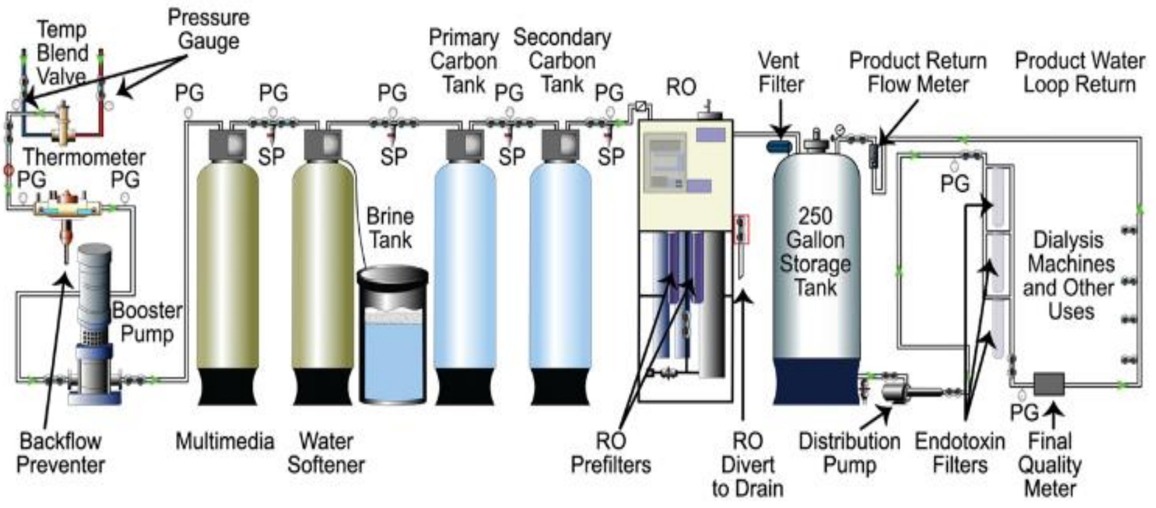
Excreted through the kidneys and gastrointestinal (GI) system. Patients on hemodialysis, on the other hand, do not have functioning kidneys to excrete the waste products. They rely on HD to take out the wastes and normalize the electrolytes .Show in table (2.1) (signs and symptoms and possible contaminant related cause). [2]

Table (2.1): Signs and Symptoms and Possible Water Contaminant –Related Causes

Symptom	Possible Water Contaminants
Anemia	Al, chloramine, Cu, Zn
Bone Disease	Al, Fl
Hemolysis	Cu, nitrates, chloramine
Hypertension	Ca, Na
Hypotension	Bacteria, endotoxin, nitrates
Metabolic Acidosis	low pH, sulfates
Neurological deterioration	Al
Nausea and vomiting	Bacteria, Ca, Cu, endotoxin, low pH, Mg, nitrates, sulfates, Zn
Death	Al, Fl, endotoxin, bacteria, chloramine

2.3 Components of Water Treatment System:

Water treatment system consist of **:** Pre-treatment (back flow preventer ,temperature blending valve ,Booster pump ,Multimedia ,Water Softener ,Brine tank, Primary and Secondary Carbon tank).Treatment component (Reverse Osmosis System). Distribution system, figure(2.1)



Figure(2.1):Water Treatment System

2.3.1 Pre-Treatment:

A. Back Flow Preventer :

A back-flow preventer prohibits the water in the water treatment components from flowing back into the potable drinking water lines. This protects the drinking water from contamination with disinfectants and cleaners that are used in the water treatment system [1].

B. Temperature Blending valve :

The temperature blending valve mixes hot and cold water to an RO membrane industry-standard temperature of around 77° F (25°C). For each 1°F temperature drop, the RO membrane produces 1.5% less purified water. Gauge must be in place with an audible alarm, as high temperatures can damage the RO membranes. A temperature gauge should follow temperature blending valves and be read and recorded at least daily [1].

Then the temperature Blending Valve us**e** to monitor Water temperature, and to look for appropriate water temperature.

C. Booster pump:

Booster pumps are used to provide a constant supply of water flow and pressure for the RO system in order to operate successfully. They should be followed by pressure gauges that are read daily and the readings record [1].

The Booster pump use for monitor Water pressure.

D. Chemical Injection Systems :

In order for the RO to operate properly, and carbon tanks to remove chlorine/chloramine effectively, the ideal incoming water pH should be 5-8.5.The PH is higher than 8.5, so a chemical injection system may be incorporated into the design of the pretreatment system, especially in the presence of chloramine. A pH higher than 8.5 with chloramines present will cause the carbon to be less adsorptive and the RO membrane performance to degrade, resulting in poor water quality. In order to reduce the pH, chemical injection systems meter a small amount of a strong mineral acid known as hydrochloric (HCl) [2] .

The lower pH will cause dissolved metals like aluminum and some salts in the feed water to precipitate. The pH after the injection system should be monitored continuously and read and the results recorded at least daily. [2].the expected range for pH should be between 5 and 8.5. Some important points to consider:

1. Place the acid feed system before the multi-media since the lower pH can cause aluminum to precipitate.
2. Online monitoring of pH is required with both audible and visual alarms in place
3. An independent test of pH is required daily. [`3]

Chemical Injection Systems use to monitor pH post acid feed pump.

E. Sediment Filters:

Large particulates of 10 microns or greater that cause the supply water to be turbid – such as dirt, silt may be removed by sediment filtration. Sediment filters are typically placed at the beginning of the pretreatment and can be cartridge type filters, single media filters, or multimedia filters .An automatic multimedia filter is backwashed on a preset time schedule (when the system is not in use) so that the media is cleansed and redistributed regularly [1].

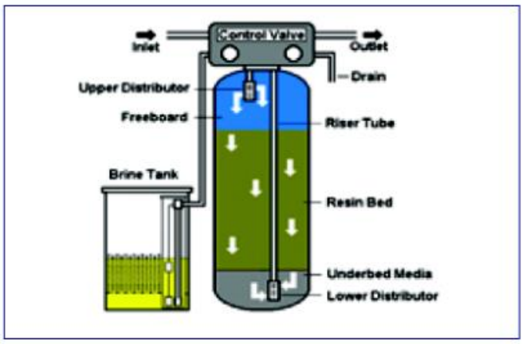
Sediment filters use to monitor Pressure drop across the device, back flush timer.

F. Water Softener

Hard water containing calcium and magnesium .Softeners turn hard water into “soft” water by removing the hardness and exchanging it for sodium as shown in figure(2.3).The resin beads within the tank have a high affinity for the actions calcium and magnesium (both divalent bonds)that are present in the source water.The softener needs regenerating. Regeneration is usually performed every day or every other day that the softener is used at a time when the water treatment system is not in use[1].

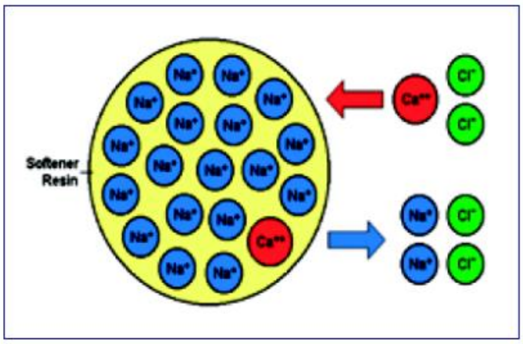
Water Softener use to monitor Post softener hardness at the end of the day, amount of salt in the brine tank, “salt bridge” in the brine tank, pressure drop across the device, settings on regeneration timer. The ardness not exceeding 1 GPG (17.24 PPM), adequate amount of salt with no salt bridge, pressure drop change from baseline of 10 PSI or more, timer set to activate when facility is not in operation.[3]

Figure 2
Water Softener



Note: Figure courtesy of DaVita, Inc.

Figure 3
Softener Ion Exchange



Note: Figure courtesy of DaVita, Inc.

Figure (2.2: a &b), a: Water softener. b : Softener Ion Exchange.

H. Carbon filter

Chlorine and chloramines are not removed by RO and actually damage the thin film-type RO membranes. Carbon filtration will remove chlorine and chloramines that are almost always present in the source water by means of a chemical process termed adsorption. As the input water flows down through the granular activated carbon (GAC), solutes diffuse from the water into the pores of the carbon and become attached to the structure as shown in Figure(2.3 A&B). [2]

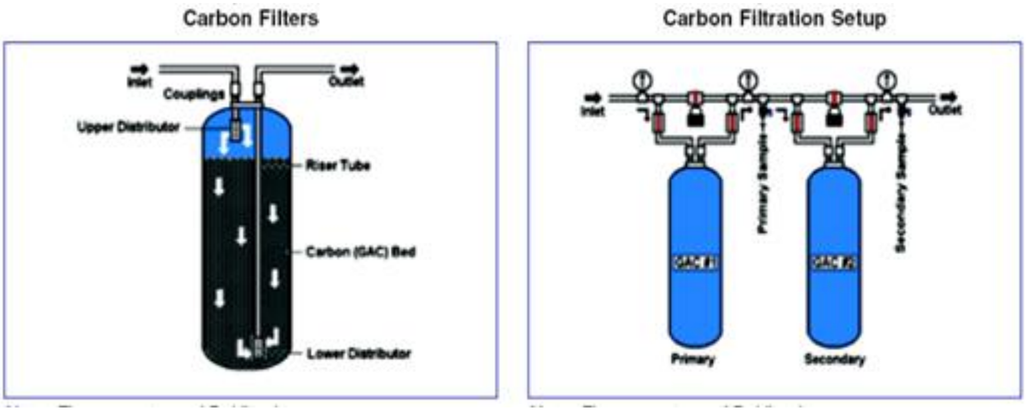


Figure (2.3: a &b), a: Carbon Filters. b: Carbon Filtration Setup.

Carbon filter use to monitor Chlorine levels within AAMI standards (0.5 PPM chlorine, 0.1 PPM chloramine), pressure drop change of10 PSI or greater, back flush timer set to activate when facility is not in operation[5].

2.3.2 Treatment Component

1. **Reverse Osmosis Systems (RO):**

   Cartridge filters are filters positioned after all the pretreatment components and immediately before the RO pump and membranes. Carbon fines, resin beads and other debris exiting the pretreatment can destroy the pump and foul the RO membranes[2].

The Reverse Osmosis Systems consist of:

1. The RO pump: (the noisy thing you hear in the RO room) increases water pressure across the RO membranes to make pure water.
2. RO membranes: The RO membrane is the heart of the system. It produces the purified water through reverse osmosis .In reverse osmosis, concentrated water (feed or supply water) is forced to flow in the opposite, or unnatural direction across a semi-permeable membrane by means of high pressure as show in figure (2. 6).Pure water passes through the membrane.RO membranes reject dissolved inorganic elements such as ions of metals, salts, chemicals, and organics including bacteria, end toxin and viruses[].

Disinfection in (RO): once a month is recommended for the entire system (if using a chemical-like per acetic acid) [1].

Reverse Osmosis use to monitor water pressure and flow at various locations throughout the
system.[3]

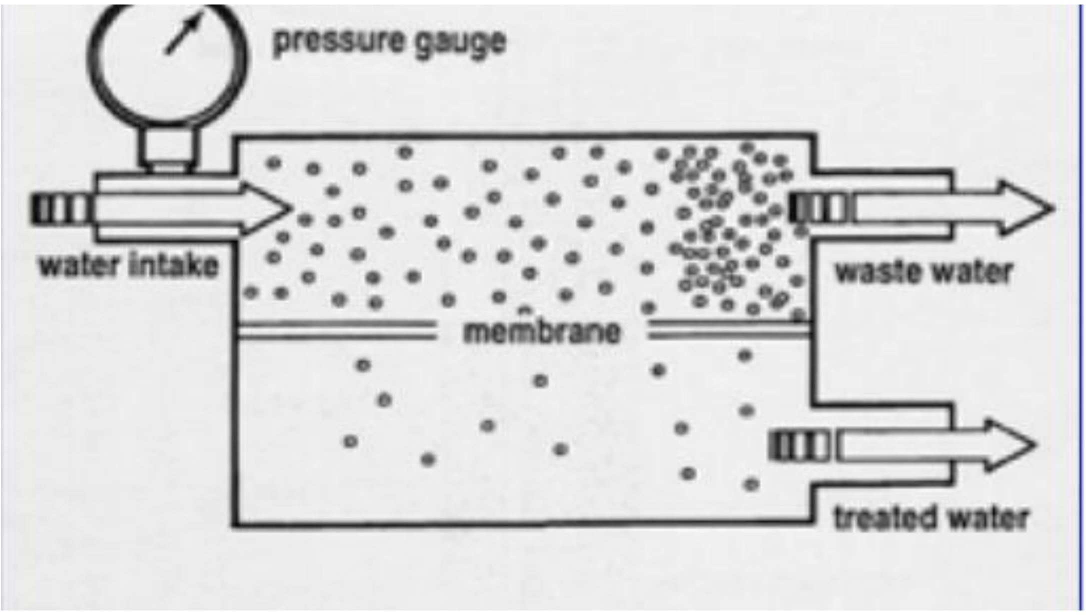


Figure (2.4): Reverse Osmosis.

2.3.3 Post treatment Components:

2.3.3.1 Deionization:

Sometimes DI is required to polish the water when RO alone cannot reduce the contaminants to within AAMI standards. Also, facilities may use DI as an emergency back-up to the RO. DI contains: resin beads that remove both cat ions and anions from the water in exchange for hydroxyl (OH-) and hydrogen (H+) ions. DI shall be followed by an ultra-filter (UF) so that the downstream components are not contaminated [2].

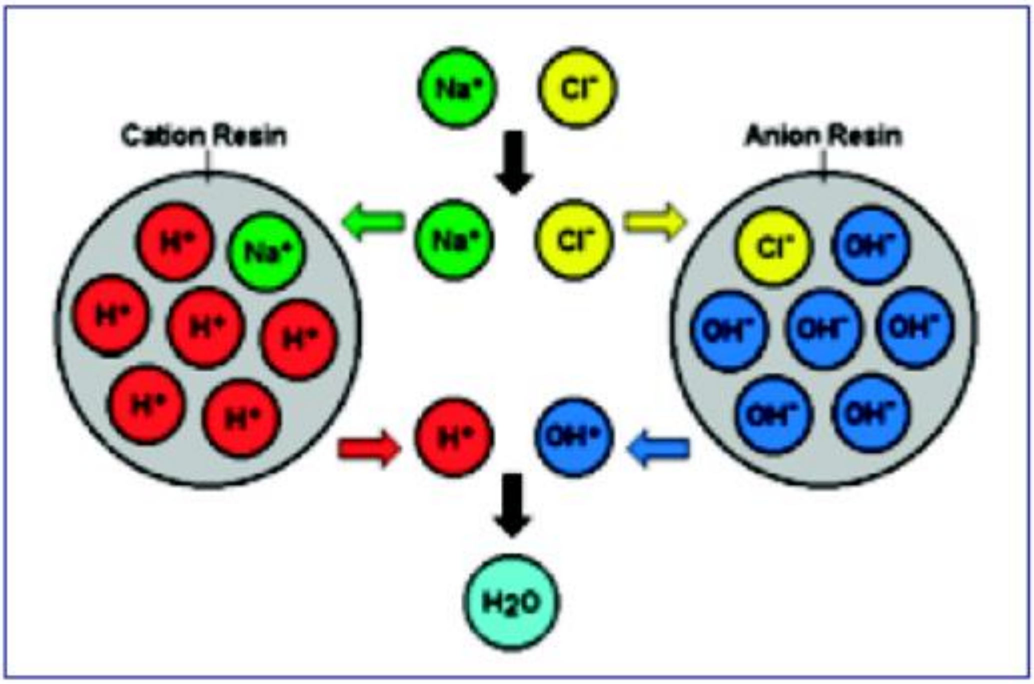


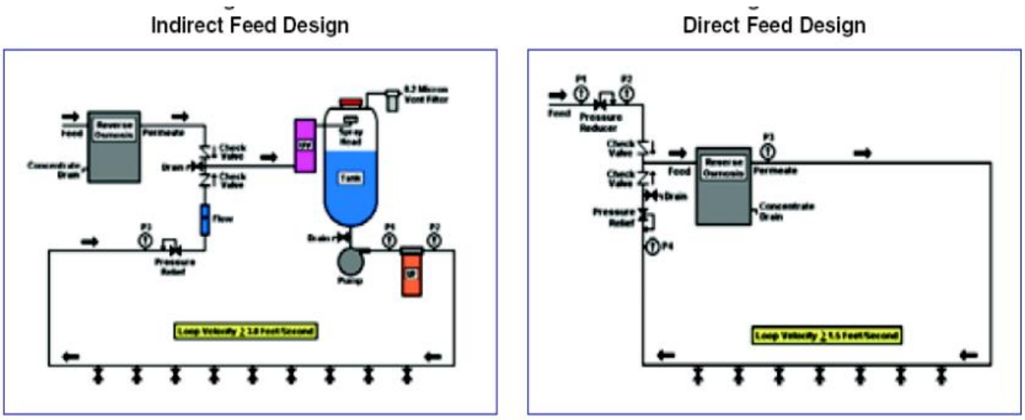
Figure (2.5): DI Exchange process.

2.3.3.2 Ultraviolet irradiator (UV):

UV is a low pressure mercury vapor lamp enclosed in a transparent quartz sleeve that emits a germicidal 254 nm Wavelength and delivers a dose of radiant energy in order to control bacteria proliferation [1].

2.3.4 Distribution System:

RO distribution systems can be grouped into two categories, direct feed and indirect feed.



Note: Figure courtesy of DaVita, Inc. Note: Figure courtesy of DaVita, Inc.

Figure (2.6: a &b), a: Indirect Feed Design.   b: Direct Feed Design.

2.3 System Disinfection

Treatment systems and dialysis machines need to be disinfected Water periodically. Chemicals such (chlorine), per acetic acid/hydrogen peroxide mixtures, and formaldehyde are commonly used for this purpose. Whenever you use these or other Chemicals in the dialysis facility to disinfect your equipment, it is necessary to test the concentrations. You should test the concentration of the solution you are using for potency, to assure that you have an adequate concentration to achieve disinfection of the system. After the disinfection procedure is complete and the system is rinsed, you must test for the absence of that chemical in the system. The results of this test must be properly documented .The test you use must be appropriate for the chemical you are using.

Distribution equipment should be disinfected no less frequently than every 4 weeks [4].

2.5Definition of Quality in Health Care:

The US joint commission for accreditation of Health care Organization defined quality in health care as(the degree of compliance with agreed standards to help determine a good level of practice and to know the expected result of the service and therapeutic or diagnostic procedure)[2].

2.6 Quality Control for Water Treatment:

Quality control for water treatment includes monitoring and maintenance.

2.6.1Monitoring

Monitoring provides information on product and source water quality and on the performance of individual system components. Product water quality must be regularly monitored to ensure it continues to meet the required standards The Association for the Advancement of Medical Instrumentation (AAMI) of the U.S. has set water quality standards that have become widely accepted [5].

6.1.1. Monitor Chemical Contamination

Full analysis of chemical contamination shall be performed by an accredited laboratory as show in table (2.2).

6.1.1.1 Test methodology:

Table (2.2) AAMI chemical contaminant standard and test methodology.[6]

Table 1: AAMI Chemical Contaminant Standards

Contaminant	**Maximum Concentration mg/L** (Unless otherwise noted)	**Test Methodology**
Calcium	2 (0.1 mEq/L)	EDTA Titrimetric Method, or Atomic Absorption (direct aspiration), or Ion Specific Electrode
Magnesium	4 (0.3 mEq/L)	Atomic Absorption (direct aspiration)
Potassium	8 (0.2 mEq/L)	Atomic Absorption (direct aspiration), or Flame Photometric Method, or Ion Specific Electrode
Sodium	70 (3.0 mEq/L)	Atomic Absorption (direct aspiration), or Flame Photometric Method, or Ion Specific Electrode
Antimony	0.006	Atomic Absorption (platform)
Arsenic	0.005	Atomic Absorption (gaseous hydride)
Barium	0.10	Atomic Absorption (electrothermal)
Beryllium	0.0004	Atomic Absorption (platform)
Cadmium	0.001	Atomic Absorption (electrothermal)
Chromium	0.014	Atomic Absorption (electrothermal)
Lead	0.005	Atomic Absorption (electrothermal)
Mercury	0.0002	Flameless Cold Vapor Technique (Atomic Absorption)
Selenium	0.09	Atomic Absorption (gaseous hydride), or Atomic Absorption (electrothermal)
Silver	0.005	Atomic Absorption (electrothermal)
Aluminum	0.01	Atomic Absorption (electrothermal)
Chloramines	0.10	DPD Ferrous Titrimetric Method, or DPD Colorimetric Method
Total chlorine	0.50	DPD Ferrous Titrimetric Method, or DPD Colorimetric Method
Copper	0.10	Atomic Absorption (direct aspiration), or Neocuproine Method
Fluoride	0.20	Ion Selective Electrode Method, or SPADNS Method
Nitrate (as N)	2.00	Cadmium Reduction Method
Sulfate	100.00	Turbidimetric Method
Thallium	0.002	Atomic Absorption (platform)
Zinc	0.10	Atomic Absorption (direct aspiration), or Dithizone Method

2.6.1.2 Monitor Microbiological Contamination:

2.6.1.2.1 Frequency of Testing for Bacteria and Endotoxin levels

Testing should be performed monthly. If standards are exceeded, testing should be performed weekly until the problem is resolved.

2.6.1.2.2 S ample Collection:

The sample ports used to collect the samples must be rinsed for at least one minute at normal pressure and flow rate before drawing the **samples**. Samples should be collected using a “clean catch” technique to minimize potential contamination of the sample, leading to false positive results. Sample ports should not be disinfected. If a facility insists on disinfecting the ports, alcohol should be used and allowed to completely dry before the sample is drawn. Bleach or other disinfectants should not be used.[3]

2.6.1.2.3 Testing Methodology

Samples for bacteriological testing should be processed within 1-2 hours or refrigerated and processed within 24 hours. The AAMI standard recommends culturing samples of 0.5 to 1.0 cc for 48 hours at 35C, using tryptic soy agar as the culture medium. Filter membrane devices such as the Millipore paddles are acceptable, but require a solid QA program that includes sending duplicate samples to a lab annually. Techniques that should absolutely be avoided are the calibrated loop, and blood or chocolate agar. This is because calibrated loops have too small a sample size (either 0.01 or 0.001 cc), and the blood and chocolate agars are too nutrient rich for water borne bacteria, which would cause them to die rather than multiply. The testing of endotoxin is performed by the LAL test.[3]

2.6.1.3 Monitor The System Function:

The requirements to monitor the system function and chemical and microbiological contamination as shown in table(2.3).[7]

Table (2.3): Monitoring for a Clinic Water treatment System

Table 4. Monitoring tasks for a clinic water treatment system

Component	Monitor	What to Look For	How Often
Pretreatment			
Blending valve	Water temperature	Appropriate temperature (65–85°F)	Start of each day of operation
Booster pump	Water pressure	Pump turns on and off at appropriate times or flow rates	Periodically
Depth/multimedia filter	Pressure drop across device; backflush timer	Δ≤15 psi; set to backflush after facility operation hours	Start of each day of operation
Water softener	Pressure drop across device	Δ≤15 psi; timer always visible	Start of each day of operation
Water softener	Media regeneration time	Set to regenerate media with brine wash after facility operation hours	
Brine tank	Salt level in tank	Adequate amount of salt pellets; no salt bridge in the tank	Start of each day of operation
Carbon tanks	Pressure drop across device; backflush timer	Δ≤15 psi per tank; set to backflush after facility operation hours	Start of each day of operation
Carbon tanks	Chlorine and chloramine levels in the water between primary and secondary tanks	Total chlorine ≤0.1 PPM	Before the first patient treatment of the day and every 4 h after the first patient until the end of day
Reverse osmosis prefilter	Pressure drop across device	Δ≤20 psi	Start of each day of operation

Purification			
Reverse osmosis device	Percentage rejection level	≥90%	Start of each day of operation
Reverse osmosis device	Product water purity	Device sensors for conductivity and TDS are set according to the manufacturer's recommendations	
Distribution			
Distribution loop	Flow of water at end of the loop	>3 ft/s (indirect) >1.5 ft/s (direct)	Periodically
Bacterial cultures and LAL testing			
Reverse osmosis device, holding tank, and distribution loop	Water cultures	<50 CFU/ml	No less than one time per month
Reverse osmosis device, holding tank, and distribution loop	LAL testing for endotoxin	<1 EU/ml	
Chemical testing			
Source water entering the water treatment system; product water from the reverse osmosis product line	AAMI inorganic chemical analysis; contamination analysis	Chemical compounds below the AAMI safety thresholds for purified dialysis water[a]	Annually and when a new water system is installed, the reverse osmosis membrane is replaced, rejection is <90%, or there are seasonal changes in source water

PPM, parts per million; TDS, total dissolved solids; LAL, limulus amebocyte lysate; EU, endotoxin unit; AAMI, Association for the Advancement of Medical Instrumentation.

2.6.2The Maintenance

System maintenance includes replacement of exhausted components and preventive measures designed to sustain system performance. Ion exchange beds of softeners and deionizers, filters and carbon-adsorption beds have afinite capacity and must be regenerated or replaced.Reverse osmosis units also require regular cleansing and disinfection to remove organic materials, scale and bacteria .Maintenance of the system involves expenses in the supply of water and electricity, and expenditures for quality control measures like regular water cultures, laboratory analysis for water chemical contaminants, and end toxin assays. In addition, 1recurrent costs include the purchase of consumables including particle filters, salt tablets for the water softener, chemical sterility and test-strips, as well as the renewal of the RO membrane which needs to be replaced every 5 years or so[8]. Maintenance of a water treatment system as shown in table(2.4)[9].

Table(2.4): Maintenance of a Water Treatment System

Table 3 : Maintenance of A water Treatment System

Component	Monitoring Parameter	Maintenance required	Recommended Frequency
Depth Filter	Pressure drop across filter	Backwashing & Rinsing	Twice a week and daily during the monsoon or when water is contains extra suspended particles/impurities.
Activated Carbon Filter	Pressure drop across filter	Backwashing & Rinsing	Twice a week
Activated Carbon Filter	Chlorine in product water	Changing of charcoal	If > 0.1 µg/ml.
Softener	Hardness	Regeneration	Failure to achieve 10 fold decrease.
Membrane filters	Pressure drop across filter	Change of filter	➢ 25%
Reverse Osmosis membranes	Inlet, Reject and Permeate pressures & flows	Increase in inlet pressure > 25%., or decrease in permeate flow by 25%	Cleaning of membranes offline
Reverse Osmosis membranes	Conductivity	Increase by 50% from baseline	Cleaning of membranes offline or Replacement

CHAPTER THREE: BACK GROUND STUDIES

Paper One: Rebecca Layman-et al, (2015). This paper discussed that nurses are responsible for understanding all of the clinical requirement of water treatment and dial sate preparation for hemodialysis as a part of the entire dialysis treatment picture, also This paper describes the composition of water treatment systems for hemodialysis, as well as the monitoring and testing necessary to assure that both water and dial sate are safe for patient use .the outcome of study that by understanding water treatment system an operation and dialysate purity issues, the nuances of patient reactions, and communicating with technicians, nephrology nurses can contribute immensely to long-term positive outcomes for patient[2].

Paper Two: Mohmed Saleh et.al,(2015). The current study aimed to determine the chemical and physical quality of dialysis machines input water and compare it to the standard (AAMI) and European Pharmacopeias in Yazd educational hospitals. This research was conducted on 24 samples of dialysis machines input water, the SPSS V16.0 software was used for statistical analyses. The evaluation of hem dialysis water quality showed that these hospitals were not significantly polluted and the water quality complied with (AAMI) and Eph standard limit [10].

Paper Two: Ali Sharyari; et.al (2015) the objective of study was to investigate the chemical and bacteriological characteristics of water used in dialysis centers of five hospitals in Isfahan, central Iran.

Methods: A total of 30 water samples from the input of dialysis purification system and dialysis water were analyzed for chemical parameters. Heterotrophic plate count and end toxin concentration of drinking water, dialysis water and dialysis fluid of 40 machines were also monitor Dover a 5month period in (2011-2012).Results: Concentration of the determined chemicals (copper, zinc, sulfate, fluoride, chloramines and free chlorine) did not exceed the recommended concentration by the Association for the Advancement of Medical Instrumentation (AAMI) exclude lead, nitrate, Aluminum and calcium. Furthermore, the magnesium; cadmium and chromium concentration exceeded the maximum level in some centers. No contamination with heterotrophic bacteria was observed in all samples, while the AMMI standard for end toxin level in dialysis fluid (<2 EU/ml) was achieved in 95% of samples[11].

Paper three: Glenda Payne;**(**2016**)**Objectives of the study are describe basic water and dial sate safety and quality expectations and identify key actions technicians must take to maintain water and dial sate quality and safety**.** The method that used is questionnaire target the biomedical engineering in heamodialysis unit and the questioners question s contain the tests that should flow to monitor chemical and microbiological contamination and the actions that are taken if they exceed the standard limit.**[**12]

Paper four: Jim Curtis et.al (2018) the purpose of this guideline is to ensure that hemodialysis is performed safely and is compatible with professionally accepted current practice and local or internationally recognized standards.

The study discussed the Basic requirements in a water treatment system ,the components of Water Treatment System, and maximum allowable chemical, bacterial and endotoxin contamination[3].

Paper five: Michael A bbaszadeh ; et.al(2021) the aim of this study was to evaluate the chemical and microbial quality of inlet and outlet water of dialysis device in hospital of East Azebaijan Province .

Method and Material :This Study was descriptive analytical in which the water of dialysis ward of three hospitals .The result of chemical and microbial of dialysis water were extracted from the relevant archives in two stage before and after reverse osmosis treatment during(2014-2016).

Result   :Evaluation of efficiency of reverse osmosis system showed that there was a significant difference between water quality before and after the system [14].

Table (3.1) Conclusion of back ground studies.

Auther	**Work**	**Date**
Rebecca Layman; et al	The paper described the composition of water treatment systems for hemodialysis, as well as the monitoring and testing necessary to assure that both water and dial sate are safe for patient use.	2015
Mohmed Saleh ; et.al	24 samples of dialysis machines input water were used to determine the chemical and physical quality and the results compared with standard (AAMI) and European. The SPSS V16.0 was used for statistical analyses.	2015
Ali Sharyari; et.al	A total of 30 water samples from the input of dialysis purification system were analyzed for chemical parameters and the results compared with standard (AMMI).	2015
Glenda Payne	Used questionnaire target the biomedical engineering in heomodialysis unit to know key actions technicians that used to maintain water and dial sate quality and safety.	2016
Jim Curtis et.al	Made guideline discussed the Basic requirements in a water treatment system, components of Water Treatment System, and maximum allowable chemical, bacterial and endotoxin contamination.[12].	2018
Michael ; et.al	this study was to evaluate the chemical and microbial quality of inlet and outlet water of dialysis device in hospital of East Azebaijan, ANOVA were used for statistical analysis.	2021

CHAPTER FOUR: METHODOLOGY

4.1 Introduction

Water treatment plays a vital role in the delivery of safe and effective hemodialysis (HD). The role of biomedical engineering in maintain quality of water treatment is to monitoring the system function, monitoring chemical and microbiological contamination and maintenance the components of water treatment system to ensuring that water quality meets the American Association for the Advancement of Medical Instrumentation standards and recommendations that lead to reduce the incidence of chemical hazards and end toxemia associated with the use of water for HD.

4.2Design of Study

Two types of analysis were used to evaluate the water quality for hemodialysis by using questionnaire and chemical analysis for treated water.

firstly: Collection to the data related with the quality of water that use in hemodailysis department, and how can the biomedical engineering contributes to getting treated water in high quality by well monitor and maintained of water treatment system .

Secondly: 1**- Design of questionnaire questions**:

Questionnaire were used in previous studies as well as quality standards recommended (AAMI), after writing the questionnaire ,a number of copies were distributed to some of engineers in the field to know the clarity of questions.

Questionnaire was carried out targeting the bio medical engineers in 10 of total centers in Khartoum state to know the awareness of the health problems that may occur due to sub standard dialysate exposure, the testing regimes for monitoring the system function, chemical and microbiological contamination, contingency plans, and the improvement of the quality control program for hemodialysis.

2- Chemical analysis for treated water:

4.3 study of population:

10 of dialysis centers in Khartoum state for questionnaires and 5 dialysis centers for sample of treated water.

4.4 Collection of data:

50 questionnaires were distributed to biomedical engineering for collection the data, also five samples of treated water were collected from different locations of dialysis centers in Khartoum State for chemical analysis.

4.5Data analysis:

After collection of data (50 questionnaires and results of five samples of treated water) they were entered into the computer, and analysis by using SPSS program.

CAPTER FIVE : ANALYSIS RESULTS AND DISCUSSIN

5.1Analysis &Result:

5.1.1Result of Questionnaire: A questionnaire below is used as one method that mentioned in the methodology in paragraph (4.4) to assessment the quality of treated water that use in hemodialysis.

5.1.1.1 Substandard dialysate problems.

Table (5.1): Substandard daily sate problems.

Class	Frequency	Percent
Hemolysis, hypotension ,anemia ,and bone disease.	30	73%
Don't Know	11	27%
Total	41	100.0%

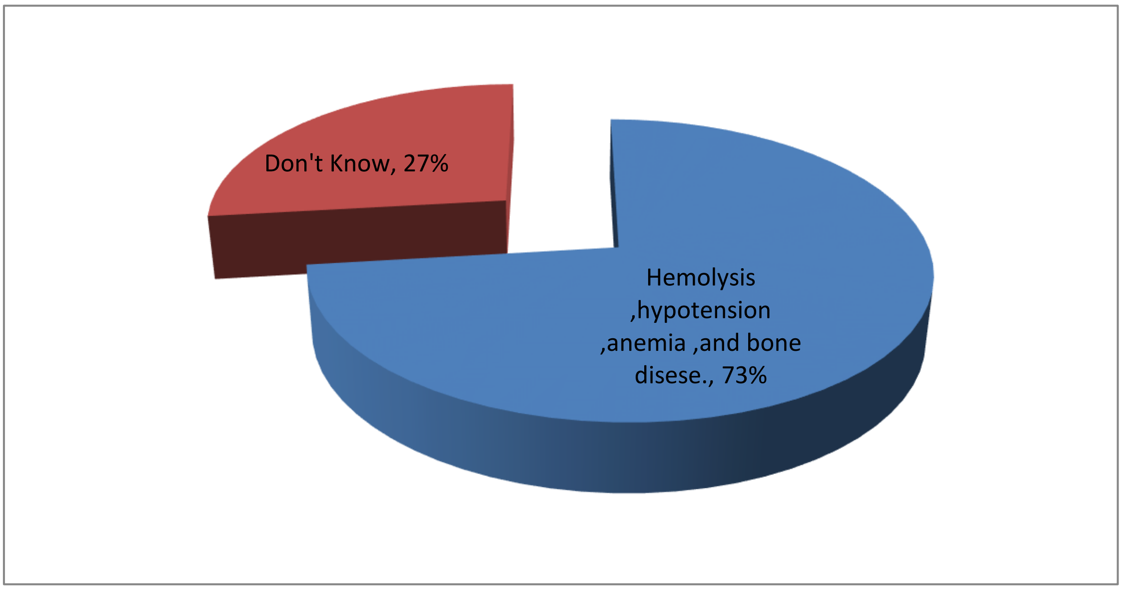


Figure (5.1): **Substandard dialysate problems**.

Result of Substandard dialysate problems : 27% Don't Know that means the biomedical engineers in some dialysis centers do not have enough knowledge about the problems that may occur due to substandard dialysate exposure that include:

C Hemolysis, hypotension, anemia ,and bone disease.

5.1.1.2Monitoring sediment filters function.

Table (5.2): Monitoring Sediment Filter Function.

Class	Frequency	Percent
Different pressure between inlet and outlet the filter (B)	41	100.0%
Total	41	100.0%

Result of Monitoring sediment filters function: The test is done to monitoring sediment filter function is B. Different pressure between inlet and outlet the filter. B is100% that means all the biomedical engineers knows the important of monitoring sediment filter function.

5.1.1.3Pressure difference in Sediment Filter.

Table (5.3): Pressure difference in Sediment Filter.

Class	Frequency	Percent
A. Back wash.	41	100.0%
Total	41	100.0%

Result of pressure difference in Sediment Filter :the action is taken if there is different pressure between inlet and outlet the sediment filter is back wash to clean the filter from Large particulates of 10 microns or greater that cause the supply water to be turbid – such as dirt. As show in table (**5.3**).A. Back wash is100% that mean all biomedical engineering know how to make the sediment filter working properly.

5.1.1.4 Back wash Sediment Filter.

Table (5.4): Back wash Sediment Filter

Class	Frequency	Percent
Daily	17	41%
Weekly	11	27%
If there is need	13	32%
Total	41	100%

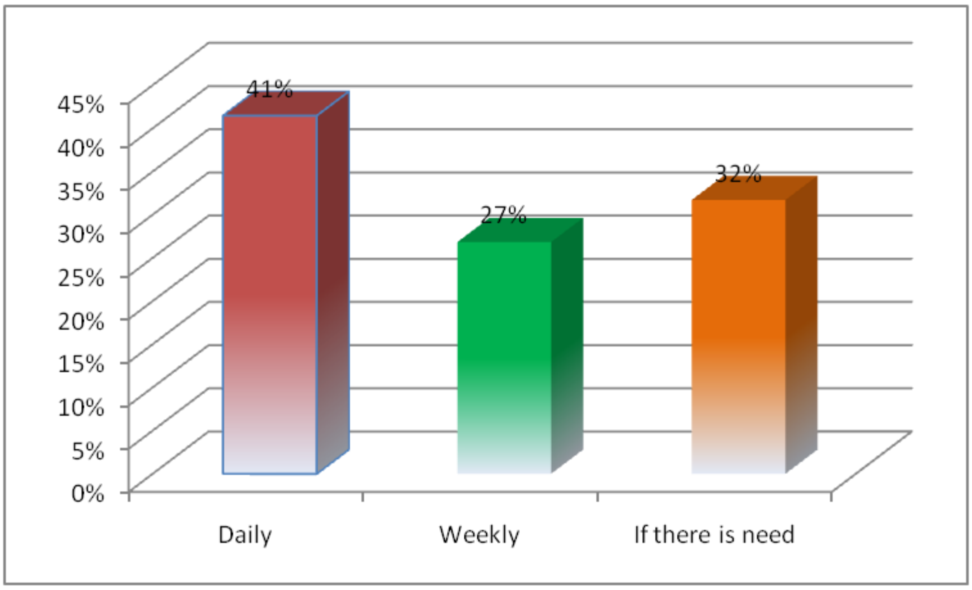


Figure (5.2): Back wash sediment filter

Result of backwash Sediment filter :by follow the standard recommendation(AAMI) the sediment filter must be back wash daily to insure that water is pure from the dirt's and to prevent other filters from clotting. Table (5.4) and figure (**5.2**) shows distributed of sample.

5.1.1.5Test to monitor the Softener Filter function

Table (55): Test to Monitor the Softener Filter function.

Class	Frequency	Percent
A. Different in pressure between inlet and out let the filter	24	59%
B. Hardness test	5	12%
C. No test is done	12	29%
Total	41	100%

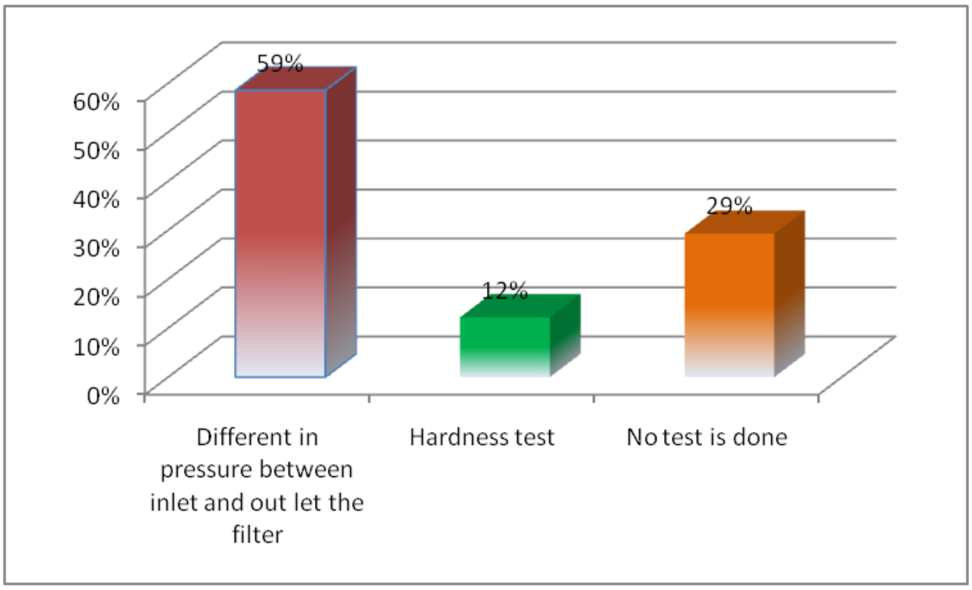


Figure (5.3): Test to monitor the softener filter function.

Result of test to monitor the softener filter function :(AAMI)standard to monitoring softener filter function are A and B. figure (5.3) showdistributed of sample, so there is need to rise the wariness to the important of monitoring the softener filter functions by using hard ness test. Hard water containing calcium and magnesium. Softeners turn hard water into "soft" water by removing the hardness and exchanging it for sodium.

5.1.1.6 Regeneration Softener Filter.

Table (5.6): Regeneration softener filter.

Class	Frequency	Percent
Every day or every other day.	21	51%
when required	20	49%
Total	41	100.0%

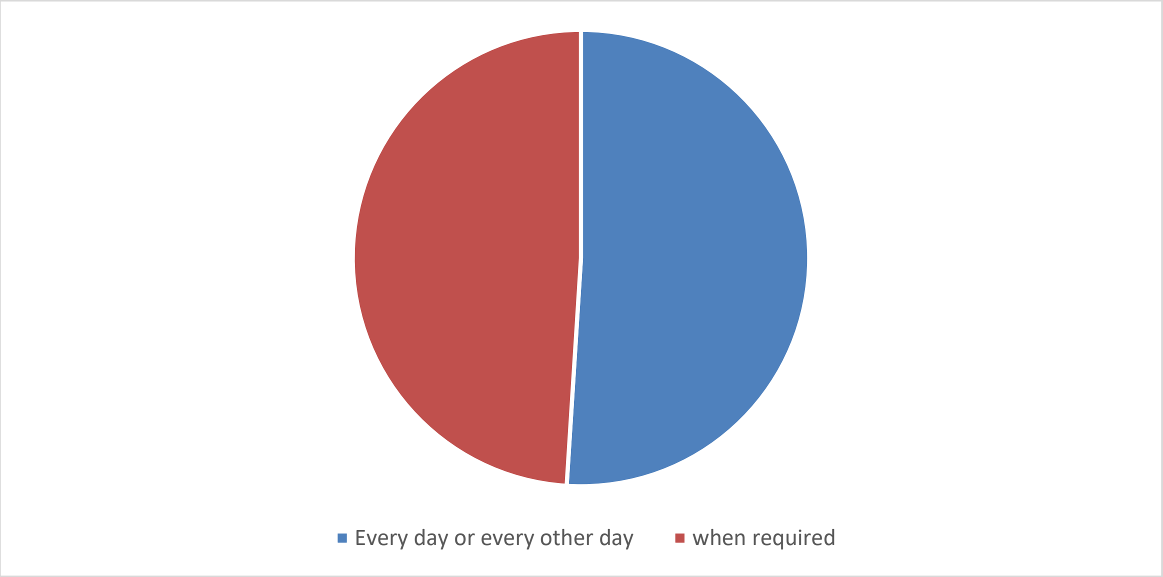


Figure (5.4): Regeneration softener filter.

Result of Regeneration softener filter :(AAMI) recommended that softener filter needs regeneration every day or every other day. Table (5.6) and figure (**5.4**) show distributed of sample, 49% when required that mean some renal centers need to make regeneration to softener filter regularly.

5.1.1.7Frequency to monitor the total Chlorine and Chloramines

Table (5.7): Frequency to Monitor the Total Chlorine and Chloramines.

Class	Frequency	Percent
Monthly	36	88%
Start of each day of operation	5	12%
Total	41	100.0%

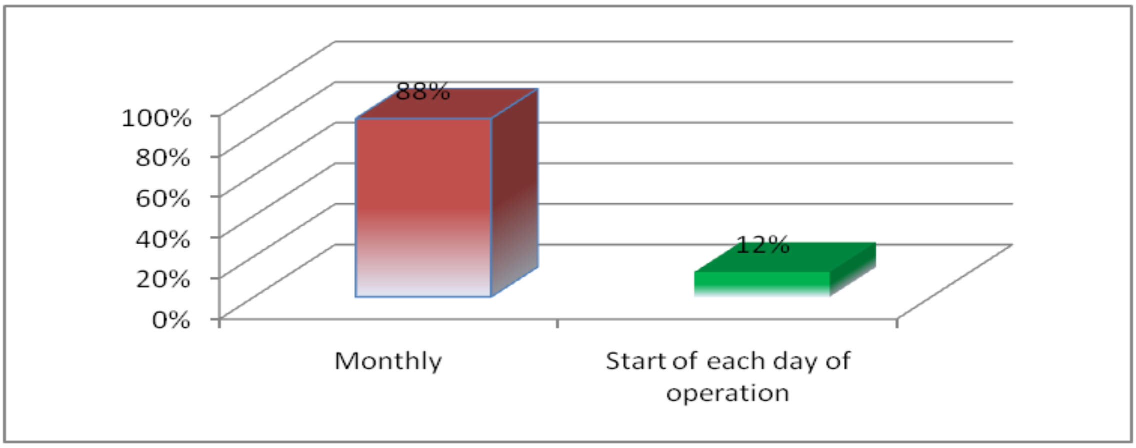


Figure (5.5): frequency to monitor the total chlorine and chloramines.

Result of frequency to monitor the total chlorine and chloramines. :(AAMI) recommended to monitor the total of chlorine and chloramines start of each day of operation .Table (5.7) and figure (5.5) show distributed of sample 88% of sample monitor the chlorine and chloramines monthly that means there is need to monitor the total chlorine and chloramines daily because there have been more reported incidents of hemolysis and related symptoms in patients due to chloramines.

5.1.1.8 **Level of pH in incoming water to Reserve Osmosis (RO).**

Table(5. 8): level of pH in incoming water to Reserve Osmosis (RO).

Class	Frequency	Percent
5-8	19	46%
Don't Know	22	53.7
Total	41	100%

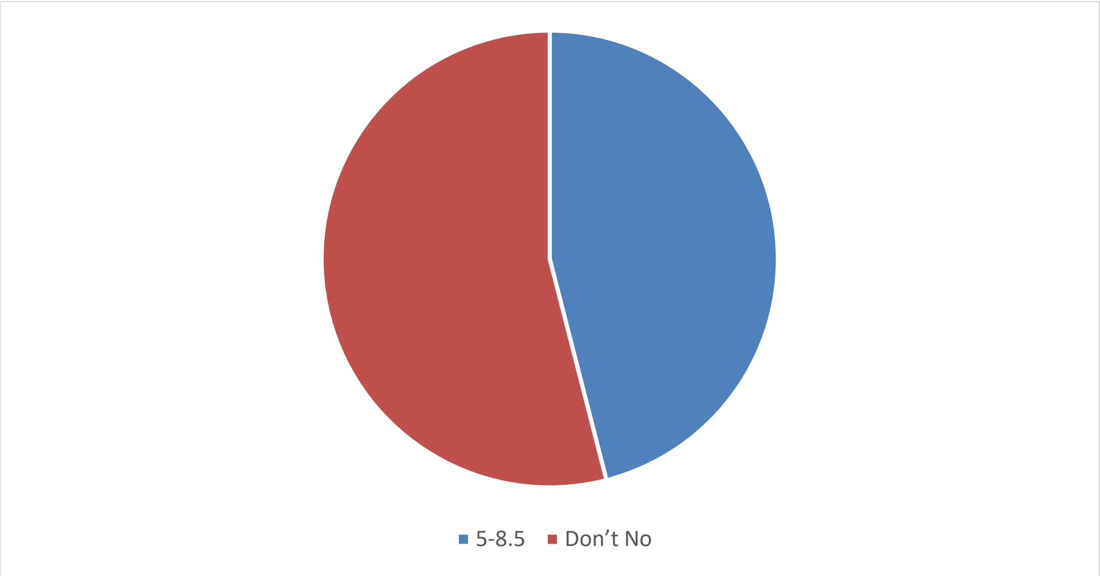


Figure (5.6): level of pH in incoming water to Reserve Osmosis.

Result of level of pH in incoming water to Reserve Osmosis (RO) :(AAMI) recommended that the level of PH in incoming water to reserve osmosis from 5-8.5 in order for the RO to operate properly, and carbon tanks to remove chlorine/chloramines effectively .Table (5.8) and figure (5.6) show 53% of engineers don’t know that means there is no monitor to PH.

5.1.1.9 Conductivity monitoring.

Table (5.9): Conductivity monitoring.

Class	Frequency	Percent
Daily	23	56%
via independent monitor	18	44%
Total	41	100%

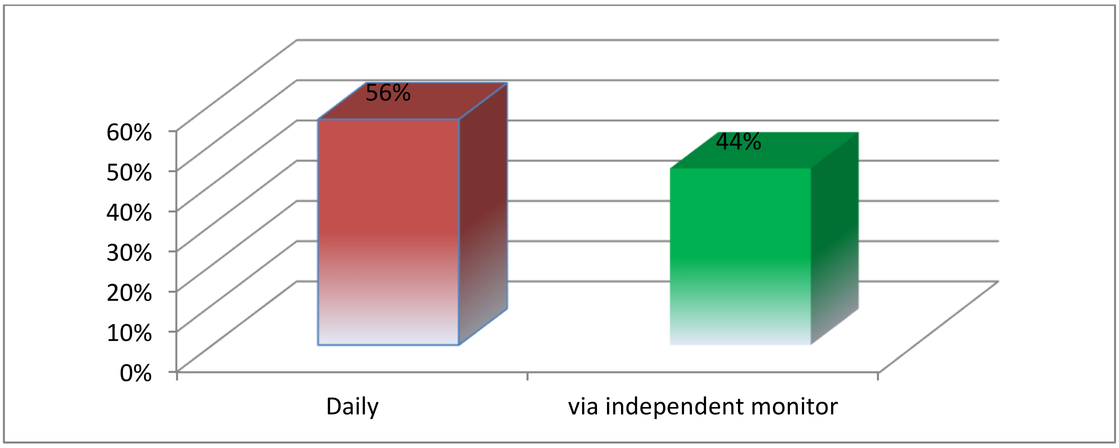


Figure (5.7): Conductivity monitoring.

Result of Conductivity monitoring :(AAMI) recommended to monitoring the Conductivity daily .Table (5.9) and figure (5.7) show that 44% via independent monitor that mean Centers need to monitor the level of Conductivity in Reserve Osmosis (RO) regularly to insure that it works properly.

5.1.1.10The disinfect in Reserve Osmosis(RO).

Table (5.10): The frequency disinfect in Reserve Osmosis (RO).

Class	Frequency	Percent
Monthly	21	51%
every three month	7	17%
. If there is need.	13	32%
Total	41	100%

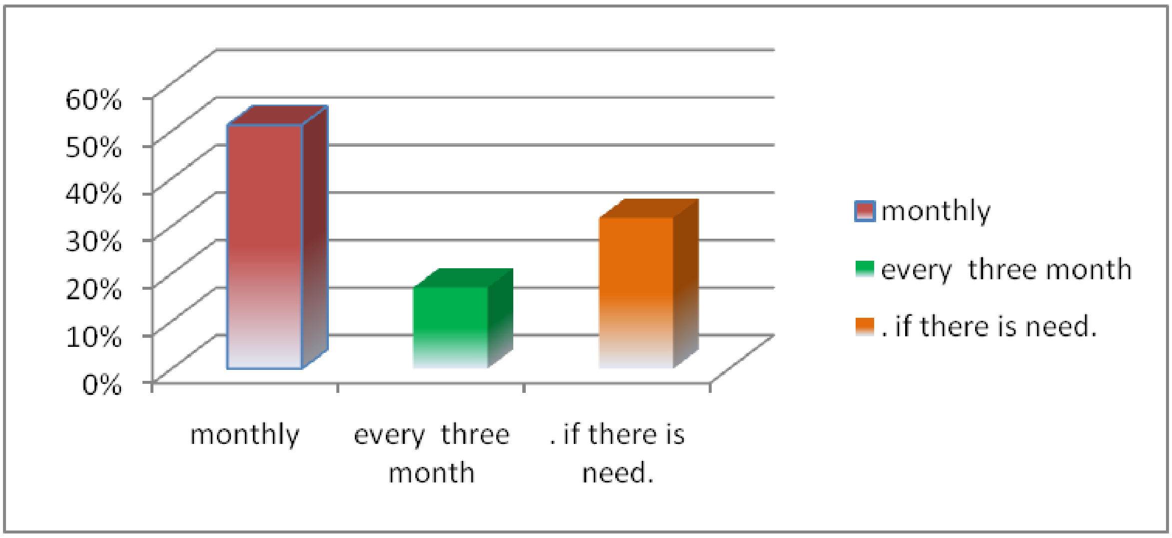


Figure (5.8): The frequency disinfect of (RO).

Result of the frequency disinfect of Reserve Osmosis (RO): (AAMI) recommended that the RO needs disinfection every month. Table (5.10) and figure(5.8) show that 51% of dialysis centers are interested in cleaning the RO every month, on the other hand in some dialysis centers there is a need to purge the RO periodically ,not only when needed.

5.1.1.11 an audible alarm of poor water quality.

Table (5.11): an audible alarm of poor water quality.

Class	Frequency	Percent
Yes	1	1%
No	40	99%
Total	41	100%

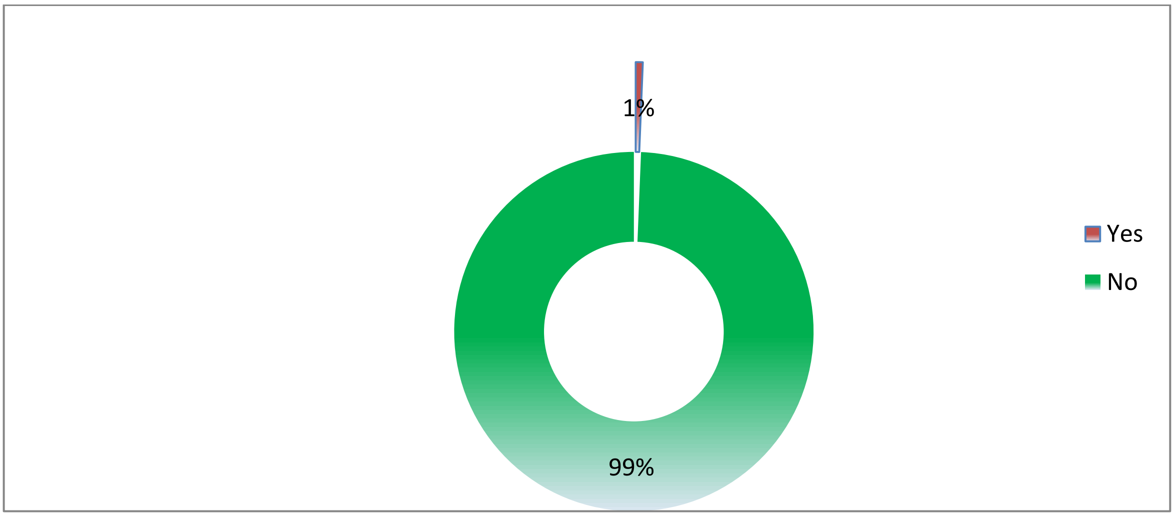


Figure (5.9): an audible alarm of poor water quality.

Result of audible alarm of poor water quality: 99% there is no using of an audible alarm to notify staff in the patient treatment area of poor water quality can help to know if there is problem in water treatment system also can prevent the dialysis machine from exposure to excess salts cause disruption over time.

5.1.1.**12Who is determined the set point for water quality alarm**?

Table (5.12): who is determined the set point for water quality alarm

Class	Frequency	Percent
the quality control management In ministry of health	31	76%
follow the world standard(AAMI)	10	24%
Total	41	100.0%

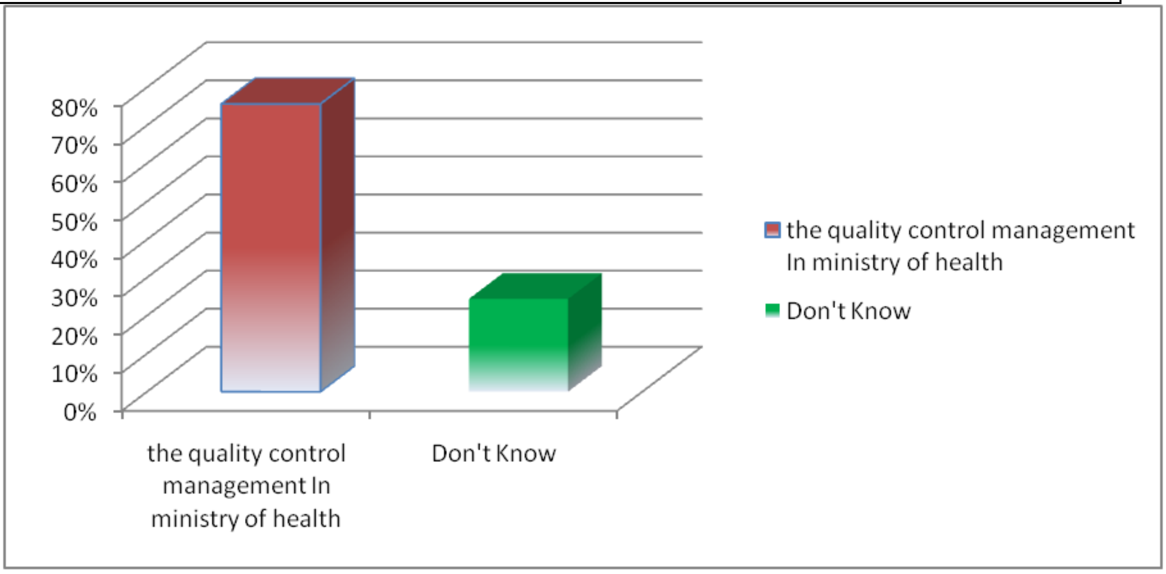


Figure (5.10): who is determined the set point for water quality alarm

Result of who is determined the set point for water quality alarm: 24% of biomedical engineers work in dialysis centers is interesting to follow the world standard (AAMI).

5.1.1.13 Chemical analysis to treated water.

Table (5.13): chemical analysis to treated water.

Class	Frequency	Percent
Yes	10	24%
No	31	76%
Total	41	100%

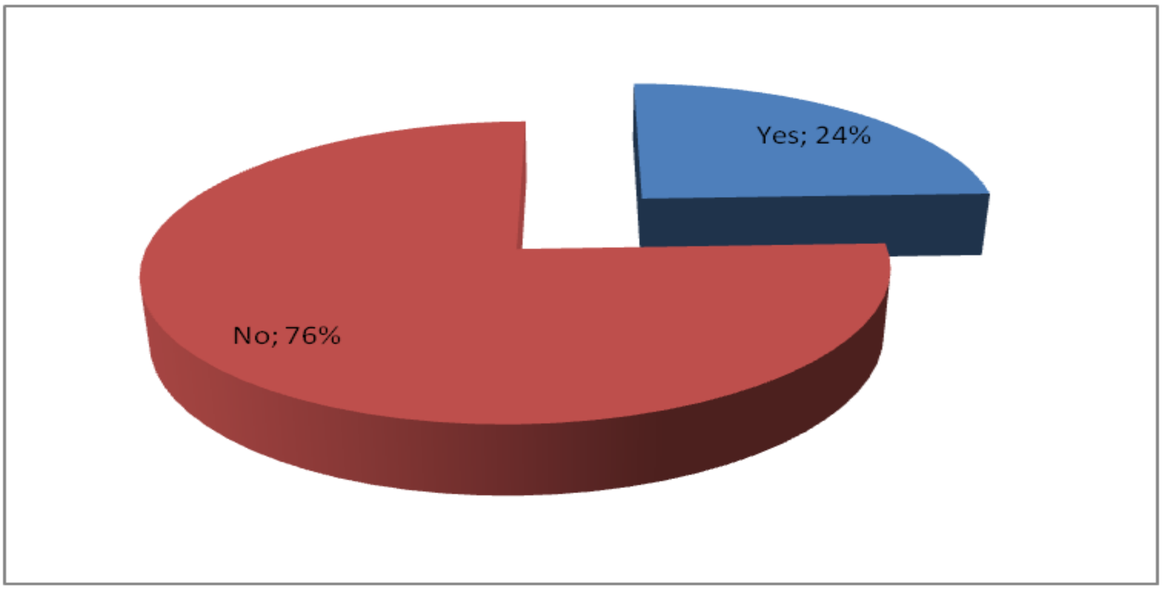


Figure (5.11): Chemical analysis to treated water.

Result of Chemical analysis to treated water: 76% there is no chemical analysis to treated water in dialysis centers**24%** of engineer's answer there are chemical analysis in their centers**.**

5.1.1.14Frequency of chemical analysis to treated water.

Table(5.14) frequency of chemical analysis to treated water.

Class	Frequency	Percent
At least annually and when RO membrane are replace and with seasonal change	10	24%
Don't done	31	76%
Total	41	100%

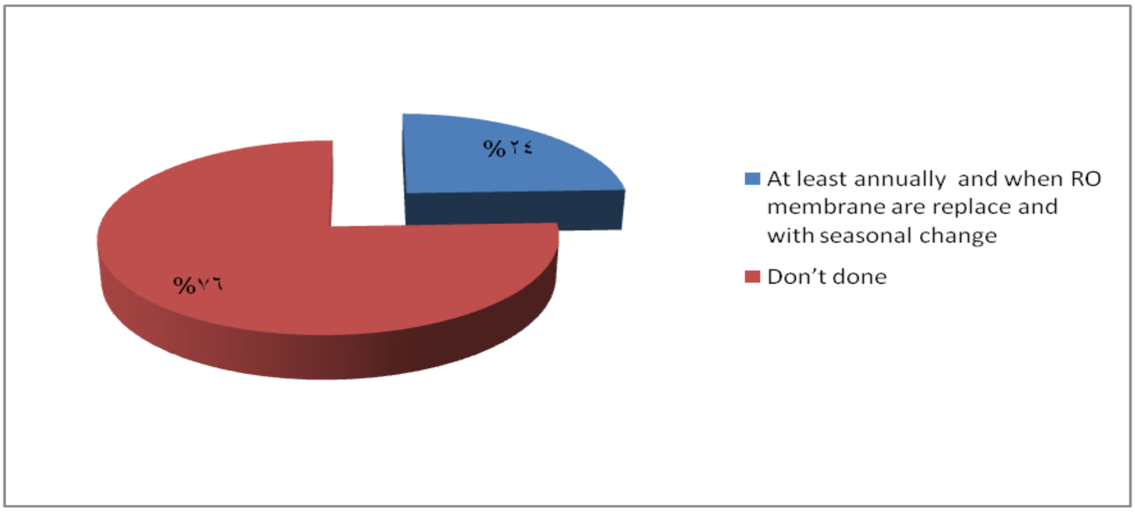


Figure (5.12): Frequency of chemical analysis to treated water

Result of frequency of chemical analysis to treated water:(AAMI) chemical analysis of water for hemodialysis shall be performed at least annually and when RO membrane are replace and with seasonal change .Table(5.14) and figure (5.12) show 24% of the biomedical engineers follow the(AAMI).

5.1.1.15Samplescollects of water and daily sate.

Table (5.15): samples collect of water and dialysate.

Class	Frequency	Percent
A-at the beginning of water treatment system	0	0
B-After (RO)system	24	59%
C-A and B	17	41%
Total	41	100%

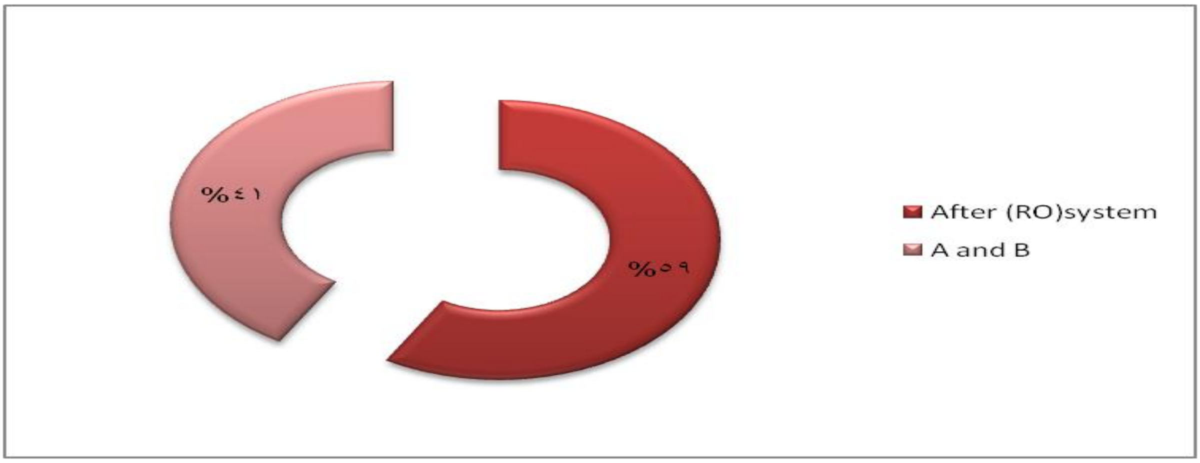


Figure (5.13): samples collect of water and dial sate.

Result of samples collect of water and daily sate:(AAMI) recommended that the samples of water and dial sate are collected at the begging of the water treatment system and After (RO) system. Table (5.15) and figure (5.13) show distributed of sample.

5.1.1.16Contingency plans in case of failure of critical components of the system.

Table (5.16): contingency plans in case of failure of critical components of the system.

Class	Frequency	Percent
No	31	76%
Yes	10	24%
Total	41	100%

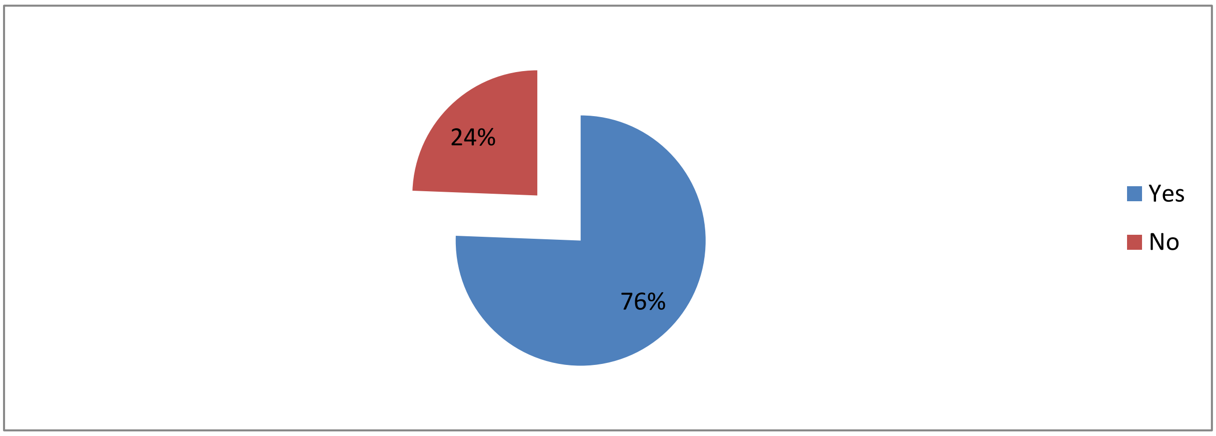


Figure (5.14): Contingency plans in case of failure of critical components of the system.

Result of Contingency plans in case of failure of critical components of the system. : 76% of biomedical engineers answer there are no contingency plans, this indicates that there is a need for contingency plans to ensure continuity of the work in the water treatment system.

5.1.1.17Suggestion to improve the quality of treated water to standard world

Table (5.17): suggestion to improve the quality of treated water to standard world (AMMI).

Class	Frequency	Percent
A-Provide training course for biomedical engineering	-	-
B-Provide financial facilities for maintenance	5	12%
C-Raising ware ness to important of use treated water	-	-
D-A , B and C	36	88%
Total	41	100%

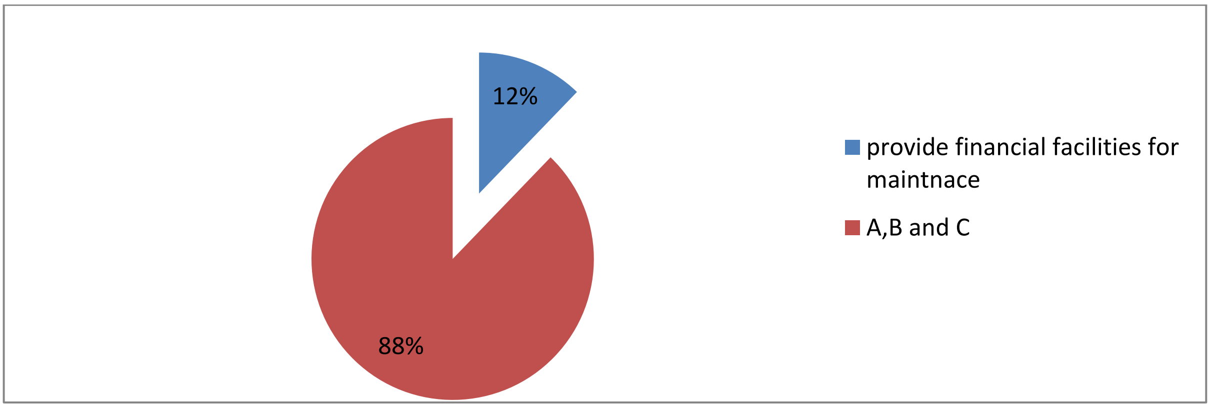


Figure (5.15): suggestion to improve the quality of treated water to standard world (AMMI).

Result of suggestion to improve the quality of treated water to standard world (AMMI):88% A, Band C. (A) provide training course for biomedical.

(B) Provide financial facilities for maintenance.

(C) Raising awareness to the important of use treated water safety for use**.**

Table (5.18): different questions for hemodialysis(HD).

No	**Item**	Yes	No
		Frequency	Frequency
		Percent	Percent
7	is there testing for total chlorine and chloramines to treated	41	0
		100%	0%
11	If there a chemical injection on the system to adjust pH?	0	41
		0%	100%
12	Is there disinfection to Reserve Osmosis system (RO)?	41	0
		100%	0%
17	Is there DI system in use or planned to back up the RO?	0	41
		0%	100%
22	Is there monitoring to water temperature in system?	0	41

5.1.2Result and analysis of examination of filtered water:

Analysis of examination of filtered water is used as second method that mentioned in the methodology in paragraph (4.4) to assessment the quality of treated water that use in hemodialysis. Five samples (A, B, C, D and E) of treated water from five dialysis centers in Khartoum state were collected in the period from February to September 2021, and analyized by specific chemical laboratory (STAC LABROTORY). The results were compared with standard world (AMMI) and the data which explained in chapter one about the water treatment system, and a analyzed By using the *Statistical Package for the Social Science (SPSS).(SPSS)*is one of statistical analysis methods that used to analysis data's, one of its methods *is* Analysis of Variance (ANOVA).

Table (5.19): Result of examination of filtered water.

Element	Standard Mg/l	A	B	C	D	E
Calcium (Ca)	**0.2**	**2**	**2**	**0.2**	**2.5**	**2**
Magnesium (Mg)	**1.2**	**2**	**2**	**1.1**	**2.5**	**0.5**
Potassium (K)	**1.6**	**0.2**	**0.4**	**0.9**	**0.6**	**0.2**
Sodium (Na)	**2.0**	**2**	**2**	**2.5**	**4**	**3**
Nitrate (N)	**2.0**	**ND**	**ND**	**ND**	**ND**	**ND**
Fluoride (F)	**0.2**	**0.15**	**0.15**	**0.17**	**0.19**	**0.3**
Sulfate (So4)	**1.0**	**1.0**	**1.0**	**0.9**	**2.00**	**ND**
Chloride (Cl)	**0.5**	**1.0**	**2.0**	**0.4**	**2.5**	**1**
Aluminum(AL)	**o.o1**	**ND**	**ND**	**ND**	**ND**	**ND**
PH.	**5-8.5**	**6.9**	**7.03**	**6.5**	**9.1**	**6.35**

ND :Not detected.

5.1.2.1 The devices and methods that used to measuring the concentration of elements of sample:

- **Aflame photometer device:** for Sodium and potassium, it depend on the emission, the higher concentration of the element in the sample the higher flame.
- **Spector photometer device:** for Ammonia, nitrite (No2) and nitrate (No3).It depend on the absorption, the higher concentration of the element in the sample the higher absorption.
- **Tri Turbidity meter device: for** sulfate.

- **The titration method** was used to know the concentration of the flowing elements: Calcium and Magnesium with a solution EDTA (Ethylene Damien Tetra Acid) 0.01 concentration.
  - Chloride using Silver nitrate solution 0.0141concentration.

5.1.2.2Analysis of Variance (ANOVA):

ANOVA analysis used in this case to study the effect of one factor that has a number of different effect levels. It analyzes the variance between dependent variables in relation to one independent variable. After knowing the existence of the difference, it is possible to trace the difference and its source.

Table (5.20): result of ANOVA test for five samples.

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
A	Between Groups	37.500	6	6.250	1.389	.571
B	Between Groups	31.500	6	5.250	1.167	.610
C	Between Groups	27.000	6	4.500	1.000	.644
D	Between Groups	37.500	6	6.250	1.389	.571
E	Between Groups	37.500	6	6.250	1.389	.571

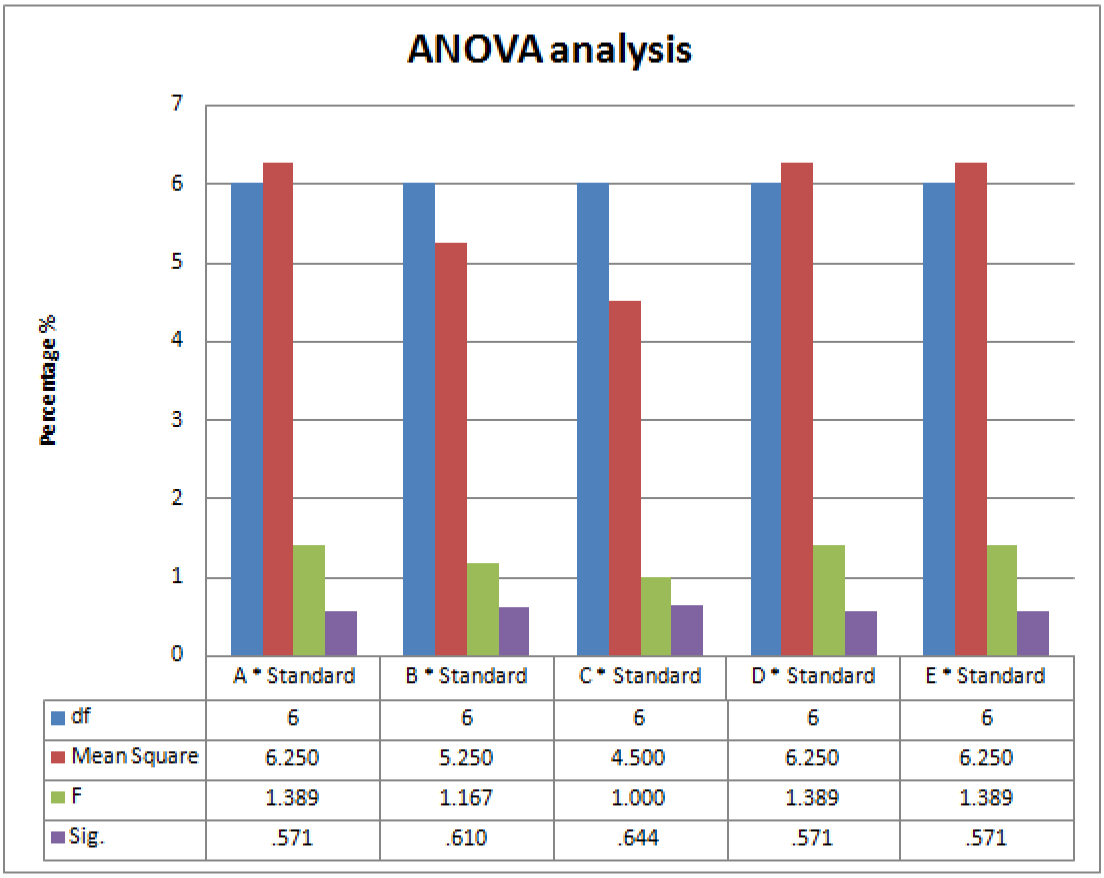
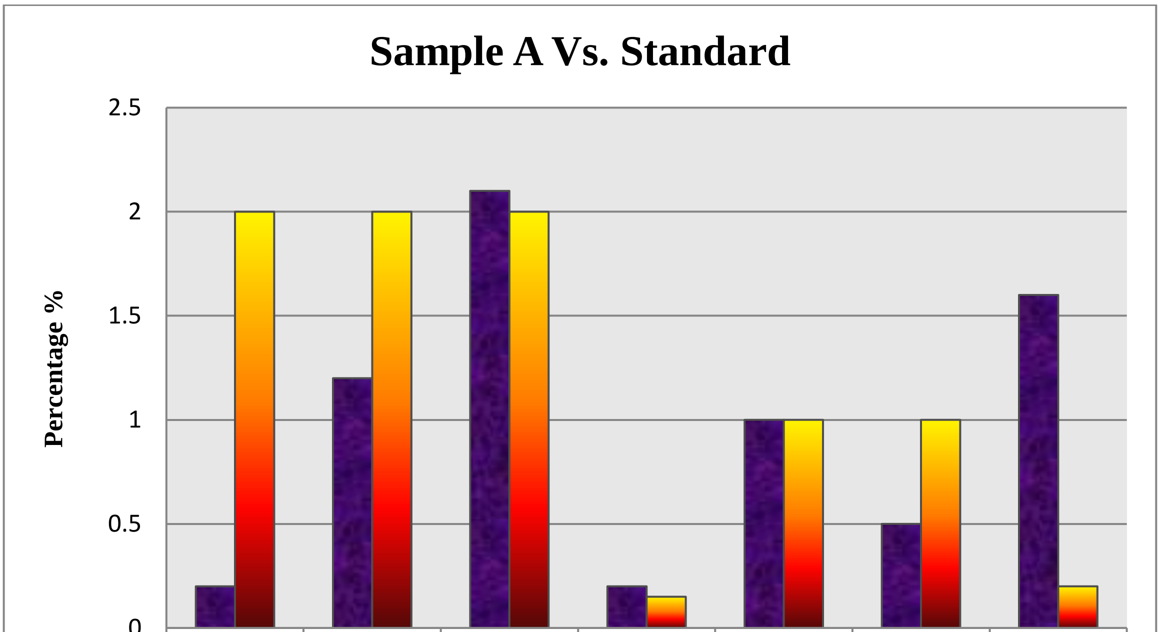


Figure (5.16) result of ANOVA test for five samples.

From the previous results, we conclude the following :By analyzing of water samples found that there are differences between the averages of the five samples of water. In other side through the level of significance ($\alpha = 0.05$) we accept the initial hypothesis, which it says that the degree of freedom (F) is equal or less than one (F= or<1) there is purity of water, except that the treated water is not pure .By observing to the table above found that there are a great degree of freedom appear between the samples.

5.1.2.3Result of Chemical analysis for sample (A,B.C.D and E) VS standard:

The result of chemical analysis for samples (A,B .C.D and E) show in table(5.19) was compared with standard as show in table (2.2) and the results show in figures blow.



	Calcium	Magnesium	Sodium	Fluoride	Sulfate	Chloride	Potassium
Standard	0.2	1.2	2.1	0.2	1	0.5	1.6
A	2	2	2	0.15	1	1	0.2

Figure (5.17) Chemical analysis for sample A.

Result of Chemical analysis for sample A:Figure(5.17)show increasing in salts percentage for(Ca, Mg, CL)compare with (AMMI)standard, that mean the treated water isn't accept, and that agree result of ANOVA analysis for sample(A)which has a degree of freedom(1.389)depend on our hypothesis it isn't pure water because the degree of freedom greater than one(F>1)**).**.

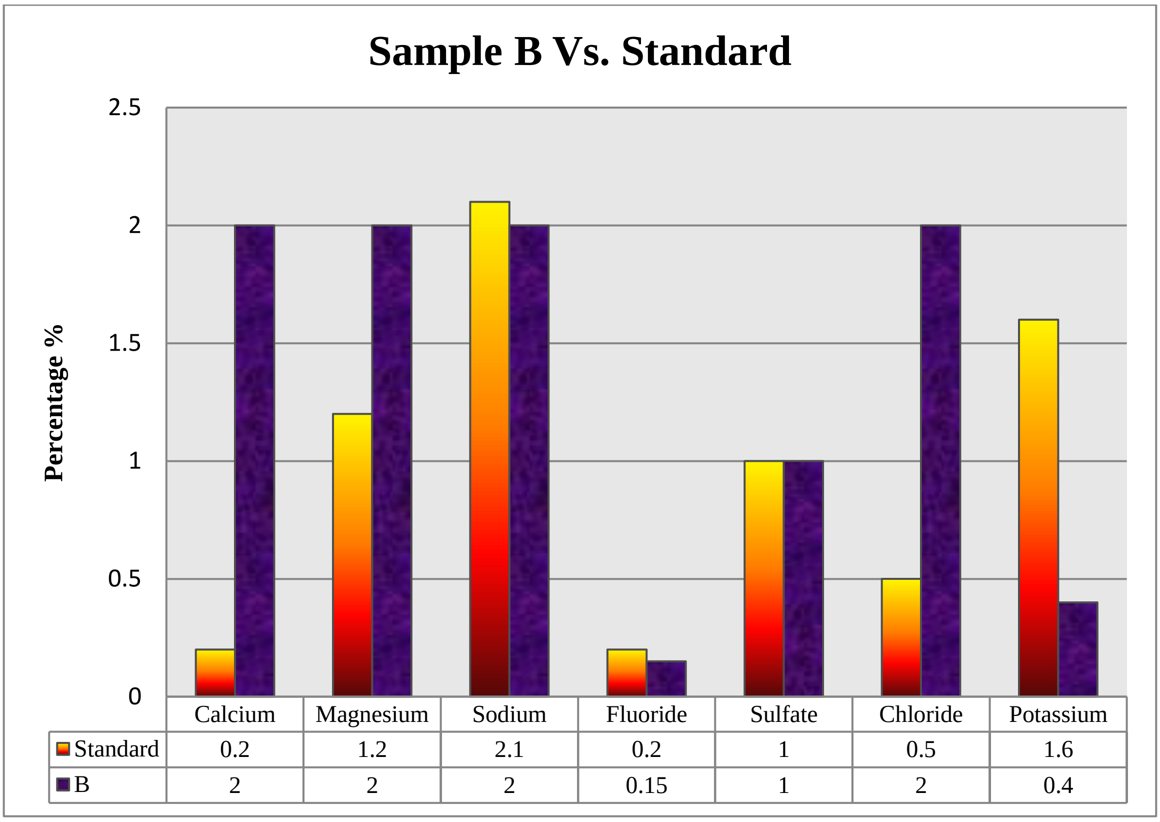


Figure (5.18) Chemical analysis for sample B.

Result of Chemical analysis for sample B: Figure(5.18)show increasing in selats percentage for**(Ca ,Mg, CL)** compare with (AMMI)standard, that mean the treated water isn't accept, and that agree result of ANOVA analysis for sample(B)which has a degree of freedom(1.167)depend on our hypothesis it isn't pure water because the degree of freedom greater than one(F>1**).**

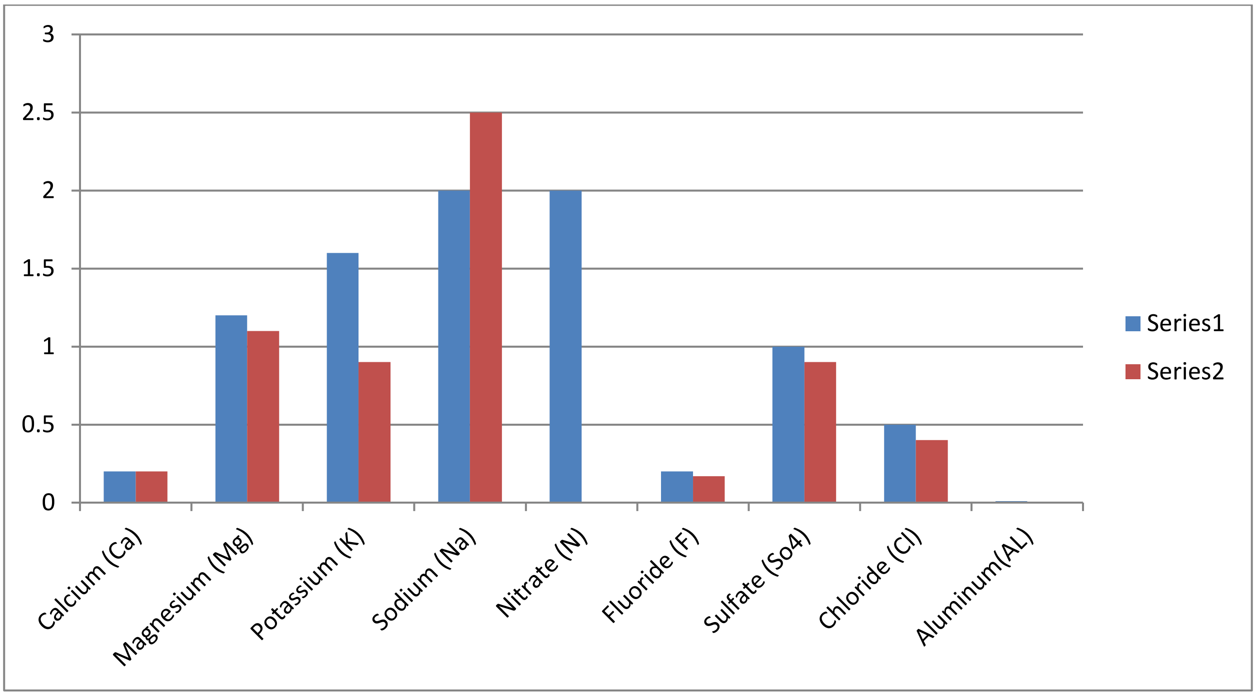
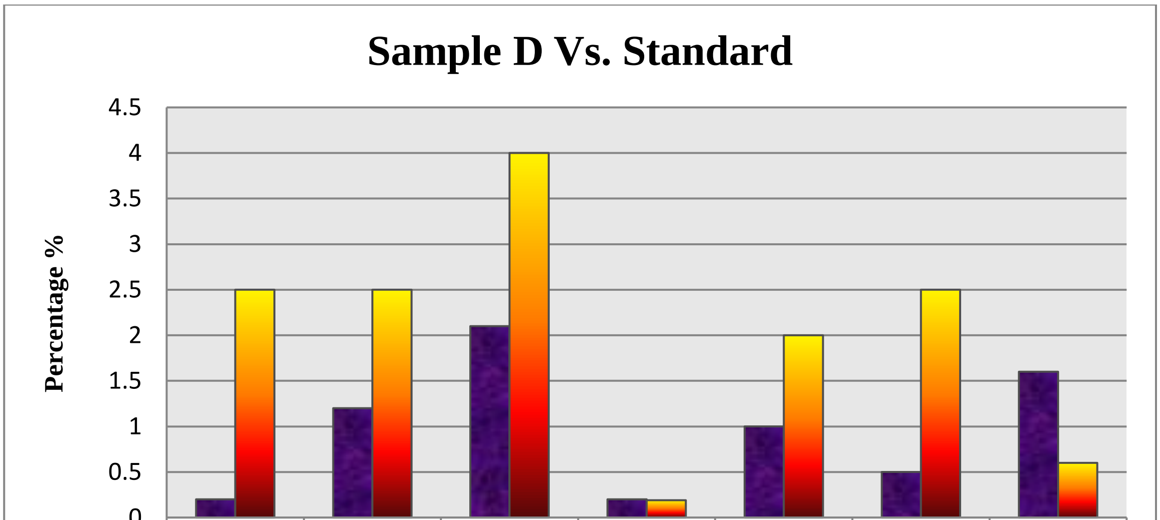


Figure (5.19) Chemical analysis for sample C.

Result of chemical analysis for sample C: Figure (5.19) show that salts percentage are less than (AMMI) standard, that mean the treated water is accept, and that agree ANOVA analysis for sample(C) which has degree of freedom (F=1), depend on hypotheses the degree of freedom is equal or less than one (F<=1) the **sample C is** accept water because**.**

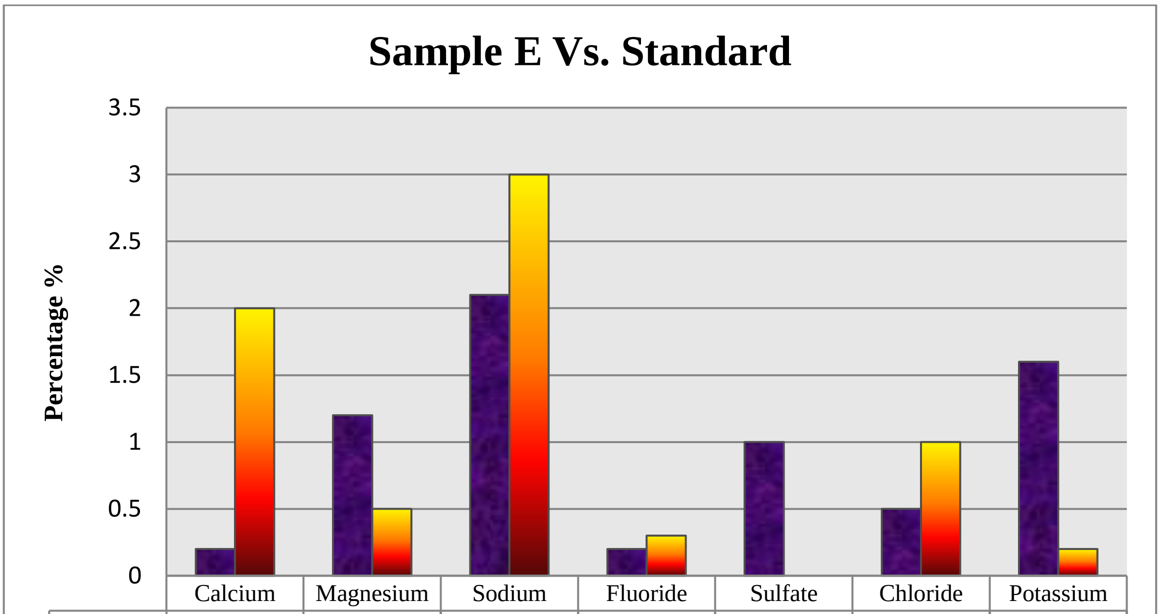


	Calcium	Magnesium	Sodium	Fluoride	Sulfate	Chloride	Potassium
Standard	0.2	1.2	2.1	0.2	1	0.5	1.6
D	2.5	2.5	4	0.19	2	2.5	0.6

v

Figure (5.20) Chemical analysis for sample D

Result of chemical analysis for sample D: Figure (5.20) Shows that there was increasing in salts percentages for (C**alcium (Ca), Magnesium (Mg), Chloride (CL), Sulfate (So4) and Sodium (Na))** comparing with the standard sample (AMMI). Which it explain that the treated water was-not accept, and that agree the ANOVA analysis for sample(B)which has a degree of freedom (1.389),depend on hypothesis it isn't accept water because the degree of freedom greater than one(F>1**).**



	Calcium	Magnesium	Sodium	Fluoride	Sulfate	Chloride	Potassium
Standard	0.2	1.2	2.1	0.2	1	0.5	1.6
D	2	0.5	3	0.3	0	1	0.2

Figure (5.21) Chemical analysis for sample E

Result of chemical analysis for sample E:Figure(5.21)show increasing in salts percentage for(Ca ,Mg, CL) compare with (AMMI)standard ,that mean the treated water isn't accept, and that result ANOVA analysis for sample(B)which has a degree of freedom(1.389),depend on hypothesis it isn't pure water because the degree of freedom greater than one(F>1**).**

5.2 Discussion:

By Analyzing the questionnaire found that the most important problems that prevent to have effective quality control program for water treatment system are:

- Some of biomedical engineers that work in dialysis centers do not have sufficient knowledge of health problems that may be caused by using substandard daily sate.
- the tests are to monitor the work of the water treatment unit are not periodically conducted in some centers to identify the problems at the beginning and thus take the necessary measures .the tests are pressure between inlet and out let the filters, hard ness test to know the level of magnesium and calcium, monitor the total of chlorine and chlormine, the PH and temperature to incoming water to RO, and the conductivity in RO.
- In the most dialysis centers there are no monitoring to chemical contamination by making chemical analysis to treated water.
- In the most dialysis centers there is no contingency plans as what to do in case of no incase of failure of critical components of the system.
- Lack of training opportunities for biomedical engineers and financial facilities for maintenance.
- on the other hand by analyze the questionnaire found that there are monitoring to microbiological contamination in all dialysis centers, and the quality control programs in some centers to monitoring operation ,chemical contamination are meet standards for quality(AAMI) ,also the procedure for maintenance of the water treatment system are enough to insure that system work properly.

Also by analyzing the results of five samples (A, B, C, D, and E) found that:

- In samples (A,B,D and E) was shown increasing of concentration Ca and Mg compared with standard(AMMI),that mean the Softener filters in water treatment system belong to the centers (A,B,D,E) aren't efficiently work, while the goal of the softener filter to remove the metals (Ca, Mg) from treated water ,to solve this problem the filter must be monitored the drop of pressure (inlet and out let filter), the range of the salt in the brain tank, and also by interring the filter to regeneration process to remove (Ca and Mg) and change them with Sodium(Na) .To avoid this problem the hard ness test must be done daily or every other day to insuring that the filter is work efficiently.

- In the collected samples (A, B, D and E) increasing of chloride was found that means the Carbon filter wasn't efficiently work. The total chloride(Cl) and chloramines test must be done daily to monitoring the work of Carbon filter, and in this case the excepted value of the test more than the standard value (0.05) so to solve this problem change the charcoal in filter.
- In collected sample (E)beside the increasing of the salts(Ca ,Mg and Cl)the values of salts (Na, Sulfate) was also increase that means the work of (RO) is not good, so there is need to clean and disinfect the (RO) membrane .
- In the collected sample (C) the concentration of salts in the sample less or equal to standard, so that means the sample is accepted.
- Refer to table(2.1) the respect diseases problem that may occur due to substandard dialysate fluid are:
    - In Centers (A, B, D) Nausea, Vomiting and Anemia.
    - In Center (E) Nausea, Vomiting, Anemia, Metabolic Acidosis and Hypertension.

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 Conclusion:

Water treatment system play role in safe and effective hemodialysis .through this research the requirements of dialysis water purification was discussed .To assess of Water quality of dialysis, a questionnaire was conducted targeting the medical engineers working in 10 of dialysis centers in state. The questionnaire included the types of tests carried out to monitor system efficiency and control of microbial and chemical contamination, as well as questions to identify the most important problems facing dialysis centers and prevent the application of quality control program.

Analysis of the questionnaire found that the most important problems are:

- The tests for monitor the function system are not periodically conducted in some centers.
- In the most dialysis centers is no monitoring to chemical contamination and contingency plans, but on the other hand there is monitoring to microbiological contamination.
- Lack of training opportunities for biomedical engineers, and financial facilities for maintenance.
- By analyzing the result of questionnaire found that 38% of dialysis centers are following the recommendations of (AAMI).
- Also by analysis the result of sample form five dialysis centers found that 80% of samples aren't pure and that meet the research problem statement there is lack of purity of treated water for hemodialysis.

6.2Recommendation:

To improve the quality of treated water to standard world that lead to produce good health care there is needs to:

- Develop the water treatment system in all dialysis centers by introducing systems to monitor and control the temperature, PH to incoming the RO such as using chemical injection system.
- Attention to monitor chemical contamination through full chemical analysis to treated water and compare the results with the standard.
- After purchasing water treatment system, the vender must tracking maintenance periodically to evaluate water quality, and provide tools to measuring hardness, PH, total chlorine and chloramine.
- Develop a protocol by the responsible authority at Ministry of Health to assess the quality of water used in dialysis, one of its clauses obligating engineers to make report containing microbial and chemical analysis of treated water.
- To insure the efficiency of water treatment system detection of elements ratio in human body must be take before and after hemodialysis process.
- Use technician to know the chemical elements concentration with way to comparing the results with standard world and display the result digital with audible alarm, uses any laser technique like LIBS.

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APPENDIX

SUDAN UNIVERSITY OF SCIENCE TECHNOLOGY

College of Graduate Studies

M.sc of Bio Medical Engineering

Questionnaire about: assessment of water quality for hemodailysis

1. Potential acute or chronic problems that may occur due to sub standard dailysate exposure include:

A. Hemolysis and hypotension only.

B. Hemolysis , hypotension , anemia and bone dieses.

C. Don’t know.

2. what test is done to monitoring sediment filter function?

A. Hard ness test.

B. Different pressure between inlet and outlet the filter.

C. Test for total chorine.

3 .what action is taken if there is Different pressure between inlet and outlet the sediment filter.

A. back washes.

B. Change the filter.

C. No action to do.

4. How often does sediment filter back wash?

A. Daily B. Weekly C. Monthly. D .If there is need

5. Whattest is done to monitor the softener filter function ?

A. Different in pressure between inlet and out let the filter.

B. Hardness test.

C. A and B.

D. No test is done.

6. How often does the softener filter need regeneration?

A. Every day or every other day.

B. Monthly.   C. when required.

7 .Is there   testing for total chlorine and chlormine to treated water?

A. Yes   B. No

8. When is the test done?

A. Weekly   B. Monthly   C. Start of each day of operation

9. What level of pH in incoming water to reserve osmosis (RO) should be?

A. 9   B.5-8   C .Don't know.

10. How often is pH monitoring?

A. Each shift   B .Daily   C. via independent monitor.

11. If there a chemical injection on the system to adjust pH?

A. Yes   B. No

12. Is there disinfection to Reserve Osmosis system (RO)?

A. Yes   B. No.

13. How often does the (RO) disinfect?

A.monthlyB. every three month. C. if there is need..

14. Is there an audible alarm to notify staff in the patient treatment area of poor water quality?

A. Yes   B. No.

15. Who is determined the set point for water quality alarm?

A. The quality control management in hospital.

B. the quality control management In ministry of health.

C. following the world standard

16.Is there DI system in use or planned to back up the RO?

A. Yes B. No.

17.Is there chemical analysis to treated water that use for hemo dialysis?

A. Yes B.N0

18 .How often is chemical analysis of water for hemodialysis shall be performed?

A. At least annually.
B. At least annually and when RO membrane are replace.
C. At least annually and when RO membrane are replace and with seasonal change.

19. How are samples of water and dialysatecollected?

A . At the begging of the water treatment system.

B. after (RO) system. C. A and B.

20.Is there monitoring to water temperature in system?

A. Yes B. NO

21. How often is test of microbiological done?

A. Monthly B. every six month. C.Annually

22. Is there contingency plans as what to do in case of no incase of failure of critical components of the system?

A. Yes B. No

23. What do you think needs to improve the quality of treated water to standard world that lead to produce good health care? A. provide training course for biomedical.

B. provides financial facilities for maintenance.

C. Raising awareness to the important of use treated water safety for use.

D.A, B and C

Thank you for your cooperation

بسم الله الرحمن الرحيم

THE REPUBLIC OF THE SUDAN	جمهورية السودان
FEDERAL MINISTRY OF HEALTH	وزارة الصحة الاتحادية
NATIONAL PUBLIC HEALTH LABORATORY	المعمل القومي للصحة العامة
NATIONAL CHEMICAL LABORATORIES	المعامل الكيماوية القومية

Date :22/9/2021
Ref. : NCL/ 5/B/1/2

REPORT ON THE PHYSICAL AND CHEMICAL EXAMINATION OF WATER

NAME & ADDRESS OF SENDER : معزه اسماعيل احمد	
SENDER REF. NO :	LAB. NO. : 307 /2021
SOURCE OF SAMPLE : (A) وحدة معالجة الغسيل الكلوى	LOCALITY :
NATURE OF SAMPLE :	DATE OF SAMPLING :

APPEARANCE: clear

Result of examination of filtered sample

COLOUR : Colourless		
ODOUR : Unobjectionable	Taste :	
CONUCTIVITY :	pH : 6.90	
TOTAL DISSOLVED SOLID	17	Mg/l
TOTAL HARDNESS as CaCO3	14	Mg/l
TOTAL ALKALINITY as CaCO3	15	Mg/l
EXCESS ALKALINITY as NaCO3	1	Mg/l
CALCIUM as Ca	2	Mg/l
MAGNESSIUM as Mg	2	Mg/l
CHLORIDE as Cl	1	Mg/l
SULPHATE as SO4	1	Mg/l
NITRATE as NO3	ND	Mg/l
NITRITE as NO2	ND	Mg/l
FLUORIDE as F	0.15	Mg/l
AMMONIA as N	ND	Mg/l
Chromium as Cr	/	Mg/l
Cobalt as Co	/	Mg/l
LEAD as Pb	/	Mg/l
SODIUM as Na	2	Mg/l
POTASSIUM as K	0.2	Mg/l
TOTAL Iron as Fe	/	Mg/l

وزارة الصحة الإتحادية المعامل الكيماوية القومية التاريخ: ٢٠٢١/٩/٢٥ Federal Ministry of Health National Chemical Laboratories

Researcher/ Hadia Ahmed El Hadi
For/Senior Consultant and Director
National Chemical Laboratories

NB: This certificate is applied only to the submitted sample and may not be applied to any other similar sample

E. mail: ncls1903@gmail.com 83779789 Fax 795164 ✉ P.O. box 287, Khartoum

جمهورية السودان

وزارة الصحة الاتحادية

المعمل القومي للصحة العامة

المامل الكيمياوية القومية

Date: 21/6/2021

Ref:NCL/5/B/12

REPORT ON PHYSICAL AND CHEMICAL EXAMINATION OF WATER

NAME&ADDRESS OF SENDER:	
SENDER REF.NO:	LAB.NO:307/2021
SOURCE OF SAMPL: (C) وحدة معالجة الغسيل الكلوي	LOCALTY :
	DATE OF SAMPLING

APPEANCE: clear

Result of examination of filtered sample

COLOUR :Colour less		
ODOUR :Unobjectionable	Taste:	
CONDCTIVITY:	PH :6.5	
TOTAT DISOLVED SOLID	16	Mg/l
TOTAT HARDNESS as CaCO3	13	Mg/l
TOTAT ALKALINITY as CaCO3	14	Mg/l
EXCESS ALKALINITY as CaCO3	1	Mg/l
CALCIUM as Ca	0.2	Mg/l
MAGNESSIUM as Mg	1.1	Mg/l
CLORIDE as Cl	0.4	Mg/l
SULPHATE as SO4	0.9	Mg/l
NATRATE as NO3	ND	Mg/l
NATRITE as NO2	ND	Mg/l
FLUORIDE as F	0.17	Mg/l
AMMONIA as N	ND	Mg/l
Chromium as Cr	/	Mg/l
Cobalt as Co	/	Mg/l
LEAD as Pb	/	Mg/l
SODUIM as Na	2.5	Mg/l
POTASSIUM as K	0.9	Mg/l
TOTAL Iron as Fe	/	Mg/l

جمهورية السودان

وزارة الصحة الاتحادية

المعمل القومي للصحة العامة

المامل الكيمياوية القومية

Date: 22/5/2021

Ref:NCL/5/B/12

REPORT ON PHYSICAL AND CHEMICAL EXAMINATION OF WATER

NAME&ADDRESS OF SENDER:	
SENDER REF.NO:	LAB.NO:307/2021
SOURCE OF SAMPLE:(D)وحدة معالجة الغسيل الكلو	LOCALTY :
	DATE OF SAMPLING

APPEANCE: clear

Result of examination of filtered sample

COLOUR :Colour less		
ODOUR :Unobjectionable	Taste:	
CONDCTIVITY:	PH :9.1	
TOTAT DISOLVED SOLID	19	Mg/l
TOTAT HARDNESS as CaCO3	16	Mg/l
TOTAT ALKALINITY as CaCO3	15	Mg/l
EXCESS ALKALINITY as CaCO3	2	Mg/l
CALCIUM as Ca	2.5	Mg/l
MAGNESSIUM as Mg	2.5	Mg/l
CLORIDE as Cl	2.5	Mg/l
SULPHATE as SO4	2.0	Mg/l
NATRATE as NO3	ND	Mg/l
NATRITE as NO2	ND	Mg/l
FLUORIDE as F	0.19	Mg/l
AMMONIA as N	ND	Mg/l
Chromium as Cr	/	Mg/l
Cobalt as Co	/	Mg/l
LEAD as Pb	/	Mg/l
SODUIM as Na	4	Mg/l
POTASSIUM as K	0.6	Mg/l
TOTAL Iron as Fe		Mg/l

THE REPUBLIC OF THE SUDAN
FEDERAL MINISTRY OF HEALTH
NATIONAL PUBLIC HEALTH LABORATORY
NATIONAL CHEMICAL LABORATORIES

[illegible]

Date: [illegible]
Ref.: NCL/[illegible]

REPORT ON THE PHYSICAL AND CHEMICAL EXAMINATION OF WATER

NAME & ADDRESS OF SENDER	[illegible]
SENDER REF. NO.	[illegible]
SOURCE OF SAMPLE	[illegible]
NATURE OF SAMPLE	DATE OF SAMPLING

APPEARANCE: clear Turbidity

Result of examination of filtered sample

COLOUR Colourless		
ODOUR Unobjectionable		
CONDUCTIVITY 23 µs/cm	pH 6.35	
TOTAL DISSOLVED SOLID	14	mg/l
TOTAL HARDNESS as CaCO3	8	mg/l
TOTAL ALKALINITY as CaCO3	13	mg/l
EXCESS ALKALINITY as CaCO3	8	mg/l
CALCIUM as Ca	2	mg/l
MAGNESSIUM as Mg	0.5	mg/l
CHLORIDE as Cl	1	mg/l
SULPHATE as SO4	ND	mg/l
NITRATE as NO3	ND; DL = 0.01	mg/l
NITRITE as NO2	ND; DL = 0.01	mg/l
FLUORIDE as F	0.3	mg/l
AMMONIA as N	ND; DL = 0.01	mg/l
COPPER as Cu	/	mg/l
ZINC as Zn	/	mg/l
LEAD as Pb	/	mg/l
SODIUM as Na	3	mg/l
POTASSIUM as K	0.2	mg/l
TOTAL Iron as Fe	ND; DL = 0.01	mg/l

REMARKS:-

ND = Not Detected
DL = Detection Level

Researcher/ Hadia Ahmed El Hadi
For/Senior Consultant and Director
National Chemical Laboratories

NB: This certificate is applied only to the submitted sample and may not be applied to any other similar sample

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