Application of Nanofluids in CO_2 Capture and Extraction from Waste Water

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Abstract-- **Carbon dioxide emission is one of the alarming problems that we are facing today and with the help of nanotechnology, the emissions have been reduced to an extent. There are certain methods to reduce the emission in the field of nanotechnology like using carbon nanotubes hollow membrane contractor, hybrid Nano absorbents, transition Nano crystals doped with carbon nanotubes for efficient carbon dioxide absorption, synthesis of graphitic carbon nitride Nano sheets, etc.**

Nanofluidshave been potential to use as an alternative for carbon capture than conventional fluids like amines. Generally, amines like MEA, DEA and MDEA are used to capture carbon dioxide. However, recent studies showed that nanofluidscangive more absorption efficiency than conventional solvents. In a current study, we reviewed and highlighted recent advances in the application of nanofluids in carbon dioxide capture. Many researchers are working on various approaches to make an efficient nanofluid system for environmental application. Butmany nanoparticles are not fully explored.

I. INTRODUCTION

Burning of fossil fuels causes emission of carbon dioxide; this results in global warming. Prior to the industrial revolution, the concentration levels of carbon dioxide haveincreased alarmingly from around 200ppm (approx.)to 400ppm (approx.), and this major problem has to be alleviated [1]. The only way for this is to reduce carbon dioxide emissions. Since $CO_2$is a highly stable gas both chemically as well as thermodynamically, it is difficult to decompose thisgas.

The conventional methods followed in industry for carbon capture are based on membrane technology, adsorption processes, cryogenic techniques, absorption operation and chemical looping method using chemicals such as methanol, ethanol and water, di-ethanolamine, polyethylene oxide [2,3].

Gas sweetening is the most common method used in industries where carbon dioxide has been removed along with the hydrogen sulfide gas. CO_2removed from flue gases has been done after post-combustion, but this amine scrubbing has disadvantages like high generation cost, corrosion problems and loss of amines during regeneration [4]. However, in recent years many studies shown that nanofluidshave been potential to be used as a carbon dioxide absorption tool and our focus is to increase this capacity by using hybrid nanofluids. Hybridnanofluids have shown more efficiency than conventional nanofluidsfor other applications like car radiators, solar panels, boiling operations. Thus, it is also possible thathybrid nanofluids will give better results in the case of a carbon dioxide capturing anddesorption.

2. *Preparation of Nanofluids*

Nanofluids are prepared by two methods:

1. One-step method: in this method, nanoparticles are synthesized directly within base fluid during crystallization or evaporation operation. [5]
2. wo-step method: generally two-step method is preferred two synthesize nanofluids. Due to its controlling ability to nanoparticles size and size determine efficiency of nanofluid performance. In this method, nanoparticles are specially prepared and then added them into base fluid like water or ethylene glycol. [6,7]

3. *Enhancement Mechanism*

3.1 Grazing (Shuttle) effect:

Kars et al.[8] proposed grazing effect in 1979. Gas absorption rate is increased by solid particle presence in liquid gas surface. These nanoparticles acts as a carrier of gas phase from interface to bulk of liquid and it increases its mass transfer rate. [9]

3.2 Hydrodynamic effect in gas-liquid Boundary layer:

Due to presence of nanoparticles, boundary layer between gas-liquid thickens and this thickened boundary layer leads to increment of mass transfer and thus CO_2 absorption increases. [10]

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3.3 Inhibition of bubble coalescence

During the collision of two bubbles in liquid medium, film of liquid drains over time to submicron thickness. This depends in surface tension. Thesemain three reasons of CO_2 absorption rate increment in nanofluids.[11]

4. CO_2 absorption enhancement by nanofluids

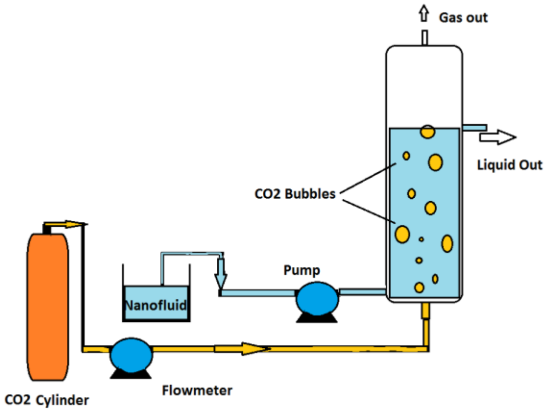

Figure 1: Schematic representation of CO_2 Absorption Process experimentation

Mohebietal. [12] used Al_2O_3 nanoparticles with 0.05 wt% concentration and Diethanolamine as a solvent to capture carbon dioxide. The author reported a 33% enhancement in carbondioxide absorption efficiency. Suresh et al. [13]used Fe_3O_4/MDEA based nanofluidswith 0.39 vol% and achieved an efficiency of 92.8%. This is a really impressive achievement. Similarly, keshavarzetal. [14] compared different nanofluids which are made of a combination of water or amine as a solvent and any one of the CNT, SiO_2, Al_2O_3, and Fe_3O_4 as nanoparticles. Ali et al. [15,16] alsoexplored many applications of hybrid nanofluids like solar panels, electronic cooling, manufacture/automotive industry and many others.

Afshariet al.[17] investigated the rheological behavior of MWCNT-Alumina/Water (80%)-Ethylene glycol (20%) nanofluid. But Application of carbon dioxide capture is not available in the literature. Ghosh, S., &Ramaprabhu, S[18], synthesized of graphitic carbon nitride Nano sheets and the experiment was carried out by using high pressure diverts apparatus and carbon dioxide absorption capacity was around 19.78mmol/g.

Sumin et al. [19] study shows the theoretical comparison and Al_2O_3 with a based fluid and with carbon nanotubes, carbon dioxide absorption is more when carbon nanotubes are used.

Lee et al. [20] compared performance of the two nanoparticles of Al_2O_3 and SiO_2 and was compared on the basis of cycles, and a common based fluid methanol was used. Enhancement was more in SiO_2.Zhang et al. [21] illustrated the different mechanisms and methods to reduce the carbon dioxide and advancement of using Nano fluids in this field.

Yao et al. [22] synthesizedpoly(2-dimethylaminoethylmethacrylate) micro gel and silica (PDMAEMA/SiO_2)a using grafting approach and adsorption of CO_2 was maximum for walnut kernel structured core.

Liu et al. [23]determined the CO_2equilibrium solubility in 1-dimethylamino-2-propanol (1DMA2P) solution. Solubility taken as a function of 1DMA2P concentration and heat ofthe heat of CO_2absorption in 1DMA2P solution estimated using Gibbs-Helmholtz equation was found to be −31.67kJ/mol.Rehman et al. [24] used hollow membrane contractor and usage of carbon nanotubes has enhanced the carbon dioxide absorption.

Li et al. [25] improved CO_2capture efficiency by enhancing the transfer of carbon dioxide between gas phase and cytoplasm by the hydrophilic oleate-modified Fe_3O_4nanoparticles.

Irani et al [26] prepared Graphene-Oxide (GO)/MDEA Nano fluid was prepared, and enhancement of 9.3% carbon dioxide absorption is seen.

Haghtalabet. al[27] used nanofluids of spherical silica (SiO_2) and zinc oxide (ZnO) nanoparticles and solubility of carbon dioxide was found at different concentrations, and it was the maximum at 1% zinc particle concentration.Nabipour et al. [28] used sulfinol-M based Nano fluid and with the usage of MWCNT and nanoparticles in it, and solubility of $CO_2$was up to 7%.

Lu et al. [29] used suspensions of Fe_3O_4, CNT, SiO_2, and Al_2O_3 nanoparticles in distilled waterwas used in hollow membrane contactor and the highest absorption rate enhancements for nanofluids are 43.8% at 0.15 wt. % Fe_3O_4. Figure 1 shows schematic representation of CO_2 Absorption process experimentation. Main challenges are to determine exit concentration of nanoparticles. Titration method is used to determine an outlet CO_2 concentration. [30]

5. Extraction enhancement by nanofluids

Extraction processes are an important unit process which falls under the separation category. It involves the separation of a mixture of substances selectively into one single pure substance or a sub-mixture of substances by the phenomena of mass transfer and by taking advantage of the property of relative solubility of certain substances in the mixture. Liquid-Liquid extraction is an important process used in industries, and they are dependent on the mass transfer rate of two phases and addition of nanofluids to them provides augmentation of mass transfer. This was observed by Bahmanyar et al. [31] in their study in which they used hydrophobic SiO_2 particles in a pulsed liquid-liquid extraction column and added the prepared nanofluids with different nanoparticles concentration into the dispersed phase of the column. They observed the mass transfer rate to be enhanced as the concentration of nanoparticles increased and the increment was more at lower pulsation intensity. They attributed this enhancement to Brownian motion of the nanoparticles inside the droplets and the enhancement is higher at lower pulsation intensity due to the bigger drop size corresponding to it thus creating more turbulence and resulting in an augmented mass transfer rate. In another study Saien et al. [32] used two different types of nanoparticles in a wider range of volume concentrations in nanofluids and studied their characteristics by placing them in the dispersed phase and observed the dependence of mass transfer characteristics on different drop sizes produced. They observed an enhancement in mass transfer rate up to a certain concentration then observed a decline in mass transfer rate. They found that the mass transfer rate increased with increasing drop size and attributed this result to enhanced turbulence provided by larger drops. The enhancement with nanoparticles was not stated as a reason for the increase in drop size as it did not affect the interfacial tension but the enhancement in mass transfer due to the addition was attributed solely to the microconvection caused by Brownian motion of the nanoparticles. In another study Ashrafmansouri et al. [33] used a spray liquid-liquid extraction column with silica nanoparticles added in the form of varying volume concentration nanofluids in the dispersed phase and checked the effect of changing the mass transfer directions for continuous to dispersed phase and vice-versa. They found out that the mass transfer characteristics were enhanced when the mass transfer direction was changed from dispersed to continuous phase to continuous to dispersed phase and attributed this finding to the lower drop size and internal turbulence produced by continuous to dispersed phase mass transfer direction. They also observed the increase to be increasing up to a certain concentration and then decreasing and provided a reason of particle agglomeration for the decline in the enhancement.

Similarly, as in the case of liquid-liquid extraction, nanoparticles can also be used for solid-phase extraction process. A related study was performed by Yousefi et al. [34] in which they used ionic liquid and magnetic MWCNT’s based bucky gels as sorbent to absorb Cr(VI) and CR(III) from water samples by forming their complex with 1,5-diphenylcarbazide. They observed that the by increasing the volume concentration of MWCNT’s in the ionic liquid the absorbance increased up to a certain value and then remained almost constant. The same was seen in the case of increase in an amount of bucky gels but in the case of sample volume the absorbance was almost constant up to a certain amount then was seen to be decreased. The mechanism of the absorbance of the chromium complex on the sorbent was due to the π–π interactions between them and the complex molecules.

In another novel study Made et al. [35] used single drop microextraction of three types of fungicides from water samples using ZnO nanoparticles in 1-hexyl-3-methylimidazolium hexafluorophosphate fluids. They checked the effects of different parameters of extraction such as amount of nanoparticles, amount of nanofluids, time of extraction, stirring rate, pH of sample solution and ionic strength on the extraction efficiency. They observed that the efficiency increased until a certain concentration and then showed a tendency to decrease due to the saturation of ionic liquids and increase due to then increase in Brownian motion was provided as a reason. They observed that volume of nanofluids increase also resulted in the increase of extraction efficiency but after a certain value was deemed unfeasible due to the dislodging of the drop. The effect of time was also observed by them to be similar to the above two values but after a certain time the efficiency became stagnant and the dissolution of nanofluids at a higher tie was attributed as a reason for this decrease after a certain value. In case of stirring rate they found that the same observations as nanoparticles concentration and the decrease after an optimum value which was attributed to the instability induced at higher stirring rates. They observed that change in pH portrayed insignificant difference in extraction efficiency although a slight increment was found in a slightly acidic pH range and the reason was attributed to the hydrolysis of analytes in alkaline media resulting in the demolition of fungicides and hence tending towards a lower extraction efficiency. They observed the effect of ionic strength by adding salt to the solution and found that the salt resulted in reduction of extraction efficiency and attributed this finding to the instability of the droplet due to bubble formation and precipitation of fungicides at high ionic concentrations.

II. CONCLUSION

Nanofluids are always been seen as alternative to replace coolant systems to promote heat transfer but it can increase mass transfer rate also, we have reviewed some of the recent advances in this field and came to know that there is still many possibilities which can be explored and needs attention

1. Applications of hybrid nanofluids are not yet explored fully.
2. The prototypen designed model of numeric validation is needs to be explored.
3. Temperature dependence of prototype designed hybrid nanofluidmodel is the most important parameter for the desorption process. Numeric validation of this workis also possible using Commercial software packages like ANSYS FLUENT or GROMACS.

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