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Short Communication

Aqueous Solutions of Glycerol and Urine for CO2 Capture

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Abstract

For decades, carbon dioxide emissions have been an environmental and health issue. Amines like Monoethanolamine (MEA) have long been used for CO_2 capture by chemical absorption. However, some drawbacks, such as toxicity, low stability and high cost limit widespread adoption of this technology. New and green solvents could be a possible solution to this issue. CO_2 solubility in glycerol-urine mixtures at ambient temperature as a green solvent was studied. The experiments were carried out in a pressure pump keeping in contact at room temperature CO_2 at 3 bar of pressure with different dilutions of glycerin and urine. The absorbed CO_2 is measured in dry samples with a microbalance.

Results indicated that the solubility of the gas in the glycerol-urine mixtures increased almost linearly with diluted glycerol. Carbon dioxide absorption values indicate that aqueous solutions of Glycerol and Urine can be a good system for CO_2 capture by physical abpsortion.

HIGHLIGHTS

The solubities of carbon dioxide in aqueous solutions of glycerol and urine were measured. The pressure was up to 3bar and temperature ambient. The measured data were represented satisfactorily by a lineal correlation.

INTRODUCTION

The global warming of our planet is a major danger for humanity and its environment. Greenhouse gas emissions are the primary cause of this climate change and far from being reduced increases year by year because of the growing of the population [1].

To avoid dangerous consequences of global warming, there is an urgent need to reduce greenhouse gas emissions. Among the options for CO_2 mitigation applied to large point sources, post combustion CO_2 capture based on chemical absorption is the most mature technology. In a typical chemical absorption process, a chemical solvent absorb CO_2 and releases the captured CO_2 upon heating. The absorption and regeneration section operates at around 40°C and 120°C, respectively. A huge barrier for implementing this technology is the high energy demand that is needed to regenerate the solvent. Therefore, to enable CO_2 capture with as low energy consumption as possible, there is a need to develop energy efficient solvents. Several other factors need to be taken into account when selecting solvents. The solvent should be environmental friendly, resistant to degradation, non-toxic, non-corrosive, have low viscosity, fast reaction kinetic with CO_2 and preferably be non-expensive. The solvent monoethanolamine is currently the most widely used solvent in the industrial process for capturing CO_2 from power plant flue gas stream. Both primary and secondary amines act as a weak base and form carbamates when reacting with CO_2 [2].

Recently a novel carbon capture solvent, glycerol has been introduced. It is available in large quantities as a by-product from bio-diesel production [3]. The solubility of CO2 in glycerol was enhanced by pressure increase and by temperature decrease [4].

Carbon quantum dots (CQD) are a new class of carbon derived nanomaterials. CQD were obtained by heating glycerol and urea in a 4aptur autoclave at 180ºC. Urea participates not only as a carbon source but also as a passivating agent of carbon nanoparticules. Glycerol also serves as a 4apturing4t medium for urea. Urea is soluble in glycerol [5].

Urine is a valuable waste stream that could be used to produce fertilizer [6]. Recycling of the Urea-Nitrogen contained in the urine would make it possible to take advantage of resources from sanitation to Agriculture [7]. Urine at room temperature has already been used for CO_2 absorption [8].

If the carbonized urea-glycerin mixtures have been used under different conditions of pressure and temperature for CO_2 absorption, we might think that urea contained in human urine could be useful for this purpose. The solvents govern the degree of dehydration and carbonization apturing of precursors. Degree of dehydration and carbonization are gradually increased in glycerol. Dehydrating process form Nitrogen-rich C dots with abundant carboxyl, hydroxyl and amide groups on the surface [9]. The narrow micropores and N content in the absorbent were considered as the important roles for CO_2 absorption. At the temperature and pressure of 25ºC and 1 bar, the absorbent had the highest CO_2 uptake [10].

The hypothesis we proposed is to check if dehydration of diluted Glycerol-Urine mixtures at room temperature could be an effective system for CO_2 absorption.

MATERIALS AND METHODS

Glycerol was supplied by the company Cofracas SA. Glycerine veg 99,7% USP. 1 litre of a dilution 1/100 in volume glycerol/water was prepared and kept in the laboratory for several months during which the tests were carried out.

The urine used in the experiments was my own family. To avoid the decomposition of urea and the formation of ammonia due to urea hydrolysis, the urine used was new produced every day. It has, on average Ph of 5,9 ± 0,3 ; EC 20,5 ± 1,2. The CO2 came from an industrial cylinder supplied by the company Air products Ltd.

We made a factorial design (2x3) with two levels of glycerol and three levels of urine. The Gycerol levels applied were 2 and 4 ml of a dilution 1/100 in 4aptur glycerol-water. Four replications with 1 ml of three dilutions of urine fresh (1/5, 1/2, 1) per volume of tap water were used. All samples were kept 3days in a reactor at CO2 pressure of 3 bar. The results were subject to an analysis of variance and comparison of means using the PC computer program Statgraphics Plus 5.1

RESULTS AND DISCUSSION

CO_2 solubility in aqueous solutions of different molar ratios of MEA and glycerol as a green solvent was studied by Babamohammadi [11]. The findings further revealed that the optimum CO_2 solubility was obtained at low glycerol to MEA ratio, as this ensured the solubility at elevated temperatures.

According to Shamiri [3], the reactions between CO_2 and MEA to be a chemical absorption are stoichiometrically limited to 0.5mol of CO_2 per mole of amine. The presence of glycerol reduces the chemical absorption capacity of MEA. In other words, the lower the viscosity of the solution, the higher the CO_2 diffusivity in the solution and, therefore, the higher CO_2 loading. This indicates that the solubility of CO_2 when using these types of solvent mixtures at high pressure is dominated by the chemical reaction rather than the physical process.

The absorption of CO_2 can exceed this limit considering physical absorption. The absorption process of CO_2 by glycerol is considered as a physical absorption. The gas CO_2 molecules are apturing in a liquid solvent without chemical reaction. The binding between the CO_2 molecules and solvent molecules, being Van der Waals type or electrostatic is weaker than that of chemical bonds in chemical absorption. Glycerol contains three free alcoholic hydroxyl groups. CO_2 is able to act as Lewis acid or Lewis base and take part in hydrogen bonding. The therminal apturin groups have a higher affinity for CO_2 molecules and consequently increase CO_2 absorption. The high polarity of the bonds in the CO_2 molecula allows a strong electron interaction with the highly polar hydroxyl groups in the solvent [3].

The CO_2 absorbed showed a statistically significant relationship with Glycerol and urine (Correlation coefficient equals 0,75 at the 99% confidence level (P<0,0001)

CO_2 (Kg) = 1,08 Glycerol (L) + 0,03 Urine (L)

Our results indicated that the absorption capacity (1,1 Kg CO_2/1 L Glycerol) was bigger than other solvents as amines (0,4 g CO_2/g MEA (Leron 2013) (0,15Kg CO_2/Kg solution amines [2], used in chemical absorption.

Figures 1 and 2 show significant differences in CO_2 absorption values in relation to the amounts of glycerol and urine used in the different treatments. The influence of glycerol on CO_2 absorption is much more important than that of urine (1,08 kg versus 0,03 kg) but in both cases they are significant. In view of the graphs we can conclude that both glycerol and urine significantly influence CO_2 capture.

Glycerol has been recognized in recent years as an effective promoting medium for the electrophilic activation of carbonyl compounds. The ability of glycerol to establish a strong bond network with the carbonyl group is behind this activating effect. Its use as solvent enabling the development of transformation que conventionally require of Bronsted or Lewis-acid catalysis. Compared to water it has the advantage of its higher boiling point, lower vapor pressure and that it is able to dissolve organic compounds usually immiscible with water [12].

Plasticizers are used to disrupt the hydrogen bonds between the starch polymeric chains, herby influencing the mechanical properties of starch films. Urea formed stronger and more stable

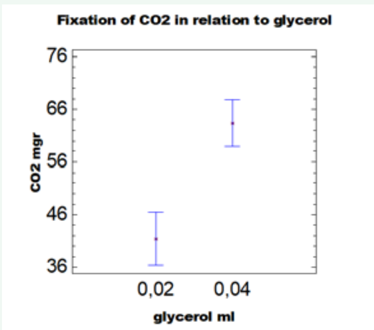

Figure 1 Mean values of CO_2 (mgr) in relation to glycerol values (ml).

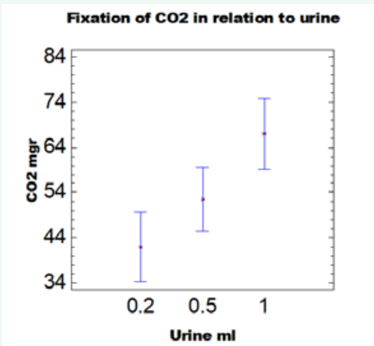

Figure 2 Mean values of CO_2 (mgr) in relation to urine values (ml).

hydrogen bonds with starch than glycerol did thus preventing the starch molecules from interacting and recrystallizing. The mixtures of Glycerol and Urea had better rheological and mechanical properties than that plasticized by single glycerol [13]. Thus, in our case we could consider that urea of urine favors the formation of hydrogen bonds between CO_2 and glycerol, increasing the absorption capacity. This effect is favoured by the aging of the aqueous glycerol solutions because the formation of mucilages is observed at the bottom of the bottle which indicates an increase in the viscosity and apturing4tion of the solution over time. With the drying of the samples the absorbed CO_2 remain attached to the absorbent. The solids obtained by not containing any toxic products could have been investigated to be reused in Agriculture or other applications. The plant nutrients consumed in human society today are lost through the established wastewater-treatment systems. Separating and recovering the urine reduces the costs of wastewater treatment and reusing them adds resource savings to the benefits.

CONCLUSION

In conclusion, aqueous solutions of glycerol and urine could be considered a long-term stable system for absorbing CO_2. The absorption capacity was bigger than other solvents as amines. Glycerol and urine are nontoxic, green and stable solvent. Can lower costs and reduce the usage of toxic and hazardous materials in capturing CO_2. The proposed strategy requires further research to know the chemical composition of solid formed, to increase CO2 absorption and study the risks associated with this waste reuse in the agro ecological environment.

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