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PERFORMANCE IMPROVEMENT OF RADON COUNTERS

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Abstract
In order to calibrate Siren PRO3 radon counter, the ion chamber-type radon counter RD200 and the radon measuring apparatus RAD7 were used. Through some experimental studies, we found that the performance of the Siren PRO3 could be improved using a linear regression analysis technique.

Introduction
Radon is a natural, inert, invisible, odorless and chemically inactive radioactive gas emitted from the earth. It is produced by the decay of uranium ore, such as radium, actinium, or thorium. Because it is inert and does not chemically bond to elements, it is released from soil into the atmosphere. Various types of equipment and components have been proposed to date for radon detection. In [1], highly sensitive, electrostatic collection chambers have been developed for low-level radon measurements using CR-39 plastic track detectors. In [2], a radon detector employs an electrically charged pressed, porous metal filter that allows radon gas diffusion, while blocking ambient light, so that it readily traps both attached and unattached Po-214 and Po-2l8 ions, that may be present in gas passing through the filter, the filter being charged positively relative to an unbiased PN junction of a photo diode detector within a detection chamber. In [3], a passive direct-reading radon monitor utilizing a custom α particle detecting MOS integrated circuit and electrostatic radon progeny concentrator has been designed. In [4], a silicon PIN photodiode was designed and fabricated in consideration of low-leakage-current and high-bias-voltage application. In [5], a fast-responding passive radon detector using electrostatic concentration and enhanced readout electronics has been designed. In this paper, to calibrate Siren PRO3 radon counter, the ion chamber-type radon counter RD200 and the radon measuring apparatus RAD7 were used. Through some experimental studies, we found that the performance of the Siren PRO3 could be improved using a linear regression analysis technique.

Ion chamber – type radon counter : RD200
The RD200M is the new innovative fastest radon sensor, which has the highest sensitivity, 30 cph/pCi/L on the market today. This sensor is optimized for the IAQ monitor, air purifier, radon detector and auto ventilation system. A breakthrough in FTLAB's patent technology which received a New Excellent Technology certification in 2015, the RD200M uses a dual probe structured pulsed ionization chamber and a special high impedance differential amplifier circuit to offer the highest signal to noise ratio. It effectively detects the secondary charges which were generated from collisions with air and α-particle caused by radon or radon's progeny. The accuracy and precision of the RD200M are ±10% at 10 pCi/L, which has been tested by the international standard Radon Testing Laboratory in KTL. Each sensor has been individually calibrated by equipments which are already calibrated to traceable international standards. Fig. 1 shows the ion chamber-type radon counter : RD200 (model:SN242), made by FTLAB, Korea. Table 1 shows the specifications of RD200.

Figure 1. Ion chamber-type radon counter : RD200 (model: SN242)

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Table 1. Specs. of RD200

Descriptions	RD200 is a real time smart radon detector for home owner which has the high sensitivity 0.5cpm/pCi/L, about 20~30 times more than conventional radon detector by FTLAB's high stable circuit technology
Type	pulsed ion chamber 200cc
First reliable data out	< 60min
Data interval	10min update (60min moving average)
Sensitivity	0.5cpm/pCi/L at 10pCi/L (30cph/pCi/L)
Operating range	10~40℃, RH<90%
Range	0.1~99.99pCi/L
Precision	<10% at 10pCi/L
Accuracy	<±10% (min. error <±0.5pCi/L
Power	DC 12 ± 0.1V, 65mA (12V DC adapter)
Size	Φ80(mm) x 120(mm), 240g
Data communication	Bluetooth LE (Android/iOS)
Data log	max 1year(1h step)
Display	0.96 inch OLED

Safety Siren PRO3 radon detector

Safety Siren PRO 3 radon counter shown in Fig.2 was used for experimental studies in this paper. The numeric LED display shows the level of radon gas in Pico Curies per liter (pCi/L). The display range is 0.0 to 999.9. The Safety Siren Pro Series 3 Radon Detector display is designed to notify the user of the level of radon gas on either a short-term or long-term basis, and is updated every hour if there is a change in the level of radon gas. The display for the short-term reading is an average of the levels of radon gas over the past seven days. The short-term reading allows the user to monitor short-term fluctuations in the home and provide a better feel for problems relating to seasonal and weather related variations in the radon levels. A green LED next to the letter "S" indicates this reading. When the short-term measurement reaches 4 pCi/L or greater, for 30 consecutive days or more, the audible alarm will sound.

Figure 2. Safety Siren PRO 3 radon detector

Radon measuring apparatus : RAD7

The RAD7 is a highly versatile instrument that can form the basis of a comprehensive radon measurement system. It may be used in many different modes for different purposes. In this paper, the performance of an ion chamber-type radon counter is evaluated using the accurate and expensive measurement system : RAD7, an electronic radon detector manufactured by Durridge Company, USA. The RAD7 radon monitor apparatus uses an air pump and a solid state alpha detector which consists of a semiconductor material that converts alpha radiation directly to an electrical signal. It has desiccant (CaSO4) tubes and inlet filters (pore size 1 μm) that block fine dust particles and radon daughters from entering the radon test chamber. The RAD7's internal sample cell is a 0.7 litter hemisphere, coated on the inside with an electrical conductor. The center of the hemisphere is occupied by a silicon alpha detector. One important benefit of solid state devices is ruggedness. Another advantage is the ability to immediately differentiate radon from thoron by the energy of the alpha particle released. The RAD7 has also the ability to tell the difference between the new radon daughters and the old radon

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daughters left from previous tests. The equipment is portable and battery operated, and the measurement is fast. Fig. 3 shows the radon measurement system : RAD7. Table 2 shows the specifications of RAD7.

Figure 3. Radon measuring apparatus : RAD7

Table 2. Specs. of RAD7

Principle of Operation	Electrostatic collection of alpha-emitters with spectral analysis Passivated Ion-implanted Planar Silicon detector SNIFF mode counts polonium-218 decays NORMAL mode counts both polonium 218 and polonium 214 decays
Built-In Air Pump	Nominal 1 liter/minute flow rate Inlet and outlet Luer connectors
Connectivity	RS-232 port up to 19,200 baud rate USB adaptor is included with every RAD7
Measurement Accuracy	±5% absolute accuracy, 0% - 100% RH
Nominal Sensitivity	SNIFF mode, 0.25 cpm/(pCi/L), 0.0067 cpm/(Bq/m^3) NORMAL mode, 0.5 cpm/(pCi/L), 0.013 cpm/(Bq/m^3)
Radon Concentration Range	0.1 - 20,000 pCi/L (4.0 - 750,000 Bq/m^3)
Intrinsic Background	0.005 pCi/L (0.2 Bq/m^3) or less, for the life of the instrument
Recovery Time	Residual activity in Sniff mode drops by factor of 1,000 in 30 minutes
Operating Ranges	Temperature: 32° - 113℉(0° - 45℃) Humidity: 0% - 100%, non-condensing
Cycle Range	User controllable number of cycles, from 1 to 99 to unlimited, per run User controllable cycle time, from 2 minutes to 24 hours
CAPTURE Software	Compatible with Microsoft Windows XP and 7, and Mac OS X Automatic RAD7 location, connection and data download Graphs radon, thoron, temperature and humidity over time Automatic humidity correction Statistical analysis tools track concentration averages and uncertainties Chart Recorder mode provides real-time RAD7 status monitoring Control RAD7 operations from computer via direct or remote connection Automatic calculation and display of radon in water for RAD AQUA Automatic combination of multiple RAD7 data

Results and discussion

The methyl methacrylate box was made for radon concentration calibration as shown in Fig. 4. The calibration experiment was done for 121 hours for varied concentration of radon gas. Fig. 5 shows the radon concentration

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of RAD7. Fig. 6 and Fig. 7 show the radon concentrations of RD200. Fig. 8 and Fig. 9 show the radon concentrations of Siren PRO3 radon detectors.

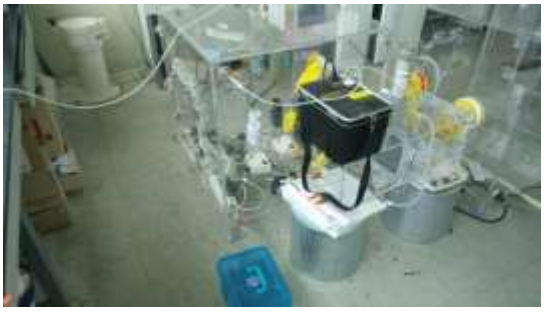
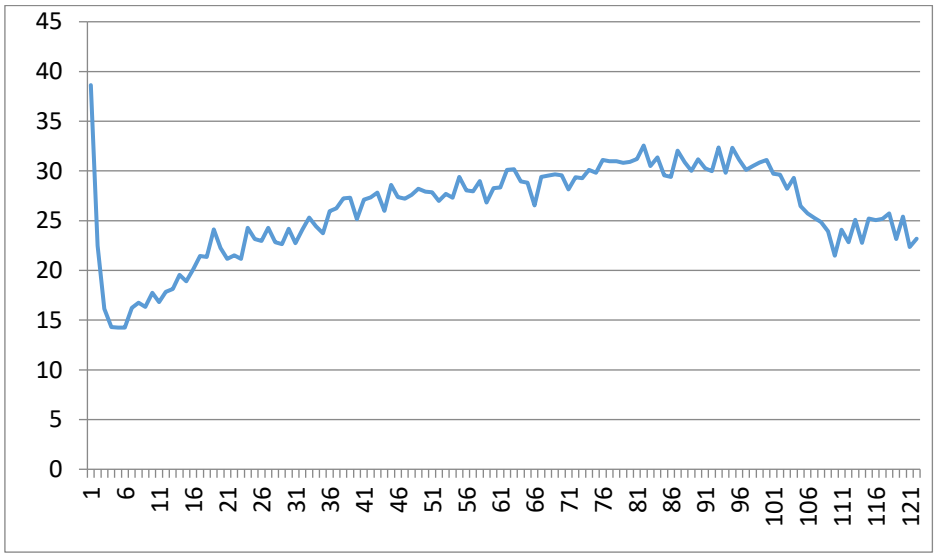
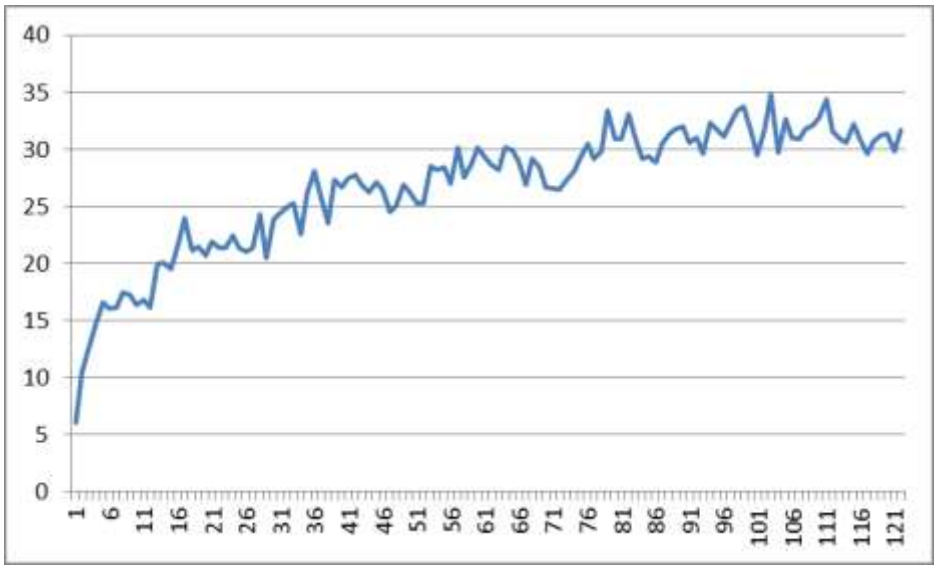


Figure 4. Experimental set-up for radon calibration



(x–axis : hour, y-axis : pCi/L)

Figure 5. Radon concentration of RAD7



(x–axis : hour, y-axis : pCi/L)

Figure 6. Radon concentration of RD200 (model: SN242)

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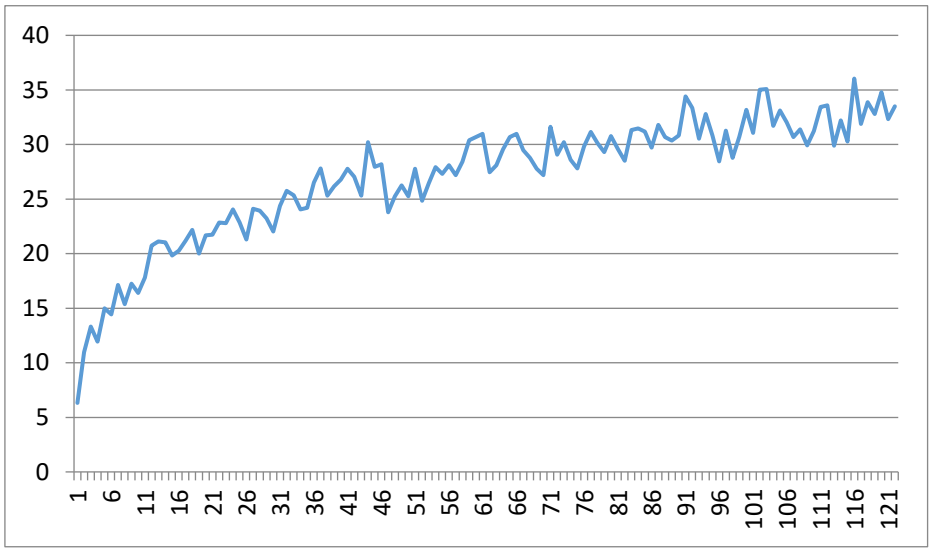
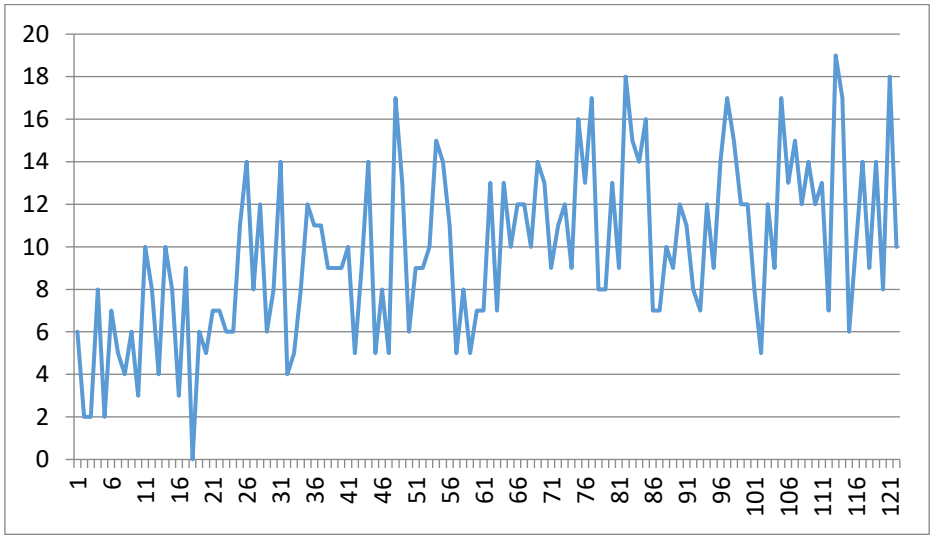


(x–axis : hour, y-axis : pCi/L)

Figure 7. Radon concentration of RD200 (model: SN207)



(x–axis : hour, y-axis : counts/hour)

Figure 8. Radon concentration of Siren Pro3 No. 1

Using RAD7, the measured radon counts per hour of Siren Pro 3 radon counters could be calibrated as shown in Fig. 10 and Fig. 11. As for the first Siren radon counter, the RMSE was 1.616 pCi/L and the correlation coefficient R^2 was 0.8382 as shown in Fig. 10. As for the second Siren radon counter, the RMSE was 2.197 pCi/L and the correlation coefficient R^2 was 0.701 as shown in Fig. 11. Similarly, using RD200, the measured radon counts per hour of Siren Pro 3 radon counters could be calibrated as shown in Fig. 12 and Fig. 13. As for the first Siren radon counter, the RMSE was 1.754 pCi/L and the correlation coefficient R^2 was 0.8417 as shown in Fig. 12. As for the second Siren radon counter, the RMSE was 2.475 pCi/L and the correlation coefficient R^2 was 0.685 as shown in Fig. 13. These experimental results suggest that Siren Pro 3 radon counters can be improved by using a linear regression analysis technique.

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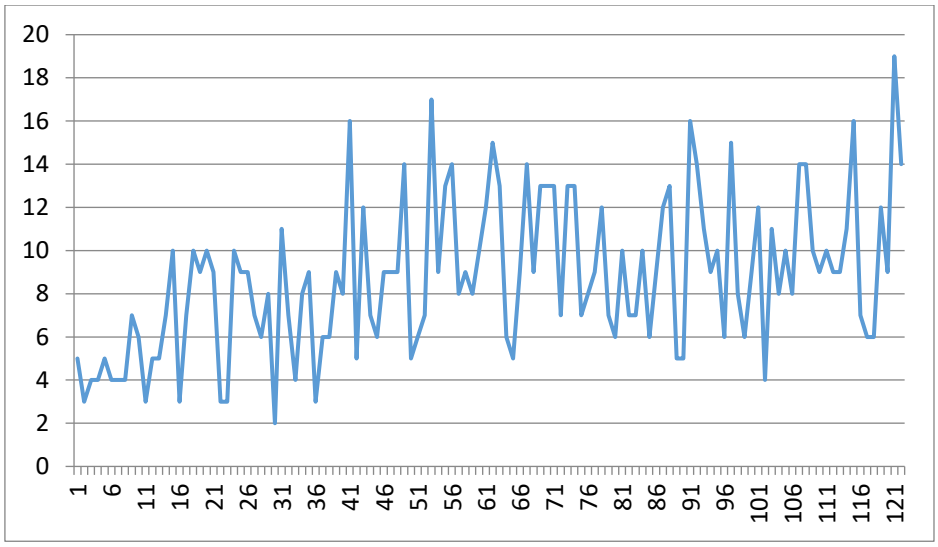

(x–axis : hour, y-axis : counts/hour)

Figure 9. Radon concentration of Siren Pro3 No. 2

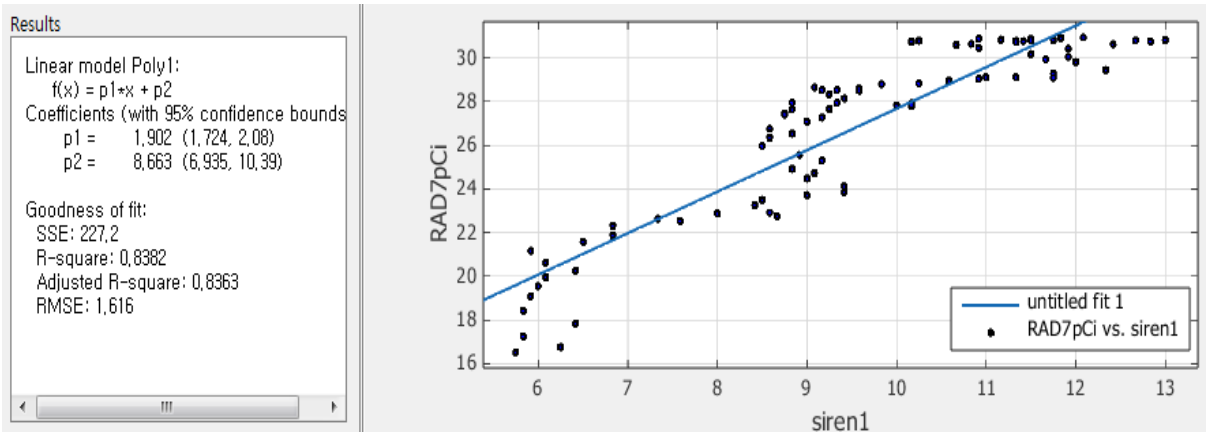

Figure 10. Linear regression analysis of Siren Pro3 No. 1 and RAD7

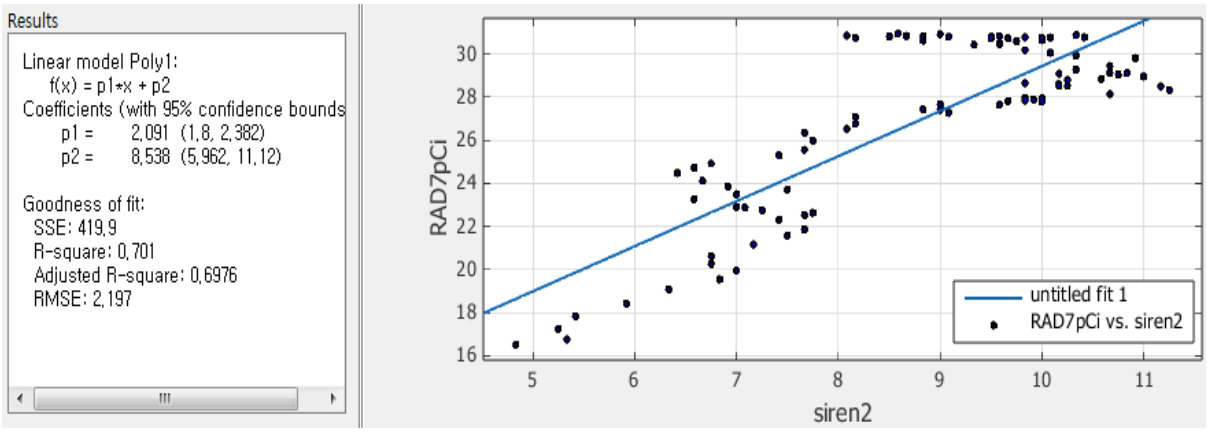

Figure 11. Linear regression analysis of Siren Pro3 No. 2 and RAD7

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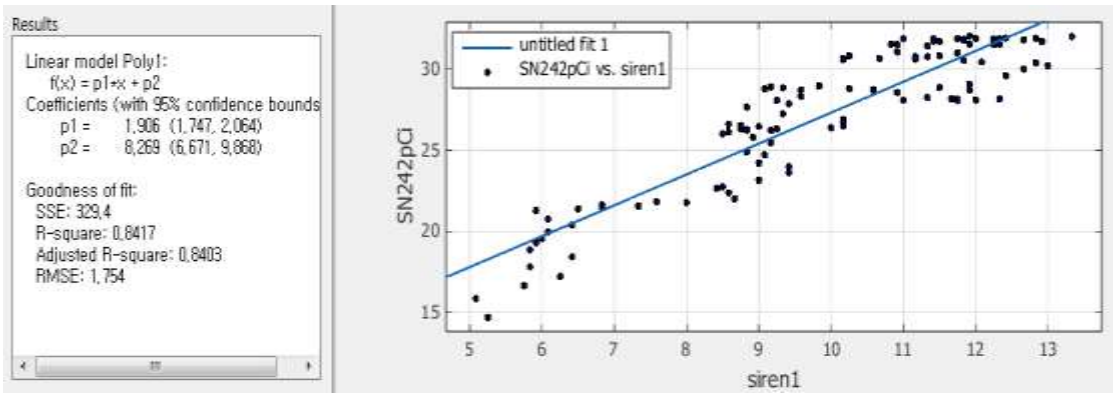

Figure 12. Linear regression analysis of Siren Pro3 No. 1 and RD200 (model: SN242)

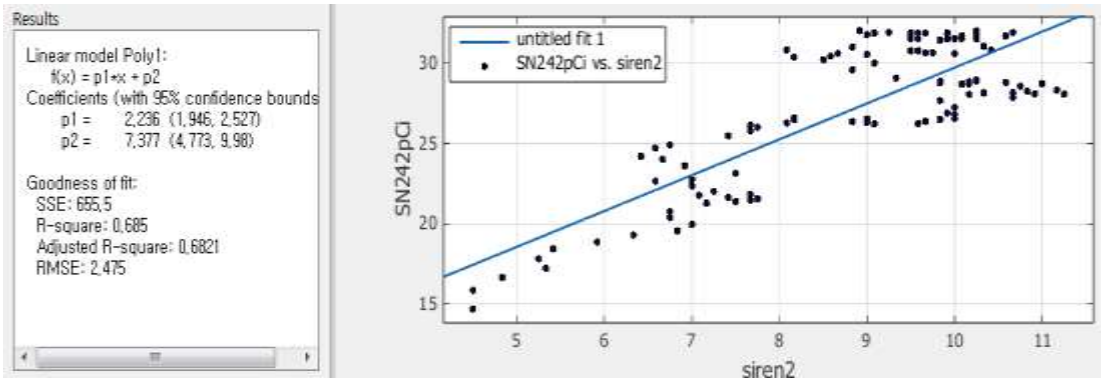

Figure 13. Linear regression analysis of Siren Pro3 No. 2 and RD200 (model: SN242)

Conclusion

Because inhaling radon and its radioactive decay products causes irradiation of lung tissue, prolonged exposure to high concentrations of radon significantly increases the risk of developing cancer. Various types of equipment and components have been proposed to date for radon detection. In order to calibrate Siren PRO3 radon counter, the ion chamber-type radon counter RD200 and the radon measuring apparatus RAD7 were used. Through some experimental studies, we found that the performance of the Siren PRO3 could be improved using a linear regression analysis technique.

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