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Original Research Article

Potential Utilization of Urine as a Power Source and Agricultural Resource; Waste to Wealth

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Abstract: Humans create an estimated 6.4 trillion litres of pee annually, which is often considered to be waste even though it has the potential to be a large source of liquid fertilizer, power, and other resources that may be used to grow the economy. This article addresses physicochemical properties, energetic value, hydrogen production methodology, socioeconomic uses, and sustainable energy sources for household use that might aid in the urea's conversion into hydrogen molecules at low-cost energy generation. The results of the laboratory examination of the examined urine showed 0.01% magnesium, 0.01% calcium, 0.03% uric acid, 0.04% ammonia, 0.1% sodium, 0.11% creatinine, 0.11% phosphate, 0.16% sulphate, 0.5% potassium, 0.61% chlorine, and 1.82% urea. Urea represents 52% of urine constituents with the highest concentration (1.82%), making it a significant source of clean fuel and the main producer of hydrogen gas. 1.08 g of hydrogen gas was produced from 15 litres of used urinals, and the amounts were 78.9 g, 146.2 g, 218 g, 289 g, and 343.5 g, respectively. In the same amount of time, a generator powered by gasoline consumes more fuel than one powered by hydrogen. Hydrogen burns more effectively than gasoline, using 33KW energy consumption compared to 33.5 MJ for the same amount of 1 kg of gasoline. When used as a generator fuel, Hydrogen is around 15% more efficient than gasoline. Hydrogen is a fully clean source of energy for both the industrial and home markets because its combustion yields solely water vapour.

Keywords: Urine, Energetic Value, Clean Fuel, Fertilizer, Hydrogen Gas.

1. INTRODUCTION

Renewable energy is energy that is produced continuously. Cleanliness, cost, stability, efficiency, and environmental effects are some of the factors that must be taken into account while making a choice. Companies must immediately transition to renewable sources since it is obvious that fossil fuel supplies will soon run out. Additionally, these fossil fuels pose a serious threat to ecological stability and the environment's delicate balance (Umar, 2017). Hydrogen piqued the interest of researchers who were looking for simple local power generating methods. A good substitute for fossil fuel has been suggested: hydrogen. Due to issues with storage and industrial-scale manufacturing, hydrogen's promise has not even been closed to being fully fulfilled. One of the most common and environmentally beneficial waste liquids on earth is human pee. Urine's primary component, urea, has a chemical formula of CON2H4, which indicates that there are four hydrogen atoms present in each urine molecule. In contrast to water, these four atoms are far less tightly bound. Because of this, getting hydrogen from human pee is quite easy (Clark, 2011).

Table 1 below lists the chemical components found in urine (Nukala *et.al.*, 2016).

Table1: Chemical Composition of Urine

Element	Quantity (g/l)
Oxygen	8.25
Nitrogen	8.12
Carbon	6.87
Hydrogen	1.51

1.1 Fossil Fuel

Hydrocarbons make up majority of fossil fuels. Fossil fuels' primary problem is not their consumption, but rather the negative consequences it causes. Due of their unreliability, fossil fuels are vulnerable to running out. Large volumes of hazardous gases, most notably carbon dioxide gas, are produced when they are burned. Global warming is mostly caused by this gas. The planet's temperature is constantly rising due to global warming, jeopardizing the lives of creatures that reside there (Mclamb, 2011).

When fossil fuels are burnt, gases such carbon monoxide, nitrogen monoxide, nitrogen dioxide, and sulphur dioxide are generated. These dangerous substances impede the growth of plants, cause smog, impair human health, and directly contribute to air pollution. Sulfur dioxide is primarily responsible for the production of acid rain, which severely damages marble crops and monuments. Due to coal mining, the land has become lifeless and barren. Due to this detrimental side effect, there are numerous areas of land where crops cannot be cultivated (Anders, 2010).

The firms that produce hydrocarbon products are aware of these severe. They are powerless until renewable energy sources can compete with traditional energy sources on an equal footing. Utilizing fossil fuels is a significant risk that contributes to global warming (Priyam, *et al.*, 2020). For the planet and its inhabitants, it is extremely damaging. Furthermore, as previously said and innumerable, fossil fuels have been the root of a great number of unpleasant accidents in the past. These toxins damage the ozone layer through global warming. The use of renewable resources is urgently required (Moll, 2015).

1.2 The World Future of Energy

Currently, the main method for producing hydrogen is stream reforming, which is essentially another method for producing fossil fuels. Hydrogen was intended to be produced in an economy based on inexpensive, clean power by electrolysis, but this method was simply discovered to be ineffective. The carbon footprint is increased through handling, transit, and storage. According to studies conducted in the previous ten years, urine contains twice as much hydrogen as water does, and requires less energy to produce. With its exhaust producing just water, hydrogen-powered vehicles have gained popularity as a form of transportation. The fundamental benefit that urine contains readily broken to a small amount hydrogen needed as fuel (Priyam *et al.,* 2020).

1.3 Physicochemical Properties of Urine

Urine's main component is loosely bound than the hydrogen atoms in water molecules. The amount of fluid consumed per person determines how much pee is excreted. The urine output will increase in direct proportion to protein consumption. A mature person consumes on average 1500 to 2000 ml each day. The body needs to get rid of the urea the protein creates. Clear light amber is the color when there are no deposits. According to a urinometer with an aromatic odor, the specific gravity of normal urine ranges from 1.010 to 1.025. Normal urine has an average pH of 6.0, which makes it somewhat acidic (Nicola, 2012). Urea, sodium chloride, and water make up the urine's three main ingredients. For an adult who consumes around 100 g of protein over the course of 24 hours, the urine's composition should be as follows. 96% of it is water, while 4% is solids (urea is 2%, and 4% is made up of various metabolic products). Other metabolic waste products include uric acid, creatinine, and electrolytes or salts like sodium chloride, potassium chloride, and bicarbonate. Uric acid is normally eliminated in the urine in amounts of 1.5 to 2 grams per day and ranges from 2 to 6 mg/dl in blood. Creatinine is the name for the metabolic waste product produced when muscles are created (Jitendra *et al.*, 2015).

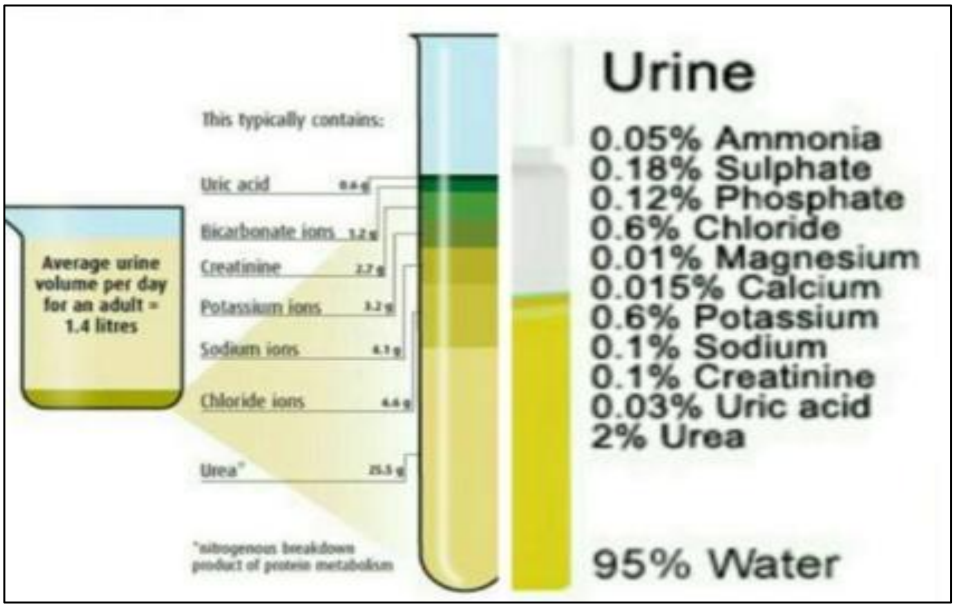

Figure 1: Urine Composition (Clark, 2011)

If a person consumes the necessary number of fluids daily, their urine production should range from 0.8 to 2 L/d, and their molarity is thought to be 1.5 l/d (Jitendra *et al.*, 2015). Table 2 provides a summary of a few compounds found in typical human urine along with their physiological ranges.

Table 2: Chemical Composition

Composition	Molar Mass (g/mol)	Normal Range	Molarity (mmol/LL)
Volume		0.8 - 2L	
pH		4.5 - 8.0	
Specific gravity		1.002-1.030 g/ml	
Osmolality		150-1150 mOsm/kg	
Urea	60.06	10-35 g/d	249.750
Uric Acid	168.11	750 mg/d	1.487
Creatinine	11.3.12	Males: 601 - 2936 mg/d	
Citrate	192.12	221-1191 mg/d	2.450
Sodium	22.99	41-227 mmol/d	92.625
Potassium	39.10	17-77 mmol/d	31.333

The daily calorific value of urine is estimated to be 100 kcal on average. It is hypothesized that 8.64 kW of electricity might be produced by one liter of feces (Barth, 2007, Kuntke *et al.,* 2012, Kameda *et al.,* 2020). Water (95%) and uric acid (0.03%) make up the majority of what is found in human urine, with lower amounts of other ions and substances like chloride, sodium, potassium, sulphate, ammonium, and phosphate also present. Numerous techniques for extracting and recovering nutrients from urine have been studied, and they have shown that typically energy production (Khorami, 2012, Joakim & Gronkvist, 2019).

1.4. Urine as Agricultural Resource

The UDDT method explained how to separate, collect, dry, and transport human feces for use as a power source and agricultural resource. UDDT can take many different forms, such as a squatting pan or toilet seat that deviates for peeing, a feature that allows the anal cleansing water to be removed in different directions so that it can be collected and properly disposed of, two chambers that are typically above ground for the collection of waste and for drying, a complicated pee piping system that connects to an infiltration system from the user interface, and a ventilation pipe to exhaust the smells and moisture from the area (Priyam *et al.,* 2020).

The UDDT design successfully separates feces from urine, which is then collected separately and used right away in the electrolysis unit. It is simpler to gather dry feces in a different container thanks to this divide. Once it has entirely dried out and has a moisture content of less than 20%, it can be recycled for agricultural use. As seen in figure 2, this sanitation system is sustainable because it runs without a water tank or force and is practical in places with a scarcity of water (Egle *et al.,* 2015, Tao *et al.,* 2019).

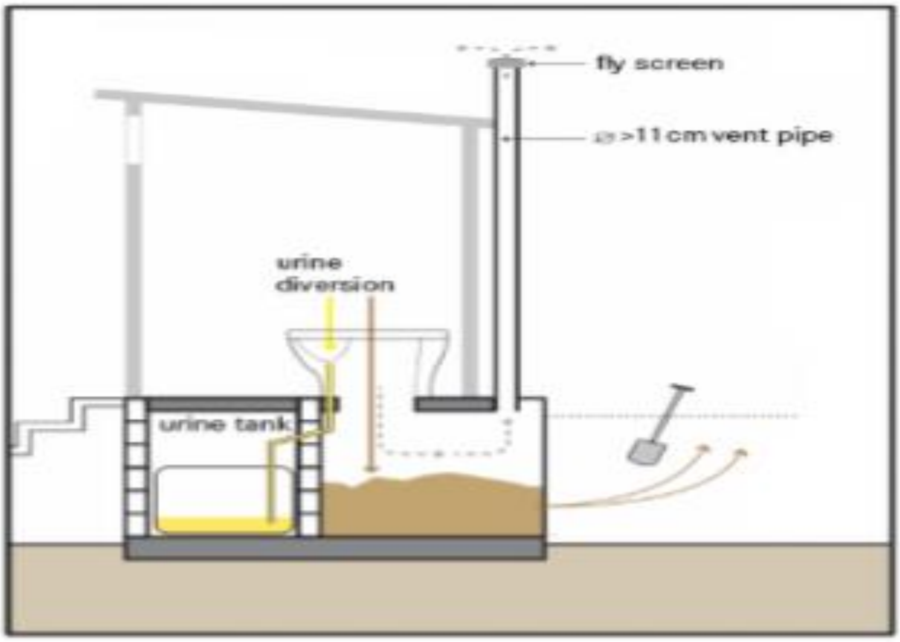

Figure 2: Schematic diagram of UDDT operation (Priyam *et al.*, 2020, Egle *et al.*, 2015)

With the use of UDDT, the urine is first separated from feces and water before being put into a collection tank with urea that is about 60% dry. Pumps are used to transport the urea. Utilizing an electrode made of nickel, the urea was successfully oxidized. Later, the hydrogen is transferred, gathered, and stored under high pressure and at a low temperature (Tao *et al.*, 2019).

A urine deviation, also referred to as a urine-diverting dry toilet (UDDT), is a sanitation option that is both safe and reasonably priced. The separate collection of feces and urine without the use of flush water provides a number of benefits, including odor-free operation and the drying out of microorganisms. The dried waste from this process can be used frequently as fertilizer on crops. The UDDT stands out for its lower water waste and source diversification of urine and feces.

1.5 Electrolytic Process of Hydrogen Extraction

The components H, C, O, and N make up the molecules of urea. It is simple to improve the utilization of hydrogen sources and energy by recycling waste items like urine and human excreta. The basic configuration for carrying out a chemical reaction is depicted in Figure 3 (Writte, 2009).

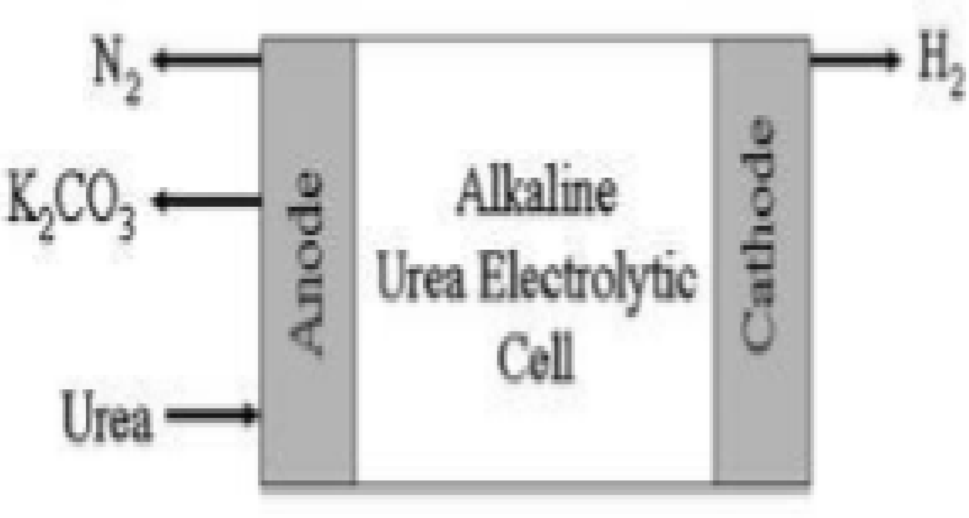

Figure 3: Diagram showing direct urea-to-hydrogen conversion (Sugato, 2014)

Figure 4 depicts the basic setup for the electrolysis procedure to generate energy based on hydrogen.

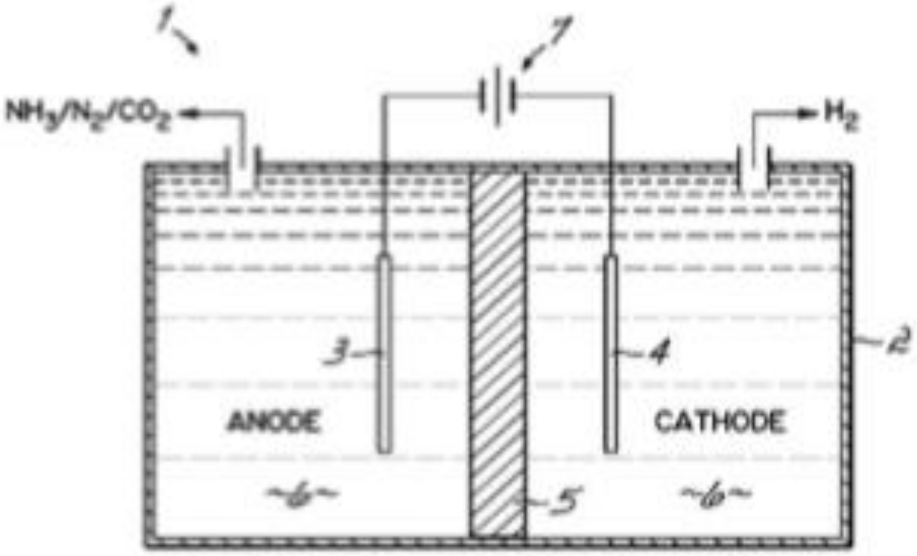

Figure 4: Basic Setup for electrolysis (Sugato, 2014)

The production of a simple electrolytic cell is depicted in Figure 3. Urine is positioned on either side of electrolytic solution number six. Nothing makes up the urea, which is the electrolyte solution's major ingredient. Anode 3 and cathode 4 are both directly connected to the cell. The anode and cathode conductors are coated with cobalt, copper, iridium, iron, nickel, platinum, and other more active conducting materials (Sugato, 2014)

It was discovered that the above-described setting for the experiment resulted in the following equations 1 to 4.

The Anodic Reaction

$CO(NH_2)_2\,(aq) + 6OH^- \rightarrow N_2\,(g) + 5H_2O\,(l) + CO_2\,(g) + 6e^-$ (1)

$Ni\,(OH)_2\,(s) + OH^- \rightarrow Ni\,OOH\,(s) + H_2O\,(l) + e^-$ (2)

The Cathodic Reaction

$6H_2O\,(l) + 6e^- \rightarrow 3H_2\,(g) + 6OH^-$ (3)

The Complete Reaction

$CO(NH_2)_2\,(aq) + H_2O(l) \rightarrow N_2(g) + 3H_2\,(g) + CO_2\,(g)$ (4)

When the current was applied and the electrode potential was at -0.44 V, the alkaline reduction of water occurred. The complete amount of hydrogen is provided by the cathode's 0.85 voltage. The electrolytic cell's potential was found to be 0.36 V, which is required to electrolyze urea under usual conditions and produce 80% less expensive hydrogen (Mai, 2018, Kuntke, *et al.,* 2014, Lundstr¨om *et al.,* 2011).

1.6 Power Generation from Urine

The electrolysis process, which uses electrical energy to break down chemical molecules, occurs when electrical energy is supplied. The item is composed of two half cells. The three parts of an electrolytic cell are a cathode, an anode, and an electrolyte. The urine utilized in this process contains urea. Chemistry-speaking, urea has the formula CH_4N_2O. When the system obtains additional electrical energy, which also increases the chemical energy, hydrogen gas is produced. When the hydrogen gas is driven through the water filter (WF), it is refined to produce pure hydrogen gas (Lundstr¨om *et al.,* 2011).

However, at extremely high pressures and low temperatures, this pure hydrogen gas was delivered to the gas cylinder (GC) and stored there as liquid hydrogen. A liquid borax cylinder is passed through by the hydrogen gas, which evaporates the moisture. The effects are known to producers of hydrocarbon byproducts. A generator and several machines are connected to hydrogen gas in a cylinder (Kirste *et al.,* 2021).

The electrolysis is the main operating mechanism of the functioning principle. Four hydrogen atoms make up the major component of urine, two of which are less tightly bound than those in water molecules. After electrolysis disassembly, a bottle produced accurately precise hydrogen. The voltage needed to degrade the molecule when applied across the cell is 0.38V, which is a significant amount for the molecule to demand. During the electrochemical reaction, urea is adsorbed onto the nickel electrode surface, at which point the nickel conducts the electrons needed to break the molecule down. Only hydrogen was created at the cathode, whilst a little amount of oxygen and hydrogen were accumulated at the anode. Although CO_2 is created, there are no gaseous byproducts at this time. For urea, the enthalpy of production is 9 (Kirste *et al.,* 2021, Deng *et al.,* 2022).

1.7 Gas Storage

The two main techniques for storing the hydrogen gas produced are above-ground storage (AS) and underground storage (US). The cost of capital for aboveground projects is higher than that of underground enterprises. Thus, it is advised to store hydrogen underground, where a significant volume can be safely stored. In order to store hydrogen fuel for our own usage in our homes, we choose the best approach that is both economical and secure [(Kuntke *et al.*,2012, Deng, *et al.*, 2022). Currently, there are two options: the Underground Storage System (USS) and the Metal Storage Cylinders System (MSCS). The installation cost of metal cylinder systems is more, but they are more pure, solid for storage, and adaptable in terms of where they can be housed. Both underground and metal containers have a different maximum allowed pressure depending on the vessel material (Tao *et al.,* 2019).

Hydrogen, the world's lightest gas, is utilized to produce power. At atmospheric pressure, this gas has a low density and weighs around 90 mg/liter. It is extremely challenging to store hydrogen because it is the lightest molecule and has a relatively low density. The basic goal of hydrogen storage is to use it as a backup fuel and reduce transportation costs through supply and demand.

The three main techniques for storing hydrogen are adsorption and absorption, chemical hydrogen storage (metal hydrides and chemical hydrides), and physical hydrogen storage ($H_{2\,(g)}$ and $H_{2\,(l)}$). The simplest method for decreasing the gas's volume while keeping its temperature constant is to raise the pressure (Li *et al.*, 2020).

1.8 Socio-Economic Impact of Energy Sources

Finding a stable, clean, and sustainable energy source from urine for the future of energy is crucial since the population is growing, which suggests that more energy is required in nonrenewable sources. Because water vapour is produced as a byproduct, hydrogen gas is a clean fuel (Cheng *et al.*, 2018).

2. MATERIALS AND METHOD

The materials used for the experiment includes generator, filters, borax, cylinder, hose, clip, car battery, two electrodes, pipes, plugs, bushing, carburetor and sealant as presented in table 3.

The following tools were utilized to get the research set up in the proper configuration: a drilling machine, a digital weight, a pipe bender, a pressure gauge, and a compressor.

Table 3 lists the necessary supplies and quantities needed to conduct the experiment.

Table 3: List of Materials and Quantity used

S/N	Materials	Quantity
1	Car Battery	1
2	Electrode(s)	2
3	Filter	3
4	Plug	0.75
5	Cylinder	1
6	Carburetor	1
7	Hose	3 Meter
8	Pipe	0.5 Length
9	Bushing	1 Inch
10	Urine	5 Liters
11	Tap(s)	2
12	Generator	1
13	Liquid borax	1
14	Wire	1 Meter

2.1 Power Generation from Urine

Figure 5 displays the urine samples that were collected and filtered for the experiment.

Figure 5: Samples of Urine Tested

Figure 6 showed the experimental set up using the materials stated in table 3. The electrolytic cell was connected to the battery with the aid of copper wire while the three filters were connected to each other in series using hoses to the gas cylinder. The filter was put in a wood material to act as a system for the flow of gas ease through the filter to avoid going back into the electrolytic cell.

Figure 6: Microbial Fuel cell

A clean twenty-litre gallon was used to collect the urine from the male's accommodation at Afe Babalola University Ado Ekiti (ABUAD). Filtered urine was then kept at room temperature. The composition properties of the sample were examined in the laboratory at ABUAD Multi System Hospital. The electrolytic cell was filled with one litre of urine, and electricity was then applied to it to break down the urine. The breakdown of urea into its component parts, including hydrogen gas, oxygen, nitrogen, and carbon dioxide, was indicated at the voltage of 0.37 (Cheng *et al.,* 2018). The water filter received the hydrogen gas. With closed monitoring, the hydrogen gas was proven to be present as water bubbles. The evolved hydrogen gas is cleaned by the water before being introduced to the borax. The hydrogen gas was subsequently injected in a gas cylinder forcefully after the borax was used as a drying agent to remove moisture and grime from it. Before being crushed into liquefied natural gas (LNG), the hydrogen gas from the borax is kept in the gas cylinder to fuel the generator.

The electrolysis of the urine and the gas cylinder's weight were measured once an hour. With different amounts of urine, 2L, 3L, 4L and 5L per experiment were performed. A 5 KW generator powered by gasoline and hydrogen gas was run for a half-hour in order to gather the voltage readings every six minutes. Using the voltage information, it was possible to calculate the voltage ratio and volumetric efficiency of hydrogen fuel and liquid fuel (petrol).

The volumetric efficiency of the fuel cell and gasoline was calculated using equation 5.

$$\frac{V_f}{T_v} x100 \tag{5}$$

Where V_f is the fuel voltage and T_v is the total fuel voltage

Figure 7 illustrates the fuel process chart involved in producing hydrogen gas from urine.

Urine
↓
Electrolytic cell
↓
(Hydrogen gas)
↓
Water Filter
↓
Borax
↓
Gas Cylinder
↓
Generator
↓
Electricity

Figure 7: Process Flow Chart

3. RESULTS AND DISCUSSION

The findings of the laboratory analysis of the urine composition and quality used are shown in table 4.

Table 4: Urine Composition

Composition Properties of Urine	
Constituents	**Percentage composition (%)**
Magnesium	0.01
Calcium	0.01
Uric acid	0.03
Ammonia	0.04
Sodium	0.10
Creatinine	0.11
Phosphate	0.11
Sulphate	0.16
Potassium	0.50
Chlorine	0.61
Urea	1.82

Table 4 shows that urea, the primary generator of hydrogen gas, contains 52% of the ingredients. It suggests a higher output of hydrogen gas. Calcium, sodium, and magnesium all had values below 10%.

Figure 8: Experimental testing of the Hydrogen gas

When tested, the yielded hydrogen gas burnt blue flame as shown in Figure 8, that is clean and odourless giving off water vapour indicating its environmental friendliness.

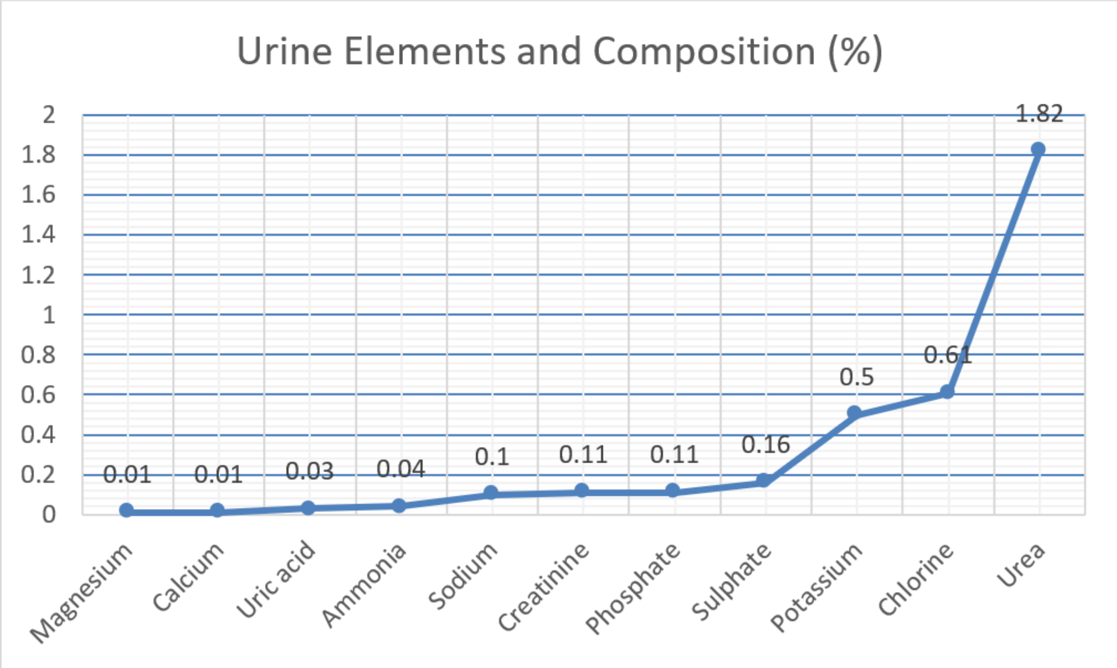

Figure 9: Graph of Urine Elements

The components and values of urine are shown in Figure 9. Magnesium, calcium, uric acid and ammonia composition values were nearly identical, according to the graph. In comparison to potassium, sulphate, phosphate, and creatinine, chlorine stands out with a 0.6% concentration. Urea, a significant source of clean fuel, has the ingredient with the highest concentration (1.82). The possibility for sustainability is demonstrated here.

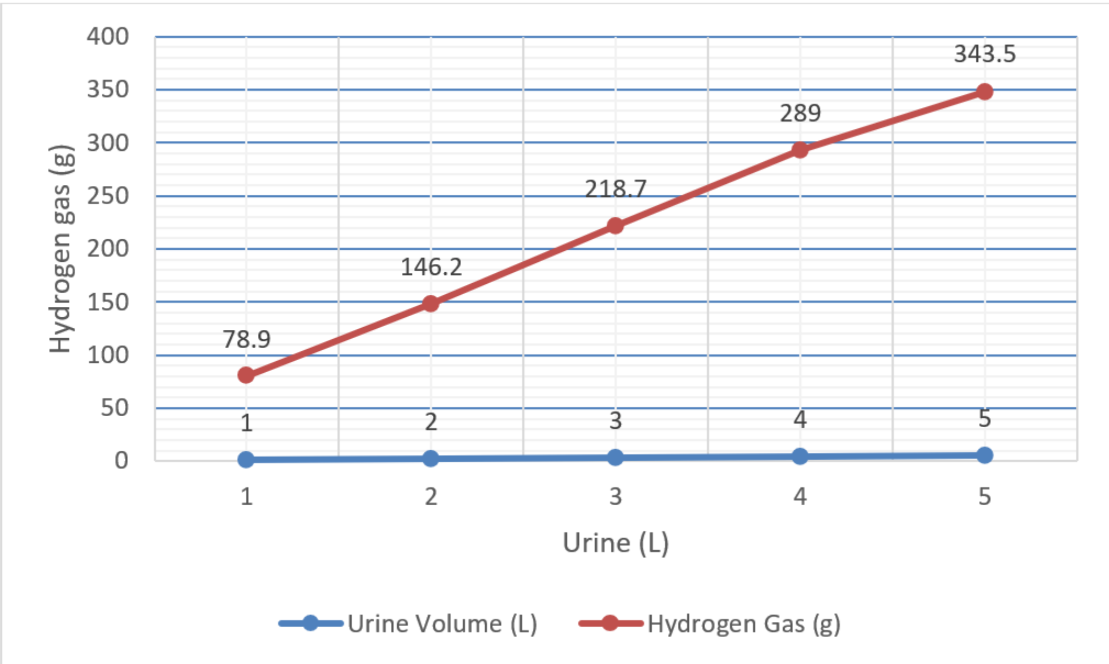

Figure 10: Hydrogen Gas Extraction

Figure 10 showed that 15 liters of pee produced 1.076 g in total of hydrogen gas. The volume of urine utilized in the electrolytic process directly relates to the mass of gas produced. The graph demonstrates that, in relation to an increase in urine volume, 78.9g, 146.2g, 218.7g, 289g, and 343.5g of hydrogen clean fuel were produced, correspondingly.

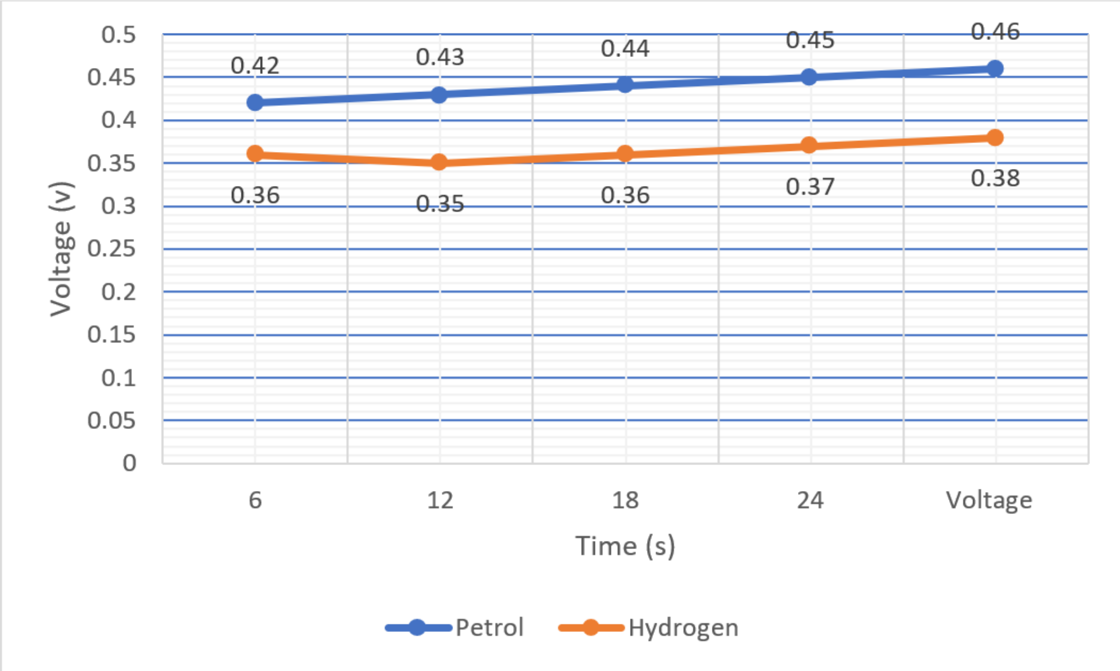

Figure 11: Voltage Ration between Gasoline and Hydrogen Gas

Figure 11 demonstrates that the voltage of gasoline is higher than that of hydrogen. A simple arithmetic calculation revealed that hydrogen is roughly 45% efficient when running on a generator, compared to 60% for gasoline.

The use of urine as a power and energy source. The application locations include residences, public restrooms, marketplaces, recreation centers, clinics/hospitals, theaters, bus stops, and railroad stations. The amount of hydrogen gas that was produced from one litre of urine run a 5KW generator. A gasoline-powered generator uses more fuel than hydrogen fuel in the same length of time. Due to the presence of oxygen, hydrogen burns more efficiently than gasoline, making fuel cells approximately 2.5 times more efficient than gasoline engines. When comparing the urine generator to other generators, it was discovered that the same amount of 1 kg of gasoline will create 33.5 MJ whereas the same for hydrogen produce 33KW.

Figure 12: Set up of the electrolysis process of urine

Some of the advantages of gas extraction from urine are no cost of fuel, pollution free equipment, low maintenance, ecofriendly product, non-toxic with the nature and odorless operation. Others are easy repair with basic tools, low investment and operational cost, no evolution of green-house gases and uses less fuel than other generators, which is a benefit.

4. CONCLUSION

Two naturally occurring sources of urine are humans and animals. In contrast, feces produced in an electrolytic cell could be used as liquid fertilizer in agriculture. After being processed, the recovered hydrogen gas will be effectively employed to supply steady energy for homes and as fuel for our upcoming cars. The most efficient small-scale and cost-effective solution for storage in our homes is an underground physical-based storage system. Governments can set up specialized urinal facilities that use a method akin to a hydroelectric plant to convert urine into power. Peeing generates energy that is later stored in a battery. The energy produced provided a practical solution to the absence of electricity in rural and small towns.

Governmental entities, organizations, and the media must run awareness campaigns to raise knowledge of the importance of energy conservation in order to reduce the harmful environmental effects of wasted pee and turn it into a viable energy source and source of income development. In order to find the best design that would assist the sustainable development mission for this sustainable and clean fuel, it is necessary to convince people that an idea can be proven in practice.

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