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Research Article

Design and Development of an Automatic Dialyzer Reprocessing System

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ABSTRACT

Hemodialysis is a process that is typically performed for people with renal failure and filters out all the waste products in the blood. The dialyzer plays a crucial role in purifying the process by excluding contaminants like creatinine, urea, and water from the blood extracorporeally when the kidneys undergo renal failure. A dialyzer also referred to as an artificial kidney, is formed of a container with a membrane that is semi- permeable and separates the dialysate from the patient's blood after it has been extracted. The dialyzers were once used and disposed of in the environment, which is harmful. This study focuses on the reprocessing of the dialyzer which might be used up to three times, so that the process can be cost- effective. The system was designed in this study by using an ESP32S microcontroller (Espressif Systems) and an LM2596 DC-DC buck converter for the process using sodium hypochlorite, formalin, and RO water for cleaning and disinfecting agents.

Keywords: *Hemodialysis, Dialyzer, Chronic kidney disease, RO Water, Sodium hypochlorite, formalin.*

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Introduction:

Almost 800 million people globally, or 10% of the overall population, suffer from chronic renal disease, a degenerative ailment. Chronic kidney disease is more prominent in people who have diabetes, high blood pressure, hypertension, and fluid or blood loss1. As per the 2023 statistics, Saudi Arabia and Belgium are anticipated to have the highest CKD rates with 24% of the population respectively2. According to studies, India's dialysis market is expanding at a rate of 31% annually, which is faster than the global average of 8%[3]. The dialyzer is the heart of the dialysis process; Toxins are removed from the blood and then passed into the dialysate, which is a solution of pure water, electrolytes, and salts like sodium bicarbonate and electrolytes. The dialyzer consists of a dialysis membrane where it separates the blood from the dialysate. During dialysis, water, and solutes are exchanged through the semipermeable membrane as blood and dialysate move in opposite directions on each side of the membrane. The dialyzer's performance determines its effectiveness and serves as a crucial milestone for the creation of hemodialysis programs.

A single patient receives multiple times using the same dialyzer, but the precise number of repetitions depends on the patient's unique clotting tendency. Here we can reuse the dialyzer multiple times with the help of this system through the cleaning, rinsing, and sterilizing process. The main advantage of Reusing dialyzers certainly reduces waste disposal, thus lowering environmental pollution and additionally, it is cost-effective.

Materials:

a) A dialyzer with a semi-permeable membrane made of polyether sulphone named the "Browndove's Pristine BD 130 UNO" was utilized.

b) To control the fluid flow, three relays are used as switches.

c) RC385Water pump, Resistors, Diodes, Transistors, and LEDs were used in the circuitry.

Chemicals:

a) RO Water was utilized to flush off the dialyzer's tiny debris and blood stains.
b) Sodium hypochlorite was used to clean the majority of dialyzers.
c) Formalin is used as a chemical germicide to prevent bacteria.

Methodology: The Dialyzer Reprocessing system is composed of three relays that regulate fluid flow. Each relay is operated with 5 volts and the circuit starts operating when the microcontroller receives a 24V DC power source, turning on the first relay in the circuit. Three distinct LED colors are used to distinguish the three relays.

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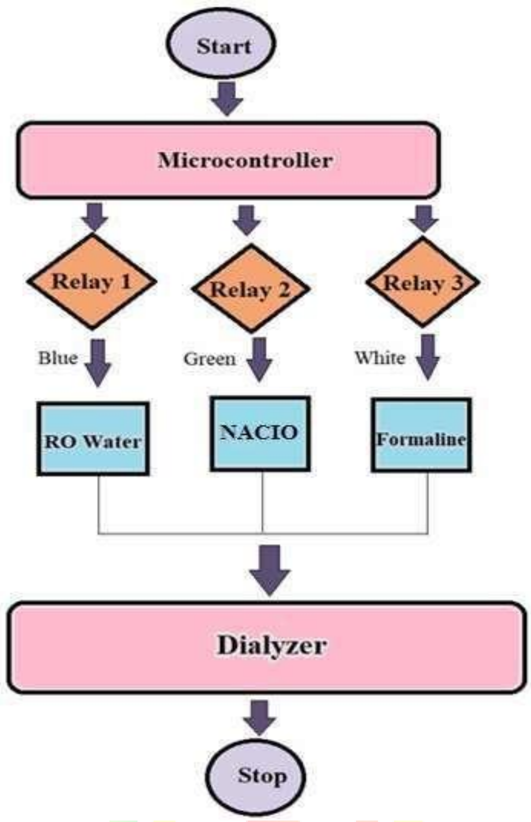

Figure 1: Flow Chart

Step 1: When the signal reaches RLY1, the connected water pump is in the ON state, while other relays and water pumps are in the OFF state. To finish the rinsing procedure, the water pump is now used to draw RO water from the container and circulate it for 30 Seconds into the dialyzer.

Step 2: After completion of the rinsing procedure, the signal reaches RLY2 connected with a water pump, which is in the ON state while other relays (RLY1, RLY3) and water pumps are in the OFF state. Now, the cleaning procedure involves the extraction of sodium hypochlorite with the water pump from the container and pump it for 20 Seconds.

Step 3: Finally, the signal reaches RLY3, the procedure is the same as the above- mentioned steps, and the disinfection procedure is continued for 10 seconds by the formalin. For Sterilization, peracetic acid was used in the dialyzer and it is stored for 24 hours before use.

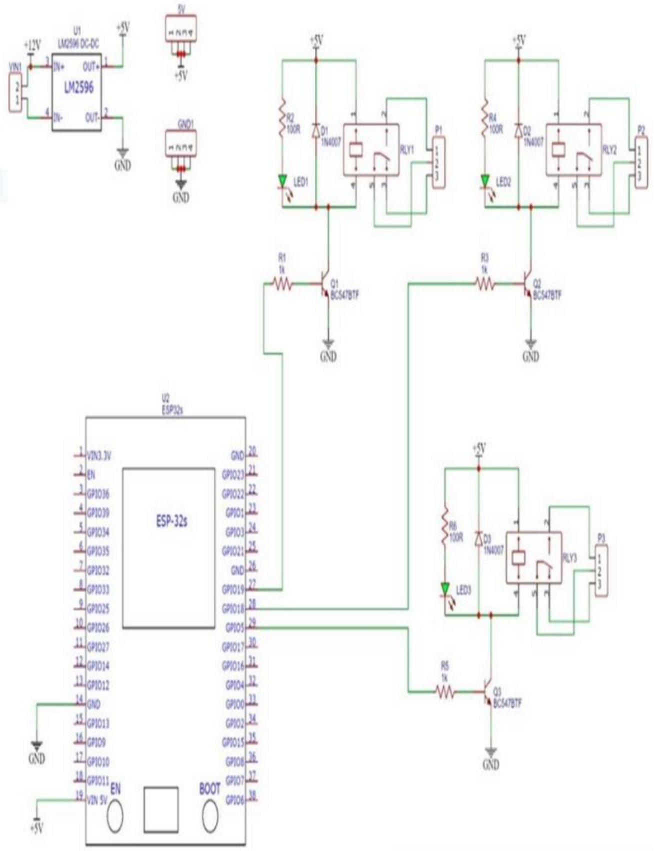

Figure 2: Schematic diagram

Existing Techniques:

Effect of Dialyzer Reprocessing on Performance and Beta 2 Microglobulin Removal Using Polysulfone Membranes

In this study, the main focus is on biocompatibility and cost-effective methods of dialyzer reprocessing. Here, polysulfone membranes have been used despite the possibility of decreased effectiveness and performance, especially in the removal of P2- microglobulin (P2M), a protein linked to the onset of dialysis-associated amyloidosis (DDA). The chemicals that were used in the polysulfone membrane are bleach and formaldehyde for cleaning the surface and eliminating bacterial impurities.

The tests that were performed are urea elimination, urea mass transmission coefficient, ultrafiltration method, and how much of the percent has been removed from the polysulfone membrane, which has been determined by 24 uses to assess the effectiveness and performance as well as the reduction of Beta2M. They have also done a study of 11 patients on hemodialysis of different ages.

The Urea Clearance during polysulfone membrane reprocessing for up to 24 uses remained unchanged during the study, however, an increase in the Mass transmission Coefficient for urea was seen in the 15th use. In this study, ultrafiltration levels were found to be low in comparison and to rise after 10 and 20 uses[4].

Dialyzer Reprocessing using Heated Citric Acid:

In this study, with the use of heat and citric acid to reprocess the dialyzer, various citric acid concentrations and temperatures were used. Initially, the reprocessing is performed with water heated up to 100–105 °C for 20 hours to avoid the use of chemical methods for disinfection.

However, due to the use of high temperatures, there is a probability that one inlet port and one outlet port for blood and dialysate might be damaged. Hence, to overcome this problem with respect to the structure of the dialyzer, the temperature is reduced to 95 °C, and 1.5% citric acid is used instead of water for 20h which helps in the destruction of spores. The test results for harmful leachable from the dialyzer membrane exposed to citric acid were negative, as per the cytotoxicity test. Moreover, 1.5% citric acid has a pH level of 2.2, which is neutralized by bicarbonate and eliminated during priming[5].

Code:

```
#define water 19
#define NaCIO 18
#define formalin 5 void setup () {
Pin Mode (water, OUTPUT); pin Mode (NaCIO, OUTPUT); pin Mode (formalin,
OUTPUT); digital Write (water, LOW); digital Write (NaCIO, LOW); digital Write
(formalin, LOW); water data ();
Delay (15000); NaCIO data (); delay (10000); formalin data ();
delay (5000); stops ();
 }
void loop () {
 }
void water data ()
 {
Digital Write (water, HIGH); digital Write (NaCIO, LOW); digital Write (formalin, LOW);
  }
void h2o2data ()
 {
digital Write (water, LOW); digital Write (NaCIO, HIGH); digital Write (formalin, LOW);
  }
void formalin data ()
 {
digital Write (water, LOW); digital Write (NaCIO, LOW); digital Write (formalin, HIGH);
  }
void stops ()
 {
digital Write (water, LOW); digital Write (NaCIO, LOW); digital Write (formalin, LOW);
  }
```

The processing logic for the control system is at the given time only one relay and the lead are on while remaining in the off state. The 30psi pump is on always.

Conclusion:

The increase in biocompatibility and eradication of bacterial contaminants utilizing chemicals in polysulfone membranes is carried out, as stated in the present ways of dialyzer reprocessing. Another method use of heated citric acid is used at different temperatures to avoid disinfection. In this article, we demonstrate how to reuse dialyzers in three steps that maximize the dialyzer's reuse potential while also completing an efficient cleaning procedure.

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