

Enhancement on Radon Adsorption Property of GAC using Nano-size Carbon Colloids

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Abstract

Granular activated carbon (GAC) is well-known as an efficient adsorbent against a number of gaseous pollutants. Radon is one of those pollutants, and radon has been classified as the second leading cause of lung cancer in USA. This study was to enhance the radon removal efficiency with applying nano-technology. Nano-size carbon colloids (NCC) was produced through electrolysis which is simple and cheap. NCC was used for impregnation with activated carbon. Surface areas of both NCC-treated and non-treated activated carbon did not show a significant difference. However, the results of radon removal efficiency show that impregnated carbon with NCC could capture about 1.3 ~ 2 times of more radon gas compared to non-treated activated carbon. It is assumed that nano-size carbon colloids might have filled up meso-pores, and meso-pores turned into micro-pores eventually. Because meso-pores initially accounted for large portion of whole pores, more radon could be captured to NCC-impregnated activated carbon.

Keywords: Radon, Nano-Size Carbon Collid, Activated Carbon

1. Introduction

1.1 Radon

Radon is an inert gas, and a naturally occurring radioactive material. Radon is well-known as one of the hazardous indoor air pollutants. Because, radon is colorless, odorless and tasteless, it is not easy to detect or remove indoor radon. Radon can penetrate into lung through respiration, and emits alpha particles during the decays. Alpha particles can cause lung cancer via DNA damage. Due to this fact, radon has been classified as the second leading cause of lung cancer.

1.2 Granular Activated Carbon(GAC)

Granular activated carbon has a relatively larger particle size compared to powdered activated carbon and consequently presents a smaller external surface. These carbons are therefore preferred for all adsorption of gases and vapors as their diffusion are faster. Granular carbons are used for water treatment, deodorization and separation of components of flow system. Generally, GAC is used for pollutant capture in the Indoor air. Also, radon is one of the indoor air pollutants which can be captured by GAC. GAC adsorbs pollutants through physical adsorption method. Pores on GAC can be classified into three types; micro-pore, meso-pore and macro-pore. This depends on the size of the pores (micro-pore : 10~100 Å , meso-pore : 100~1,000 Å, macro-pore : 1000~100,000 Å). Pore size is very important because the adsorption efficiency can vary according to the size of target pollutant. In this study, target pollutant is Radon (²²²Rn), and the diameter of radon is approximately 0.44 nm (4.4 Å).

1.3 Nano Technology

Nano Technology is the study of the control of matter on an atomic and molecular scale. Generally, nanotechnology deals with structures of the size 100 nanometers or smaller and involves developing materials or devices within that size. Nanotechnology is very diverse, ranging from novel extension of conventional device physics to completely new approaches based on molecular self-assembly, to developing new materials with dimensions on the nanoscale, and even to speculation on whether we can directly control matter on the atomic scale. Nano Technology is a significant field at the crossroads of engineering and material science. This study focused on producing nano size carbon colloids using an electrochemical method that is a relatively cheap method, and applying this to the removal efficiency assessment of radon through a adsorption test.

2. Method

2.1 Manufacture of Nano-Size Carbon Colloid

Three isotropic graphites are used as electrodes. As one can see in Figure 1., there is a cathode between two anodes. Two anodes and one cathode between anodes are used to increase the surface of working electrodes and decrease the dimension of the device; thus, the amount of carbon nano colloids acquired is larger than in the case of a ‘one cathode – one anode’ process. The electrodes used in this study are 65 mm(W), 30 mm(H), and 15 mm(Th). The distance between the electrodes immersed in a bath of distilled water can be varied from 10 to 120 mm. The current density can also be Varied from 0.1 to 3 mA/cm². The electric power applied to the electrodes is DC 15~30 V.



Figure 1. Graphite(L), NanoCarbon Generator(C)



Figure 2. Filtering(L), Sonification(C), Nano-Size Carbon Collid(R)

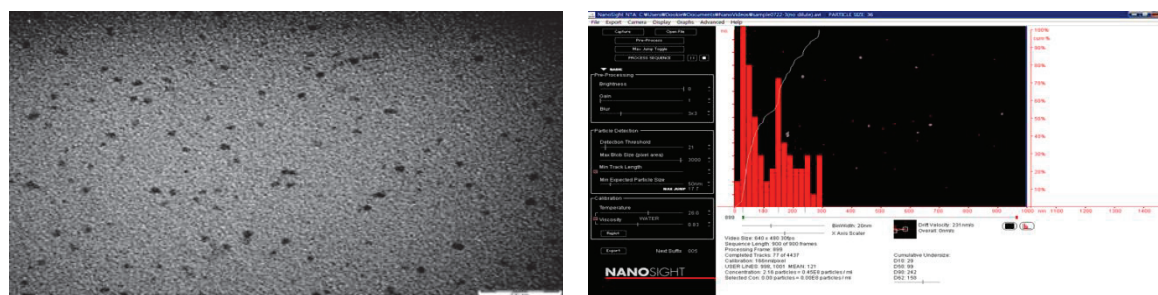


Figure 3. TEM(x80k)(L), Distribution of pore Size(Nano Carbon Colloids)(R)

2.1 Manufacture of impregnated Charcoal

Produced 500 ppm of nano-size carbon colloids with activated carbon were mixed on stirrer for impregnation, and it lasted 24 hours. After stirring, the mixture was dried under 100 °C to remove moisture for 2 hours.



Figure 4. Nano-size Carbon Colloid 500 ppm(Left), mix at NCC(Center), impregnation (Right)



Figure 5. Production of impregnated charcoal

2.2 Experimental Method

Standard radon source used in this study is SRM 4968 (NIST, USA), and active radon detector is RAD7 (DURRIDGE Co, USA). First of all standard radon source is located in the center of an air-tightened chamber, and RAD7 measures reference radon concentration until it reaches the highest level. Secondly, cartridges filled with impregnated charcoal were connected to the outlet of the chamber and test the radon removal efficiency. The control case was performed with normal GAC(non-treated with NCC).

Experimental material(Nano Size Carbon Colloid Charcoal)



Control material(Granular Charcoal)

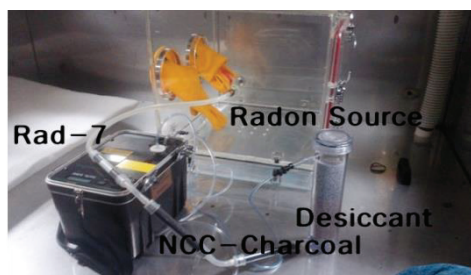


Figure 7. Progress of experiments

3. Results

The experiments were performed in total twice. The first result indicates that impregnated carbon(NCC-charcoal) showed higher adsorption efficiency compared to GAC (NCC-charcoal breakthrough point: after 12 hours, GAC breakthrough point: after 7 hours). The second result also showed similar phenomena (NCC-charcoal breakthrough point: after 14 hours, GAC breakthrough point: after 7 hours). Impregnated charcoal could capture radon about 1.7~2 times longer than GAC, and showed better removal efficiency (1.3~2.0 times better than GAC).

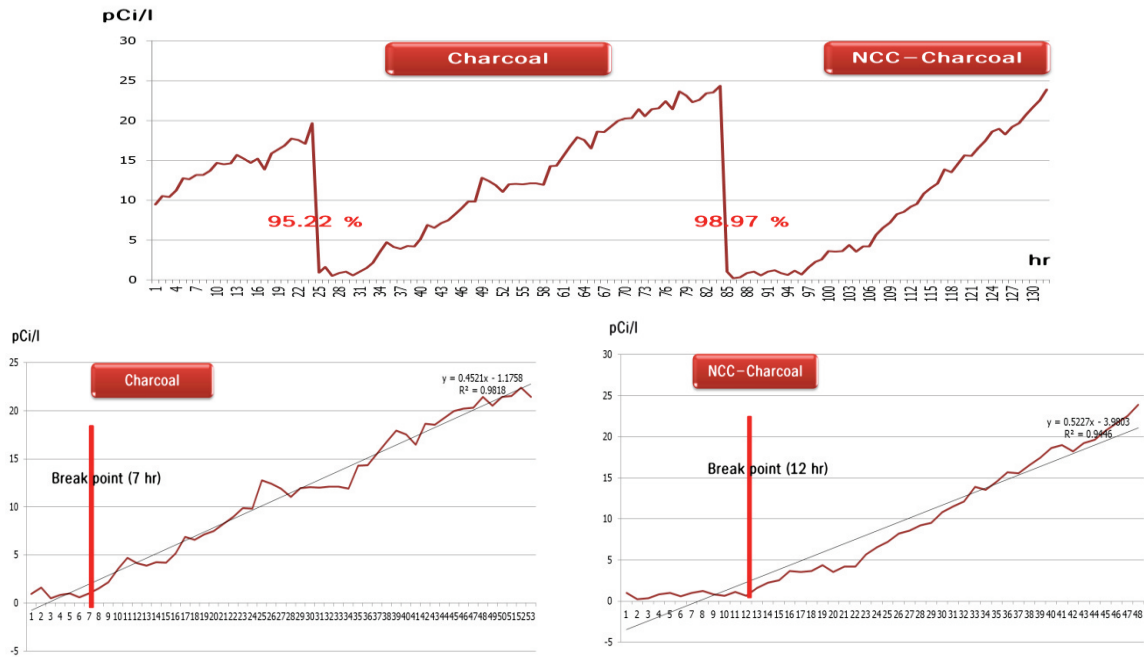


Figure 8. 1st result of experiments

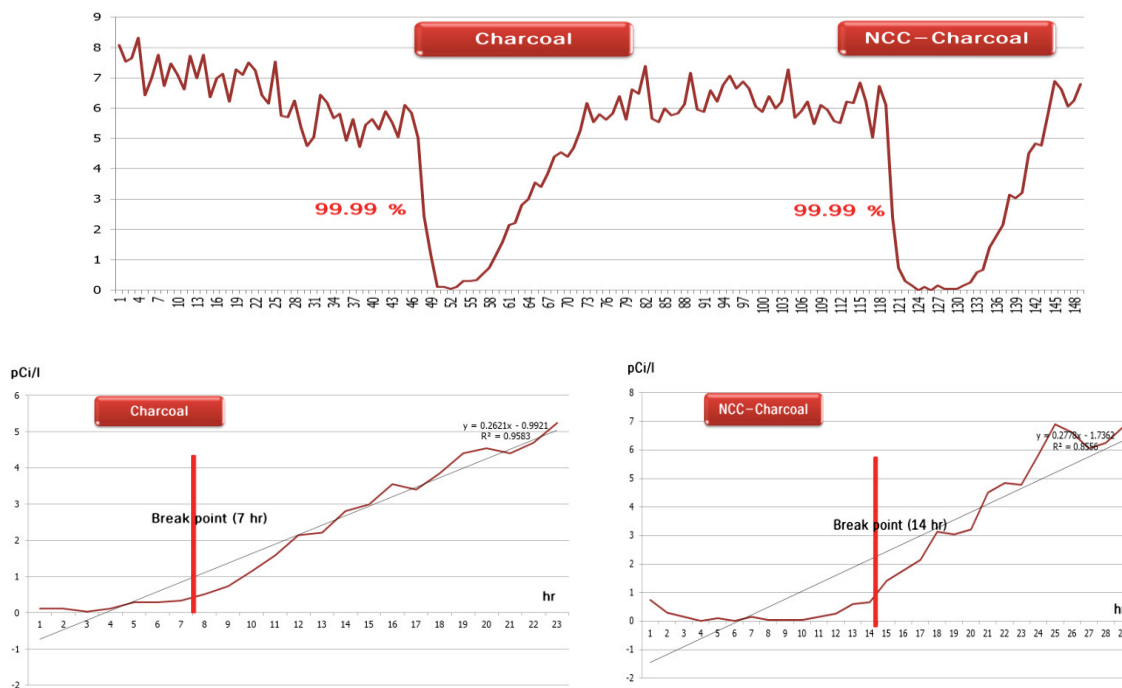


Figure 9. 2nd result of experiments

The result of BET analysis showed that the surface area of impregnated charcoal(NCC-charcoal) is smaller than one of Granular activated carbon(GAC). Surface area(BET) of NCC-charcoal was 1242.2141 m²/g, and one of GAC was 1256.0340 m²/g. Also, portion of meso-pore decreased according to pore size analysis. It is assumed that total surface area decreased due to adsorption of nano-size carbon colloid onto GAC while the micro-pores which are suitable for radon to be adsorbed increased. Calculation of radon removal efficiency via this study can be performed by following equation.

$$E = \frac{C_R Q t}{AW}$$

Where, E is radon removal efficiency, CR is input radon concentration, Q is air flow rate, t indicates the time until the breakthrough occurs, A is surface area(BET) and W is weight of charcoal used.

Table 1. Radon removal efficiency(1st)

Sample	Input Concentration	Surface Area	Weight/Volume	Removal Efficiency
NCC	901.02 Bq/ m ³	1242.2141 m ² /g	47.4793 g/ 150 mL	0.01100 Bq/ m ²
GAC	648.78 Bq/ m ³	1256.0340 m ² /g	44.4852 g/ 150 mL	0.00547 Bq/ m ²

Table 2. Radon removal efficiency(2nd)

Sample	Input Concentration	Surface Area	Weight/Volume	Removal Efficiency
NCC	249.00 Bq/ m ³	1242.2141 m ² /g	47.4793 g/ 150 mL	0.00303 Bq/ m ²
GAC	185.54 Bq/ m ³	1256.0340 m ² /g	44.4852 g/ 150 mL	0.00239 Bq/ m ²

Table 3. BET data and pore size analysis

Sample	Surface Area	Rate of meso-pore
NCC	1242.2141 m ² /g	77.1735 m ² /g
GAC	1256.0340 m ² /g	85.3038 m ² /g

4. Conclusion

In this study, BET(total surface area) of impregnated charcoal and meso pore rate of total pore is smaller than GAC. However, radon removal efficiency of impregnated charcoal was higher than non-treated GAC (impregnated charcoal : 0.01100 Bq/ m², 0.00547 Bq/ m², GAC : 0.00547 Bq/ m², 0.00239 Bq/ m²). These BET and pore rate analysis show that the meso-pore portion of impregnated charcoal decreased due to the application of nano-size carbon colloid while micro-pore rate increased. In conclusion, NCC impregnated charcoal is more effective in radon removal process.

Acknowledgements

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