



## INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

### AN EFFECTIVE METHOD FOR REDUCING THE ATMOSPHERIC CO<sub>2</sub> CONCENTRATION TO COMPENSATE THE ANNUAL CARBON EMISSION

Tamara Tulaikova\*, Alexandre Michtchenko

\* Prokhorov General Physics Institute, Wave Research Center, Moscow, Russia.

National Polytechnic Institute, School of Mechanical and Electrical Engineering, Zacatenco Mexico, D.F.  
Mexico.

#### ABSTRACT

In the article we describe the approach for purification of atmosphere from free carbon dioxide CO<sub>2</sub> compound. The proposed technique consists of two stages. During the first stage the alkaline reagents are added into atmospheric clouds in order to increase their pH water up to 10 - 11. At the second stage the technique of precipitation enhancement could be applied to induce the transport of carbon dioxide compounds from atmosphere to the ground. At such method one can observe the efficient ensemble of all rain droplets with perfect CO<sub>2</sub> absorption. It was shown by corresponding calculations that there is a considerable increase of the gas/water interface; further estimations indicated good perspectives in application of proposed approach. If one uses our technique involving two stages for even in less than 0.5% for Earth surfaces, the resulting effect can compensate for annual carbon emission.

**KEYWORDS:** .

#### INTRODUCTION

Nowadays atmospheric carbon dioxide levels are the highest of all known recorded levels. According to IPCC Fifth Assessment Report the predicted climate trend indicates the global overheating with raising of ocean level up to 1 meter to 2100, and other ecology problems. All known natural restore mechanisms have limited capacities in regards to the amount of incoming pollution and also they operate within specific time constants, for more details see the paper (Hansen 2006, Kleidon 2010). Our current approach represent solution for the novel and very difficult global problem of the purification of Earth's free atmosphere from the industrial CO<sub>2</sub>, it is one of possible additional method with high efficiency. The main idea of our method is the climate modification by cloud management and with using modified precipitation enhancement. Our approach incorporates the possibility of stepwise CO<sub>2</sub> purification in two stages to be conducted in various areas of the free atmosphere. The first stage consists of spraying the alkaline compounds, such as KOH, Na<sub>2</sub>CO<sub>3</sub>, etc., inside the cloud to increase the pH in cloud medium (Yunge, 1965). The alkaline reagents increase the solubility of CO<sub>2</sub> in water, and then rain droplets become saturated by atmospheric CO<sub>2</sub> during their fall to the ground (Tulaikova, 2012). There are known that precipitations in industrial regions today have pH = 3 - 4 that is very bad for soil (Izrael, 1989). The second stage incorporates the precipitation enhancement to induce transport of CO<sub>2</sub> from the atmosphere to the ground and further more to the ground water.

The techniques for precipitation enhancement were described in the earlier study (Langmuir 1937). Modern methods describing precipitation enhancements have been developed worldwide, for example see the papers (Mather 1997, Shmeter 2005, Daly 2007). The most popular technologies to stimulate precipitation are sprinkling of hygroscopic particles or glaciogenic substances into 'warm' or 'cold' clouds. Dynamics of the modification of cloud by hygroscopic particles indicates that only first few seconds display fast changes in the main cloud characteristics such as spectrum dispersion in cloud droplets (Connolly 2006, Drofa 2006), and this method can't provide quite result in half of experiments. Therefore, additional principles can be very useful to get rains in right time moments, in particular to the proposed technology. The coalescence processes for large (10 μm) cloud droplets can effectively be continued using vibrations of the drop ensemble with the application of special acoustical power (Richardson 1952, Boucher 1960). In particular, studies were conducted in fogs and mists, in which the majority of industry aerosols were successfully purified by up to 99% according to the papers (Mednikov 1963). Considering processes inside the clouds, corresponding regimes for cloud droplets have been found at low frequencies of  $f = 50 - 100$  Hz with low acoustical

power up to  $Q \sim 1 \text{ kW/m}^2$  according to recent work (Tulaikova 2010). For the further method development one can include a variety of weather/region characteristics such as humidity, temperature, regional atmosphere admixtures, wind or turbulence, and local droplet spectrum in cloud.

**ANALYSES OF THE METHOD AND FEATURES**

The purification effect strongly correlates with changes of  $pH$  level in cloud water. In usual precipitation with  $pH \leq 7$  the concentrations of the dissociated ions are relatively small. There is an established method to describe the insoluble and dissociated portions of the weak acid that remains after attaining the equilibrium of saturation for water by  $CO_2$ :  $CO_2 + H_2O \Leftrightarrow H_2CO_3$ ,  $H_2CO_3 \Leftrightarrow HCO_3^- + H^+$ , and  $HCO_3^- \Leftrightarrow CO_3^{2-} + H^+$ . Therefore,  $CO_2$  solubility significantly increases at high levels of  $pH$  due to  $H^+$  concentration. The effect was shown in the study (Yunge 1965, Rasool 1973); there in a cloud with  $3 \text{ mkg} / \text{m}^3$  of  $NH_3$  the medium became alkaline at  $pH = 7$ . As a result the total concentration of dissolve and dissociated portions became  $[H_2CO_3] = C_1 \approx 0.71 \text{ mg/l}$ ;  $[HCO_3^-] = C_2 \approx 3.3 \text{ mg/l}$ , with  $[CO_3^{2-}] = C_3 \approx 10^{-3} \text{ mg/l}$ . The ratios of carbon in the first, second and third cases of the listed compounds are as follows: 0.1935; 0.1967; and 0.20. The partial masses of carbon in 1 liter of water becomes as follows:  $N_1 = C_1 \cdot 0.1935 = 0.14 \text{ mg/l}$ ,  $N_2(7) = 0.65 \text{ mg/l}$ , and  $N_3(7) = 2 \cdot 10^{-4} \text{ mg/l}$ , also their sum is  $N_S(7) = 0.79 \text{ mg/l}$ . The ionic concentrations of  $[HCO_3^-]$  and  $[CO_3^{2-}]$  increase in 10 and 100 times accordingly by each unit of  $pH$ . The concentrations of carbon in 1 liter of water with  $pH = 10$  for each compound and its total are, correspondingly, as follows:  $N_1 = 0.14 \text{ mg/l}$ ,  $N_2(10) = 649 \text{ mg/l}$ ,  $N_3(10) = 200 \text{ mg/l}$ , and  $N_S(10) = 849 \text{ mg/l}$ . For example, a layer of precipitation with a height of  $h_w = 1000 \text{ mm}$  falls on a unit surface of  $A_l = 1 \text{ m}^2$ , so the resulting mass of carbon equivalent to  $M(10) = 850 \text{ g}$  when the  $pH = 10$ . Then water volume is  $U_w = A_l h_w$ , and the carbon mass is, as follows:

$$M_c^{U_w}(pH) \approx [ 0.1935 \cdot C_1 + 0.1967 \cdot C_2(pH) + 0.2 \cdot C_3(pH) ] \cdot U_w \tag{1}$$

Using this approach we can now estimate the concentration of  $CO_2$  that is removed from the atmosphere under cloud by precipitation. Now, let's define the volume of purified air in the atmosphere  $U_a = 10^3 \text{ m}^3$  in precipitation, there  $h_a = 1 \text{ km}$  is the altitude of the cloud over land, and the unit square of the surface is  $1 \text{ m}^2$ . The reduced  $CO_2$  concentration  $C_{a-}$  was estimated by dissolving the carbon mass in alkaline precipitation using an assumption that the initial concentration of  $CO_2$  was detected under the cloud. The molar mass of  $CO_2$  is 44 g, so the share of carbon in it is 0.2727. The vertical  $CO_2$  distribution was considered almost uniform (Machida 2003). The concentration of removed  $CO_2$  could be estimated according to the following formula:

$$C_{a-} \approx \frac{0.1935 \cdot C_1 + 0.1967 \cdot C_2(pH) + 0.2 \cdot C_3(pH)}{0.2727} \cdot \frac{h_w}{h_a} \tag{2}$$

Data for  $CO_2$  reduction are displaying in Table 1 according to the calculations then air altitude  $h_a = 1 \text{ km}$ , but water layer  $h_w = 100 \text{ mm}$  for example.

*Table 1. The concentration decrease in the air  $C_{a-}$  following alkaline precipitation, when  $h_w/h = 10^{-4}$ .*

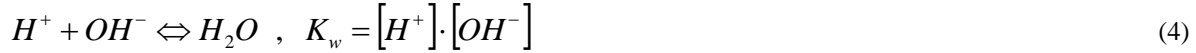
<i>pH</i>	5.6	9	10	10.5	10.8	11
<i>C<sub>a</sub>(pH), Ppm</i>	0.03	13	170	812	$2.4 \cdot 10^3$	$5.3 \cdot 10^3$
$\frac{C_{a-}(pH)}{C_{a-}(5.6)}$	1	445	$6 \cdot 10^3$	$2.7 \cdot 10^4$	$8 \cdot 10^4$	$1.8 \cdot 10^5$

Shown at the bottom row of the Table 1 is the efficiency measure of atmospheric purification associated with the  $pH$  increase in comparison with usually value as  $pH = 5.6$ . In general, clouds can be located at various altitudes  $h_a$ . In the case clouds are located higher than 1 km from the ground,  $h = 6 \text{ km}$  (see for example data in Table 1, column  $pH=10.8$ ), then the corresponding value of the efficiency measure of  $C_{a-}$  should be divided by associated altitude  $h$ . For the special case of the complete atmospheric purification the value of efficiency measure is  $C_{a-} = 400 \text{ ppm}$  due to the volume increase of purified air. Also depending on different level of precipitations observed during drizzle, rain or storm one can obtain various precipitation rates taking altitudes  $h_w$  from corresponding meteorological data.

Let's consider a chemical model for the introduction of *KOH* into clouds in the form of additional liquid aerosol. The dissociation reaction of *KOH* in water is the following:



The alkali facilitates the dissociation of water molecules, and also alkali binds to free ions  $[H^+]$ :



The required molar mass of *KOH* can be obtained from the known relation:

$$n_{KOH} = K_w / [H^+] = [OH^-] \tag{5}$$

The value  $pH = 10$  corresponds to free ions concentration  $[H^+] = 10^{-10}$  and  $[OH^-] = 10^{-4}$ . Taking the molar concentrations for *KOH* and *OH* from relation (3) we obtain molar concentration of alkali approximately  $n_{KOH} = 10^{-4}$  mol/l according to relation (5). Taking into account molar mass of *KOH* we calculate the mass concentration value  $N_{KOH} = 56 \cdot 10^{-4}$  g/l. The range of *KOH* concentrations associated with a particular  $pH$  values are presented at Table 2. Note that the values of water dissociation constant are taken for two temperatures:  $K_w = 10^{-14}$  at  $T = 20^\circ C$ , and  $K_w = 10^{-14.926}$  for  $T = 0^\circ C$  according to (Sillen 1964). The corresponding calculations of the *KOH* mass for these temperatures are listed at second and bottom rows of Table 2. We mean higher  $T$  due to rapid heating for small-size droplets up to surrounding during their fly to the ground.

One can interpret data from the Table 2 in the following way. Suppose in a cloud a content of a liquid water is  $W = 1$  g/m<sup>3</sup>, so the air volume 1 m<sup>3</sup> contains the 1 cm<sup>3</sup> of water, and this air volume 1 m<sup>3</sup> is listed in Table 2 considering required alkali concentration to detect a particular  $pH$ -level after recondensation. For example, let the cloud has a volume 1 km<sup>3</sup> and water concentration  $W = 1$  g/m<sup>3</sup>, hence the required mass of *KOH* to add into the cloud should be equal to 5.6 kg at  $pH = 10$ , or 56 kg at  $pH = 11$ . Analogous alkali concentrations one can see at the Table 2.

Table 2. The concentration of *KOH* to obtain an appropriate  $pH$  in water.

$pH$	9	10	10.4	10.8	11
$n_{KOH}$ , g/cm <sup>3</sup> , (20°C)	$5.6 \cdot 10^{-7}$	$5.6 \cdot 10^{-6}$	$1.4 \cdot 10^{-5}$	$3.5 \cdot 10^{-5}$	$5.6 \cdot 10^{-5}$
$n_{KOH}$ , g/cm <sup>3</sup> , (0°C)	$0.7 \cdot 10^{-7}$	$0.6 \cdot 10^{-6}$	$1.7 \cdot 10^{-6}$	$4.2 \cdot 10^{-6}$	$6.6 \cdot 10^{-6}$

Key items were examined as a potential advantage of the precipitation in comparison with flat ocean surface. First, due to their small dimensions of rain droplets the falling time must exceed the gas saturation time. The fall velocity  $V_g(r)$  can be approximated using the stationary speed of droplet gravitation sedimentation as follows:  $V_g(r) \approx \sqrt{2rg\rho_w / \rho_a}$ , where  $\rho_a$  and  $\rho_w$  are the density for air and water respectively,  $r$  is a drop radius and  $g$  is the acceleration due to gravity. The largest radius has been estimated as 3 mm up to known drop disintegration. However, at the beginning of the precipitation the droplets have grown then  $r \geq 100$  μm the stated radius for gravitational sedimentation. The falling time for droplet can be estimated as  $t_h \approx h_a / V_g(r)$  within the initial altitude of  $h_a = 1$  km, for example calculations, so  $t_h = 257$  sec then  $r = 1$  mm. During  $CO_2$  solubility, the next step demands estimations for the saturation time  $t_{aw}$  in falling droplets. The process of a concentration establishment depends on the ration of the aerated volume  $U_r$  for a drop to the area of its surface  $S_r$  in a gas flow, as follows:

$$t_{aw} \approx \frac{4\pi r^3 / 3}{4\pi r^2 K_{aw}} \approx \frac{r}{3K_{aw}} \tag{6}$$

The process also depends on the gas exchange constant  $K_{aw}$  at the gas-water interface, the time of saturation is  $t_{aw}$ . The constant  $K_{aw}(V)$  depends on the flow speed  $V \equiv V_g(r)$ . In the past, the intensity of  $CO_2$  gas exchange has been measured

depending on the velocity of air flow  $V$  over the water surface, according to (Hoover 1969, Liss 1973, Broecker 1978, Wanninkhof 1996). We employed the following experimental measurements for constants of gas exchange through a gas/liquid interface:  $K_{aw} = 4 \cdot 10^{-3}$  cm/s then  $V = 3$  m/s;  $K_{aw} = 6.4 \cdot 10^{-3}$  cm/s then  $V = 5$  m/s; also  $K_{aw} = 1.1 \cdot 10^{-2}$  cm/s if  $V = 7$  m/s. Unifying the previous equation (6) with measured constraints for  $K_{aw}(V)$  yields the  $t_{aw}$ . Calculation yields  $t_{aw} = 6$  sec for droplet with typical rain radius  $r = 1$  mm, but falling time is  $t_{h,} = 257$  sec. Largest droplet  $r = 3$  mm has  $t_{aw} = 11$  sec, but  $t_{h,} = 148$  sec due to velocity  $V_g = 6.8$  m/sec. Since  $t_{aw} \ll t_h$  there is enough time for gas saturation during droplet flying to the ground from a  $h \geq 1$  km altitude.

Another advantage of the method relies on a substantial joint surface of all small droplets in considered precipitation volume. For estimations we assume that rain droplets are porous medium with an increased surface for gas/liquid interactions. Due to the small  $CO_2$  concentration in cloud media the probability of collision between water droplets and  $CO_2$  molecules is low. Hence a substantial decrease in  $CO_2$  concentration requires many hours and there is a non-reactive reserve amount of alkaline the cloud. The erosion of  $CO_2$  as well as a significant decrease in its concentration occurs in the sub-cloud precipitation volume. For the analysis below we utilize the Marshall-Palmer approximation for the droplets spectrum in precipitation:

$$\varphi(r) = n \cdot b \cdot \exp(-br) \quad (7)$$

This formula includes empirical constant  $b$  ( $cm^{-1}$ ), and the droplet number concentration  $n$  ( $cm^{-3}$ ) that depends on the precipitation rate  $I$ , in millimeters per hour. This empirical relation described different types of precipitations with a 99% experimental coincidence for the parameters  $b$  and  $n$  estimations according to (Borovikov 1961, Kobayashi 2007). The obtained parameters are  $b = 57 \cdot I^{0.21}$  with  $n = 5 \cdot 10^{-3} I^{0.21}$  at the drizzle;  $b = 41 \cdot I^{0.21}$ ,  $n = 2 \cdot 10^{-3} I^{0.21}$  for the rain and  $b = 30 \cdot I^{0.21}$  with  $n = 5 \cdot 10^{-4} I^{0.21}$  in case of the storm. To calculate the water volume  $U_w = AIT\tau$  felt on the ground one take a sum of all of the falling droplets of the precipitation layer  $I$  on a ground surface  $A = 1$  m<sup>2</sup> during  $T = I$  hour, considering droplet speed  $I = 3$  mm/hour. In the water volume estimation the  $\tau$  coefficient aims to scale the water volumes  $U_w = 3$  liters for the precipitation rate  $I = 3, 10$  and  $30$  mm/hour for a drizzle, heavy rain and storm accordingly. Considering coefficients  $\tau_1 = 1$ ,  $\tau_2 = 0.3$ ,  $\tau_3 = 0.1$  one can obtain the relations  $I_1\tau_1 = I_2\tau_2 = I_3\tau_3$ . In precipitation we consider the complete droplet spectrum  $r = 0.05 - 4$  mm. A water volume was divided into sub-volumes, each correspond to a particular value of droplet radius, was denoted as  $U_{1w}$  and has droplets volume  $q(r_m) \cdot U_w$ .

The ratio of droplets with a radius  $r_m$  within the unit water volume can be obtained as  $q_m = \varphi_m(r_m) / \sum_m \varphi_m(r_m)$ . The

number of droplets in each sub-volume is given by  $N_m = 3U_{1w} / (4\pi r_m^3)$ . To get the total number of falling droplets in the water unit we sum droplet in all sub-volumes of  $U_{1w}$  are described by the following equation:

$$N = \sum_m N_m = \frac{3AIT\tau}{4\pi} \sum_r \frac{q(r)}{r^3} \quad (8)$$

According to above estimation the total number of falling droplets in the water unit are:  $N_d \approx 7 \cdot 10^{11}$  for drizzle,  $N_r \approx 4 \cdot 10^{11}$  for rain and  $N_s \approx 2.5 \cdot 10^{11}$  for storm. Suppose that each droplet falls inside an air cylinder with a length  $h$  and a ground area  $\pi r_m^2$ , hence the cylinder surface is equal to  $S_m \approx h2\pi r_m$ . Therefore a total sum of cylinder surfaces for all droplets is given by:

$$S \approx \sum_m N_m S_m = 1.5AhIT\tau \sum_r \frac{q(r)}{r^2} \quad (9)$$

From equation (9) one can deduce a substantial increase in air/water interface available for purification as a result of precipitation per air volume  $\sim 1 \cdot 10^3$  m<sup>2</sup>. The corresponding calculations for increased atmospheric air/water interface considering altitude  $h_a = 1$  km, ground surface area  $A_l = 1$  m<sup>2</sup> for precipitation time  $T = 1$  hour (then  $I_l \tau_l = 1$ ) indicate:  $S_d \approx 3 \cdot 10^8$  m<sup>2</sup> for drizzle,  $S_r \approx 2 \cdot 10^8$  m<sup>2</sup> for rain, and  $S_s \approx 10^8$  m<sup>2</sup> for storm. For comparison the surface on considered air volume is  $h_a A_l = 4 \cdot 10^3$  m<sup>2</sup>.

On the other hand, the natural ocean of our planet stores great mass of  $CO_2$  due to alkali properties of the ocean water where is  $pH \approx 8.3$ . These calculations show that the same principle can be used in atmosphere by rains, but with high efficiency due to advance pH modification, control and management. Let's assume the initial cloud modification to  $pH = 10$ , and precipitation layer  $h_w = 10$  mm at surface  $S = 1$  km<sup>2</sup>, then it gives  $10^7$  liters. The total removed carbon mass will be 8.5 tons in such modified precipitation water during one rain. Then  $pH = 11$  the same rain will transport the 265 tons of carbon ions that is equal to 972 tons of  $CO_2$  to the ground during this one rain.

The other advantage of proposed approach is good response in plants to the modified alkaline precipitation. In the proposed experiment the precipitation was modeled indoors (Tulaikova, 2015). We assume the highest average  $pH = 12$  level in a droplet. During several kilometers of the fall small droplets are absorbing  $CO_2$  to use their reactive amount of alkaline. To emulate this process in an indoor experiment, the changes were introduced in alkaline solution during long-time diffusion. To obtain approximate  $pH = 12$  level  $KOH$  was dissolve in water and resulting mixture was kept indoors during sufficiently long time  $t = 9$  hours to achieve a complete  $CO_2$  absorption by diffusion. The diffusion of  $CO_2$  molecules can be described by relation  $L = \sqrt{D \cdot t}$ , with a diffusion coefficient in water,  $D$ . The significant amounts of free ions of  $K^+$ ;  $HCO_3^-$ ;  $CO_3^{2-}$  exist in the solution. After 9 hours of preparation solution was added to brown pot(right side) with common plants as beetroots (10 grains), carrots (20 grains), parsley (2 grams). Control pure water was added to blue pot (left side) with the same plants. These two watering processes were repeated regularly every day during January 2014, results are in the photos on Figure 1a,b,c. The second experiment was done later with the same soil after deleting previous plants; the next portion as 20 grains of dill with 5 grains of cucumber ware planted directly in both plant pots. The same watering process was repeated regularly every day during February 2014, results are presented at Fig.1d. One can see a strong vegetation growth by enriched solution watering according to proposed method for all studied plants.

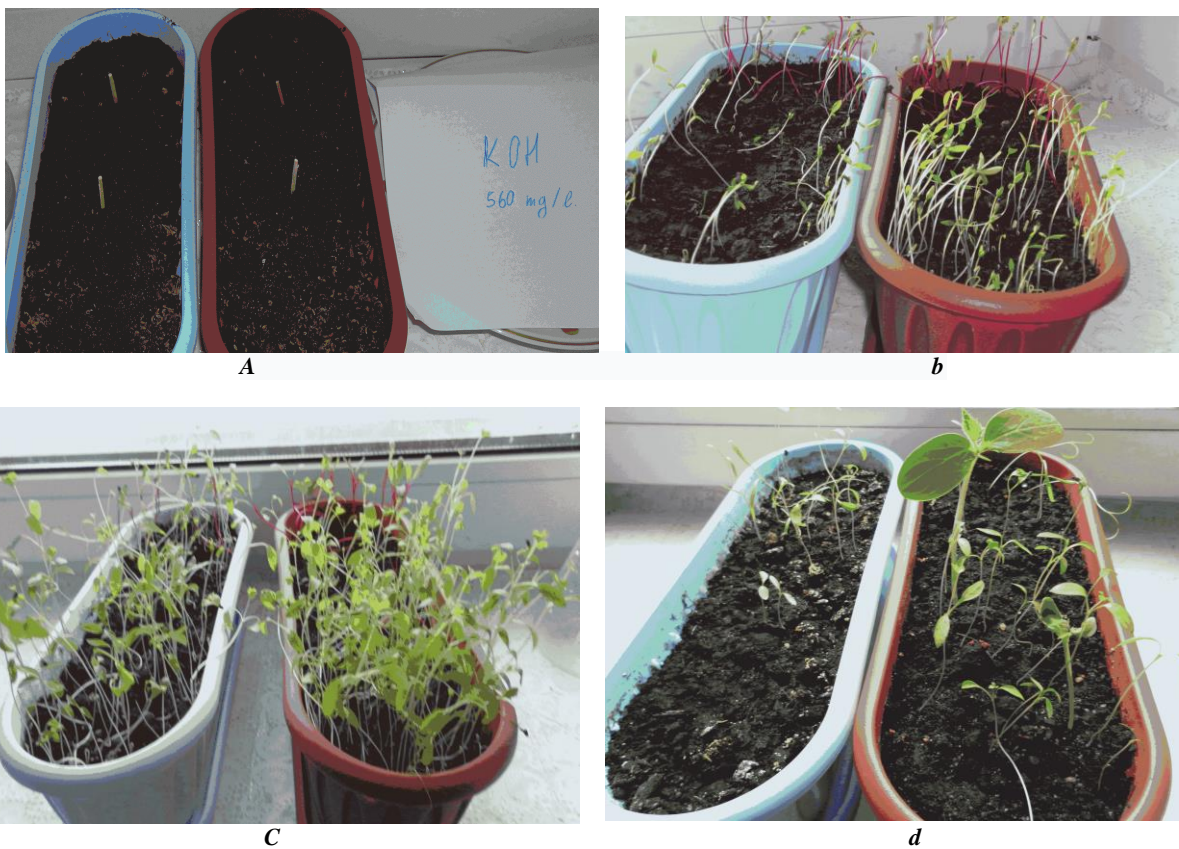


Figure 1,a-d. The indoor plants after 0(a), 18(b) and 30 (c) days correspondingly after watering in experiment; (d) - The next plants after 19 days in the same soils with the same watering procedures.

## DISCUSSION

Let's generalize an application of the proposed method for the whole Earth on the global scale. It is known that the surface area of our planet is  $A_E \approx 5,1 \cdot 10^8 \text{ km}^2$  and the average annual layer of precipitation is  $h_w \approx 1,000 \text{ mm}$ . Using formula (1) one can estimate the mass  $mc^1 \approx 849 \text{ g}$  of removed atmospheric carbon at  $pH = 10$  in 1 meter of precipitation water measured per  $1 \text{ m}^2$ . The results of similar estimations are presented at the second row of the Table 3 at range of  $pH = 10 - 11$ . The carbon ratio in  $CO_2$  is 0.2727, the  $CO_2$  mass presented at the 3<sup>th</sup> row. The calculated mass of formed carbon at the surface of the whole planet is  $M^A_C = mc^1 \cdot A = 0.849 \cdot 5,1 \cdot 10^{14} = 4,3 \cdot 10^{14} \text{ kg}$  at the  $pH = 10$ , as listed at the 4<sup>th</sup> row of the Table 3. Hence there is a higher amount of carbon oxide  $M^A_{CO_2} = M^A_C / 0.2727$  obtained from atmosphere and its value listed at the 5<sup>th</sup> row of the Table 3. The global  $CO_2$  emission reached an amount of  $3,06 \cdot 10^{13} \text{ kg}$  by the year 2010. So in further estimations let's consider the global annual emission of  $CO_2$  with amount  $AE = 3,2 \cdot 10^{13} \text{ kg}$ . To compensate this annual  $CO_2$  emission from the ratio  $AE / M^A_{CO_2}$  we can estimate the minimal Earth's surface (%A) to apply the method, the corresponding details are given at the 6<sup>th</sup> row of the Table 3. In our approach the precipitation has to be applied on 2% - 0.06% of planet surface. In principle the proposed method can completely eliminate the annual carbon emission.

To conclude let's estimate the added mass of alkali sufficient to perform modification in clouds. The  $KOH$  mass ( $Q_{KOH}$ ) can be estimated using the concentrations values listed in the Table 2, the precipitation layer of 1m and the planet surface  $A$  and its necessary percent (%A) taken from the Table 3. The sufficient mass of alkali at  $pH = 10$  level is estimated as:

$$Q_{KOH}^{10} = 5,6 \cdot 10^{-3} \cdot 1,5 \cdot 1 \cdot 10^{14} \cdot 0,02 = 5,7 \cdot 10^{10} \text{ kg} \quad (10)$$

Note that similar estimations are presented at the bottom row of the Table 3 then pH level changed up to 11.

**Table 3. The carbon mass ( $M^A_C$ ) and  $CO_2$  mass ( $M^A_{CO_2}$ ) at the Earth's surface  $A = 5,1 \cdot 10^8 \text{ km}^2$ ; the minimal required surface  $P(A)$  and mass  $Q_{KOH}$  of  $KOH$  to compensate an annual carbon emission.**

1) $pH$	5.6	10	10.5	11
2) $mc^1$ , kg/m <sup>3</sup>	$1,6 \cdot 10^{-4}$	0.849	4.05	26.5
3) $m_{CO_2}^1$ , kg/m <sup>3</sup>	$5,9 \cdot 10^{-4}$	3.11	14.8	97.2
4) $M^A_C$ , kg	$8,2 \cdot 10^{10}$	$4,3 \cdot 10^{14}$	$2,1 \cdot 10^{15}$	$1,35 \cdot 10^{16}$
5) $M^A_{CO_2}$ , kg	$3 \cdot 10^{11}$	$1,6 \cdot 10^{15}$	$7,7 \cdot 10^{15}$	$5 \cdot 10^{16}$
6) $P(A)$ , %	No possible	2%	0.42%	0.06%
7) $Q_{KOH}$ mil.tons		57	38	22.8

The hygroscopic particles are introducing in cloud with the help of airplanes, usually. The helicopter can be used for a works for precipitation enhancement with some advantages. The main advantage is the following. Rotor blade of the helicopter rotates with maximal angular velocity, so the linear velocity at the end of each blade reaches the speed of sound. Typical helicopters blade has a length of 10 meters and its partial speed varies linearly from 0 to 300 m/sec. Note that helicopter is moving forward with some speed, for example 100 m/sec; then supersonic motion of one blade is produced in small time periods. This effect takes place because there are the same directions of helicopter motion and one of its blades moving in the same direction with its own speed. It means that each of the blades overcomes the supersonic regimes and produces the shock wave. The shock wave has a steep front and bigger difference of pressure and local temperature comparable to surroundings. A shock way is a very best acoustical source for droplets in a cloud, such wave pushes the droplets to effective coalesce. Fast condensation inside the shock wave can be seen many times directly and also in photographs when airplane breaks the sound barrier. The helicopter has multiple advantages in comparison with airplane, and it can be used successfully for meteorological applications, in particular for precipitation enhancement.

## CONCLUSION

Calculations show high efficiency of proposed method with principle possibility to compensate the annual carbon emission. This process causes an enhanced purification in a particularly chosen surface location. Although the added alkali efficiently reduces  $CO_2$  concentration locally, on the global scale it is hard to achieve the same effect. In addition, the rains will bring cooling to local regions during realization with appropriate help to agriculture. There is no expansive method because it uses the great water masses inside natural clouds and natural possibility of falling droplets

during rains. Note that it is possible to simplify the method by conducting the spontaneous rainfall from alkaline clouds.

### ACKNOWLEDGMENTS

We thank to Professors Nikolay Berestnev, Thomas Choularton, Richard Claus, and to Russian Academicians Vitaly Adushkin, Feodor Bunkin and Yuri Izrael for useful discussions and remarks. . We are grateful to Dr. Svetlana Amirova for the help in a work.

### REFERENCES

- [1] Boucher R.M.G. 1960: Acoustic energy in fog dispersal techniques. *Ultrasonic news*, **4**, 11-19.
- [2] Borovikov, A.M., 1961: *Physics of clouds*. Hydromet-press, Leningrad.
- [3] Broecker, H.C., and J. Peterman, 1978: The influence of wind on CO<sub>2</sub> exchange in a wind-water tunnel including the effect of minelayers. *J.Mar. Res.*, **36**, 595-610.
- [4] Connolly P.J., Heymsfield A.J., Choularton T.W. 2006: Modeling the influence of rimer surface temperature on the glaciation of intense thunderstorms: the rime-splinter mechanism of ice multiplication. *Q.J.R. Meteorol. Soc.*, **132**, 3059-3077.
- [5] Daly, Ch., and W.P. Gibson, 2007: Observation bias in daily precipitation measurements at United States cooperative network stations. *BAMS*, **88**, 899-912.
- [6] Drofa, A.S. et al, 2006: Formation of cloud microstructure: the role of hygroscopic particles. *Izvestiya. Atmospheric and oceanic physics*, **42**, 355-366.
- [7] Hoover, T.E., and D.C. Berkshire, 1969: CO<sub>2</sub> exchange at the air-sea interface. *J. Geoph.Res.*, **74**, 456-464.
- [8] Hansen J., Sato M., Ruedy R., Lo K., Lea D.W., Medina-Elizade M. 2006: Global temperature change. *Proc. Natl Acad. Sci. USA*, **103**, 142, 88-93
- [9] Kleidon, A., Y. Malhi, and P.M. Cox, 2010: Maximum entropy production in environmental and ecological systems introduction. *Philos. T R Soc. B*, **365**, 1297-1302.
- [10] Kobayashi, S., and T. Oguchi, 2007: Backscattering enhancement on spheroid-shaped hydrometeors: Considerations in water and ice particles of uniform size and Marshall-Palmer distributed rains. *Radio Science*, **42**, doi:10.1029/2006RS003503.
- [11] Langmuir, L., and V.J. Schaefer, 1937: Improved methods of conditioning surfaces for adsorption. *J. Am. Chem. Soc.*, **59**, 1762-1763.
- [12] Liss, P.S., 1973: Processes of gas exchange analysis an air-water interface. *Deep-Sea Res.*, **20**, 221-238.
- [13] Izrael, Yu.A., I.M. Nazarov, A.J. Pressman, F.J. Rovinsky, A.G. Ryaboshapko, L.M. Filippova, 1989: *Acid rain*. Hydrometeoisdat, Russia
- [14] Machida T., Kita K., Kondo Y., Blake D., Kawakami S., Inoue G., Ogawa T. 2003: Vertical and meridional distributions of the atmospheric CO<sub>2</sub> mixing ratio between northern midlatitudes and southern subtropics. *J. of Geophysical Research*, **108**, NO. D3, 8401, doi:10.1029/2001JD000910.
- [15] Mather, G.K., and D.F. Terblanche, 1997: Results of South African cloud - seeding experiments using hygroscopic flares. *J. Appl. Meteorology*, **36**, 1433-1447.
- [16] Mednikov, A.P. 1963: *Acoustic coagulation and precipitation of aerosols*. ANUSSR, Moscow.
- [17] Rasool, S.I., Ed., 1973: *Chemistry of the lower atmosphere*. Plenum, New York.
- [18] Richardson E.G. 1952: Behavior of aerosols in acoustical and turbulence fields. *Acoustic*, **2** , 141-147.
- [19] Shmeter, S.M., and G.P. Beryulev, 2005: Efficiency of cloud and precipitation modification with hygroscopic aerosols. *Rus. Meteorology and Hydrology*, **2**, 43-60.
- [20] Sillen, L.G., Ed., 1964: *Stability constants of metal-ion complexes, Reference book*. Chemical society, London.
- [21] Tulaikova, T.V., and Amirova S.R, 2012: *The effective possibility for atmosphere CO<sub>2</sub> purification*. Lap-Lambert, Germany.
- [22] Tulaikova T., S. Amirova. "The method for effective CO<sub>2</sub> purification in the atmosphere". Global Journal of Science Frontier Research . Vol. 15-H, No.1, Version 1.0 , 2015, pp. 1-9.
- [23] Tulaikova, T.V., Michtchenko A.V., Amirova S.R., 2010 : *Acoustic rains*. Phymathbook, Moscow.
- [24] Wanninkhof, R., and M. Knox, 1996: Chemical enhancement of CO<sub>2</sub> exchange in natural water. *Limnol. Oceanogr.*, **41**, 689-687.
- [25] Yunge, H., 1965: *Chemical compounds and radio-activity in atmosphere*. Clarendon, Oxford.