



Bioresources increase as human population increases

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Abstract

The aim of this work is to advance the fact that human feces and urine need to be utilized as bioresources because they grow with the human population. As the world population flies past the seven billion mark, the need for energy and renewable energy sources increases. It is the perspective of the current work that one of the natural places to search for renewable resources is from the human population itself. This review work surveys the studies that are promising in making human wastes more acceptable and available as safe renewable bioresources.

Keywords: Human, feces, urine, renewable, bioresources

Introduction

Old world cultures were aware of the value of human feces and urine. There was an old Chinese farmer's saying, when a house visitor uses one's toilet, it is good luck to the family because the visitor has made a resource deposit'. Another old superstition was that if one dreamt of toilet functions and its products, one would soon be endowed with a monetary gain or windfall of any magnitude. In the Asian subcontinent of India, the residents in the countryside still practice the open latrine principle to this day. In keeping with the laissez faire attitude with respect to nature and the environment, these rural Indians have allowed the nutrients in human feces and urine to naturally recycle back into the environment. Even when collected and used as manure in agriculture, the fundamental philosophy is the same. The unfortunate aspect of this behavior is that many in the urban areas do the same, with no thought to their contribution to agriculture, but out of habit.

Matt Damon, the world famous Hollywood movie actor, stated that 783 million Indians (out of approximately 1.25 billion total population) do not have access to clean water [1]. One of the contributing reasons is because of this open defecation culture in rural India. Matt Damon is the founder of water.org, a non-profit organization to bring accessibility of clean water to more people in the world.

The view of human feces and urine as wastes in the USA and other modern industrialized nations, have created a huge and expensive task for the municipalities and local governments. There are regulations for the use of treated sewage sludge as fertilizer, if allowed at all. Water is reclaimed from sewage water via treatment to eliminate solids and selected impurities. Recycled water can be used to aid in charging groundwater aquifers which typically depends on other sources for recharging, like rainfall. Sometimes, reclaimed

water is allowed for landscaping irrigation. In limited situations, recycled or reclaimed water can be used to strengthen the flow quantity of streams for aesthetical reasons or for the advantage of ecosystems.

However, urine does have large quantities of nitrogen in the form of urea (9.3g/L), as well as non-negligible quantities of potassium. Urine is rich in nitrogen, phosphorus and potassium, which are the macronutrients needed for growing plants and agricultural crops. This is a well-known fact because NPK (Nitrogen, Phosphorus, Potassium) rating is used for the labeling of fertilizers. The nitrogen fertilizer has developed to be the leading costs in the production of crops and thus food. Urine could be a good source.

Feces as biofuel for combustion

Engineers have been implementing rather deep-water sewage outfalls for urban wastewater for over a century, based on the principle of the ocean's dilution effect will condition the sewage. The result is that the public health risk is removed and the costs of handling and managing the sewage is cut. This sewage management practice is logical from a public health standpoint. However, it is not sustainable from a conservation of mass standpoint. Nutrients in human waste originate from the food eaten, and are taken from agricultural soils. If these nutrients are not cycled back into these soils, via a fertilizer for instance, the soil will progressively lose its fertility, resulting in widespread malnutrition and farmer income loss.

The mining of phosphate as a fertilizer for agricultural lands have been going on for a while. Consumption will increase because of the rising human population and the growing appetite for meat. Agriculture of crops for biofuel will also result in accelerated usage of phosphate. If there is an statistical increase in consumption of 2% annually over the whole world,

the reserves that are economically viable is about 60 years, and the reserves that can be mined is about 100 years [2]. This rather short period is in complete violation of the philosophy of sustainability.

Dry human feces could be popularized as a biofuel. The dry sewage could be burned in a gasifier to produce syngas, a mixture of hydrogen gas and carbon monoxide. Then the syngas is fed into a Fischer Tropsch (FT) reactor to manufacture diesel, gasoline or any other chain hydrocarbon that is the object biofuel. Typically, one would manufacture diesel in a low temperature FT because high temperature FT for gasoline synthesizes some methane which is not as desirable. The low temperature sometimes does give rise to heavier waxes and oils that can be hydrocracked back down to diesel. This occurrence does not happen with the high temperature FT. Commercial units are available that do this. The U.S. military and others are practicing this technology already. The technology started back at the beginning of the twentieth century.

Fire has been known as a sanitizing agent, arguably since its discovery. It might logically be assumed that using dry human feces for burning would be rather ideal, avoiding health safety issues, etc. One objection to using dry human feces as a biofuel for combustion is that of creating more greenhouse gases (GHGs). However, all fossil fuels that currently dominate the realm of energy resources, produce GHGs. Another, more important negative argument is that combustion of human feces does not return the essential nutrients back to the agricultural lands to complete the cycle of elements.

Relevant modern research and development

Engineers and scientists at Singapore's National Technological University (NTU) have invented a new toilet system [3] that will divide human waste into solids and liquids at source, as well as cut down the amount of water for flushing when contrasted to present-day Singaporean conventional toilets.

From [3], "Called the No-Mix Vacuum Toilet by the developers, it has two chambers that divide the solid and liquid wastes. The method employed is vacuum suction technology, similar to that used in aircraft toilets. Solids would be disposed by using only 1 liter of water and flushing liquids use only 0.2 liter. The current Singaporean toilet uses about 4 to 6 liters of water per flush. It is estimated that when installed in a public restroom used and flushed about 100 times daily, this vacuum toilet will conserve about 160,000 liters of water annually. The NTU engineers and scientists will be installing toilet prototypes in two NTU restrooms. This system is designed to be an essential part of a complete resource recovery system, not just to conserve water.

The principle is that the No-Mix Vacuum Toilet system will convey the liquid waste to a treatment facility where elements used for fertilizers such as nitrogen, phosphorus and potassium can be recovered. Concurrently, the solid waste will be conveyed to a bioreactor where digestion occurs and biogas comprising methane is produced. Methane does not smell

and can be used for cooking instead of natural gas. Methane can be used to provide fuel for fuel-cell type batteries or the very much larger electricity generation stations. Reclaimed water (water from shower, kitchen sink and laundry) can be returned to the drainage systems without expensive treatment. Food wastes can be conveyed to the bioreactors or converted via composting and then added to the soil. The foregoing processes result in a total recovery of resources."

Electricity production from renewable resources without the production of carbon dioxide (a major GHG) is highly sort after [4,5]. Microbial fuel cells (MFCs) are batteries that can convert the energy within chemical bonds in organic compounds to electrical energy via the catalytic reactions of microorganisms. In the present day, the MFCs have aroused great interest amongst researchers [6-8]. Bacteria can be used in MFCs to generate electricity while biodegrading the organic wastes [9,10].

Reviews have been written about MFCs [11], touching on the viability of using wastewater in MFCs. Several other reviews on MFCs have been published. Bullen et al., [12] gathered together many experimental results on MFCs reviewed in their publication on biofuel cells. The biochemical reactions that take place determined the type of the biofuel cells; the electrode reaction was also used for type determination. The performance of the various fuel cell batteries were examined. A number of applications were discussed. Whereas a respectable amount of chemical development of enzyme electrodes had been achieved, engineering development of biofuel cells was declared to be still at its infancy.

Pham et al., [13] published about MFCs with respect to their advantages and disadvantages. The basis of comparison was the conventional anaerobic digestion technology for the production of biogas. The microbial fuel cell technology has some advantages, e.g., its suitability for the treatment of low concentration substrates below 20°C, where anaerobic digestion typically does not work. MFC technology complements the anaerobic digestion technology, rather than strives to outdo the latter. Hence, there are many niche applications for MFCs. On the other hand, there are significant limitations with respect to large-scale applications. The shortcomings include investment costs, engineering matters concerning scaling up and issues restricting performance, with respect to electron transfer at the anode and the cathode.

Rabaey and Verstraete [14] reviewed the microbial metabolism in MFCs. There is still scarce information published about the energy metabolism and nature of the bacteria using the anode as electron acceptor. A very limited number of electron transfer mechanisms have been achieved unambiguously. The understanding of the bacteria behavior with regards the aforementioned factors is vital to develop and make better the energy production by MFCs. Contingent on the MFC operational parameters, various metabolic pathways are employed by the bacteria. Suitable organisms are selected that way. Performance is thus also related to the organisms.

Rabaev and Verstraete discussed how bacteria employ an anode as an electron acceptor and to what degree these one-cell micro-organisms produce electricity.

MFC designs, performances and characterizations were written up by Logan et al., [15]. From [15], "The building and study of MFCs demands a mastery of various disciplines, extending from electrochemistry to microbiology to material science and environmental engineering. A mastery of these dissimilar disciplines is required to study and report about MFC systems. In their work, Logan et al., reviewed the various materials and procedures used to build MFCs, methods employed to evaluate system performance, and suggestions on the relevant significant information to find and publish in MFC studies."

Chang et al., [16] wrote about the properties of electrochemically active bacteria employed in mediatorless MFCs. They also reported the rate limitations in electron transport. Lovley [17] concentrated his work on the MFC systems called Benthic Unattended Generators (BUGs) for powering remote-sensors or monitoring devices. He considered BUGs from the angle of microbial physiologies. More recent publications about MFCs include [18,19]. Various biocathode combinations and materials were studied in the MFCs [19]. They did find the combination that provided the highest power density.

Scientists and engineers from the University of Bristol, United Kingdom and Bristol Robotics Laboratory, have declared success in manufacturing electricity from urine using MFCs. Their research was reported in the journal published by the Royal Society of Chemistry, Physical Chemistry Chemical Physics, [20]. The objectives of the researchers included the study of untreated urine being the medium for generating electricity through MFCs and the evaluation of energy yield from urine when thus employed.

Facts and figures

It is estimated that 6.4 trillion (US) liters of urine is produced annually [20], based on a world population of 7 billion and an average daily urine output of about 2.5 liters per adult human. More conservative estimates put human waste production at 1 pound (0.45 kg) of feces per day [21] and 1.5 liters of urine per day [22]. The differences in estimate (with regards urine) are probably due to the latter being for the statistically average human being in the seven plus billion people in the world, while the former is for adults. The more conservative figure gives an estimate of 3.8 trillion (US) liters of urine produced worldwide annually.

It is common knowledge that the statistical average human person drinks about 1.5 to 2 liters of water and other fluids a day, and 3 liters is a generous upper limit. Foods also contain liquids that should be considered in the calculations. With these input figures, the estimates for output figures [20-22] do fall within the range of acceptability, taking into consideration errors.

Based on the figures published by the scientists and

engineers from the University of Bristol and Bristol Robotics Laboratory, the amount of electricity that can be generated via either amounts of urine would be significant, but not necessary capable of replacing any current energy resources. The fact is that human wastes can complement other renewable energy resources. To be considered are also the costs of installing, maintaining and operating such MFCs. The point however, is that human wastes (and urine in particular, after the University of Bristol's report) will not be a product that needs to be treated and disposed of into the environment as a nuisance/contaminant, but will be a viable bioresource.

Discussion and conclusion

The literature survey of the current work did arrive at the finding that translational research needs to be done to make the microbial fuel cell technology more feasible from an economic standpoint, and in scaling up the batteries. The research is translational rather than basic research or applied research, mainly because the field is multidisciplinary. Resources need to be provided by governments and the private sector worldwide, to speed the transformation of human wastes to renewable bioresources. Further research should spotlight on power density, reactor configuration and material costs. Urine will definitely help to reduce this last factor of material costs, if it is proven to be practically workable on a scalable basis.

With the world population zipping past the seven billion number like an unstoppable comet, the need for energy and renewable energy sources inevitably becomes more pressing. The human population itself can provide renewable bioresources. This perspective seems to be in harmony with the natural conservation and sustainability laws of the universe. The present review has surveyed the studies that are the foundation stones for researches, discoveries and developmental works that will render human wastes more available as safe renewable bioresources. The talent has come mainly from the developed nations, the will to implement unusual technology with traditionally noxious materials (as human wastes are popularly considered) and finances will have to come from the developed nations. The places for proving ground will probably be contributed from the less developed nations, as these later have nothing to lose if careful and safe (with regards health issues) procedures are followed.

The advocacy for change in the multicultural, highly diverse nation of India is complex. The open latrine culture is still widespread. It might need a great political leader like Mahatma Ghandi, or even a saint like Mother Teresa. All bets are off with regards ordinary scientists and engineers, like the current writer/researcher. Perhaps, appealing to the diverse groups of Indians that changing to modern sanitary toilets would benefit their children, communities and country might be effective. Living without sanitary facilities is not necessary and a better, more healthy existence is achievable. Improving one's lot in the current situation, even if it is just getting rid

of bad habits giving rise to unhealthy conditions, is working towards a better existence. Maybe when human feces and urine are recognized as renewable bioresources and given the attention they deserve by the materialistic world, the ancient land of India will see a complete 'conversion' in the daily habits of her peoples with regards sanitation.

Competing interests

The author declares that he has no competing interests.

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