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Research Article

Utilization of Bio-Organic Waste as a Source of Electricity for Sustainable Development

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Abstract

The continuous production of waste causes management issues. The traditional methods used for management of waste like combustion and landfills causes pollution. Also, the energy demand is increasing rapidly because of industrial growth and the burgeoning population. Access to clean and green energy is vital for society's sustainable growth in order to meet this escalating demand of energy. When approached scientifically, these two issues can aid in the resolution of one another. In the present study, the viability of cow's urine as an electrolyte has been examined. For this purpose, a power generation set up was designed using a container, cow urine and two electrodes (Cu and Zn). The system worked like a cell in which cow urine acted like an electrolyte. Power of the cell was found to be 0.6 mW. To enhance the output of cell, cow urine was adulterated with other electrolytes. Several mixtures of cow urine with different electrolytes were analysed to determine the best combination to be used as the electrolyte. Maximum power i.e., 11.6 mW was observed for the cell working with a 50 % mixture of 2M NaOH (aq) and cow urine. This combination has a great potentiality to be used as an electrolyte.

Keywords: Sustainable growth, bio-waste, cow urine, electrolyte, cell

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Introduction

Since ages, energy has been the basic need for all kind of human activities and industrial applications. It plays an important role in socio-economic development, prosperity and the sustainable growth of a country [1]. Due to growing industrialization and increasing global population, the demand of energy is increasing exponentially [2]. We cannot think of any activity in today's scenario without energy. The burgeoning growth of population has been one of the major factors that influences the demand of energy. According to latest UN projections the population of world is expected to be around 8.5 billion in 2030 and 9.7 billion in 2050. More than half of the projected increase in the global population up to 2050 will be concentrated in eight countries: the Democratic Republic of the Congo, Egypt, Ethiopia, India, Nigeria, Pakistan, the Philippines and the United Republic of Tanzania. Due to rapid increase in the number of people demanding access to affordable energy, the demand of energy will increase tremendously. The majority of energy generation is still dependent on thermal power stations based on conventional sources of energy i.e. fossil fuels [3]. Fossil fuels are primarily compounds of hydrocarbons including oil, natural gas and coal. Fossil fuels are very efficient but non-renewable and will deplete in times to come. The combustion of fossil fuels emanates harmful gases such as carbon dioxide, sulphur dioxide, oxides of nitrogen, etc. These toxic gases when directly released in atmosphere cause air pollution which leads to smog formation and deterioration of health and plants. The sulphur dioxide gas released from coal combustion causes formation of acid rain and destruction of historical monuments [4]. Thus, the unabated use of these fuels is hazardous to environmental health. So, this necessitates an emergent need to explore alternative sources for production of electricity which are clean energy and environment friendly [5, 6].

So, the need of the hour is renewable energy. Its sustainable and clean nature has enthralled the researchers to work on it. The sources of renewable energy are wind, solar, geothermal, hydropower, tidal and biomass. Renewable energy sector is quite new in most of the countries and can attract a number of companies for investment. It can generate the ocean of opportunities for the unemployed section of society. Renewable energy can reduce the fluctuations in electricity prices as their costs depends only on the initial invested capital and is free of the fluctuating costs of coal, oil and natural gas which depends on political stability in various regions of the globe. One of the remarkable properties of the renewable sources is their abundance in nature. But sources like solar energy, wind energy are of intermittent nature and there's a high need for advanced energy storage technologies for continuous availability of energy. Further, these are subjected to geographic limitations [7, 8]. The waste material can be considered as a good source of energy as production of waste is increasing every day. For a developing country like

India, converting the waste material into energy is economically important. The use of biomass such as POME (the liquid waste of palm oil industry), Glycerol or Biodiesel Waste, etc. as raw material for H_2 production is a good alternate to fossil fuels. Various methods are used to convert biomass into hydrogen such as gasification of biomass, algal photolysis and anaerobic digestion. The gasification process starts with processing the organic materials at high temperatures, but without combustion. The reaction emits hydrogen, carbon dioxide and carbon mono oxide gases. The carbon monoxide so produced, combine with more steam and produce more carbon dioxide and hydrogen. Carbon dioxide is recycled through the natural plant respiration cycle and produces more biomass. The other method involves biological agents, such as anaerobic bacteria or fermentation, which uses the same gasification process, but in the absence of oxygen. Each method produces hydrogen gas that can be used for energy storage or in fuel cells. The gasification method is the most developed, but it is yet to reach the commercial stage [9, 10].

Several technologies are being implemented in order to enable the conversion of bio-waste in electric energy. The bio cells are designed to support devices with high voltages and low power requirements. Bio-fuel cell can directly convert chemical energy to electrical energy via biochemical pathways [11-13]. Bio cell plays a dual role in energy storage and electricity generation and is identical to a chemical fuel cell. The essential feature of the bio-cell is that the electrolyte used is an organic compound.

Cow urine, as an electrolyte, has been recognized as a feasible source of energy having an extra feature that it does not produce greenhouse gases. So, Bio-battery technology could provide a new method of generating electricity in rural areas. In India, a large part of population lives in villages. The livelihood of people in rural areas is mainly dependent on the agricultural activities and domestic animals such as cows, buffaloes, etc. Cows were considered as the sign of prosperity and were the backbone of the ancient Indian economy. From the Vedic era, cow's urine has been used as a medicine. In Veda, cow's urine was considered to be like nectar. Sushrut Samhita mentioned the various medicinal properties of cow's urine and it was known to cause weight loss and found to rectify kidney, cardiac and leprosy problems, indigestion, edema, *etc*. [14]. In Indian mythology, cow urine is supposed to be as pious as water of river Ganges at Gangotri. It is found to inhibit the growth of Malassezia fungi that cause dandruff. It is antioxidant and acts as anti-cancer by repairing damaged DNA. It helps in healing wounds in diabetic patients as it enhances granulation tissue formation [15]. It contains sodium, nitrogen, sulphur, vitamins (A, B, C, D, E), minerals, manganese, iron, silicon, lactose, carbolic acid, enzymes, creatinine and hormones. The deficiency of all these may cause serious problem. So, many diseases can be cured by consumption of cow urine [16]. The success of the power generating project based on renewable energy is determined by accessibility of the renewable energy source in adequate magnitude and reliability at a remote site [17, 18]. In the rural areas, an appreciable amount of cow urine is available. All this motivates us to work on cow urine for generation of electricity. The chemical composition of cow urine is 95 % water, 0.2 % urea, 0.03 % uric acid, 0.015 % calcium and 0.01 % magnesium. Uric acid is an organic acid. In the body, uric acid is formed due to purine metabolism and excreted with urine. In mammals, it is further converted to allantoin by enzyme uricase. Uric acid is a strong antioxidant because it has de-localized lone pair of electrons. These electrons participate in generation of electricity from cow’s urine. The possibility of generating electricity from cow urine has not been extensively explored; therefore, the objective of the present study is to study the electrolytic properties of cow urine and to enhance these properties by adding suitable electrolytes. For this purpose, a power generation set up was designed by using cow urine and various other electrolytes. The current, voltage and power output of this system were measured. The effect of different adulteration levels of cow urine with different electrolytes was studied.

Experimental

The experimental arrangement consists of followings.

Selection of sample

Early morning cow urine sample was collected from a *Gaushala* (cow shed) located in village Arya Nagar near Hisar, Haryana. Identical rectangular electrodes of Cu and Zn having size 5.1 cm×15.2 cm were used as cathode and anode respectively. The electrodes were purchased from local market of Hisar. Mixtures of three different electrolytes namely Potassium Chloride (KCl), Sodium Hydroxide (NaOH) and Sodium Sulphate (Na_2SO_4) with cow urine were used as an electrolyte for VI analysis, at different adulteration levels.

Measurement techniques

Current, Voltage and Power output of the power generation system were measured using digital multimeter.

Preparation of electrolyte solutions and measurement

Cow urine was collected from *Gaushala* located in village Arya Nagar near Hisar, Haryana. Zn and Cu electrodes were purchased from local market of Hisar. 2M KCl (aq) solution was prepared by dissolving 74.55 g of KCl in water and diluting it to 500 ml volume of solution. 2M Na_2SO_4 (aq) solution was prepared by dissolving 142 g of Na_2SO_4 in water and diluting it to 500 ml volume of solution. 2M NaOH (aq) solution was prepared by dissolving 40 g of Na_2SO_4 in water and diluting it to 500 ml volume of solution. 50 ml solution of 2M KCl was added to 450 ml cow urine and mixed thoroughly with the help of stirrer, to get 10 % mixture of 2M KCl with cow urine. Similarly, solutions with 30 % and 50 % (v/v) adulteration levels were prepared by adding 150 ml and 250 ml of 2M KCl solution to 350 ml and 250 ml of cow urine, respectively. Also, 10 %, 30 % and 50 % mixtures of 2M Na_2SO_4 and 2M NaOH with cow urine were prepared by repeating above steps with corresponding salt solutions. 500 ml cow urine solution was taken in a container. Cu and Zn electrodes were dipped into it such that these are parallel to each other and at a distance 6 cm apart as shown in the **Figure 1**. The system worked like a battery cell. The current and voltage between electrodes were measured using digital multimeter.

Similarly, current and voltage output of the cells working with different electrolyte solutions, were measured. Power of each cell was determined by using the following relation. Power = Current × Voltage. Unit of power is milliwatt (mW).

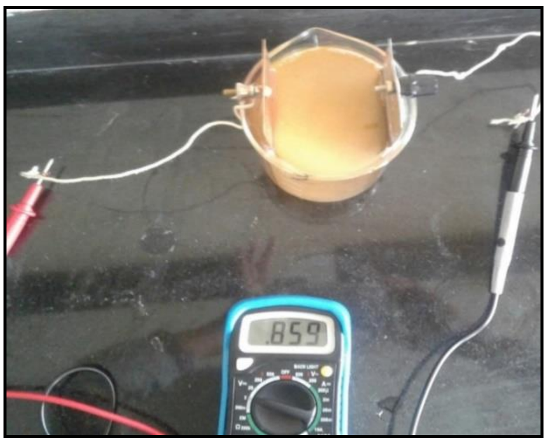

Figure 1 Power generation set up

Results and Discussion

As the Zn and Cu electrodes were immersed in 500 ml cow urine, the current was observed to flow in the external circuit between terminals of anode and cathode. The current, voltage and power output of this cell are given in **Table 1**. The generation of electricity can be understood by looking at the chemical composition of cow urine. It is composed of water, urea, various minerals, salts and uric acid [19]. From the perspective of an electrolyte, uric acid is an important constituent of cow urine. It is a diprotic acid having first dissociation coefficient 5.4 and 2nd dissociation coefficient 10.3. This signifies that in a solution with pH greater than 5.4, acid urate ions are formed by the loss of one H^+ ion, but in alkaline solutions with pH greater than 10.3, urate ions are formed by the loss of two H^+ ions. Due to alkaline nature of cow urine, uric acid forms acid urate ions in cow urine. In the cell working with cow urine, copper urate ions are formed by the oxidation of copper electrode. The ionic bond of this salt is contacted with Zn plate and electrons are liberated on anode. These electrons go to the cathode and reduce the copper ions. In this way, current flows from cathode to anode in a cow urine cell [20].

Table 1 Output of the cell for different electrolytes

Electrolyte	Voltage (V)	Current (mA)	Power (mW)
CU	0.730	0.9	0.6
2M KCl	0.804	3.9	3.1
2M Na_2SO_4	0.905	4.5	4.1
2M NaOH	1.210	12.0	14.5

The **Figures 2** (a) and (b) represent the current and voltage outputs of cells working with different electrolytes. The graphs show that the cell using 2M NaOH as electrolyte, has maximum output followed by cells using 2M Na_2SO_4, 2M KCl, cow urine respectively. The trend of ionic conductivities of different electrolytes can be attributed to this observation. The ionic mobilities of anions follow the order $OH^- > Cl^- > SO_4^{2-}$ and that of cations follow the order $K^+ > Na^+$ [21]. But sulphate ions carry twice as much charge as hydroxyl and chloride ions. So, ionic conductivities of electrolytes follow the order NaOH > Na_2SO_4 > KCl. Output of the cell working with cow urine was found to be minimum.

Various electrolytes mixtures were prepared using cow urine and other three electrolytes, at 10 %, 30 % and 50 % adulteration levels. The current and voltage output of cells using the mixture of cow urine and other electrolytes at different adulteration levels are given in **Table 2**.

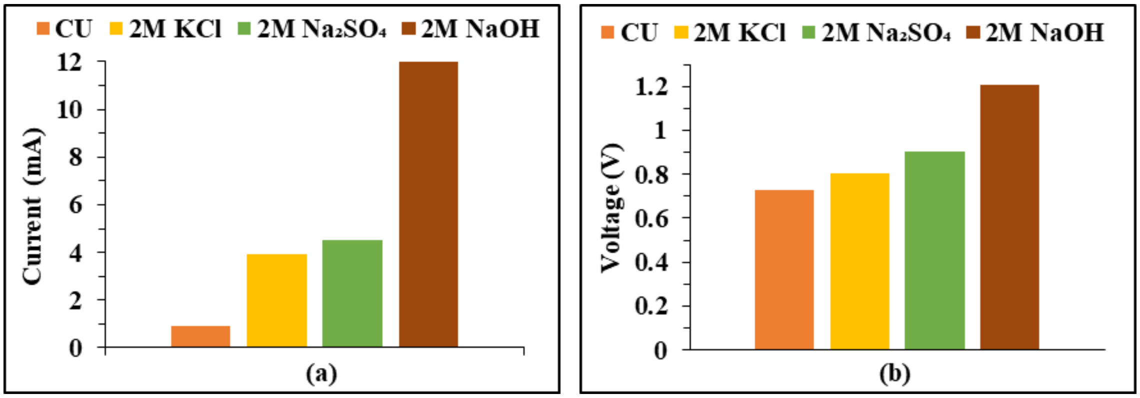

Figure 2 (a) and (b) Current and Voltage output of the cell with different electrolytic solutions

Table 2 Current and voltage output of the cell for different electrolyte mixtures

Adult. level (%)	Electrolyte					
	2M KCl		2M Na_2SO_4		2M NaOH	
	Current (mA)	Voltage (V)	Current (mA)	Voltage (V)	Current (mA)	Voltage (V)
10	1.0	0.740	2.2	0.768	3.5	0.902
30	1.8	0.786	2.8	0.800	8.5	0.987
50	3.2	0.797	3.6	0.855	10.0	1.161

Figure 3 represents the current and voltage outputs of the cells using 10 % mixtures of different electrolytes with cow urine. At 10 % mixture of each additive, there has been increase in the current and voltage of the cell. Similarly, **Figure 4** and **5** give output of cells using mixture of different electrolytes with cow urine, at 30 % and 50 % adulteration levels respectively. It is evident from the figures that at any adulteration level, mixture of cow urine with NaOH exhibited maximum current and voltage followed by Na_2SO_4 and KCl respectively. The NaOH, being a strong base, favors the dissociation of uric acid and formation of urate ions. In this way, it increases the ionic conductivity of cow urine. Being a strong electrolyte, NaOH completely dissociates in water to form Na^+ and OH^- ions. In this way, it increases the number of ions in electrolyte mixture. Both of these factors contribute to the increased ionic conductivity of mixture of NaOH and cow urine. Na_2SO_4 and KCl are also strong electrolytes and dissociate completely in the presence of water. When mixed with cow urine, both of these salts lead to increase in ionic conductivity of solution by increasing number of ions in the mixture.

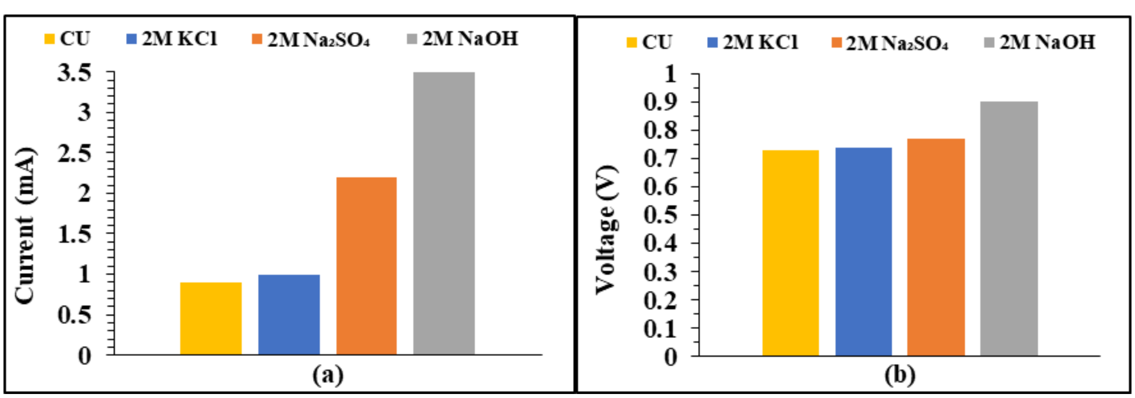

Figure 3 (a) and (b) Variation of current and voltage of the cell for 10 % adulteration level

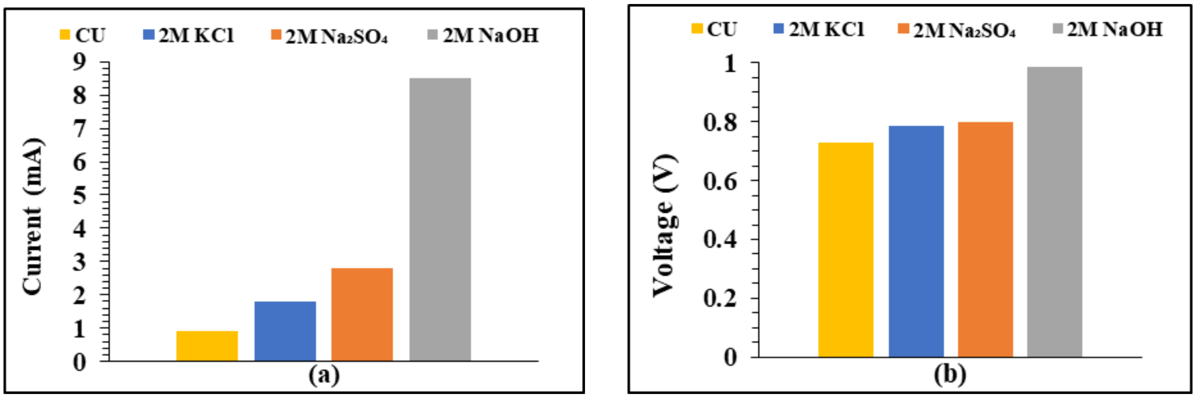

Figure 4 (a) and (b) Variation of current and voltage of the cell for 30 % adulteration level

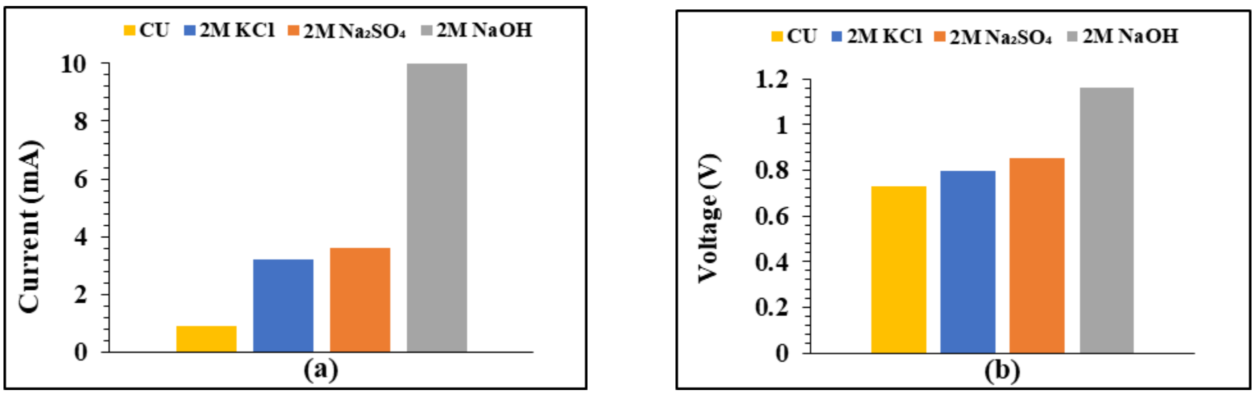

Figure 5 (a) and (b) Variation of current and voltage of the cell for 50 % adulteration level

The power outputs of cells working with different electrolyte mixtures are tabulated in **Table 3**. The **Figure 6** shows the comparison of power output of cells using cow urine with different electrolytes at 10 %, 30 % and 50 % adulteration levels.

It can be seen that at any particular concentration, mixture of NaOH with cow urine resulted in more output in comparison to the other electrolytes. It may be due to the two commending properties of NaOH i.e. basic nature and more ionic conductivity. Each of these properties plays a positive role in improving the cow urine cell production.

Table 3 Power of cells working with different electrolyte mixtures

Adult. Level (%)	**Electrolyte**		
	2M KCl	**2M Na_2SO_4**	**2M NaOH**
	Power (mW)	**Power (mW)**	**Power (mW)**
10	0.7	1.7	3.2
30	1.4	2.2	8.4
50	2.5	3.1	11.6

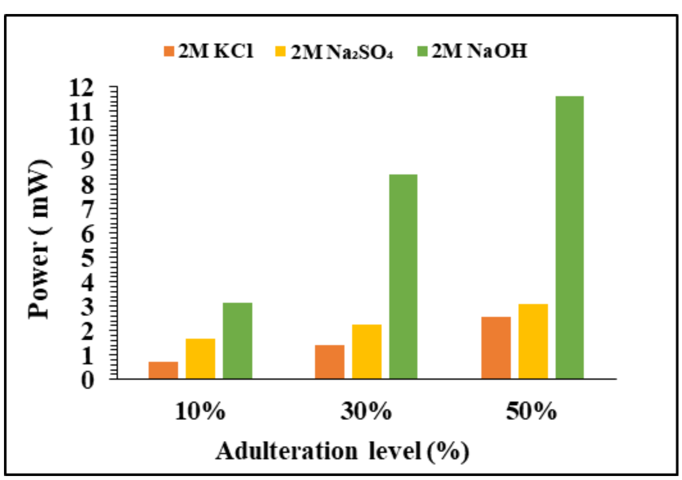

Figure 6 Variation of power with type of additive at different adulteration levels

Conclusion

Power output of the cell utilizing cow urine as an electrolyte, was found to be 0.6 mW. Various mixtures of cow urine with different electrolytes have been analyzed in order to find the best combination to be used as an electrolyte. There was increase in power of the cell when cow urine was adulterated with KCl, Na_2SO_4 and NaOH. At any specific degree of adulteration, the addition of NaOH has increased the power of the cell to a greater extent than that of Na_2SO_4 and KCl. Maximum power i.e. 11.6 mW was observed for the cell working with 50 % mixture of 2M NaOH (aq) and cow urine. That was nearly 80 % of the power produced by a cell which used 2M NaOH (aq), as an electrolyte. This combination can serve as a good alternate of NaOH (aq) and can be used as an electrolyte in batteries and supercapacitors. So, the present study introduces a clean, green, carbon-free and economically sustainable energy source that produces electricity by electrolytic conduction. It can provide a solution to the problem of animal waste management in rural areas and animal farms by simultaneously fulfilling their energy demands.

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