

## SHORT COMMUNICATION

# An effective and ecofriendly suggestion to decrease atmospheric carbon dioxide by using NH<sub>3</sub> gas

H. Eryilmaz\*

Artvin Coruh University, Engineering Faculty, Department of Environmental Engineering,  
Seyitler, Centrum, Artvin, Turkey

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**ABSTRACT:** Global warming is increasing permanently, because the concentration of CO<sub>2</sub> in the atmosphere is rising continuously. According to National Oceanographic and Atmospheric Administration, the concentration of CO<sub>2</sub> in the atmosphere was 407 ppm in June 2016 and 413 ppm in April 2017 as a last record for now. If the effects of other greenhouse gases, such as CH<sub>4</sub>, N<sub>2</sub>O, SF<sub>6</sub>, NF<sub>3</sub>, chlorofluorocarbons, hydrofluorocarbons, perfluorocarbons are added, the effective concentration may reach or exceed 550 ppm CO<sub>2</sub>-equivalent. According to the United Nations Intergovernmental Panel on Climate Change-2014 Climate Change Report, this is about two times higher than 278 ppm CO<sub>2</sub> concentration in the pre-industrial year 1765. Thus, very urgent solutions must be found. The aim of this article is to suggest a vital, fast and very meticulous solution using NH<sub>3</sub> gas in the atmosphere in order to decrease the atmospheric CO<sub>2</sub> without delay. The laboratory experiments in the gas phase for (NH<sub>3</sub>+CO<sub>2</sub>) reaction showed us that to use NH<sub>3</sub> gas in the atmosphere will be a very fast, effective method for decreasing CO<sub>2</sub> concentration of atmosphere. (NH<sub>3</sub>+CO<sub>2</sub>) reaction is also quantitative in the cold atmosphere strata and there will be no more free ammonia in the atmosphere and no public health problem.

**KEYWORDS:** Atmospheric CO<sub>2</sub>; Chemical CO<sub>2</sub> absorption; Decreasing CO<sub>2</sub> concentration; Global warming; NH<sub>3</sub> gas.

## INTRODUCTION

In June 2016, the concentration of CO<sub>2</sub> in the atmosphere reached 407 ppm and in April 2017 reached 413 ppm according to NOAA. Measurements were made by two independent CO<sub>2</sub> monitoring programs (NOAA and Scripps) at the Mauna Loa Observatory in Hawaii, about 3400 meters above sea level. In the 2015 Paris Climate Conference (COP 21), the World Leaders agreed to stabilize global warming at maximum 2°C above pre-industrial level, at the end of the twenty-first century. But, if GHGs emissions increase with the present growth rates, "IPCC 2014- AR5-Scenerio RCP 8.5" says

that the warming will be about 4°C (2.6-4.8°C) (IPCC, 2014) at the end of the twenty-first century. Additionally, if all "Intended Nationally Determined Contributions" (INDCs) of UN countries to mitigate GHGs emissions are calculated totally, it seems that the global warming will be 2.7-3.0 °C, i.e. certainly above 2°C. So, COP 21 Agreement could not solve the problem exactly, but simply postponed it, to solve after 2020s. Also, the withdrawal of the USA from the Paris Climate Treaty in 2017 makes the situation even more difficult. For a successful worldwide solution, the lifestyle of human being should be changed. This means using less consumption goods and especially, saving as much as possible the carbon based energy. Apart from these precautions, science and technology can provide more effective methods in solving this

\*Corresponding Author Email: [h.eryilmaz@artvin.edu.tr](mailto:h.eryilmaz@artvin.edu.tr)

Tel.: +90 4662151040 Fax: +90 4662151057

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problem. For instance, some of them are Carbon Capture and Storage (CCS) methods (Spigarelli and Kawatra, 2013; Zaman and Lee, 2013; Wang *et al.*, 2011). In the specialized literature, there is a wide and comprehensive review (Boot-Handford *et al.*, 2014) for these CCS procedures. These methods can be divided into two main groups:

1) Physical methods: Liquefaction of CO<sub>2</sub> at high pressure and low temperature is a known process and it may be possible for gas mixtures with a high percentage of CO<sub>2</sub> but, not proper for atmospheric CO<sub>2</sub> because of its very low concentration. It is necessary to use some physical adsorbents in this case. A large number of adsorbents have been proposed for CCS. The widely investigated adsorbents are aluminosilicate-based zeolites, metal-organic frameworks, activated carbons, carbon-based decomposition materials, and amine-based materials, amine-modified mesoporous silicas. Another alternative physical method is separation of CO<sub>2</sub> from gas mixtures with membranes made from polyphenyleneoxide, polymethylsiloxane, polypropylene, ceramic (Rubin *et al.*, 2012), polyimide, polycarbonate, polyacetylene, poly ethylene oxide, poly aniline, poly sulfone, etc. (Spigarelli and Kawatra, 2013). Absorptions in a solvent (for example; selexol, rectisol, fluor, purisol, etc.) under high pressure-low temperature and then regenerations of CO<sub>2</sub> with pressure-swing or temperature-swing are also investigated methods. But operations need high pressures and usually, solvents are not cheap (Spigarelli and Kawatra, 2013).

2) Chemical absorption methods: In the case of chemically CO<sub>2</sub> absorption CCS methods, it is necessary to use some basic materials to bind the atmospheric CO<sub>2</sub> directly as a chemical compound. Some of them are MgO, CaO, Ca(OH)<sub>2</sub>, NaOH, Na<sub>2</sub>CO<sub>3</sub>, K<sub>2</sub>CO<sub>3</sub>, NH<sub>3</sub>, organic amine compounds (Piperazine (PZ), 2-Methyl PZ, Aminoethyl PZ, Hydroxyethyl PZ, 2-Amino-2-methyl propanol, Monoethanolamine (MEA), Methyldiethanolamine, bis-Aminoethylether, etc.), ionic liquids (as cations: 1,3-dialkylimidazolium, N,N-dialkylpyrrolidinium, alkylopyridinium, tetraalkylammonium, tetraalkylphosphonium, etc. and as anions: bis(trifluoromethylsulfonyl)imide, trifluoromethanesulfonate, hexafluorophosphate, tetrafluoroborate, etc.). But these CCS methods are applicable only for power plants using huge amounts

of fossil fuel, or for extremely big industrial plants producing iron, steel, cement etc. Among these carbondioxide capturing basic compounds, ammonia is a very cheap one and very much on the market and so, there are very many articles about it, but all of them are with aqueous NH<sub>3</sub> solution in liquid phase ( Darde *et al.*, 2010; Darde *et al.*, 2012; Zhao *et al.*, 2012; Chen *et al.*, 2012; Dong *et al.*, 2012; Darde *et al.*, 2012(10); Shuangchen *et al.*, 2013; Han *et al.*, 2013; Zhang and Guo, 2013; Li *et al.*, 2014; Li *et al.*, 2014; Qi and Wang, 2017). NH<sub>3</sub> has minimum molecular weight (MW), and because of this, has the biggest theoretical Carbon Capture Capacity (CCC) as (kg CO<sub>2</sub>/kg base). One of these amine compounds, monoethanolamine (MEA) which is mostly used base for CCS, has only 0.72 CCC but NH<sub>3</sub> has bigger 2.59 CCC, if calculated 1 mol base for 1 mol CO<sub>2</sub> theoretically. It means that NH<sub>3</sub> has 3.6 times CCC of MEA. But in practice, only 3.0 times CCC has been reached with NH<sub>3</sub> solution (Yeh *et al.*, 2005), just a little less than theoretical 3.6 value. Another advantage is that the price of NH<sub>3</sub> is about one fifth of the MEA's price. So, regardless of other financial factors, the NH<sub>3</sub> method will be fifteen (3 x 5 = 15) times cheaper than the MEA method approximately. Additionally, MEA and its bicarbonate salt are poisonous compounds and cannot be used directly. Separation of CO<sub>2</sub> from the MEA salt and regeneration of MEA require a lot of energy. It has been estimated that its energy consumption is about 1/3 of a power plant (Spigarelli and Kawatra, 2013). But in the NH<sub>3</sub> method, regeneration will be not necessary. After capture of CO<sub>2</sub>, its storage is necessary. Several ideas have been proposed for the long-term storage of captured CO<sub>2</sub>. These proposals include storing CO<sub>2</sub> in various geologic formations e.g., oil and gas fields, coal beds, and saline aquifers, injecting CO<sub>2</sub> into the deep ocean. Unfortunately, because of ocean currents and supersaturation in deep waters, a large fraction of the injected CO<sub>2</sub> will be released to the atmosphere after a few hundred years. Additionally, direct ocean storage may affect marine-ecosystems. In CO<sub>2</sub> injection into the deep ocean, CO<sub>2</sub> hydrates (5.75 H<sub>2</sub>O•CO<sub>2</sub>) are formed. These compounds are nonstoichiometric crystalline compounds that form at high pressures and low temperatures by trapping CO<sub>2</sub> molecules in hydrogen-bonded cages of H<sub>2</sub>O (House *et al.*, 2006). The researching of CO<sub>2</sub> hydrate stability is still going on. The effect of pressure (100-250 bar), temperature (274-288 K), and salinity (3.5%

w/w electrolytes) on hydrate dissolution rates in the ocean have been investigated (Daeseung *et al.*, 2015). They found that higher pressure, lower temperature and high salinity significantly decrease the hydrate breakdown and dissolution. In the  $\text{NH}_3$  method, pH of sea water and marine-eco system will not change. Because,  $\text{CO}_2$  is an acidic substance,  $\text{NH}_3$  is a basic substance, but  $\text{NH}_4\text{HCO}_3$  formed from  $\text{CO}_2$  and  $\text{NH}_3$  is a neutral substance. As can be found in the catalogs of chemical companies such as Merck; J.T. Baker; Sigma-Aldrich etc., pH of a 0.1 N solution of  $\text{NH}_4\text{HCO}_3$  in water is 7.8 at 25 °C. Also seawater pH was given to a range between 7.8 and 8.0 (Ohline *et al.*, 2007). Clearly, 7.8 is approximately between 7.5-8.0 and the concentration of  $\text{NH}_4\text{HCO}_3$  in sea waters will be always under 0.1 N. Thus, the pH of sea water and marine-eco system will not be changed.

#### Chemical data for the $\text{NH}_3$ method

The first study using aqueous  $\text{NH}_3$  for CCS was done in 1997 (Bai and Yeh, 1997). But, the following data have been received from (Ma *et al.*, 2014): If  $\text{CO}_2$  gas is passed through aqueous  $\text{NH}_3$  solution, mainly  $\text{NH}_4\text{HCO}_3$  is formed. The other particles in the resulting solution are  $\text{CO}_2$ ,  $\text{NH}_3$ ,  $\text{O}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{NH}_4^+$ ,  $\text{H}^+$ ,  $\text{OH}^-$ ,  $\text{NH}_2\text{COO}^-$ ,  $\text{HCO}_3^-$ , and  $\text{CO}_3^{2-}$ . In the simplest way, reaction steps are ( $\text{CO}_2 \rightarrow \text{NH}_2\text{COOH} \rightarrow \text{NH}_2\text{COONH}_4 \rightarrow \text{NH}_4\text{HCO}_3$ ). The yield of  $\text{CO}_2$  absorption is 90% at 54°C temperature and in 4-5 seconds. The absorption temperature is a very important factor in the yield. According to another study (Yeh *et al.*, 2005); if the 40°C is decreased to 10°C, the yield increases by 12%, in 28%  $\text{NH}_3$  solution. The thermal decomposition of 20%  $\text{NH}_4\text{HCO}_3$  solution is (0% at 4°C), (6% at 49°C), (16 % at 60°C), and (29% at 71°C). This means that  $\text{NH}_4\text{HCO}_3$  is very stable in the cold. Also, the Standard Free Energy of formation value,  $\Delta G^\circ$ , for  $\text{NH}_4\text{HCO}_3(\text{s})$  is  $\Delta G^\circ = -26.5$  kcal/mol (Zhang *et al.*, 2003). These value means that the reaction takes place spontaneously and easily. Especially in the cold conditions, it shifts completely to the right side.  $\text{NH}_2\text{COONH}_4$  formation reaction is very fast under atmospheric pressure and in room temperature, because of its low activation energy, 48.6 kJ/mol (Ma *et al.*, 2013). The reaction rate is as Eq. 1.

$$R_r = 1.66 \times 10^{11} \exp\left(\frac{-6100}{RT}\right) [\text{CO}_2][\text{NH}_3] \text{ mol m}^3/\text{s} \quad (1)$$

Also,  $\text{NH}_4\text{HCO}_3$  formation (the last step) is a fast

reaction with the low activation energy. As a result, all steps of  $\text{NH}_4\text{HCO}_3$  formation from ( $\text{CO}_2 + \text{NH}_3$ ) are fast and completely resulted reaction.

#### Suggestion of a new method to decrease atmospheric $\text{CO}_2$ with $\text{NH}_3$

The CCS studies are still in progress, but for the time being, these methods cannot be used for  $\text{CO}_2$  emitted from vehicles, buildings, etc. and not also for atmospheric  $\text{CO}_2$ . Although it is believed that CCS difficulties may be solved in the following years, the decrease in GHGs emissions will not be sufficiently enough, and the concentration of  $\text{CO}_2$  in the atmosphere will be higher and higher.  $\text{CO}_2$  concentration emission from various sources can be found in IPCC 2014 AR5 report. Also, daily atmospheric  $\text{CO}_2$  concentrations can be taken from the web page, (<https://www.co2.earth/global-co2-emissions>). In 2010, total World GHGs emission was 49 Gt  $\text{CO}_2$ -equivalent and only 76 % of it was  $\text{CO}_2$  in itself, according to IPCC 2014 AR5 report (IPCC, 2014). And for the same year 2010, the atmospheric  $\text{CO}_2$  concentration was 388 ppm according to NOAA. So, we can make a prediction using the values given by these two authorized organizations. Assuming that the ratio 76 %, above mentioned for year 2010, was the same ratio in April 2017; and the concentration of  $\text{CO}_2$  was 413 ppm in April 2017 as mentioned above, it can be calculated easily with a simple mathematical proportion that, the total effective GHGs concentration in the year 2017 was approximately 543 ppm  $\text{CO}_2$ -equivalent as shown in Eq. 2.

$$(413 \text{ ppm } \text{CO}_2) \times (100 / 76) = 543 \text{ ppm } \text{CO}_2\text{-equivalent} \quad (2)$$

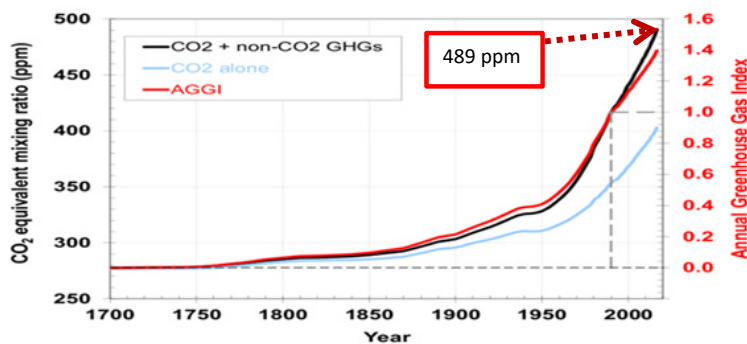
This is about 2 times that of the pre-industrial 278 ppm. In Fig.1, the NOAA graphics show that, this calculation approximately is correct; and nowadays, total effective GHGs concentration must be around 500 ppm as a prediction. In terms of  $\text{CO}_2$  equivalents, all GHGs in the atmosphere in 2016 were 489 ppm as shown in Fig. 1, of which 403 ppm was  $\text{CO}_2$  alone, and the rest 86 ppm was from other GHGs. Certainly, the global warming will increase constantly under these circumstances.

In that case, what is the solution? Although the forests and the oceans absorb the atmospheric  $\text{CO}_2$ , this is not enough to overcome the problem. One of the appropriate ways, perhaps the best way for

decreasing  $\text{CO}_2$ , seems to use  $\text{NH}_3$  gas in the upper layers of the atmosphere directly, by beginning with small amounts of  $\text{NH}_3$  and then increasing its dose gradually. The reaction of  $\text{NH}_3$  solution with  $\text{CO}_2$  to produce  $\text{NH}_4\text{HCO}_3$  is a known reaction in laboratory and industry. Because of this, we have repeated this reaction in laboratory, only in the gas phase, but not in a solution. It is necessary to apply the experiments in the high altitude of atmosphere to make a complete and perfect method. However, these experiments have not been performed due to the inadequate opportunities. Perhaps, it may be possible for us later in the further studies. Thus, the experiments of  $(\text{NH}_3+\text{CO}_2)$  gas phase reactions were made only in the laboratory of Artvin Çoruh University, Science-Technology Research and Application Center in 2018.

### MATERIALS AND METHODS

The gas phase reaction of  $(\text{NH}_3+\text{CO}_2)$  was made in a glass desiccator. “Air  $\text{CO}_2$ ntrol 3000” instrument of Dostmann Electronic GmbH was used to measure the  $\text{CO}_2$  concentration of the air in the desiccator. A firefighting tube was used as  $\text{CO}_2$  source in the desiccator. In the beginning, 25%  $\text{NH}_3$  solution in a test tube and the  $\text{CO}_2$  measuring instrument were placed in an empty desiccator separately and the desiccator was closed tightly.  $\text{CO}_2$  of the air in desiccator was reacted with  $\text{NH}_3$  vapors coming from the solution and the values of remaining unreacted  $\text{CO}_2$  were read with several minutes’ intervals. As shown in Fig. 2 (curve B), decreasing of  $\text{CO}_2$  was very slow and, after about six h, became zero. It was very surprising. After similar experiments, the reaction was repeated with 25%  $\text{NH}_3$  solution in a wide watch glass, instead of



Source Graphic NOAA Annual Greenhouse Gas Index (AGGI)

Fig. 1: GHGs concentrations of the atmosphere in 2016

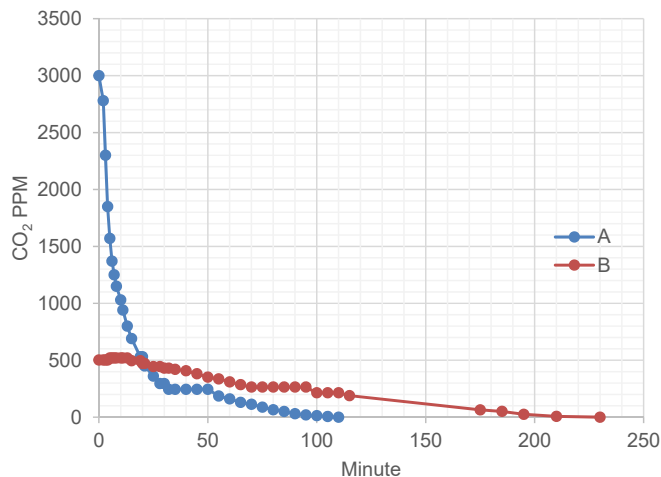


Fig. 2: Decreasing  $\text{CO}_2$  concentrations in time by the reaction with  $\text{NH}_3$ .

narrow test tube. This time, the reaction took place very fast, because of fast evaporation of  $\text{NH}_3$  gas from  $\text{NH}_3$  solution in the wide watch glass. The Fig. 2 (curve A) shows the results of the experiment starting with high  $\text{CO}_2$  concentration, above 3000 ppm (H in the instrument). It is clear that the reaction will be faster by direct injection of ammonia into the cold atmosphere strata.

## RESULTS AND DISCUSSION

It can be seen from Fig. 2 curves that, to use  $\text{NH}_3$  gas in the atmosphere will be a very fast, effective method for decreasing  $\text{CO}_2$  concentrations and perhaps, stopping global warming. Anyone can think by looking at the curves that, all the  $\text{CO}_2$  in the atmosphere will be removed. No, it never happens. Because, the amount of removed  $\text{CO}_2$  will be equivalent only to the amount of injected ammonia into the atmosphere. Some advantages of  $\text{NH}_3$  gas method can be listed as follows:

1. Among the basic substances previously mentioned ( $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{Ca}(\text{OH})_2$ ,  $\text{NaOH}$ ,  $\text{Na}_2\text{CO}_3$ ,  $\text{K}_2\text{CO}_3$ ,  $\text{NH}_3$ , amine compounds and zeolites); only  $\text{NH}_3$  is a gas, and it diffuses easily in the atmosphere.
2. Among them,  $\text{NH}_3$  has the minimum MW and the maximum CCC in ( $\text{kg CO}_2 / \text{kg base}$ ).
3. Only  $\text{NH}_3$  can be sprayed as 100% pure substance.

The amine compounds are poisonous. All other basic substances, except  $\text{NH}_3$ , must be solved or dispersed in water and then sprayed. Because of this dilution, their concentrations will be decreased, and additionally they have bigger MWs than  $\text{NH}_3$ , so their CCC will be much less. For example, MW of  $\text{NaOH}$  is 40 g/mol, and it can be solved only 42 g in 100 g water at  $0^\circ\text{C}$  (temperature of atmosphere around 3 km above). So, 1 kg of saturated 30%  $\text{NaOH}$  solution can catch only 0.34 kg  $\text{CO}_2$  according to ( $\text{NaOH} \rightarrow \text{NaHCO}_3$ ) transformation, but pure 1 kg  $\text{NH}_3$  can catch 2.59 kg  $\text{CO}_2$  according to ( $\text{NH}_3 \rightarrow \text{NH}_4\text{HCO}_3$ ) transformation. It is about 7.6 times of that  $\text{NaOH}$  solution as CCC. So,  $\text{NH}_3$  has the largest CCC compared to all other basic substances. In the 3-4 km height of atmosphere, temperature is under  $0^\circ\text{C}$  and so, ( $\text{NH}_3 \rightarrow \text{NH}_4\text{HCO}_3$ ) transformation will be 100% because of negative  $\Delta G^\circ$  value. Because of the crystal  $\text{NH}_4\text{HCO}_3$  density is 1.58 g/cm<sup>3</sup>,  $\text{NH}_4\text{HCO}_3$  crystals produced in the atmosphere falls into the oceans without or with very little decomposition, and into the warmer lands only with 5-6% decomposition. But, the rest of  $\text{NH}_4\text{HCO}_3$

will be absorbed by the earth and oceans as a fertilizer and because of very low  $\text{NH}_4\text{HCO}_3$  concentration, there will not be any eutrophication in the oceans. Some very fine  $\text{NH}_4\text{HCO}_3$  crystals may be suspended in the air for a while but, because of its high solubility in water,  $\text{NH}_4\text{HCO}_3$  will fall into oceans and lands as rain droplets.  $\text{NH}_3$  less than 25 ppm in air is not harmful, and in water for example, the average of the mean acute toxicity values for 32 freshwater species is 2.79 mg  $\text{NH}_3/\text{L}$ , about 3 ppm (Serezli *et al.*, 2016). Essentially, free  $\text{NH}_3$  concentration in the atmosphere is very low and under ppm level, because of  $\text{CO}_2$  and other acidic gases. Nowadays, it is about 20 ppb (Wikipedi, 2018). Essentially,  $\text{NH}_3$  is a natural gas. The primary natural resources of  $\text{NH}_3$  gas are agriculture, livestock, plant decomposition, some volatilization from soils and oceans. Even so, its concentration is always under ppm level, because, very high amounts  $\text{CO}_2$  and other acidic gases make with it ammonium compounds and in this way, free  $\text{NH}_3$  concentration in the atmosphere remains always below the ppm level and completely harmless for public health. After  $\text{NH}_3$  was sprayed in the atmosphere and the reaction completed with excessive  $\text{CO}_2$  of the atmosphere,  $\text{NH}_3$  concentration of air will also be under ppm level and completely harmless.  $\text{NH}_4\text{HCO}_3$  falling down on oceans will not change the pH of sea water, because, pH of 0.1 M  $\text{NH}_4\text{HCO}_3$  solution is only 7.8 at  $25^\circ\text{C}$  and approximately, this pH value is the same with pH of sea water. This means that,  $\text{NH}_4\text{HCO}_3$  is not an acidification material for soil and water. Additionally, it is impossible for  $\text{NH}_4\text{HCO}_3$  concentration to be more than 0.1 M in the sea water, on the contrary, it will be much less, perhaps in the ppm range. In addition  $\text{CO}_2$ , other acidic pollutants such as  $\text{NO}_x$ ,  $\text{SO}_x$ , HF, HCl, HBr,  $\text{H}_2\text{S}$ , and also Hg species will be captured from the atmosphere by  $\text{NH}_3$  because of its basic properties. These ammonium salts, e.g., ammonium sulfate, ammonium nitrate, also scatter incoming solar radiation and make cooling effect on global heating and so, this is an added benefit of the ammonia method (Zhu *et al.*, 2015).  $\text{NH}_4\text{HCO}_3$ , falling down on sea and land, will accelerate ( $\text{CO}_2 \rightarrow \text{Biomass}$ ) transformation as an N and C fertilizer, particularly in seas, lakes and oceans. In a new study (Samimi and Moghadam, 2018), an aquatic plant, *Lemna gibba*, has been used very effectively to remove  $\text{NH}_3$  from petrochemical waste water below 15 ppm. This shows also that dilute  $\text{NH}_3$  under 15 ppm concentrations in water is certainly

harmless for nature.  $\text{NH}_4\text{HCO}_3$  is also used both as a fertilizer in the soil and as baking powder in the production of cakes, biscuits, pastry, etc. in industry and at home because of this harmless. It must not be forgotten that, in baking systems,  $\text{NH}_3$  concentration is much more than the atmospheric concentration of  $\text{NH}_3$  gas.

#### Application conditions

A cold and moist atmosphere is necessary to activate ( $\text{NH}_3 + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{NH}_4\text{HCO}_3$ ) reaction. This means 3-4 km altitude in the troposphere. But, an altitude of 5-6 km may be necessary to give sufficient time for completion of the reaction before falling down on seas and lands. In the practice, experiments must be started certainly with low  $\text{NH}_3$  concentrations. Although starting with low concentrations,  $\text{NH}_3$  spraying operations must be applied in high altitude of atmosphere in certain places, such as cold and remote regions of the vast Pacific Ocean in south of the World, for safe and harmless application. After  $\text{NH}_3$  has been sprayed from an aeroplane, because of transporting and mixing processes by the winds,  $\text{NH}_3$  will spread slowly in the atmosphere but, in a short time, will react with acidic  $\text{CO}_2$ ,  $\text{NO}_x$ ,  $\text{SO}_x$ , HF, HCl, HBr,  $\text{H}_2\text{S}$  gases and will turn into ammonium compounds. Also by this way, all other acidic pollutants in the air will be cleaned. Application must be started with the small amounts of  $\text{NH}_3$  and must be increased step by step. The conditions of application should always be under control and observation. All applications must be controlled very tightly and constantly by official organizations such as UN, NASA, NOAA etc. Of course, the  $\text{NH}_3$  which would be used in this method, must be produced industrially with hydrogen coming preferably from a non-carbon process, e.g., from water electrolysis. Coal, coke, natural gas, petroleum and CO are cheap natural resources for hydrogen production but, in this case, again  $\text{CO}_2$  occurs. But at the beginning, it is not necessary for first experiments in the atmosphere.

#### CONCLUSION

According to the IPCC statement, the main cause of increasing global warming is represented by human activities. Unfortunately, the world population and energy needs increase consistently, so very urgent solutions are necessary. The  $\text{NH}_3$  gas spraying method can be a fast and effective solution, if it is applied

carefully. At least, the current study method will be useful to keep atmospheric  $\text{CO}_2$  concentration and global warming under a constant level, which is already the target of the COP21 agreement. Of course, this will be an expensive application, but its cost must be paid by United Nations, related organizations and the other NGO's to save future of the peerless planet "EARTH".

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#### CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript.

#### ABBREVIATIONS

<i>AR 5</i>	5. Assessment report
<i>°C</i>	The degree Celsius
<i>CaO</i>	Calcium oxide
<i>Ca(OH)<sub>2</sub></i>	Calcium hydroxide
<i>CCC</i>	Carbon capture capacity
<i>CCS</i>	Carbon capture and storage
<i>CH<sub>4</sub></i>	Methane
<i>CO<sub>2</sub></i>	Carbon dioxide
<i>COP 21</i>	Twenty- first Conference of the Parties, Paris 2015
$\Delta G^\circ$	Standard free energy of formation
<i>GHGs</i>	Greenhouse gases
<i>g/mol</i>	Gram per mole
<i>Gt</i>	Giga ton
<i>h</i>	Hour
<i>HBr</i>	Hydrogen bromide
<i>HCl</i>	Hydrogen chloride
<i>HF</i>	Hydrogen fluoride
<i>Hg</i>	Mercury
<i>IPCC</i>	Intergovernmental Panel on Climate Change
<i>K</i>	Kelvin scale, absolute thermodynamic temperature scale
<i>K<sub>2</sub>CO<sub>3</sub></i>	Potassium carbonate
<i>Kg</i>	Kilogram
<i>kJ</i>	Kilojoule



<i>kJ/mol</i>	Kilojoule per mole
<i>km</i>	Kilometre
<i>M</i>	Molarity
<i>MEA</i>	Monoethanolamine
<i>mg</i>	Milligram
<i>MgO</i>	Magnesium oxide
<i>mol m<sup>3</sup>/s</i>	Mole x Cubic metre per second
<i>MW</i>	Molecular weight
<i>Na<sub>2</sub>CO<sub>3</sub></i>	Sodium carbonate
<i>NaOH</i>	Sodium hydroxide
<i>NASA</i>	National Aeronautics and Space Administration of USA
<i>NF<sub>3</sub></i>	Nitrogen trifluoride
<i>NGO</i>	Non-Governmental Organization
<i>NH<sub>3</sub></i>	Ammonia
<i>NH<sub>4</sub>HCO<sub>3</sub></i>	Ammonium hydrogen carbonate
<i>N<sub>2</sub>O</i>	Dinitrogen monoxide
<i>NO<sub>x</sub></i>	Nitrogen oxides
<i>NOAA</i>	National Oceanic and Atmospheric Administration
<i>R<sub>r</sub></i>	Reaction rate
<i>ppb</i>	Parts per billion
<i>ppm</i>	Parts per million
<i>PZ</i>	Piperazine
<i>SF<sub>6</sub></i>	Sulfur hexafluoride
<i>SO<sub>x</sub></i>	Sulfur oxides
<i>UN</i>	United Nations

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#### AUTHOR (S) BIOSKETCHES

**Eryilmaz, H.**, Ph.D., Assistant Professor, Artvin Coruh University, Engineering Faculty, Department of Environmental Engineering, Seyitler, Centrum, Artvin, Turkey. Email: [h.eryilmaz@artvin.edu.tr](mailto:h.eryilmaz@artvin.edu.tr)

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