Using Bio-digester Tanks to Process Sewage at Domestic Levels

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Abstract- *In response to the growing problem that has manifested us in the form of water pollution from domestic sewage sources we have designed a product to be installed in homes. It would convert the average toilet into a bio-toilet that is capable of producing renewable cooking gas by processing the domestic waste. This paper is a study into the potential of this model's success. The various areas covered discuss the consumer mindset towards adopting the product and its accompanying lifestyle changes, the fuel efficiency of the bio-gas produced and the overall usability of the unit.*

Keywords- Waste management, renewable energy, biogas, domestic sewage treatment, toilets

1. INTRODUCTION

A toilet is a permanent part of any home across the world. The conventional flush toilet developed as a part of modern living has provided us with a clean and comfortable method of disposal of excreta. However, the pollution issues coupled with this existing system of water-based sewage and its irresponsible disposal have taken a toll on our ecosystem. The untreated sewage is polluting groundwater, rivers, lakes and coastal areas. Not to mention, water used in toilets take up 20% to 25% of that used by the whole family [1]. Similarly, cooking gas is a commodity used the world over.

However, its source lies in petroleum products, otherwise known as "fossil fuels". As we all know, fossil fuels are not a sustainable source of fuel as the time taken to generate them naturally runs into the thousands of years. Another issue at hand is the dependency of individuals on cooking gas agencies to deliver liquefied petroleum gas cylinders on time, failing to do so leading to consumer inconveniences.

The majority of metropolitan cities in the South of India also suffer from seasonal acute water shortages, thus, any method of sanitation that utilises less water has the potential to take off in popularity. Another factor to consider here is climate change patterns, given the rising temperatures and irregular rainfall patterns, a product that uses considerably less water and promotes a sustainable lifestyle would have a favourable long term outlook amongst the consumer market.

2. OBJECTIVE

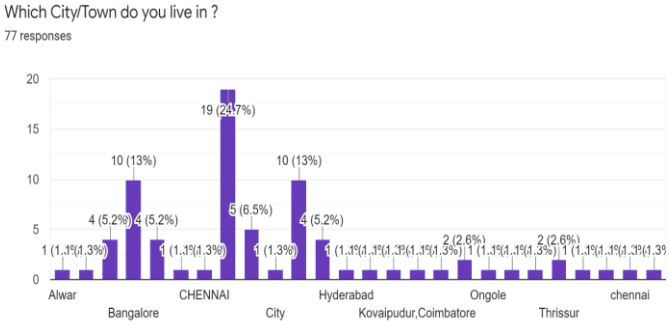
Our main goal is to design a product that will one day, replace the conventional, out-dated models currently used in our homes and businesses. Even though sewage treatment plants are in use across India, their efficacy is in question as reports of aquatic biodiversity dwindling are on the rise. Another issue caused as a result of our dependency on the sewage system is the resurgence of water-borne diseases affecting our population, even causing death to those unfortunate enough to not have access to effective healthcare [2].

An added bonus to our model would be the production of bio-fertilizer as a byproduct of the reaction occurring within the bio-digester tank unit. This bio-fertilizer would be of use to farmers who would in turn supply us with our required raw materials. Not only is this a quid pro quo transaction of goods with a partner farm, it's a visible representation of the societal benefit our system introduces. Now, our consumers will be able to see the beneficial impact they are creating when they buy our line of sanitation products. If our product works as expected, it will practically advertise itself.

We hope that our product would instill a sense of ecological responsibility in the consumer market not just to make smart environmentally conscious purchases with respect to sanitation, but to also develop methods of sustainable living that will cure the environment of the disease we have wrought upon it.

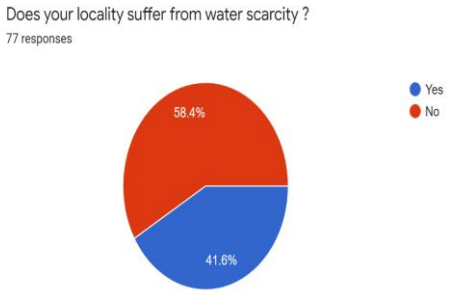
3. MATERIALS AND METHODS

3.1 Survey Results

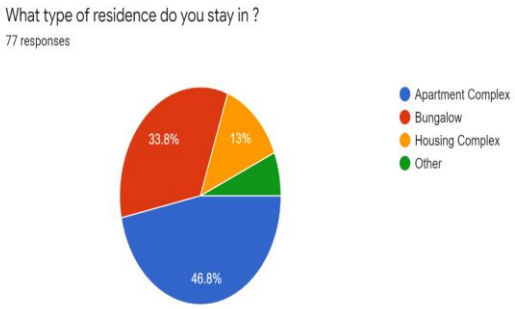


From the given chart above we can see that most of the people that have answered are mostly from Bangalore, Chennai, Hyderabad and other cities. We can come to the

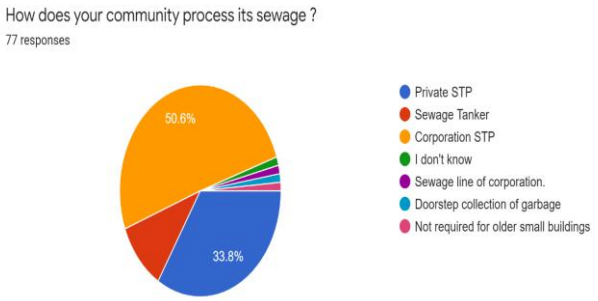
conclusion that the majority of the people live in metropolitan areas.



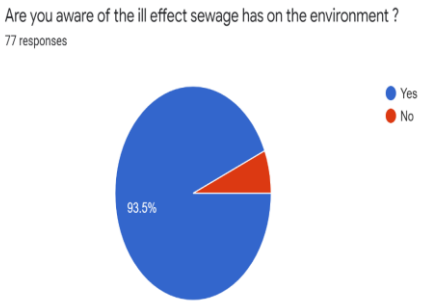
We can see that 41.6% of the people that took the survey suffer from water scarcity in their area where our product would play a key role in combating the issue. We assume that the people who suffer from water scarcity are predominantly from the aforementioned metropolitan areas.



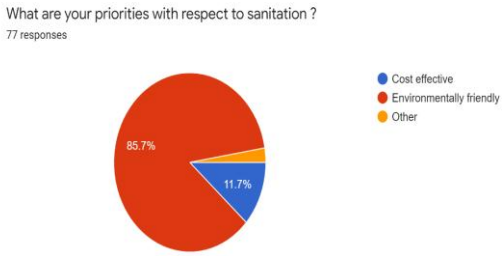
From the chart we can see that most of the consensus picked Apartment complex as the type of residence they stay in, this would be the ideal place to implement our product due to there being a single source for multiple outputs. The next widely used mode of residence is bungalows where we can still use our product but with the added benefit of more customization. Then housing complexes are chosen and the finally unspecified segment.



Sewage is currently processed in many different ways some more effective than others.



Unless sewage is treated properly it has mostly negative effects on the environment. Usually sewage is disposed of in water bodies unfortunately if not treated properly the harmful bacteria in waste material like E. coli, can pollute these water bodies and in turn also the marine life that are living in them, they also produce atmospheric emissions and liquid effluents that make it harmful to live next to these facilities. From the Pi chart above we can see that the people are aware of the ill effects of the sewage on the environment.



From the result we can see that the majority of the survey audience prioritise an environmentally friendly method for their sanitation solution and another small percent wises to have a cost-effective solution. Our product aims to cater to both the audiences and also provides a no compromises approach which means that we do not sacrifice aesthetics in the name of functionality.

3.2 Prototype Model

We have made the digital model of floating dome bio-digester tank setup along with toilet and gas tank linkage along with a physical model for representation.

The components like the tanks and the pipe connecting the bio-digester to the gas tank will remain constant whilst the pipes connecting the toilet to the bio-digester and the gas tank to stove top will fluctuate in length from house to house.

In order to make the modification without changing the toilet, we would channel off the pipe from the toilet into our bio-digester tank. This is the pipe that normally leads into a sewage tank below any apartment complex.

This modification can be done without much effort or mess as these pipes are exposed in apartment buildings, running down the sides of the building.

The two main tanks used would vary in size with different clientele, smallest variant being 750 litres and 500 litres together along with a gas tank of approximately 500 litres.

All of the piping would be PVC with the exception of the gas pipe connecting to the stove.

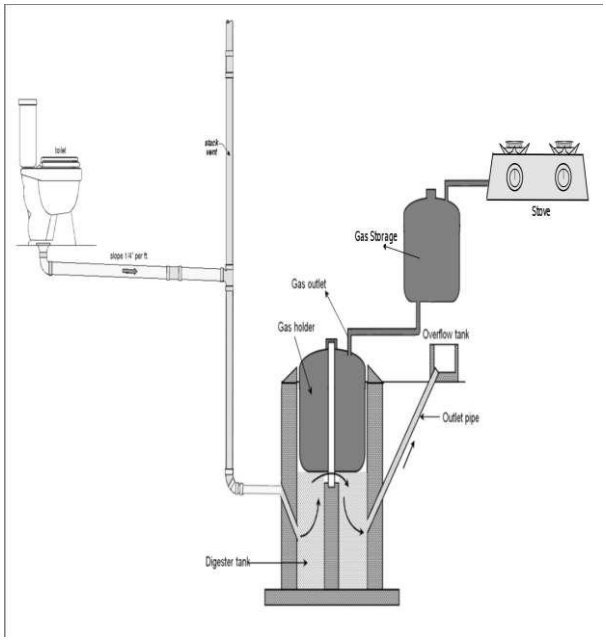
The spent-slurry collection tank next to our bio-digester unit will store the bio-fertilizer product from this unit after it has been digested and overflows.

This slurry can be used to fertilize soil and will be collected during maintenance checks. With the consumer's permission we will distribute this bio-fertilizer to our partner farms.

Also, because the waste from the toilet will only travel till the tank, that too using gravity, the toilet will not require as much water to transport the waste.

So another change we can make is modifying the consumer's existing toilet to use less water per flush, otherwise known as low flow. This will be done by changing the flow from the valves.

All of this will be described below.



3.3 Prototype Construction Method

1. Choosing the location of digester unit: It is preferred to have the unit close to the house, as we will require less piping to facilitate the operations. Another preference is that the unit be on the ground for more structural stability although this is not a mandatory requirement. Temperatures should be above 25 degrees Celsius, but in our target audience cities, this is a perennial occurrence so we can expect a good output.

2. Estimating the tank size to be used: For 5 kilograms of waste generated per day, the tank of 750 liters will suffice. This amount of waste corresponds to a family of 3-4. So, we can scale up for different family sizes or even apartment complex blocks.

3. Installation [3]: First of all, we need to install the tanks at the desired location. This means using our larger tank as a digester and cutting the top off the smaller tank as well as the larger tank and affixing the smaller tank inside the larger one to collect the gas initially and act as the floating dome part of our bio-digester. The cutting of these HDPE tanks can be done using even a hacksaw.

4. The second thing we need to do is install a waste feed pipe into the bottom of our digester tank, this will be done by channeling off the sewage pipe from the customer's toilet into the tank using PVC pipes and brackets. According to the Chennai Metropolitan Water Supply and Sewerage Act of 1978, PVC is listed as material which can be used for fittings and fixtures with respect to plumbing.

5. Then, we need to fix the guide rails on the digester tank, so that the gas tank can easily move up and down on its grooves as it collects gas. This will help to stabilize the tanks throughout the course of their operation.

6. These guide rails will be a set of PVC pipes on the tank to keep the top and bottom tanks aligned throughout.

7. Adding the gas pipes which will carry the gas produced from the digester to the gas collection tank next to it, and from that tank to the kitchens where it will be attached to the stove top. These pipes are made of standard gas piping. The length of the pipe used will vary from house to house.

8. Next we need to affix a slurry outlet pipe, this will channel out the processed slurry from our tank into a slurry collection tank made of HDPE, the pipes used here will also be of PVC, and they will be connected at the top of the larger tank.

9. All fixings done using PVC must be sealed with PVC solvent cement and/or epoxy industrial resin.

10. The first time we feed the tank, it must be with combined slurry of approximately 80 kilograms cow dung and 200 liters water along with a kilogram of palm sugar. This is done to ensure microbial colony formation within our bio-digester tank.

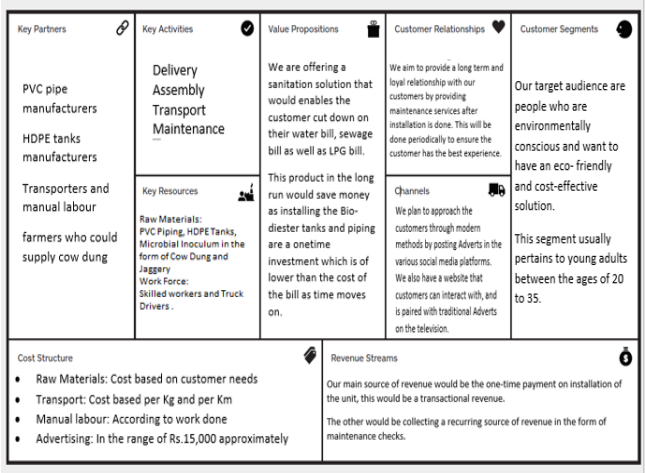
11. After about two days we can expect some formation of bio gas, and after two weeks time we will be able to utilize this bio gas for cooking purposes. Finally, after a

month's time, we will be able to generate enough cooking gas to sustain a household daily.

Our methods of construction were adopted from Mr. J. Antoni Raj's model of a floating dome biogas plant he constructed at his home [4]. Slight modifications were made in order to run our product on human fecal matter.

4. RESULTS

4.1 Proposed Business Model Canvas



4.2 Company Name

The idea behind the name is that it should reflect our product's functionality. "Bio" refers to the zero-chemical working process our bio-digesters operate under in order to synthesize cooking gas that can power a household's cooking needs sufficiently, hence the 'Synth".

4.3 Company Logo

4.4 Problem Statement

Any sanitation method should offer consumers two key aspects: Comfort and an environmentally friendly disposal of waste. However, the existing options only cater to one of these options at a time.

Eco-friendly bio-toilets offer little in the way of comfort whilst standard models albeit user-friendly, are not sustainable in their usage of resources. We seek to offer our consumers the best of both worlds with a product that's less wasteful, generates fuel and is comfortable to use.

Mission Statement

"It is not a consumer product, it's the gateway to a sustainable lifestyle."

Our company provides sanitation and a source of energy production whilst saving money in the long run. We do this by installing sanitation-energy solutions in houses that still depend on conventional methods of fuelling and sewerage. At the heart of it all, we feel that the time has come to give our customers an opportunity to make better, more sustainable choices for their homes.

Vision Statement

"Empowering our consumers to give back to the environment"

Here at Biosynth, we believe that a customer's ability to make an environmentally conscious choice need not be limited by money or lack of market options, so we have taken an oath to give you the most effective method of clean sanitation at affordable prices.

4.5 Legal Areas Concerning Our Operations

The Chennai Metropolitan Water Supply and Sewerage Act of 1978 was used as reference whilst designing our prototype. The materials were chosen from the list of permitted plumbing construction materials.

This law essentially states that an individual can make changes to the pipelines in their house provided that the sewage is properly disposed of and not allowed to seep into the environment.

Also, if such modifications are to be made, the materials used must be proper and up to regulation.

Polyvinyl Chloride and High density Polyethylene come under the list of approved materials.

4.6 Consumer Segments

The survey regarding this service was conducted among residents of Chennai, Coimbatore, Bangalore and Hyderabad.

From the results of the survey, it was ascertained that a consumer's top priorities are reduced water usage and annually cheaper sanitation solutions.

Majority of the survey answers were from those living in apartment complexes (46.1%) and bungalows (34.2%).

Thus our target consumer would be a resident in an apartment complex in a city that requires cheaper, environmentally friendly sanitation options which consume less water.

Customer Relations

Seeing as we are selling a product that would be a long-term investment to most consumers, we would be placing a certain emphasis on our customer interaction skills. Our services would include onsite assembly of the unit as well as periodic maintenance checks every couple of months. As a result, we would be looking to ensure a healthy, constructive environment between our consumers and workers. We aim to ensure customer loyalty as our product's value shows best in the long-term.

Channels

This is how our customers will encounter our product and its accompanying services for the first time. To keep in tune with the times, we would opt for an online advertising strategy as it is more efficient, more likely to be seen and ensures higher success rate over conventional methods like flyers or Billboards.

When we say online, we refer to ads on Instagram, Youtube, Facebook and other emerging social media platforms and Television Advertisements.

Moreover, we feel that by channelling our advertising focus online, we stand a better chance at capturing the attention of the type of audience who would see the value and benefits our product line holds.

4.7 Value Proposition

We are offering a sanitation solution that would enable your average city resident to cut down on their water bill, sewage bill as well as LPG bill.

Any individual who requires lesser expenses and desires an eco friendly lifestyle would value this product and accompanying service.

Thus by purchasing our service, they would be saving money in the long-term, as the cost of installing a bio-digester tank and bio-toilet would be less than the amount spent per year on water and gas.

Also, in the results of the survey conducted, it became apparent that residents did desire an environmentally friendly lifestyle that too at lower cost. We can see a possible market especially in cities that suffer from periodic water scarcity (Chennai). Overall, 93.4 percent of responses suggest that they would like to see our product in their community.

We offer a service comparable to our market counterparts, with one distinct advantage being that you get to keep using the toilet you are comfortable with. No need to go outdoors, no need to buy a new toilet.

4.8 Key Activities

We would ensure that the delivery of the materials takes place according to a scheduled time decided by the consumer and arrives in proper condition.

It is of paramount importance that the assembly of the unit is done in a controlled manner to ensure that the product functions at it's peak efficiency. We would send our most skilled technicians to install the device to make sure the customer does not run into any issues with our product.

It is essential to maintain a standard transport system for procuring our raw materials (Piping, Tanks, Microbial Inoculums). To this end, we plan on using the highways via Heavy Goods Vehicle. We value customer satisfaction and as a result of this, we would focus our efforts towards providing solutions towards our customers regarding issues ascertaining to the product. This can be customers via email or toll-free number.

Key Partners

Our product requires PVC piping and HDPE tanks for construction as well as a one-time instalment of cow dung to initiate the microbial activity in the bio-digester tank.

We would also be requiring transport systems (trucks) in order to move our product. Construction would be done onsite using manual labour (our workers).

We would require a tie-up with a company that sells the above required plastic products, along with farmers who could supply cow dung, all on a regular basis.

Key Resources

Raw Materials:

PVC Piping, HDPE Tanks, Microbial Inoculum in the form of Cow Dung and Jaggery

Work Force:

Skilled workers and Truck Drivers would be required to assemble and maintain the working product.

COST STRUCTURE PER UNIT

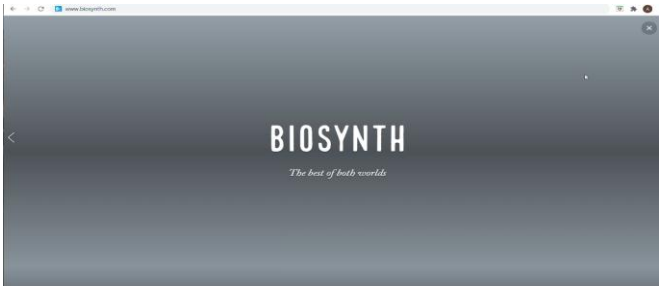
ITEM/SERVICE	COST
Assorted PVC pipes	1,500
PVC solvent cement	450
M-Seal epoxy compound	450

700 L HDPE Tank - 1	7,000
500 L HDPE Tank - 2	10,000
80 kg cow dung	400
1 kg unrefined palm sugar	200
Shipment rate (per km)	58
Advertising- social media	5000
Advertising - television	10,000

4.9 Revenue Stream

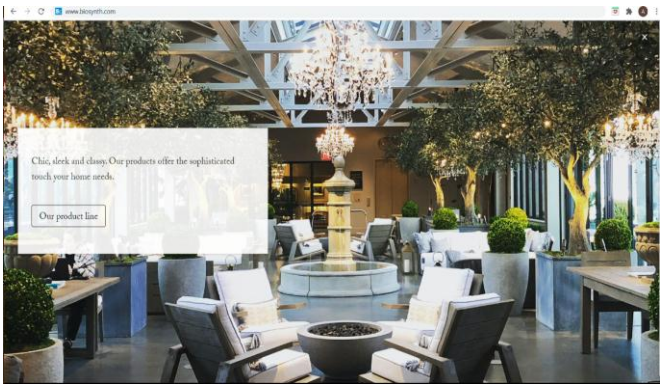
Our main source of revenue would be the one-time payment on installation of the unit, transactional revenue. We would be collecting a recurring source of revenue in the form of timely maintenance checks. The above costs are subject to variation due to the variation of installation charges and material requirement from unit to unit.

Webpage



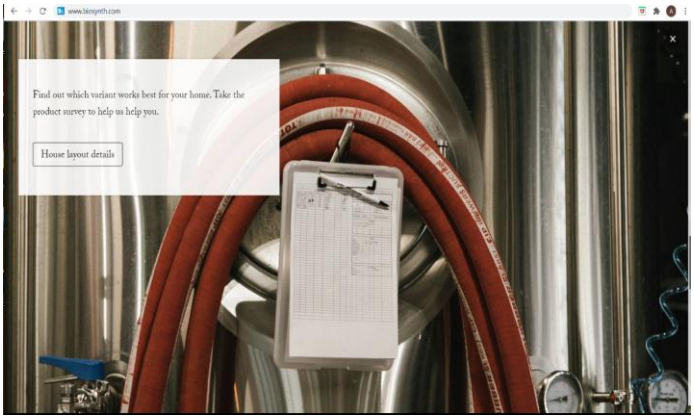
Page 1

The first page of the webstie provies the name of the company along with a quote that describes our product efficiently. The meaning behind the quote "The best of both worlds" under our context is that we provide a soolution to the modern world for a more efficient and eco-friendly solution to current conventional toilets that are more harmful to the environment and use a lot of water.



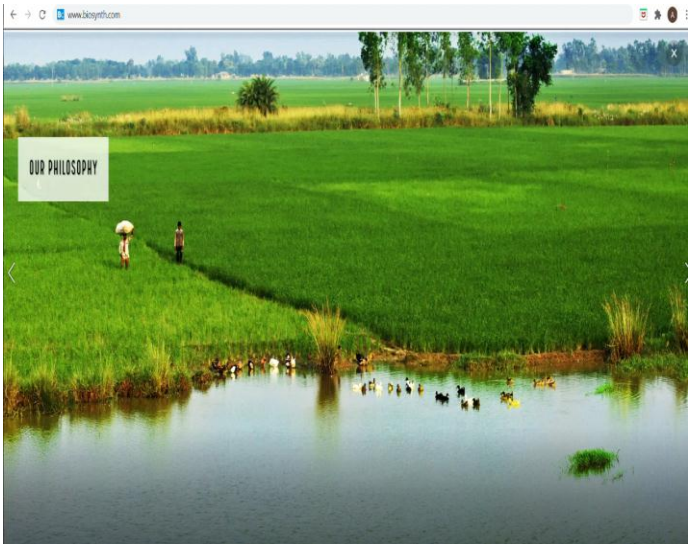
Page 2

In this page we show the cutomers that we provide an asthetically pleasing solution to the problem. There is a button that is available that when pressed gives a list of the different product specifications we provide.



Page 3

In this page the customer must use the button provided that takes them to another page where they'll have to provide the details of their house layout, size etc. Which we would use to then strategically plan out the way and method in which we are going to provide the customer with the product.



Page 4

Here the greenery signifies the main objective and philosophy of our company that is to provide a green solution to lead to a environmentally friendly and green lifestyle.

5. DISCUSSION

The main goal of our project is to introduce a product to our consumers that will provide them with cooking fuel whilst taking care of their sanitation issues in a novel manner. As far as our market research shows, there is no

other product in India that offers this service at a home-based level. Mostly, bio-toilets have been installed and used either in public buildings or in select rural areas that have been the focus of government projects. So, we would be breaking new ground with this venture and thus there are certain issues we are wary of. With respect to the installation of our system, there are precautions that should be taken. Skilled engineers would be called in to install the product as it is particularly dangerous if a faulty product is used or if our system is installed improperly.

Similar concerns surround the use of bio-gas as a cooking fuel. Our consumers would be required to switch from LPG to bio-gas. For many consumers, this change might seem daunting and they may be hesitant to switch technology as studies have shown. But we encourage consumers to take the jump and make the change as it will benefit them in the long run.

From a consumer's point of view, the toilet will not have any changes made to it aesthetically, so there is no compromise in terms of comfort.

Even when sewage is treated in sewage treatment plants, it can still harm the environment and can emit noxious fumes which affect those who live near large STPs.

By channelling the waste from a toilet into a bio-digester tank, we would be using the sludge to produce other products like cooking gas and bio-fertilizer instead of allowing the waste to travel via the sewerage system and reach our country's water bodies where it can cause marine biodiversity death.

5.1 Comparison with Regular Toilets

When bio-toilets and dry composting toilets are compared with conventional flush models, the primary query is about consumer acceptance. How will the public accept this new technology? Will they accept it all? Thus in order to determine this, we need to do side by side comparisons of our proposed model with conventional models and other bio-toilets on the market [5].

A study done in 2014 by Dr. Vinod Kumar and Abhishek Garg titled "Marketing of bio-toilets: Opportunities and Challenges" published in the International Journal of Innovative Research and Development addressed many of these concerns with a questionnaire that revealed the public point of view on Bio-toilets [6].

According to the study, consumers that are more informed about climate change, water shortages and environmental pollution tended to buy into the idea with more confidence. Similarly, if consumers were given assurance that toilet would be comfortable to use and would save them money in the long-term, they would be more inclined towards purchasing the model.

There are several market options that already exist here. BioLet is brand that specializes in outdoor eco-friendly bio-toilets. However, their market is primarily based in North America and thus their influence in Indian markets is quite limited at best. We wanted to set ourselves apart from their model of keeping the toilet outside the house, giving our consumers a more convenient product.

The majority of the brands present like Eram Scientific and EcoSan produce toilets that can be used only as public toilets [7]. We aim to bring this technology to a consumer's home in such a way that comfort is not compromised.

5.2 Safety of Bio-fertilizer From Bio-toilets

We need to be able to produce safe bio-fertilizer that can be used to improve crop yields without introducing pathogenic microorganisms into the food system. To estimate the efficacy of bio-fertilizer made from human fecal matter we referred to studies previously done regarding use of human fecal matter in agriculture.

A study done by Chen Dong and his colleagues in 2018, published in the journal Acta Astronautica titled "Effect of fertilizer prepared from human faeces and straw on germination, growth and development of wheat" showed that when human faeces were fermented in an anaerobic environment and used for agriculture, the fermented residue extracted had a positive effect on wheat growth, development and germination. When the residue was at 5 % concentration, it achieved peak germination [8].

Another study done on the pathogen content in human faecal sludge and cow dung in 2016 [10] revealed that heat treatment of 60 degrees Celsius for 60 minutes was enough to inactivate all the pathogens found in the bio-fertilizer obtained. The main pathogenic microbes included *Entamoeba histolytica, Ascaris lumbricoides and Hymenolepsis nana*. This study was published in the Journal of Bacteriology and Parasitology.

Thus the bio-fertilizer can be used in agriculture to beneficial effect providing a good yield. It can also be treated to inactivate the pathogens present in the by-product.

5.3 Potential of Methane as a Fuel Source

A study done in Pakistan in 2019 by Nazia Yasmin illustrates that for long-term use of technology, it is more decisive that users are consistent with their previous decision. The users are content when the technology meets their expectations and because they formed positive perceptions about the practicality of the technology, which furthered their decision to continue using the biogas facility. Users' pre-adoption beliefs about benefits and cost determine the adoption of the technology. The financial aspects of savings, user-

investment, working cost, maintenance cost, as well as the non-monetary aspects of ease, efficiency, compatibility and convenience, are paramount in the observed product adoption process [11].

Now, let us see how methane in biogas compares to standard liquefied petroleum gas as a cooking fuel. Various experiments and studies have already been conducted to test the heat transfer rate and emission rate of both fuels. The International Journal of Hydrogen featured an article in its July 2012 edition which explains that methane gas allows for a higher rate of heat transfer as compared to LPG due to its longer flame which leads to a higher integrated heat transfer [12].

Although not as a cooking fuel, a study published in 2018 demonstrated that a generator displayed higher efficiency values of 26.22% using methane when compared to 8.26% while using LPG [13].

5.4 Green Living Trend Potential in South India

It has been established that our company aims to become a proponent of clean, sustainable living in our country. So, let us take a look at the prospects for green living in India. An article from the Journal of Cleaner Production in 2018 illustrates a "Green Building Sustainable Model" and the capability of adapting it to Indian cities and towns. A questionnaire from this study was circulated and the results look promising for clean living based products and businesses [14].

Millennial consumers will probably be our primary consumer market base and this estimate was made using data from a survey conducted by Sidharth Muralidharan and Fei Xue in a study done to establish the connection between personal social networking and green consumer socialization in India and China [15]. Knowing this, we would advertise our product on social media like Instagram and Facebook.

6. CONCLUSION

Our aim is to bring a service into the market which will not only benefit the average consumer in terms of convenience and finance over a long-term, but will also promote more and more individuals to take up sustainable forms of living. We are yet to see a venture take off in this niche and hope to bridge that market gap.

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