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Waste Wash- Retrofit Mechanism for Toilet Greywater Harvesting

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ABSTRACT:*Water crisis has been declared as the fifth global risk in terms of impact on society. In India, on an average, households consume 400 gallons of water every day and 24% of this consumption is due to toilets. This toilet use of water is tagged as the largest source of wastage of water in households. Currently, there are smart toilets and vacuum toilets to resolve the problem. Smart toilets, currently at best offer a touch-free option or give a manual dual option for the amount of water one chooses to flush. However, they use fresh clean water while flushing and are high-cost. Even if they include the siphonic flush system, this gravity flush system needs to be flushed multiple times to reduce the stickiness around the commode, defeating the purpose. Vacuum toilets need a vacuum station to dispose of the excretion being inefficient as well as high cost. A normal person passes stool once a day and passes urine 6-7 times in a day. Urine comprises 95% water and 5% other wastes - urea, ammonia, inorganic salts. Inspired by this data, through filter chambers and electronics, an automatic or manual, portable device can be created that reduces water consumption. Through the use of sensors, the intensity and amount of waste can be calculated, and whereby solid waste can be differentiated from the urine waste; and further the water output can be controlled to be multivariable and dependent on the nature of waste, and the urine wastewater can be simultaneously filtered by a three-stage filter. The recycled filtered urine wastewater can be used as greywater to help dispose of the majority of the excretion from the commode. Minimal clean water, through the already existing valve, can help give a rinse to the commode to maintain hygiene. Due to its portability and flexibility (manual or automatic) features, this solution can easily be implemented.*

INTRODUCTION

Climate change, global warming, droughts, all a result of water shortages. The water crisis has been an ongoing issue since the 1800s and has prolonged till now. According to the UN's Food and Agriculture Organization, water demand is expected to grow by 55% by 2050, and it is assumed that 1 in 5 countries will face a water shortage. Currently, the breakdown of water usage by continents is shown in figure 1.1.

Four billion people, almost two thirds of the world's population, experience severe water scarcity for at least one month each year. Over two billion people live in countries where water supply is inadequate. Half of the world's population could be living in areas facing water scarcity by as early as 2025.

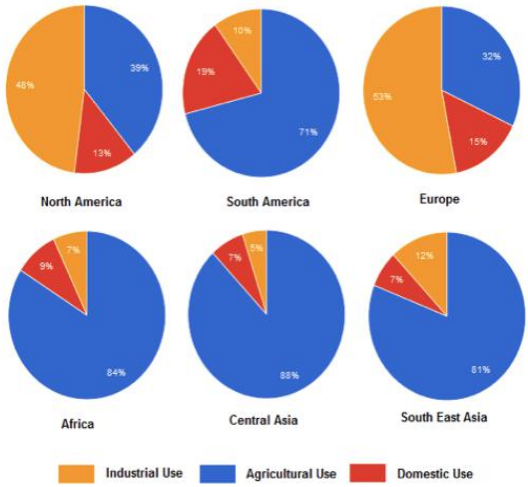


Figure 1.1

Water scarcity is basically the lack of freshwater resources to meet the standard water demand.

Types of water scarcity:

Two types of water scarcity have been defined: physical or economic water scarcity.

Physical water scarcity is where there is not enough water to meet all demands, including that needed for ecosystems to function effectively.

Economic water scarcity is caused by a lack of investment in infrastructure or technology to draw water from rivers, aquifers, or other water sources, or insufficient human capacity to satisfy the demand for water.

The water crisis leads to an even bigger issue, sanitation, and hygiene. The decline in safe water supply leads to inadequate sanitation, a problem for 2.4 billion people, and leads to a release of deadly diseases, such as cholera and typhoid fever, and other water-borne illnesses. With access to clean and safe water, people will be able to practice good hygiene and sanitation.

Nearly 200,000 Indians pass away each year as a result of insufficient accessibility to consumable water, while 600 million people are water-stressed due to the limited availability of 1,700 cubic meters of water yearly.

Research published in June 2018 predicts that India will undergo an acute lack of availability of water within two decades. The report approximates that the need for water will duplicate the obtainable supply by 2030.

In addition to this, water scarcity may lead to economic decline. This is because water scarcity would have a direct impact on agriculture, health, and incomes, affecting day-to-day lives.

For the last six years, India has been in a critical situation regarding water shortages. Droughts have had significant impacts on the livelihood of people around the nation. Water shortage around India has been significant as an average of 2,800 liters of water is used daily. Due to the critical state of the land, farmers have not been able to contribute agriculturally to the country's Gross Domestic Product (GDP). Recently, India has seen the biggest decline in GDP than ever. In 2019, the GDP was 2.871 trillion USD and in 2020, it was 2.623 trillion USD. The decrease in production in the agriculture sector has also led to an increase in unemployment in that sector. In 2018, the agriculture sector accounted for more than 50% of India's workforce and has since seen a decrease to 41.24% in 2020. A summary of all of India's water usage is shown in figure 1.2.

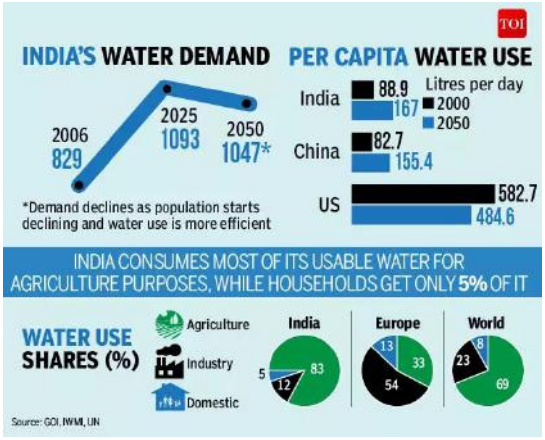
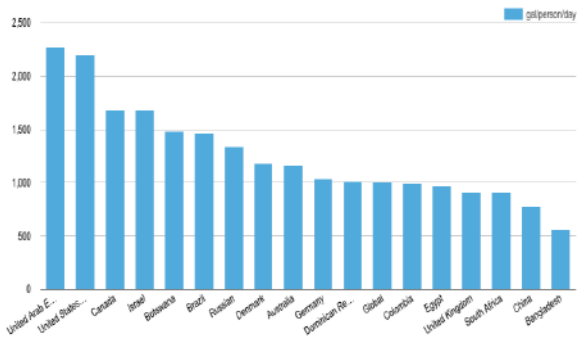


Figure 1.2

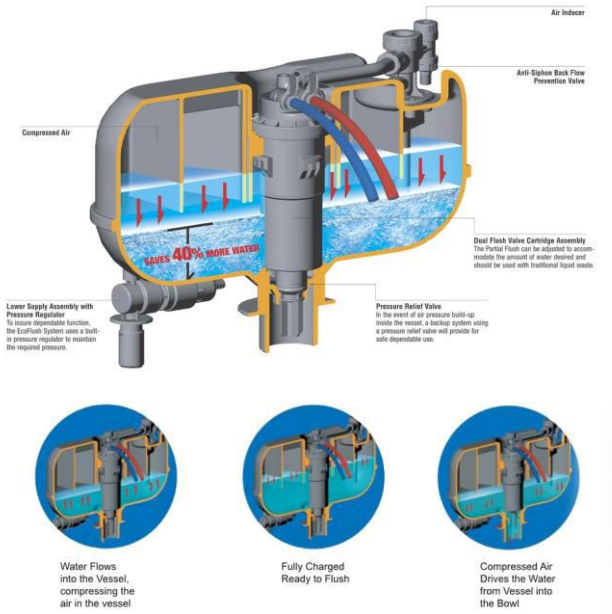
The decrease in agricultural production has caused distraught amongst farmers and other agriculture producers. Not only do droughts have an impact on the environment and economic state of the country, but they also have an impact on the water quality. The water quality is affected as the decrease in water flow limits the amount of dissolved oxygen. This impact on the water quality can have a significant impact on the health of the population. As of last year, Sep 2019, more than 50% of the population doesn't have access to clean drinking water. Our solution solves the major problem of water shortage around India. By implementing our solution in households, the daily water usage levels will decrease. This will have a great impact on societies and communities across the country.

For example, in Mumbai per day wastes generate around 900 million liters by 20,667,656 people. If even ¼ of the population installed this device, each day at least 826 million liters of water will be recycled as per our study.



Literature review:
During the research we have considered the present technical solution, design solution and government policies for water conservation. A few of them are as follows:

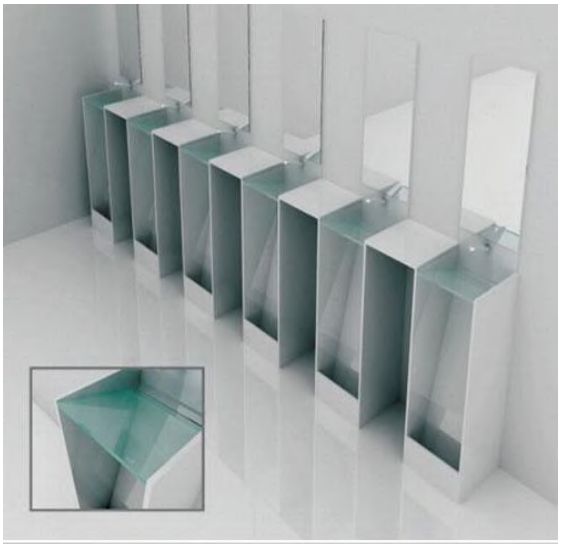
ECOFLUSH

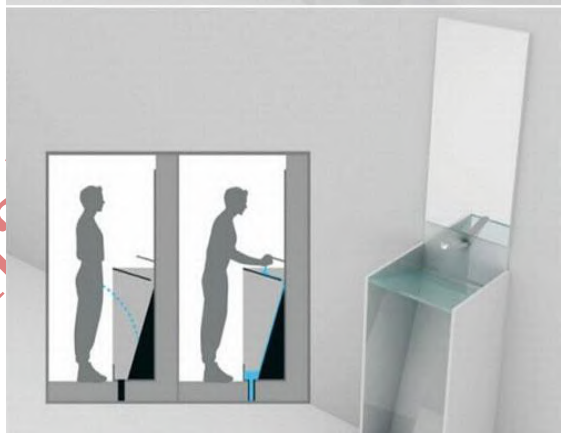


EcoFlush is an innovative toilet pressure assisted system that offers exceptional flushing performance when added to any compatible toilet. Featuring patented WDI technology, EcoFlush is truly a remarkable solution for improving toilet flushing efficiency while conserving precious water resources. EcoFlush pressure-assisted systems can make your toilet more functionally and environmentally efficient. Unlike gravity-assisted toilet systems, WDI EcoFlush pressure-assisted flushing systems "push" waste and water throughout a toilet. By introducing air during the toilet's flush-to-filling cycle, the EcoFlush pressure-assist system injects an extra level of power into every flush. This extra power aids in both flushing efficiency and towel bowl cleansing to keep your toilet extra clean.

URINAL & SINK COMBO

To save water, Eco Urinal is designed to use the water that was used for washing hands to flush the urine. By this process, we don't have to use water twice after using the urinal. Moreover, it reduces the establishment expenses by optimizing the materials. The upper space of this urinal is made with glass, and it helps to secure a clear view for users. It also promotes people to maintain their sanitation because people need to wash their hands to flush the urine after use.





USING WASTEWATER IN AGRICULTURE

• Public health: Wastewater has the potential to cause diseases because it contains bacteria, viruses, and parasites. Also, the inclusion of heavy metals in wastewater can
be very dangerous for human health. Wastewater use in agriculture creates risks for the population living within and outside the wastewater irrigation zone.

• Crops: Wastewater is attractive and economically valuable for farmers because it
contains important nutrients for crop growth. However, a high concentration of chemical pollutants in wastewater may be toxic to plants.

• Soil resources: Accumulation of nitrogen, phosphorus, dissolved solids and other
constituents such as heavy metals in the soil affect its productivity and the sustainability of land use for agriculture. Salt accumulation in the root zone may have harmful impacts on crop yields.

• Groundwater resources: The leaching of nutrients and salts included in wastewater has the potential to affect the quality of groundwater. The degree of impact depends on several factors, including the quality of groundwater, the depth of the water table, soil drainage and the amount of wastewater applied for irrigation.
• Property values: Using wastewater for irrigation may influence the land property values positively or negatively. Low soil productivity due to the use of wastewater in irrigation may negatively affect the land prices and lease revenues. However, the value of wastewater as a source for irrigation may positively affect the value of the land.
• Ecological impacts: Drainage of wastewater from irrigation schemes into water bodies may indirectly affect aquatic life and negatively influence overall biodiversity, e.g. the presence of water birds. • Social impacts: The use of wastewater in agriculture has different social impacts on food safety, health, and welfare, quality of life, property values, and sustainability of land use.

GOVERNMENT EFFORTS

The Government's Partnerships to End Open Defecation and Increase Sanitation Efforts

In 2014, India's Prime Minister, Narenda Modi, began advocating to enhance cleanliness efforts by October 2019. Since he announced this objective, there has been significant progress in making clean water and hygiene amenities available.

In 2014, the amount of people living in agricultural areas who defecate openly has decreased from 550 million to 320 million. Overall, clean drinking water and proper sewage disposal have improved from 39 percent in October 2014 to over 90 percent in August 2018.

UNICEF Action endorses the federal and local governments in providing water, sanitation and hygiene in India. UNICEF's Child's Environment Programme advocates for the government's Total Sanitation Campaign, which has the goal to enhance the availability and utilization of sanitation facilities. The National Rural Drinking Water Programme works to implement clean water to each and every family in India; the Child's Environment program collaborates with Integrated Child Development Services to ensure that proper hygiene facilities are present in schools.

USAID collaborates with India's government to implement healthful towns by growing access to safe water and cleanliness. Together, USAID and the Government of India assess and distinguish various models to enable consumable water and toilets, which they can put into effect for various localities.

In order to eliminate defecation by 2019, India began the five-year Swachh Bharat (Clean India) Mission to cease open defecation. USAID promotes the commission by educating others about these matters and initiating action from the people and government officials.

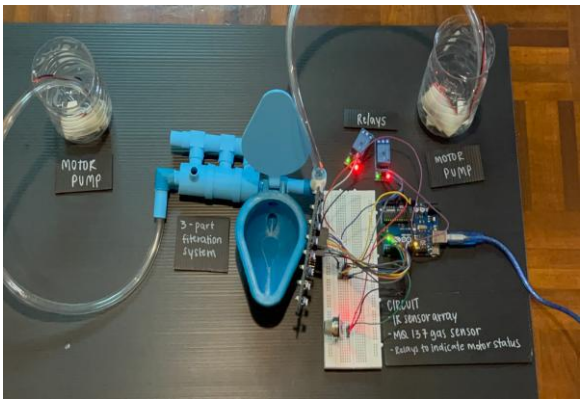
The overall goal of USAID is to implement techniques to have safe, clean water access that is inexpensive. The organization also collaborates with civilians to compose sanitation facilities as well as encouraging hand washing along with refraining from defecating in the environment.

In 2017, 300,000 citizens had access to water, sanitation and hygiene in their homes. As a result of the community efforts, 25,000 communities have stopped defecating in the environment, while 175,000 people are able to obtain clean, consumable water.

SOLUTION

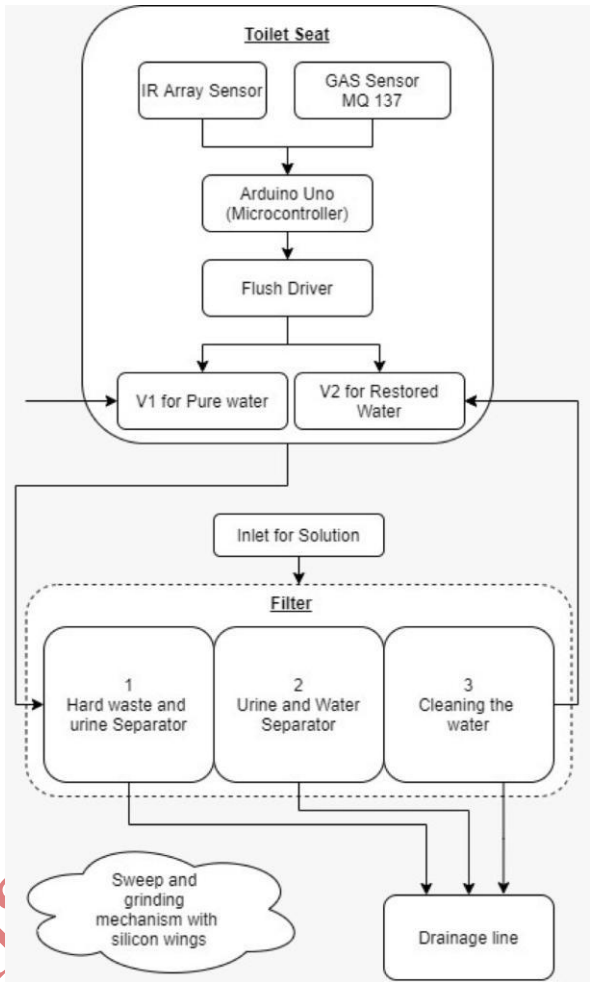
The innovative aspect of this prototype is that it can be retrofitted to existing systems and differentiate between urine and feces and can treat both separately for recycling. It can filter flushed urine water to be used as greywater for flushing again. It's also a multivariable design, which means the output of water is dependent on the amount of waste; helping reduce the usage of water, leading to less consumption of water. While positively benefiting the environment, it is also user-friendly, maintains hygiene, and is cost-effective. This design is attachable to existing toilets, thereby avoiding the cost of replacing the toilet or adding a new toilet; and the cost of this device itself is affordable. Moreover, it maintains hygiene as after cleaning with the greywater, the commode is washed through a layer of clean water. Lastly, this device can be used manually or automatically, making it user-friendly and flexible for use. Reusing the urine passed and flushing water as greywater, 80%-90% of the water is reused,

reducing the water consumption of the flush from the average of 200 liters per day to 40-20 liters per day. Saving 160 to 180 liters of water, from one toilet, each day, in a year one toilet, due to this device, can save up to 58400 to 65700 liters in a year. Reducing the percentage of water wastage can directly help to solve the water crisis.

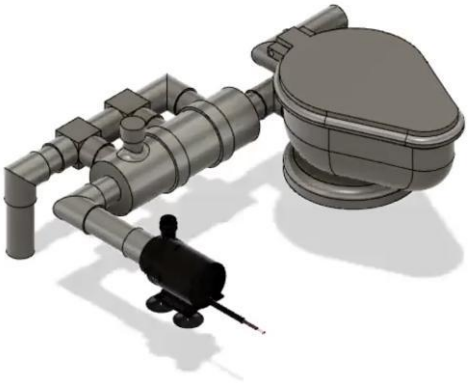


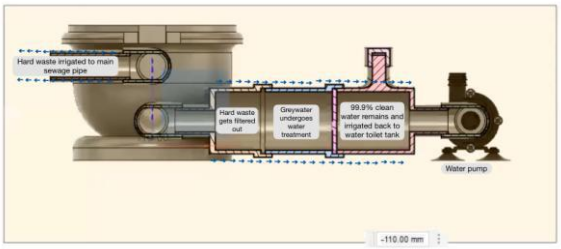
The design is a modern approach towards saving water. In our solution, a pipe directs toilet wastes into our filtration box. The filtration box has 3 main parts in it. The first part filters out any hard waste. The second part filters out liquid waste. We also have a chemical treatment solution that treats liquid waste. The last part filters out any other impurities that the last two filters may not have been able to get rid of. The method to this solution is as follows. The user will first do their business in the toilet and then our circuit, consisting of a system of an IR array and a gas sensor, will detect the amount of waste and dispense both the greywater and clean water in relative proportions according to the amount of waste. Next, the water would be irrigated into the filtration box.

The CAD model was made using Fusion360. The designed model was 3d printed using PLA. The 3d printed model is a miniature version of the proposed solution. The prototype is designed and tested on 3D printed PLA parts which consume 12V 2A power. The real-life application of this system would require a radius of 200mm for the filtration system. The length of installation of the filtering pipe is 1m, encompassing all 3 filtering stages.

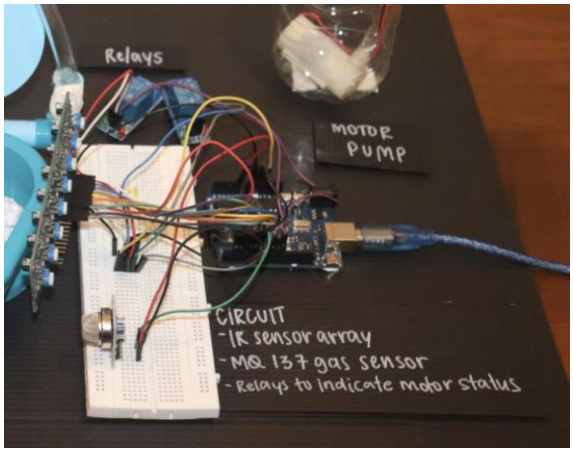


CAD Design:



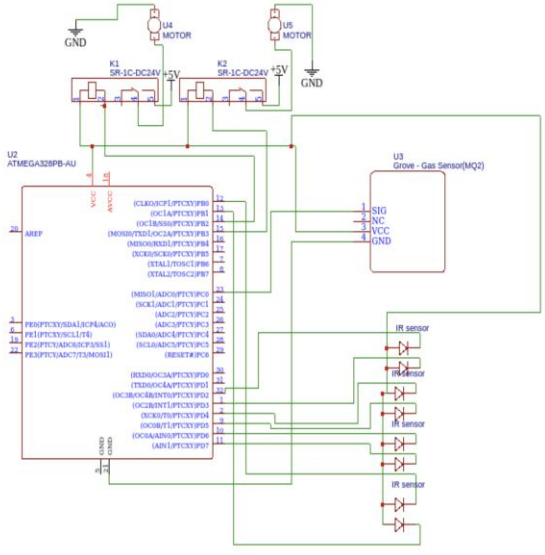


CIRCUIT



The circuit is composed of an IR sensor array, MQ137 gas sensor, two relays, and 2 motor pumps. The IR sensor array was used to detect whether the waste is solid or liquid while the gas sensor measures the intensity of the waste to determine the amount of water necessary for the flush cycle. The relays were lit when hard waste was detected and the corresponding motor pump was activated. This system is driven by an atmega328 ic Chip, which works on embedded c programming. To understand the type of waste the code was developed using the PD (Proportional derivative) method. And to understand the waste intensity a technique called RT vs FT was used.

CIRCUIT DIAGRAM



Picture	Component	Price
	MQ 137 Gas sensor	□2,074
	Relay 2x	□130
	Motor pump 2x	□160
	IR Sensor Array (8)	□400
	Arduino UNO	□400

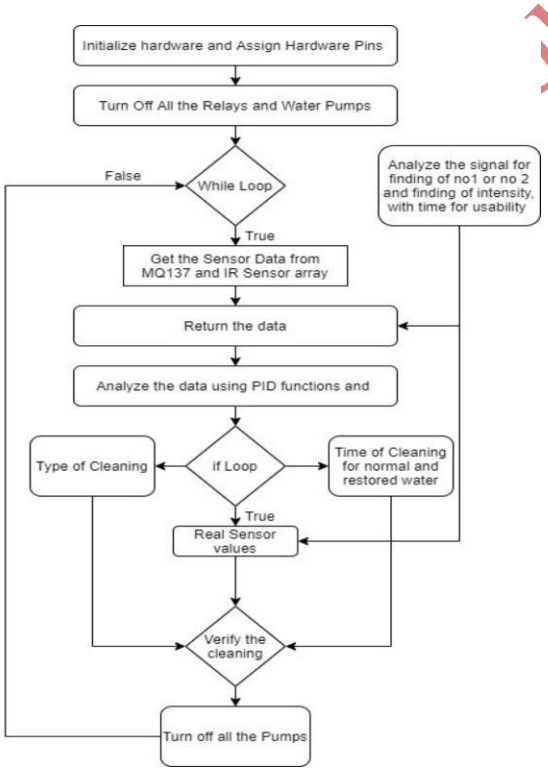
ALGORITHM

In our solution we are using 2 types of sensors: an IR array and MP137 Ammonia Sensor interfaced with a microcontroller to control the entire process through controlling the water-pump using 3 relays.

Alongside we have created customized parts to retrofit existing toilets using 3D printing designed and simulated through Autodesk Fusion 360 Software. This design has a 3 stage filter that does segregation between hard waste (poop) and liquid waste (pee). To recycle the water we are using chlorine and some other compositions of chlorine to convert sludgy water into grey water. This water can be stored in a separate tank for initial cleaning.

In our algorithm, we have used a 10-bit array sensor that gives digital data, using a PI function that can convert this data into the integer format. This shows how my sensors got cut at an instance of time. This procedure helps us to distinguish between hard waste and liquid waste. Alongside we have used an MP137 sensor which can give us the intensity of the ammonia produced due to waste. This intensity we have converted along with proportional constant value gives us the required cleaning time.

Cleaning time has a 70% duty cycle which uses 70% gray water and 30% normal water for cleaning toilets. The filtration process requires 15 min to clean the reused water sent to the gray water tank, and minimal waste dropped into drainage lines. We believe this system is very efficient in terms of cost, maintenance, installation, and friendly use.



PROGRAM

Firstly, we set up all the input and output pins using the set up function.

```
void setup (){
pinMode(reRelay, OUTPUT);
pinMode(flRelay, OUTPUT);
pinMode (d0, INPUT);
pinMode (d1, INPUT);
pinMode (d2, INPUT);
pinMode (d3, INPUT);
pinMode (d4, INPUT);
pinMode (d5, INPUT);
pinMode (d6, INPUT);
pinMode (d7, INPUT);
Serial.begin (9600);
}
```

Below is our main code which is using the relay control function, gas sensor reading function, and IR sensor reading function.

```
void loop(){
getIrData ();
Serial.println("Mode of Opration:"+String(stats));
getGasData();
Serial.println("Intensity:"+String(intensity));
 // relayFunction(1000);

  if (stats == 1){
relayFunction (intensity);
   stats = 0;
  }

  else if (stats == 2){
relayFunction (intensity);
   stats = 0;
  }

  else {
digitalWrite(reRelay, LOW);
digitalWrite(flRelay, LOW);
  }
}
```

Relay control function:

```
void relayFunction(int t){
Serial.println("Relays are activated");
digitalWrite(reRelay, HIGH);
digitalWrite(flRelay, HIGH);
  delay(t);
Serial.println("Relays are De-activated");
digitalWrite(reRelay, LOW);
digitalWrite(flRelay, LOW);
```

```
  delay(t);
}
```

IR sensor reading function:

```
void getIrData(){
  a = digitalRead (d0);
  b = digitalRead (d1);
  c = digitalRead (d2);
  d = digitalRead (d3);
  e = digitalRead (d4);
  f = digitalRead (d5);
  g = digitalRead (d6);
  h = digitalRead (d7);

  delay (100);
int value = ((a*10)+(b*10)+(c*10)+(d*10)+(e*10)+(f*10)+(g*10)+(h*10))/8;
  if (value >= 2){
    stats = 2;
  }
  else if (value == 1){
    stats = 1;
  }
  else {
    stats = 0;
  }
}
```

Gas sensor reading function:

```
void getGasData(){
sensorValue = analogRead(A0);
  intensity = sensorValue;
}
```

RESULTS & CONCLUSION

To validate this device, when the prototype was tested, the results received helped to verify its utility and impact on society. Firstly, when confirming if the device can differentiate between the different wastes and accurately treat them by performing 98%, no inaccurate results were gained. When using the filtration box, it was found that out of 9/10 times, the filtration process successfully sends 80% to 90% of the water back to the tank. Further, After testing the flush 10 times, 8 times the result came to be proving it to have a 98% succession in reusing 80% to 90% of the water for the next flush. Lastly, when the feature of using 70% greywater and 30% clean water was tested by 10, 9 out of 10 times the system accurately maintained the above ratio between the usage of grey and clean water. This helps conclude how this product will overall reduce water wastage through reusing water and illustrates the success of this device.

FUTURE SCOPE

We have completed an entirely functioning prototype (through 3D printing, coding, and circuits) with a high success rate, that saves 80% to 90% of the water for every flush. Therefore, through this project, this design could be promoted for implementation and in the future, can be fitted into existing devices and introduced into the toilet systems.

This device can also be brought to the attention of Mr. Rajendra Singh, also known as “Waterman.” His work as a water conservationist and environmentalist is dominant in society, especially in India. Through this, this device’s implementation could be enhanced - creating a substantial impact on the Environment

We also plan to develop the prototype further to make it waterproof and even more user-friendly. Another thing is to introduce this product to the market and advertise it to become a commercial product so that everyone can join us in saving the environment.

Acknowledgement

I would like to express my heartfelt gratitude to On My Own Technology for extending their help in carrying out the particular project. I shall remain grateful for their help and guidance.

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Links:
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