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DESIGN AND DEVELOPMENT OF URO-DISLYSER WITH BIODEGRADABLE BAGS USING IoT TECHNIQUE FOR ICU PATIENTS

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Abstract

Urine Drainage Bag (UDB) has been frequently acknowledged by patients who are suffering from urine incontinence, urinary retention, urinary tract infections, and urological surgeries in which a patient is impotent to out-migration. In ICUs, physiological parameters of a patient are measured by monitoring devices. These devices can also supervise whether the values of the parameters lie within a pre-established range set by the clinician. Just like the basic parameters of the patient monitor, urine output is another parameter which has to be sensed and supervised frequently by the healthcare staff. The automation is done digitally by the monitoring device, “Uro-Dislyser”. Along with the designed low-cost device named Uro-Dislyser, which is capable of sensing and supervising urine output, regular plastic urine bag is replaced by biodegradable bag. This biodegradable bag is designed in a way that can serve the purpose of better hygiene and mental health, and can be used as a fertilizer in agriculture field. The Internet of Things (IoT) is programmed along with the load cell and the alarm rings to indicate the level of urine in UDBs.

Keywords: Uro-Dislyser, Biodegradable bag, urinary incontinence, urinary retention, manure, ZnO nanoparticles, carnauba wax

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1. Introduction

Intensive Care Unit (ICU) is the general term for specialist hospital ward that provide intensive gad in the treatment and monitoring of patients with the critical analysis or unstable condition, which require continuous close monitoring and support from the specialist equipment and medications in order to ensure normal bodily functions [1]. In some cases, ICUs are the place where life or death decisions are taken on professional judgment, relying on available evidence. In general, ICUs treat a variety of patients' illnesses. As recommended in National Institute for health and Care Excellence (NICE) clinical guidelines, monitoring adult patients' vital signs in ICUs often occurs at least every 12 hours, but the diverse health status of each individual in ICUs generates different requirements for health monitoring. Therefore, patients may require a different level of attention depending on their conditions. Some patients may require frequent care, while the others of more stable conditions may require less. These are based upon the severity of patients' conditions judged by nurses, which can be subjective.

At simplest, patient monitoring has been considered as a labour-intensive activity because it involves at least an observer (usually a nurse) to observe and determine changes in patients' condition at least hourly. Therefore, this work aims to develop a device named Uro-Dislyser, which is capable of automatically sensing and supervising the urine output.

Plastics are known as synthetic or semi synthetic materials that contaminate this planet significantly [2]. Recent studies showed that this plastic material can induce global warming and accelerate ocean level. Therefore, the biodegradable Urine Drainage Bag (UDB) is designed for creating safe and healthy human society. Novel coronaviruses (CoVs) can cause infection in humans, bats and animals such as cat, cow, dog, pig and turkey. CoVs caused the most devastating epidemics in this world. These viruses have the potential to transmit from human to animal, animal to human and human to human. Therefore, to combat these CoVs and other pathogens, the biological prospective of Nanoparticles (NPs) should be acknowledged urgently. Zinc oxide nanoparticle is the most useful metal oxide nanoparticle in natural applications because of their magnificent biomaterial, budget friendliness and non-virulent property. Recently, Zinc oxide nanoparticles have been employed as anti-biofilm and anti-fungal agents. Furthermore, Zinc oxide nanoparticles have surfaced a promising eventuality in biomedicine, especially in the antibacterial field.

Therefore, in this work, the eco-friendly NPs with the combination of carnauba wax to fight against all the future infectious agents is suggested. The Carnauba wax and natural based

nanoparticles have more water repellent efficiency and complete eradication of pathogenic microbes within the UDBs. These UDBs and human urine can be used as a natural fertilizer for agriculture purposes. Overall, this approach designs patient friendly UDBs and natural friendly fertilizer.

2. Methodology

This biodegradable polyboard urine bag device is permanently attached to the bed and the alarm is connected to the weight sensor with the help of an IoT device. Fig 2.1 shows the functional block diagram. Various levels of urostomy pouches such as 250 mL, 500 mL, 750 ml, 1000 mL and 2000 mL are fixed depending on the patients. In addition, a Liquid Crystal Display (LCD) has been fixed with an alarm to track and indicate the level of urine. A biodegradable urine bag is designed using a polyboard material. The interior of this polyboard material is coated with carnauba wax and some chemical reagents. The chemical used here is zinc oxide nano particles, in order to kill the microbes and it serves as a fertilizer. This novel approach is hygienic for patients, physicians, nurses, and patient care technicians. This eco-friendly product with antimicrobial activity and simple and modern technologies with low cost is the most impressive characteristic feature of this modern world.

This proposed product ensures to reduce the discomfort of the hospital staff and to avoid infection from the patient's urine bag. Moreover, it ensures that the product rectifies all the problems such as the rising of synthetic or semi-synthetic related pollutants, the prevalence of infectious agents through human waste or urine, and global pandemic situations caused by commercially available urine bags. Finally, these disposable bags containing the patient's urine can be used as fertilizers for agricultural purposes.

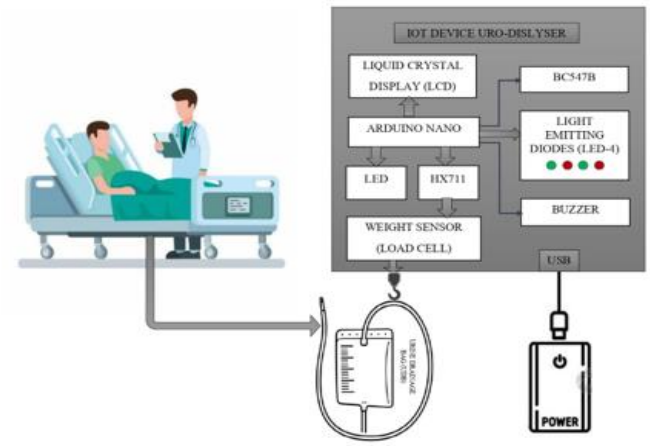


Figure 2.1. Functional Block Diagram

Fig 2.2 shows the internal circuit diagram of Uro-Dislyser. There are four modes in the uro-dislyser, from 250ml to 2000ml, which describes the levels of urine bag, that should be set before hanging the bag, according to the patient's usage. For the mode 500ml, the buzzer will ring at 450ml indicating that the bag is full. To collect urine from infants and small children, 250ml mode can be set, similarly for the elderly or diabetic patients who have undergone a surgery may require 1000ml or 2000ml. For each mode, the alarm will be set to ring before 50 ml to indicate the staff nurse that the urine bag must be changed. The buzzer has been set to ring every 2 minutes, to make sure it is noticed by the staff or nurses. This cycle repeats for five times. And the duration of buzzer is 10 seconds.

The urine bag will be hanged on the load cell. A load cell converts the force into an electrical signal that can be measured and standardized. When force is exerted on the load cell, the structure and resistance of the strain gauges changes. The weight of the urine bag will be measured, it will send the instruction via Arduino nano to the LCD to display the output level of the urine bag of the patients. This bag is made in biodegradable material especially for easy disposal and to reduce the burdens of staff or nurses, and also to reduce the infections, because there is no need to use the same bag for many days. Normally, patients reuse urine bags after the decontamination process performed daily by the rehabilitation nursing staff. These bags are reused for two to eight days, which will be reduced by using the biodegradable urine bags. The overall result is a considerable reduction in the workload of the healthcare staff, since they do not need to continuously supervise the physiological parameters of each patient in the critical care unit.

In addition to the alarm, there is an LED, that blinks if the urine bag gets full. It will be helpful for the staff during nighttime, to change the urine bag. The LCD displays the maximum level of the urine bag which has been set for the patient and actual level which is being hanged on the equipment. The actual level of the urine bag will be displayed in the LCD continuously. After the urine bags gets full, the equipment is set to the zero -set mode, and the new urine bag has to be hanged.

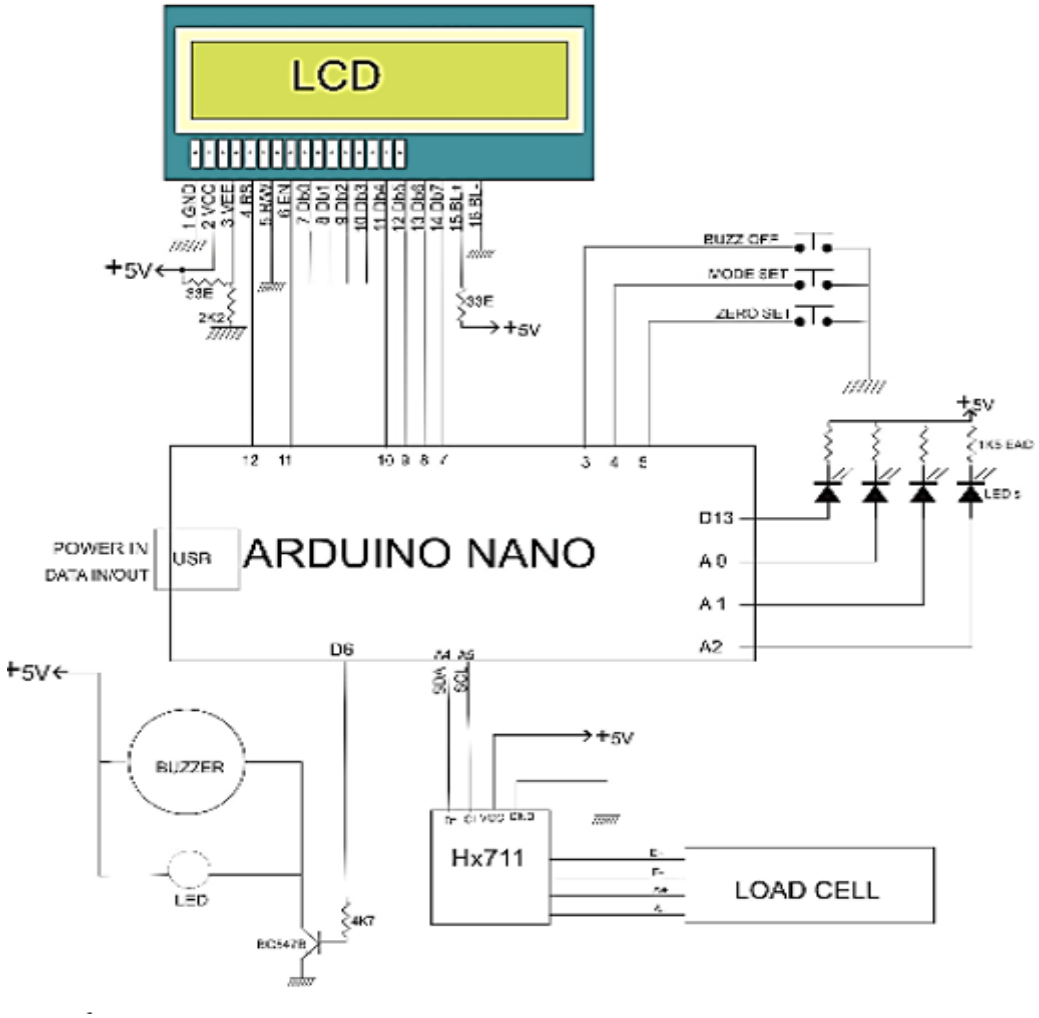


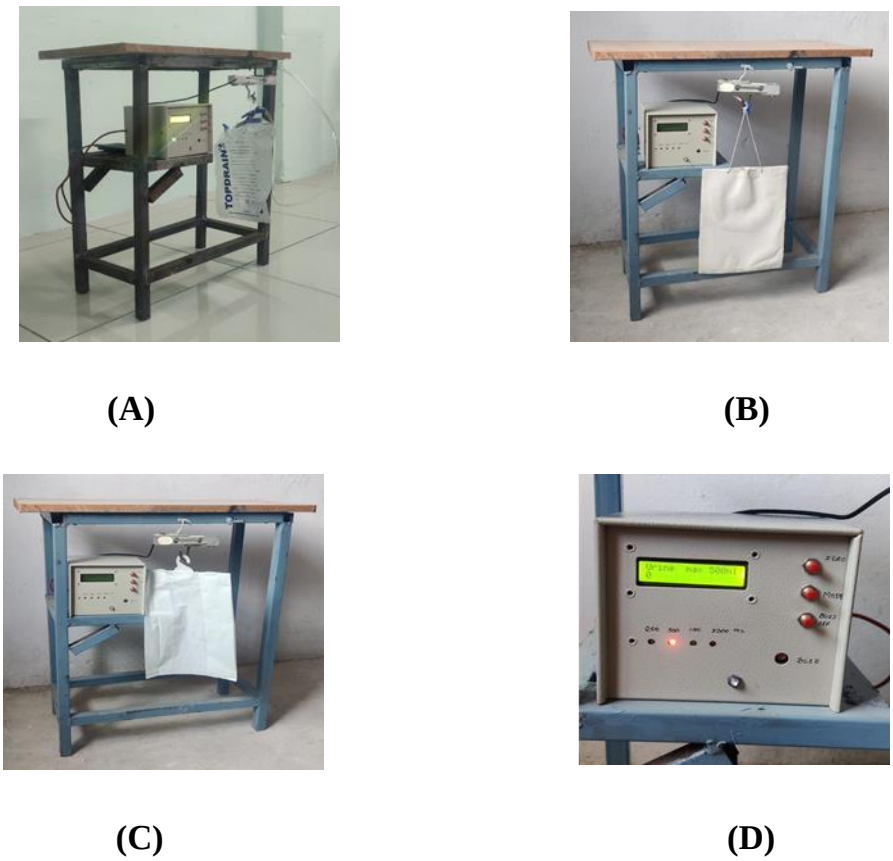
Figure 2.2. Internal Circuit Diagram of Uro-Dislyser

The uro-dislyser device is constructed based on the principle of load cell. The Arduino nano is a small, complete, and breadboard friendly board based on the ATmega328. The Arduino takes inputs from the load cell that are attached to the urine bag of the patient whose urine level is being measured. The output part of the circuit has a voltage of 5 volts. The buzzer, LED and NPN transistor are connected to the digital pin D6 of the Arduino nano via 4k7 ohm resistor. Buzzers are audio signaling devices that generate sound in the frequency range of 1 to 7 kHz. The 4k7 ohm resistor can be used for limiting current and matching load. BC547 is used for current amplifier and Pulse-Width Modulation (PWM).

The load cell is connected to the Hx711 amplifier in the circuit. The HX711 amplifier is a breakout board that allows to easily read load cells to measure weight. The load cell wires on one side to Hx711 amplifier and the microcontroller on the other side. The HX711 communicates with the microcontroller using two-wire interface. The HX711 load cell amplifier is used to get measurable data out from a load cell and strain gauge. The HX711 is a precision 24-bit Analog-to-Digital Converter (ADC) that is designed for weighing scales and is connected to the A4 and A5 pins of the Arduino nano. The four LEDs which are set for each mode in the device, are connected to 1kohm resistor with a voltage of 5 volts. There are three modes connected to the circuit. The buzz off mode is set to off the buzzer when the urine bag gets full. The zero-set mode is used to set the device to zero and start the device and while changing the urine bag of the patient. The mode set is used to set the levels of the urine bag. The LCD is an electronic module that can be interfaced with Arduino to display the output on its screen.

A. Proposed System:

A prototype that is similar to a patient monitoring system has been designed. Patient monitor is a device that is used to record the patient parameters like heart rate, oxygen saturation, temperature parameter, blood pressure and respiration rate. Similarly, this equipment Uro-Dislyser is used to measure the urine level of the patient. Fig. 2.3(A) shows the example setup of equipment uro-dislyser with the regular urine bag hung on the load cell. The urine bag shown here can hold upto 2000ml of the patient's urine. The tube of the urine bag is connected to the catheter of the patient. Fig. 2.3(B) shows the example setup of equipment uro-dislyser with the polyboard biodegradable urine bag hung on the load cell. The biodegradable urine bag shown here can hold upto 2000ml of the patient's urine. This bag can be used once, and it can be biodegraded after usage due to the presence of nano particles and carnauba wax. Fig. 2.3(C) shows the details of Uro-Dislyser with agro biodegradable plastic urine bag. Fig 2.3(D) shows the IoT link for the buzzer and android mobile message for the indication of the filling levels of urostomy pouches. Finally, the reading is recorded and stored and the device displays the urine level according to the bag used for the patient. After the urine level exceeds the specified limit in the urine bag, alarm rings for indication and the message is sent to the registered mobile number.



(A) **(B)**

(C) **(D)**

Figure 2.3. Full view of Uro-dislyser **(A)** Uro-dislyser with regular plastic urine drainage bag; **(B)** Uro-dislyser with polyboard biodegradable urine drainage bag; **(C)** Uro-dislyser with agro bioplastic urine drainage bag; **(D)** Working of IoT device uro-dislyser

3. Merits of The Proposed System

To avoid the spread of infectious disease through urine sample, for instance, the pandemic novel coronavirus disease (COVID-19), and to diminish the biomedical waste throughout the world, this work focuses on neutralizing or destroying recent or upcoming infectious pathogens from urinary sample and also highlights the advantages of disposable UDBs and their applications. The goal is to reduce the discomfort of the hospital staff and to avoid infection from the patient's urine bag.

A. Social Relevance:

This work develops biodegradable and disposable poly board, which is an environment friendly product. Moreover, results show that Carnauba wax and natural based nanoparticles have more water repellent efficiency and complete eradication of pathogenic microbes within the UDBs is possible. Finally, these UDBs and human urines can be used as a natural fertilizer for agriculture purposes. Overall, this approach designs patient friendly UDBs and natural friendly fertilizer for agriculture purpose. This research aims to reinstate heavenly earth which may not have polybag pollution, and also diminish biomedical waste at a low cost. Moreover, the advanced and available technologies assist for better and patient friendly UDBs that can be mainly employed to during pandemic situations. Fig. 3.1 shows the merits of the proposed system step by step procedure.

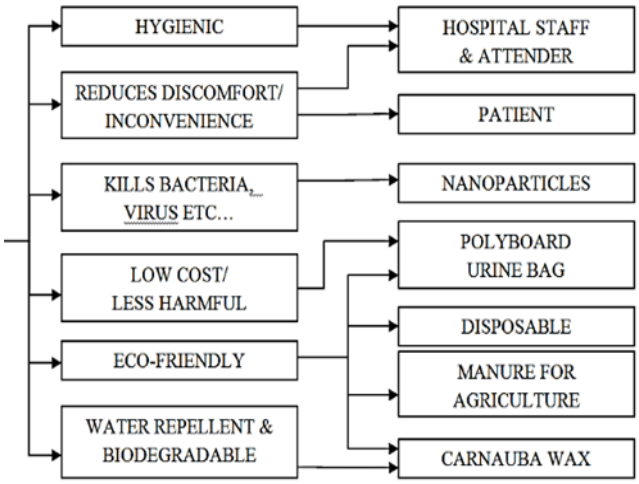


Figure 3.1. Merits of the Proposed System

B. Objectives:

The main objectives of this proposed system are:

• To avoid the spread of infectious disease through urine sample, and to diminish the biomedical waste throughout the world.

• This study focuses on neutralizing or destroying recent or upcoming infections pathogens from urinary sample and also highlights the advantages of the disposable UDBs and its applications globally.

• The target is to reduce the discomfort of the hospital staffs and to avoid infection from the patient's urine bag.

• The disposable urine bag with alarm indication can be used to aid medical staff or care takers.

C. Design consideration for public health, safety, and environment:

- This method is hygienic for patient, hospital staff, as well as for the attender.
- Compared to normal plastic urine bags, this polyboard urine bags are cost effective and less harmful.
- It reduces the inconvenience/discomfort of hospital staff and attender.
- Polyboard is an eco-friendly material made from commercial waste that can be recycled constantly.
- The polyboard material is biodegradable.
- Carnauba wax is also an eco-friendly product that's biodegradable, water repellent, and a natural product used in food storage too.
- This wax can withstand heating temperature from 82 – 86 °c.
- Agro-bioplastic is a complete 100% degradable plastic material which makes it eco-friendly for usage.
- Layer of nanoparticles is coated along with carnauba wax to kill the bacteria, virus, etc. inside the bag.
- Hence, these disposable bags can be used as fertilizers for agricultural purposes.

4. Results and Discussion

A. Interpretation of results:

The proposed prototype was tested on two patients in a hospital. The figures below show the working process of the equipment uro-dislyser with the biodegradable bag attached to patient-1 lying on a bed. This patient-1 happens to be an adult, so the 1000ml biodegradable urine bag was used and the mode was set to 1000ml in the uro-dislyser. Figure 4.1(A) shows the LCD displaying the starting level of urine set to 0 when a new bag is attached to the patient. Figure 4.1(B) shows the LCD displaying the level of urine as 772ml, as the bag gets filled.

Once it reached the level of 950ml, the alarm rang. Thereby the workload of the hospital staff was reduced since checking frequently on the patient for the filling of urine bag wasn't required, as the uro-dislyser does the monitoring process.

(A) **(B)**

Figure 4.1. (A) Prototype Displaying Start Level with Biodegradable Bag Attached to Patient-1 **(B)** Prototype Displaying Urine Level to 772ml

For patient-2, a 500ml bag was used and the mode was set to 500ml in uro-dislyser. The monitoring done by the uro-dislyser was very much similar to the patient tested first. However, the timing as well as the bag usage depended on the condition of each patient. Apart from them, with the help of the physician, patients who were admitted to ICU wards of 8 multi-specialty hospitals around Madurai, Tamil Nādu, were also tested. The patients were 12 males, 10 females, 8 pregnant women, 11 children (below the age of 10), and 12 aged persons who were admitted due to different health problems. The same procedure was followed for all the 53 patients, and the readings were monitored and recorded.

The results were concluded by comparing the patients. Patient-1 happens to be a diabetic patient, so a higher-level urine bag was used. Normally, 500ml of plastic bag is used for these patients due to the cost, irrespective of the stage of the disease. This only increases the monitoring and replacement work of nurses, but when it comes to the usage of this biodegradable bag, it can be used despite the cost and the stage of the disease, which majorly reduces the work of monitoring, replacing, and discomfort especially during hectic times like pandemic situations where there would be shortage of time and people to provide individual and proper focus. Patient-2 happens to be a victim of accident. Since this patient was admitted,

urine bag of normal range had to be used which is 500ml. Therefore, depending on the patient, bag level usage as well as the mode level to be set in uro-dislyser vary.

B. Comparison between plastic bag and biodegradable bag:

Plastic urine bag used for patients served the purpose of collecting urine during critical stages of patients. Apart from its purpose, it has disadvantages of cost, hygiene as well as mental health. Figure 4.2(A) shows the plastic urine bag of level 2000ml which is used for a single patient. Even after it gets full, it is reused and causes other health problems and affects the mental health of patient. Figure 4.2(B) shows the biodegradable urine bag of level 2000ml which is used for a patient and gets thrown away after it gets full. Moreover, the biodegradable bag can be reused as a manure material for agriculture. The bag's interior is coated with carnauba wax and ZnO nanoparticles. Carnauba wax helps to avoid the leakage of urine from the material polyboard. It retains the liquid content and helps in converting urine into manure with few other reagents added already, i.e., the nanoparticles. ZnO nanoparticles are used since it helps in boosting the catalytic chemical reactions and hence it finds its major usage is in medicine, food, agricultural field, etc. It satisfies all the conditions like killing of microbial content in urine and making it a good fertilizer for agriculture.

There are various types of nanoparticles, but ZnO nanoparticles are preferred as it enhances the bioavailability of Zinc for plants. This results in growth of the plants, improves dry matter, and keeps the roots fresh. The ZnO nanoparticles when mixed with the urine, releases slowly as a fertilizer thereby making the biodegradable bag usable in a good way. ZnO nanoparticles has a strong resistivity to microbes. This fertilizer can imply other applications like improving the deficiency of zinc, dripping of root, coating of seed before transplant of crops, germination of seeds, suppression of diseases, protection of plants, etc. Despite the usage of these chemicals and wax, these biodegradable bags are available at a very low cost than the normal urine bag. The normal urine bag costs more than Rs300/- whereas biodegradable bags range from Rs5/- to Rs20/- depending on the level. It can be concluded that the biodegradable bags are ecofriendly as well as economical. The usage of these bags would cause a greater impact in medical as well as agriculture field.

(A) **(B)**

Figure 4.2. (A) Plastic Urine Bag **(B)** Biodegradable Urine Bag

COST ANALYSIS:

Normal plastic urine bag (2000ml) = Rs.300/-

Biodegradable urine bag (2000ml) = Rs.10/-

Usage of same plastic bag for 1 week = Rs.300/- (causes infections)

Usage of biodegradable urine bag for 1 week = 10*7 = Rs.70/- (biodegradable)

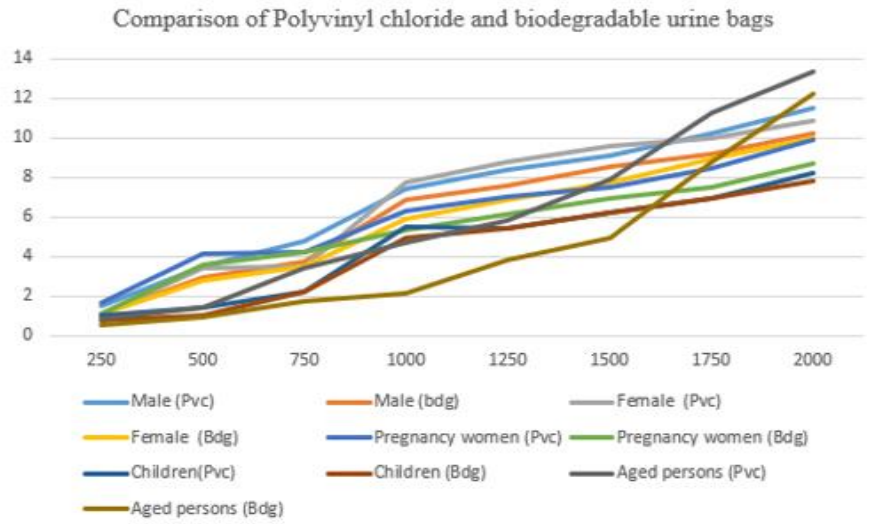


Figure 4.3. Comparison of Polyvinyl Chloride and Biodegradable Urine Bags

5. Conclusion

This research has successfully designed the biodegradable urine drainage bag along with the automated monitoring device. People who suffer from urinary retention may include conditions of prostate enlargement and spinal cord injury. Indwelling urinary bags are used for such people who have urinary incontinence. Compared to normal plastic urine bags, this polyboard urine bags are cost effective and less harmful. Moreover, the alarm in the monitoring device which beeps with the bag is full, will lessen the burden and other difficulties of care takers. This work aims to reinstate heavenly earth which may not have poly bag pollution and may diminish biomedical waste at a low cost. Moreover, the advanced and available technologies will assist for better and patient friendly monitoring. This biodegradable urine drainage bag can be employed during pandemic situations to constrain the contamination.

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