- **Hemodialysis machines:** Figure 3 shows the block diagram of the dialysis machine. The dialysis fluid would be used at a rate of 500 ml min^{-1}, so that 240 l of dialysis fluid will be used in an 8 h dialysis period.

There are three main part of hemodialysis machine:

- Blood circulation
- Dialysate circulation.
- Dialyzer

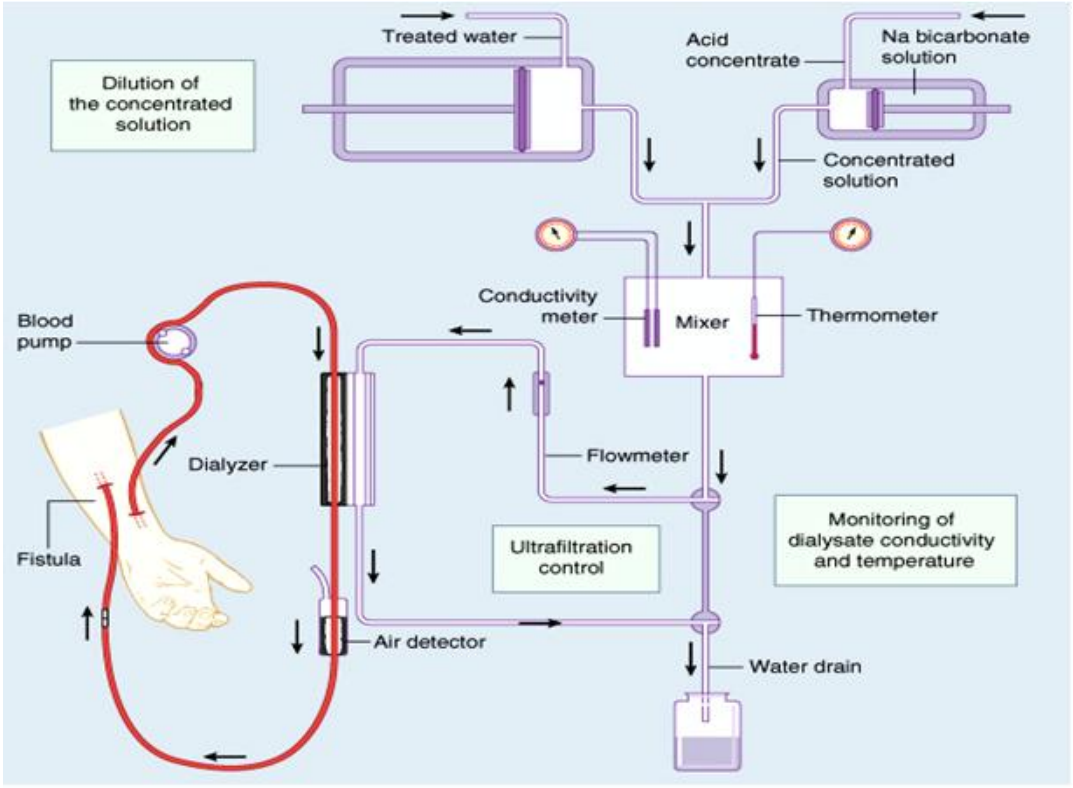


Figure 3 the block diagram of the dialysis machine.

The dialyzer

- The dialyzer functions as an artificial kidney to clean the blood of wastes and extra fluids, it has two parts, one for the blood and the other for a washing fluid called a dialysate, a thin membrane separate the two apart, the dialyzer contain a semipermeable membrane that is encased in a plastic, because of its semi permeability, solutes are allowed to pass through tiny pores allowing some to come through but keep others out, as in figure 4.

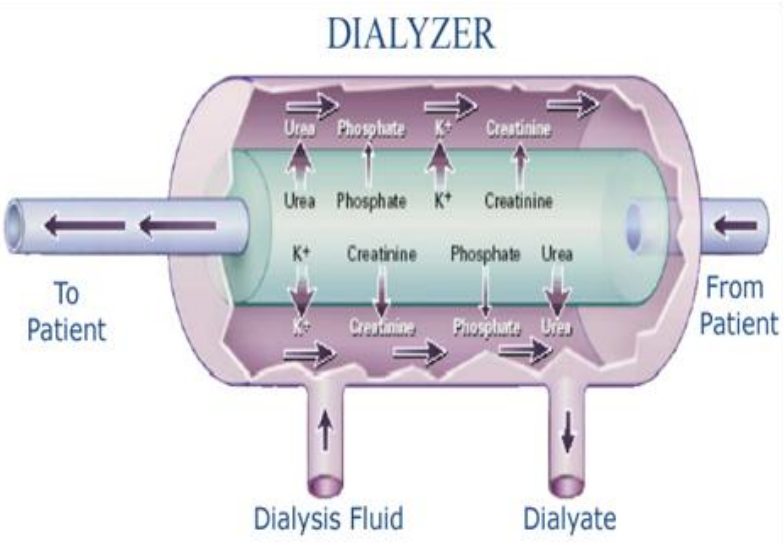


Figure.4. the Dialyzer in general

- The fluid used to clean the blood (dialysate) flows in the opposite side of the membrane, while waste and extra fluid are removed from the blood and end up in the dialysate by controlling three processes: diffusion, ultrafiltration and osmosis. See figure 5

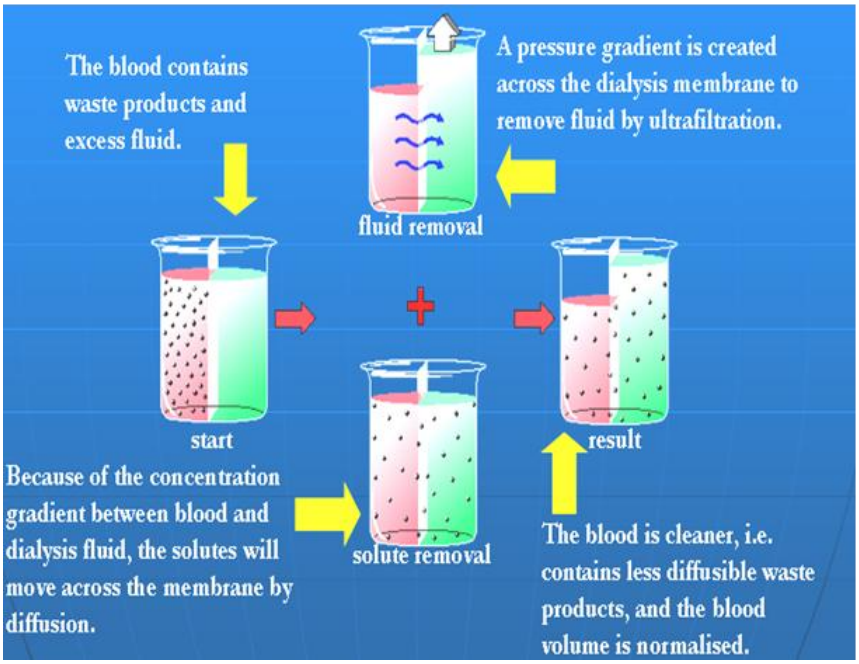
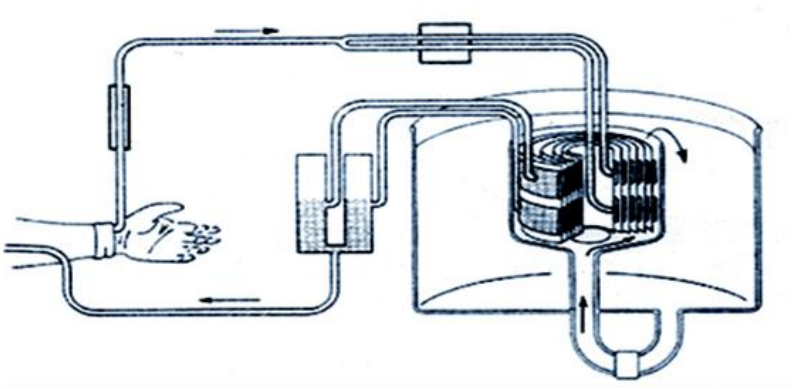


Figure 5. Transport principles of Hemodialysis

Types of Dialyzer:

- **Coil Dialyzer** Cellophane tubing forming semi permeable membrane flattened between two supporting structures such as mesh structure. Tubing and mesh together were winding concentrically around a central core. Blood flowed in cellophane tubing and dialysate pumped up through coil outside tubing, it has disadvantages, high blood pressure in the tubes risk of membrane rupture, and high bacterial contamination risk in open dialysate tank, also large blood volume is taken outside the body . See figure 6.



- **Parallel Plate Dialyzers**
- This dialyzer uses several parallel plates with ridges and grooves in them, the dialysate flows along the grooves, a semipermeable membrane rests between the ridges and the blood flow on the membranes. With these dialyzers, resistance to blood flow is low; the diagram below illustrates one type of parallel plate dialyzers, the disc hemofilter as in figure 7.

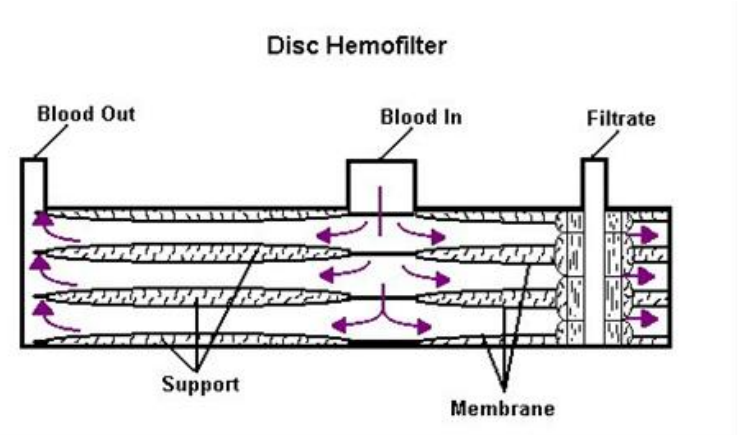


Figure 7. The Disc hemofilter

- Some advantages to the use of this dialyzer are its low resistance to blood flow, because of this fact, there is not as much need for the use of an anti-blood clotting solution.
- Another advantage of this dialyzer is that its filtration rate is controllable and predictable; the next advantage of this dialyzer is the amount of blood contained within the dialyzer is relatively low.
- The less blood that is out of the body at one point in time, the better the dialyzer, and the final advantage of the parallel plate dialyzer is that it is inexpensive.

Hollow Fiber Dialyzer

- This type of artificial kidney is the most common type used; this artificial kidney makes use of countercurrent flow.
- Countercurrent flow is where the blood is flowing in one direction and the dialysate is flowing in the opposite direction.
- The hollow-fiber dialyzer comes in many different sizes.
- It looks like a cylinder filled with thousands of tiny hollow fibers (about 10000 fibers). Blood flows into one end of the dialyzer and through these thousands of tiny hollow fibers, at the same time, the dialysate is pumped into the cylinder and across the tiny hollow fibers, this method keeps fresh dialysate circulating constantly. Figure 5illustrate the hollow fiber dialyzer.
- The volume of blood filtered at the same moment is low and these type of dialyzer is disposable.

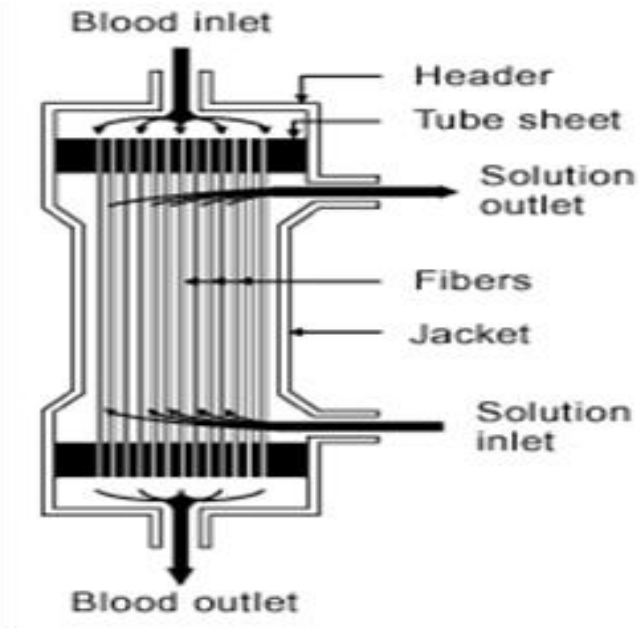


Figure 8. Structure of a typical hollow fiber dialyzer

The Blood Circulation:

- The blood pump takes and returns the blood from the patient via the arterial and venous needles.
- The blood is confined to the disposable plastic tubing and doesn't come in contact with any part of the machine; the blood pump is the distinct feature on all dialysis machines, it designed to give blood flow rate of 50-350 ml/min.
- The pumping is done by squeezing the plastic tube inside the pump using a pair of spring loaded rollers as in figure 9.

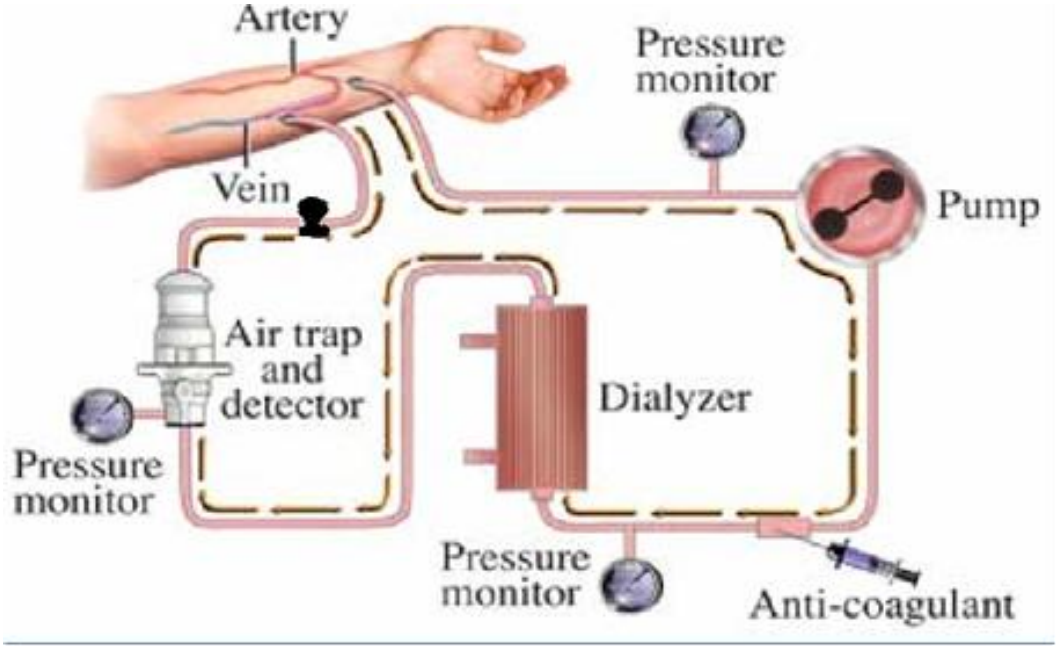


Figure 9. The Blood circulation subsystem

- The suction is done by the elasticity of the tube, which expands after released from the rollers and sucks the blood from the arterial needle.
- The blood coming from the pump is injected with heparin using plastic syringe type of pump having capacity of 30cc, the delivery of heparin form the pump is calibrated in cm/h.

- After that the blood flows to the Dialyzer and the blood that leaves the Dialyzer returns to the patient through the venous needle.
- Along the blood lines there are two pressure chambers that are used for gauging the blood pressure without touching the blood using strain gauge, both pressures are displayed on the machine in prominent locations.
- Each pressure display has a preset for max/min values, which if reached stop the pump and start the alarm.

- The first display is the arterial pressure, which in most machines measures the negative pressure of the suction. In very few centers the arterial pressure is measured after the pump and it shows the positive pressure where the blood enters the dialyzer.
- The second gauge measures the venous pressure where the blood is returned to the patient, in addition, an air trap and an air detector is attached to the venous chamber may use ultrasound method for detecting the air bubble.
- Air in the blood is very dangerous; therefore, even a small amount of air or foam stops the machine and starts the alarm. At the exit from the venous chamber there is a valve that closes the line whenever the pump stops, to prevent uncontrolled blood flow in or out of the venous needle.

The Dialysate circulation:

- Dialysate is the cleansing solution used in the dialysis process to remove excess fluids and waste products from the blood during dialysis, it is made from carefully measured chemicals containing sodium, chloride, potassium, magnesium and a buffer of sodium bicarbonate, the doctor will determine how much of any given substance should be in the individual dialysate bath.
- The dialysate is then added to purified water (the regular water, which has been filtered to remove chlorine**,** bacteria**,** toxins and any minerals that doesn't need)using proportional pump of fixed ration of 34:1, after this process takes place, the mixture of dialysate and purified water is delivered to the hemodialysis machine to do its work of cleansing the blood, the dialysate is monitored for conductivity (a measurement of the amount of chemicals and the water composition of the dialysate), temperature, flow rate and pressure, an alarm will sound if anything is wrong with the composition of the dialysate.

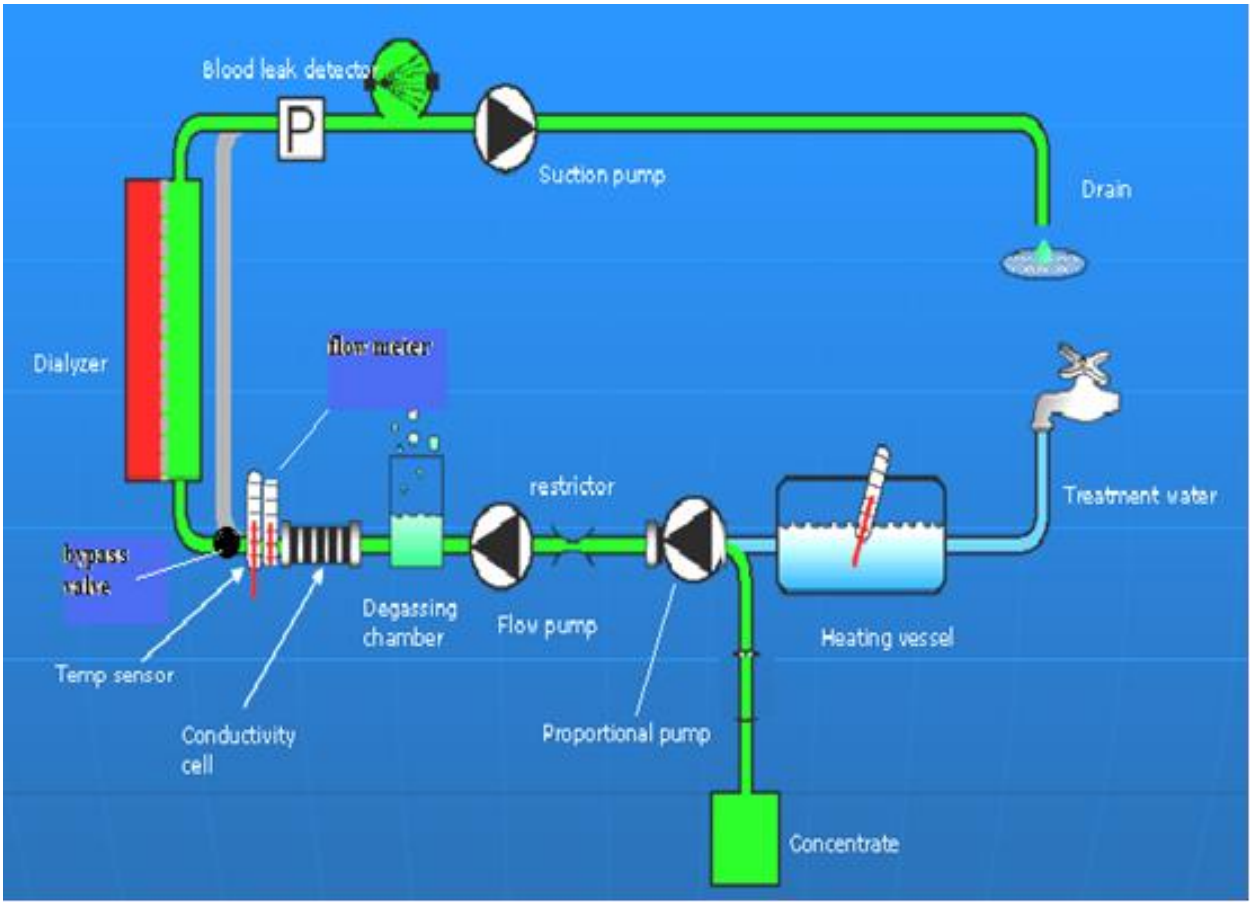


Figure 10 represents the dialysate circulation.

- Also, there is a degassing chamber to remove the desolved gas from the dialysate. If the pressure of a fluid decreases, dissolved gas escapes. This happens when a fluid is pulled by a pump through a narrow restrictor.
- A blood leak detector measures the color of the dialysate fluid exiting the hemodialyzer and alarms if blood is detected, the presence of blood in the dialysate fluid signals a leaking hemodialyzer, this is done by using photo electric transducer.
- If anything goes wrong with the composition of the dialysis fluid, or if traces of blood are detected, or the temperature of the dialysate, the dialysis fluid is led into bypass at the same

time as an alarm alerts the operating nurse, the bypass function can also be activated manually

Device Alarms:

Hemodialysis delivery devices should be monitored with the ongoing of the treatments, and provide visual and audible alarms in the event of an unsafe situation, often the system will have different levels for alarms conditions. For instance, a high return pressure may first trigger a "Caution" at a designated level, and then a "Warning" alarm at a higher level. Alarms present on hemodialysis delivery devices may include the following:

1. Pressure alarms
2. Temperature alarms
3. Blood leak alarm
4. Air embolism alarm
5. Vascular access disconnect alarms
6. Conductivity / pH alarms
7. Water quality alarms

Email (amal.alzubedy@gmail.com)