Effect of temperature and humidity on the performance

of Charcoal CanisterPassive Rn detectors

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**Abstract**

The dependence of radon adsorption on the temperature up to 35 °C was studied for 4" open face (OF) charcoal canister at different values of relative humidity using a radon calibration chamber with variable and controlled radon concentration, humidity, and temperature which was previously constructed. Sets of calibration factor (CF) and adjusting factor (AF) curves were established at 20, 25, 30, and 35 °C and,different humidity (RH%). These curves are used to extend the use of open-faced charcoal canisters for higher temperature and humidity applications. The optimum exposure time to achieve the best detection accuracy was estimated between 2 and 4 days depending on relative humidity. The open-faced canisters havehigher efficiency of radon absorption at low temperature.

**Key words:** radon; charcoal canisters; calibration; humidity, temperature dependence

## 1. Introduction

Radon and its progeny are of great interest in our daily life because of its potential in biological hazards. The concentration of radon can be determined either by the detection of alpha particles emitted by radon and its progeny or by the detection of gamma rays emitted by its decay products. Alpha track detectors are normally used for estimating the average radon concentration over long-term periods, while for short-term averages the activated charcoal method is usually employed **(Bigu 1986; Cohen and Nason 1986; Scarpitta and Harley 1991a and b; Arafa et al. 1994; Luetzelschwab et al. 1994).**

Different types of charcoal canisters 4" open-faced, 2.75" open-faced, and 2.75" diffusion barrier are availableon the market. The necessary calibration curves to evaluate radon concentration using charcoal canister method are available in the literature for 4" open-faced canister but at room temperature only**(Gray and Windham 1987).**

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The aim of the present work is to construct a set of calibration curves and to account for the high indoor temperature and humidity present during the summer in some hot countries like Egypt where the temperature ranges between 19 and40°C in summer and between 9 an 20°C in winter while the relative humidity ranges between 42 and 78% RH during summer and between 43 and 81% RH in winter. This would help in extending the calibration range of carbon canisters to deal with environmental conditions different from those in North America and Europe.

As the temperature affects radon adsorption, the variation of radon adsorption coefficient with temperature at different ranges of relative humidity was measured for open charcoal canister detectors.Radon goes through a process of adsorption and desorption to charcoal that depends on several factors. The most important factor affecting the adsorption and desorption is the presence of water vapor in air **(Scarpitta and Harley 1990**). The amount of adsorbed water vapor is directly proportional to the relative humidity at constant temperature. As the charcoal adsorbs the water, it has fewer sites available for radon atoms, or water can displace radon that has already been adsorbed. In addition, temperature affects the ability of charcoal to adsorb radon **(George 1984; Prichard and Marien 1985; Ronca- Battista and Gray 1988; Pojer et al. 1990; Luetzelschwab et al. 1994).**

## 2. Materials and Methods

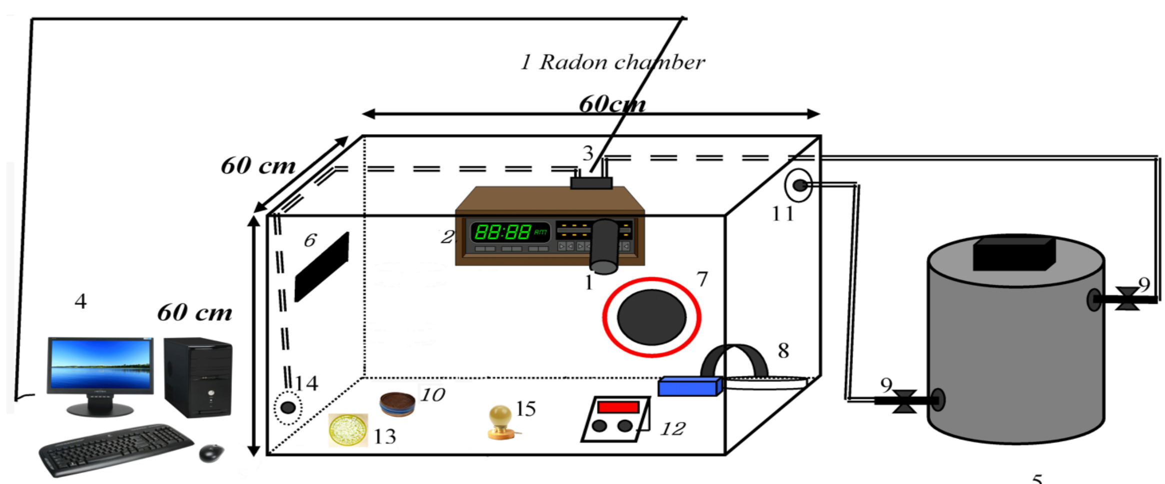
### Materials

In the present study, a cubic chamber with 60 cm sides and a volume of 216 L was constructed of 5-mm- thick transparent sheets of Plexiglas (Polymethylmethacrylate PMMA). The chamber parts are solvent welded together by chloroform then sealed by a commercial silicon rubber**(El-Samman et al. 2002).** The chamber is connected to a commercial radon source consisting of cylindrical drumof 63 L containing a quantity of powdered uranium ore by rubber tubes and valves to control the inlet and outlet flow of radon to the main chamber through the fully programmable pump built into the Pylon AB-5 radon monitor. The radon concentration inside the chamber is 250 Bq.m-3 with this source. Higher concentrations up to 1,850 Bq.m-3were achieved by adding a number of $^{226}$Ra sources. Each source was kept in a sealed plastic bag and added one by one inside the drum.

There are two openings in the front face of the chamber. The first (10 cm x 4 cm) is to insert or take out the canister. This opening is covered by a thick rubber sheet from inside and it is covered by a sliding sheet of the same Plexiglas from outside to minimize the perturbation of radon concentration in the chamber while inserting the canister. The second opening is 15 cm in diameter. A thick rubber glove is clamped to the inner circumference of the opening in such way that permits the operator to handle everything inside the chamber at any time.

A radon monitor (Pylon AB-5 portable radiation monitor with uncertainty± 4% for radon sources) coupled to a continuous passive radon detector chamber (CPRD) is used to measure the radon concentration inside the chamber during the experiment. The radon concentration is printed each hour on a Pylon printer connected to the AB-5. The average radon concentration is calculated and printed automatically at the end of each run.

A thermo-hygrometer device with liquid crystal display is placed inside the chamber to measure the relative humidity and temperature. A small aquarium- aerating pump is operated inside the chamber with outlet connection passes through flask containing water in order to increase the humidity level. To dry the air inside the chamber, a small dish containing fresh $CaCl_2$ crystal replaced the flask of water inside the chamber. The thermo-hygrometer sensor provides uncertainhumidity measurement (±3%) over 10-95% RH. The temperature is varied using an electric soldering iron that is placed inside the chamber and connected to a temperature controller with uncertaintyof ±1°C. To insure the homogeneity inside the chamber, the AB-5 monitor is programmed to operate the pump to circulate chamber air through the radon source during a period of one hour each five hours. A schematic diagram of the chamber is shown in Fig. 1.




1- Radon chamber.
2- AB-5 Monitor.
3- AB-5 internal pump.
4- Computer.
5- Radon source.
6- Rectangular port.
7- Circular port.
8- Water container.
9- Two valves.
10- Charcoal canister.
11- Inlet tube.
12- Hygrometer.
13- CaCl2.
14- Outlet tubes.
15- Small lamb.

**Figure (1):** Radon calibration chamber.

## Methods

In the present work the calibration method is based on a 2days exposure of a charcoal canister containing a known amount of activated charcoal to a known radon concentration as described by the EPA **(Gray and Windham 1987)**. During the exposure time, charcoal adsorbs radon gas and water vapor. After exposure, the canister is sealed, weighed to estimate the water gain, and then left for at least 3 hours to achieve equilibrium between radon and its gamma-emitting progeny.

The gamma spectrum from the canister is analyzed by a gamma spectrometer consisting of a 7.5 cm x7.5 cm Nal (Tl) scintillation detector shielded by virgin lead of 3 cm thickness. The output of the detector is amplified and analyzed by multichannel analyzer plug-in trump card from ORTEC mounted on personal computer. The intensities of gamma lines (Net CPM) from $^{214}$Pb (295, 352 keV) and $^{2l4}$Bi (609keV) are measured. The results are used to deduce radon concentration ($R_n$) using the following relation (Gray and Windham 1987):

$$R_n = \frac{NCPM}{(CFxExT_sxDF)} \quad (1)$$

where $T_s$ is the exposure time (min), *CF* is the calibration factor, equivalent to the average radon adsorption rate (L min$^{-1}$), *E* is the efficiency of the detection system (CPM/Bq), and *DF* is the decay factor (for time elapsed from midpoint of exposure to counting time).

In the present work, charcoal canisters supplied by local agent of F&J were used: A 4" open-faced canister containing 70 ± 1 g of cocount shell calgon 8X16 mesh activated carbon with 10 cm diameter and 1.5 cm carbon bed depth.

## 3.Results and Discussion

To test the response of activated charcoal at different radon concentrations, a 4" open-faced canister is placed in the chamber at a given radon concentration and normal environmental conditions (temperature between 20-25°C, and humidity between 40% to 60%) for 48 h. The average radon concentration was varied in 13 steps from 250 to 1,570 Bq.m$^{-3}$ as measured by the AB-5 monitor. The canisters were sealed and counted by gamma spectrometer. Fig. 2 illustrates the variation of radon concentration in Bq m$^{-3}$ versus the counting rate for the selected gamma region of energy (295, 352, and 609 keV). The scattered data from the straight line is attributed to the effect of variations in temperature and humidity. The results show that the radon collected by the canister is linear with the $^{222}$Rn concentration inside the chamber.

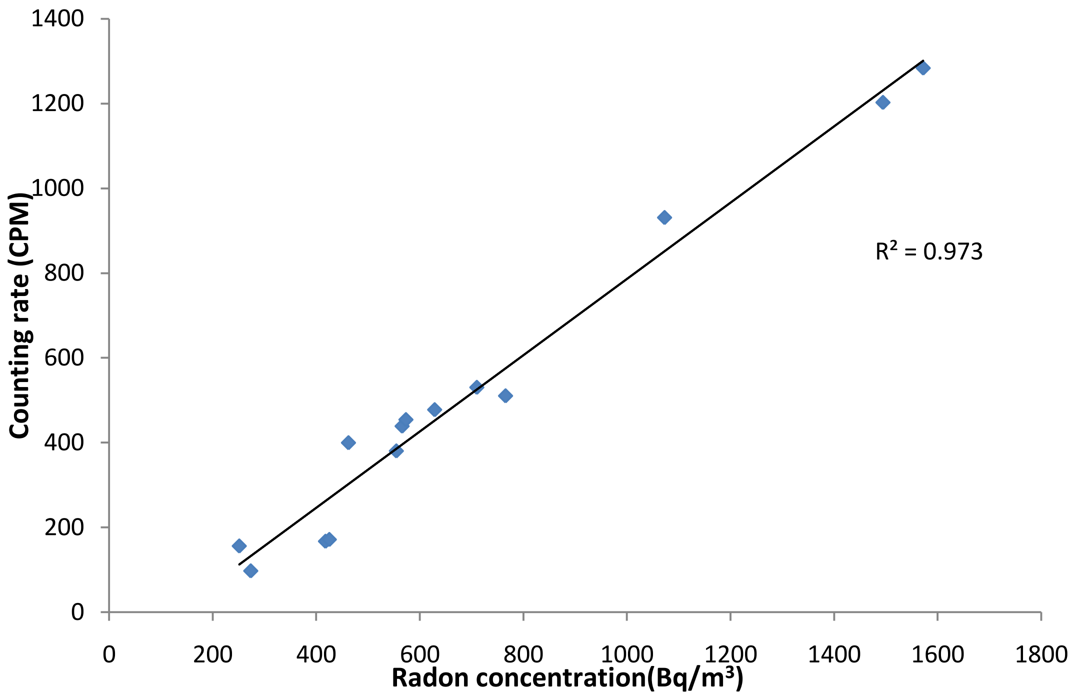



**Fig. 2: variation of counting rate with radon concentration**

**Calibration curve of 4" open face charcoal canisters:**

To establish the calibration curves for the 4" open-faced activated charcoal, two steps were carried out.**First**,2 fresh canisterswere exposedto a constant radon concentration in the radon chamber for a period of 2 days. The average radon concentration is measured by the AB-5 monitor.The humidity inside the chamber was varied in arbitrary steps to have water gain range up to 0.5 gm. The experiment was carried out at temperature of (20, 25,30 and 35°C). At the end of the exposure time of 48hrs, the canisters were sealed, weighed, and counted as previously explained. As radon concentration is known during the experiment, the calibration factor CF is calculated using equation(1).

Fig. 3, shows the relation between the water gain and CF for 4" open-facedcharcoal canister, for an exposure time of 48 hours at different temperature 20, 25, 30 & 35 °C. This figure shows that the calibration factor decreases exponentially with increasing water gain for the open-faced charcoal canister which can be explained the occupation of water molecules to radon's sites in charcoal leading to reductionof the number of radon atoms. This figure shows that the rate of change of CF with temperature ΔT is nearly constant (i.e. when temperature decreases by 5 degrees, the CF is shifted upward by 0.02 (l/min).

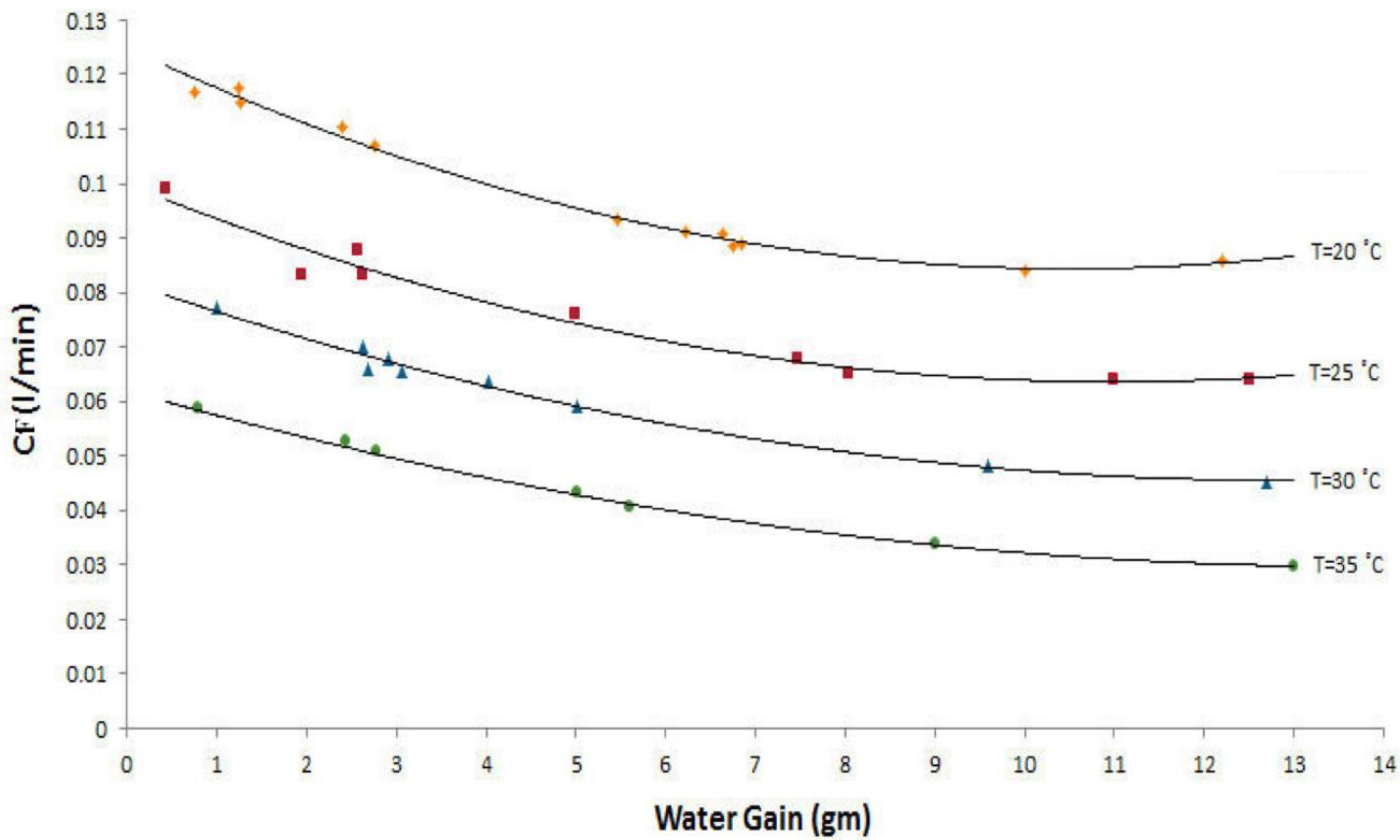



Fig. (3):Calibration factor (CF) versus water gain at different temperature for 4″ open faced charcoal canister.

One can easily notice that this behavior is similar for all temperatures ranges where CF values decreases by 48% when temperature increasing from 20 to 35 ºC as shown in figure (3).

Figure (4) illustrates the variation of CF with temperature at different humidity (20%, 50% and 80%). From this figure we notice that, at high relative humidity, there are two factors affecting the adsorption process which are the temperature and the relative humidity. While at low relative humidity, the decrease in the calibration factor with the temperature can be attributed to the effect of temperature only on the adsorption of radon.

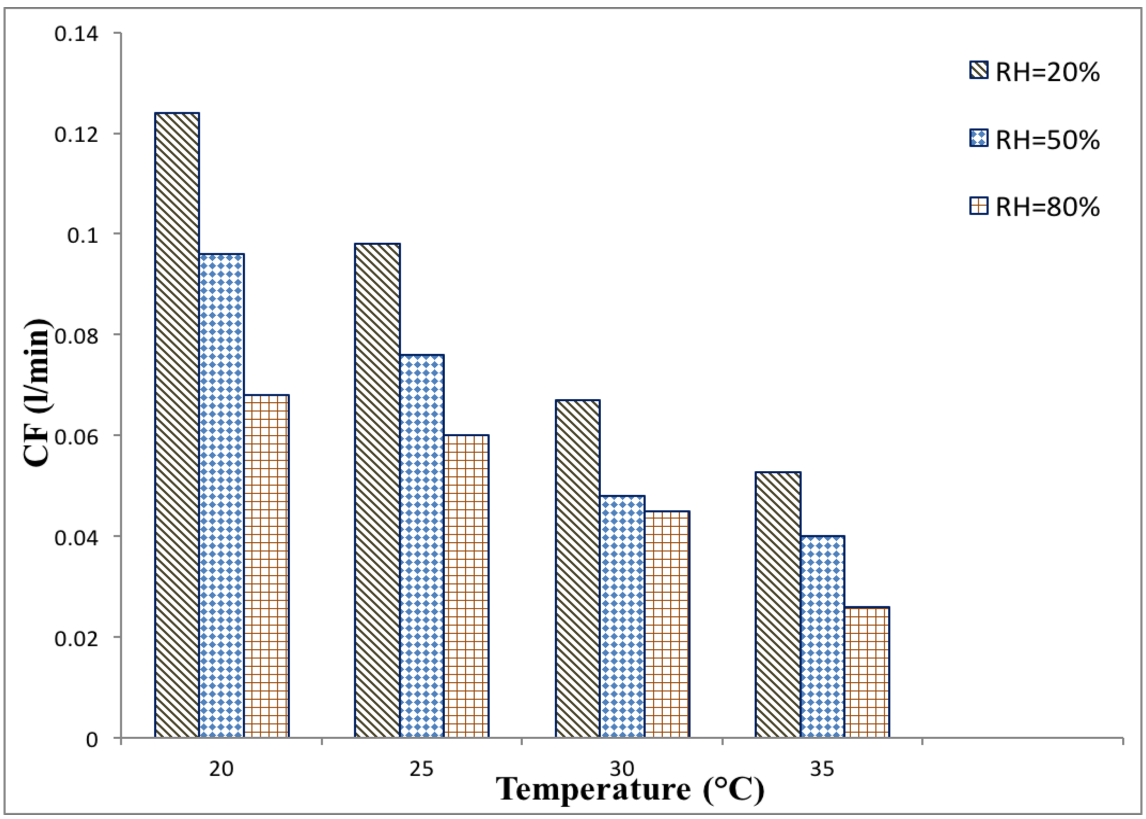
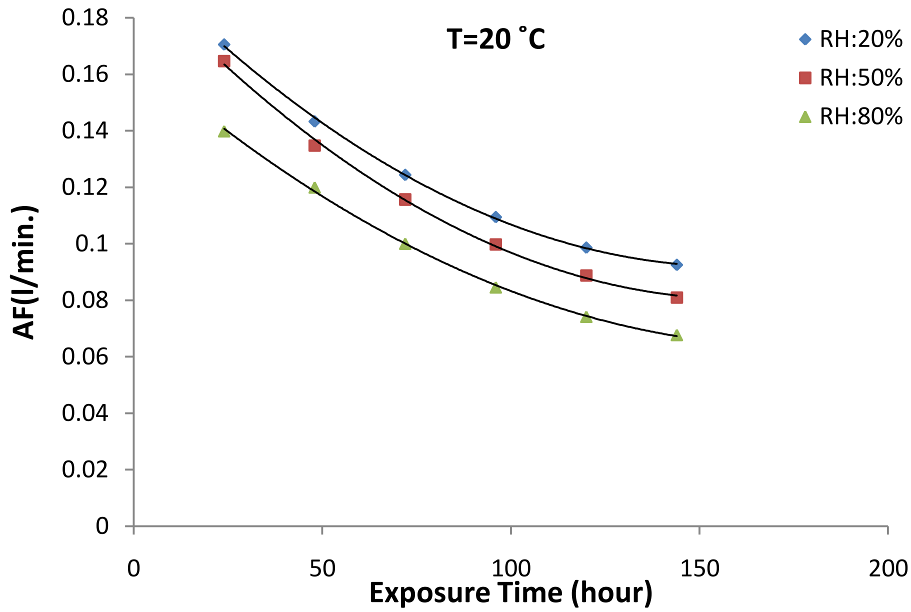
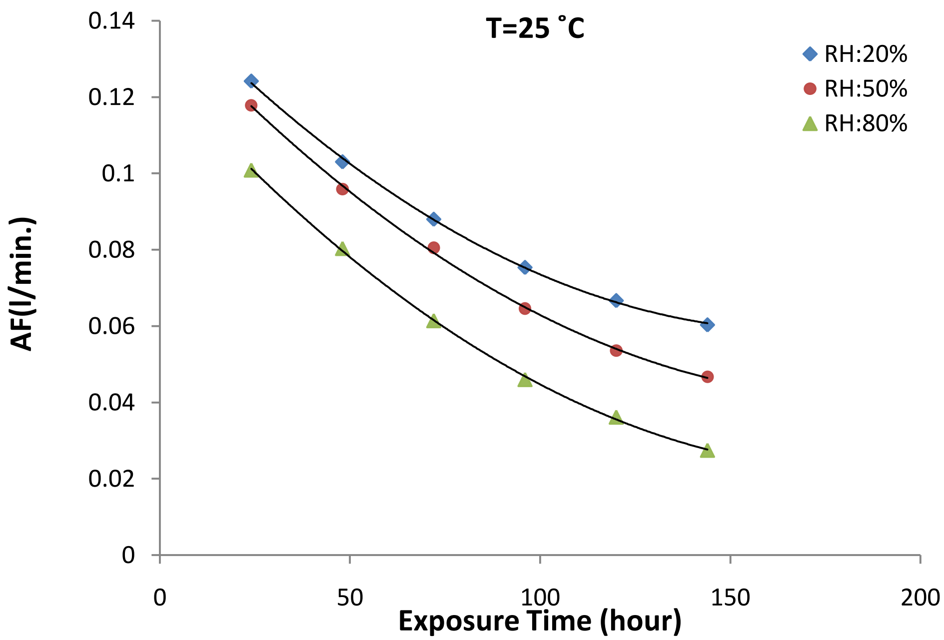



**Figure (4)**Temperature versus calibration factor (CF) for 4″open-faced charcoal canisterat differenthumidity.

Figure 4, shows, in general, that the calibration factor decreases as the temperature increases from 20 to 35°C. Also the CF decreases as RH% increases.

**Second**, as the water gained during the measurements is determined not only by the humidity and temperature but also by the exposure time, in order to account for the effect of humidity and exposure time (different from 48 hours) on the value of CF calculated by Eq. (1), three adjustment factor (AF) curves were established. Fig. 5, shows the variation of the adjustment factor as a function of exposure time in hours at relative humidity 20, 50, and 80% and at 20, 25, 30 and 35 $^{\circ}$C for the 4" open-faced charcoal canister.



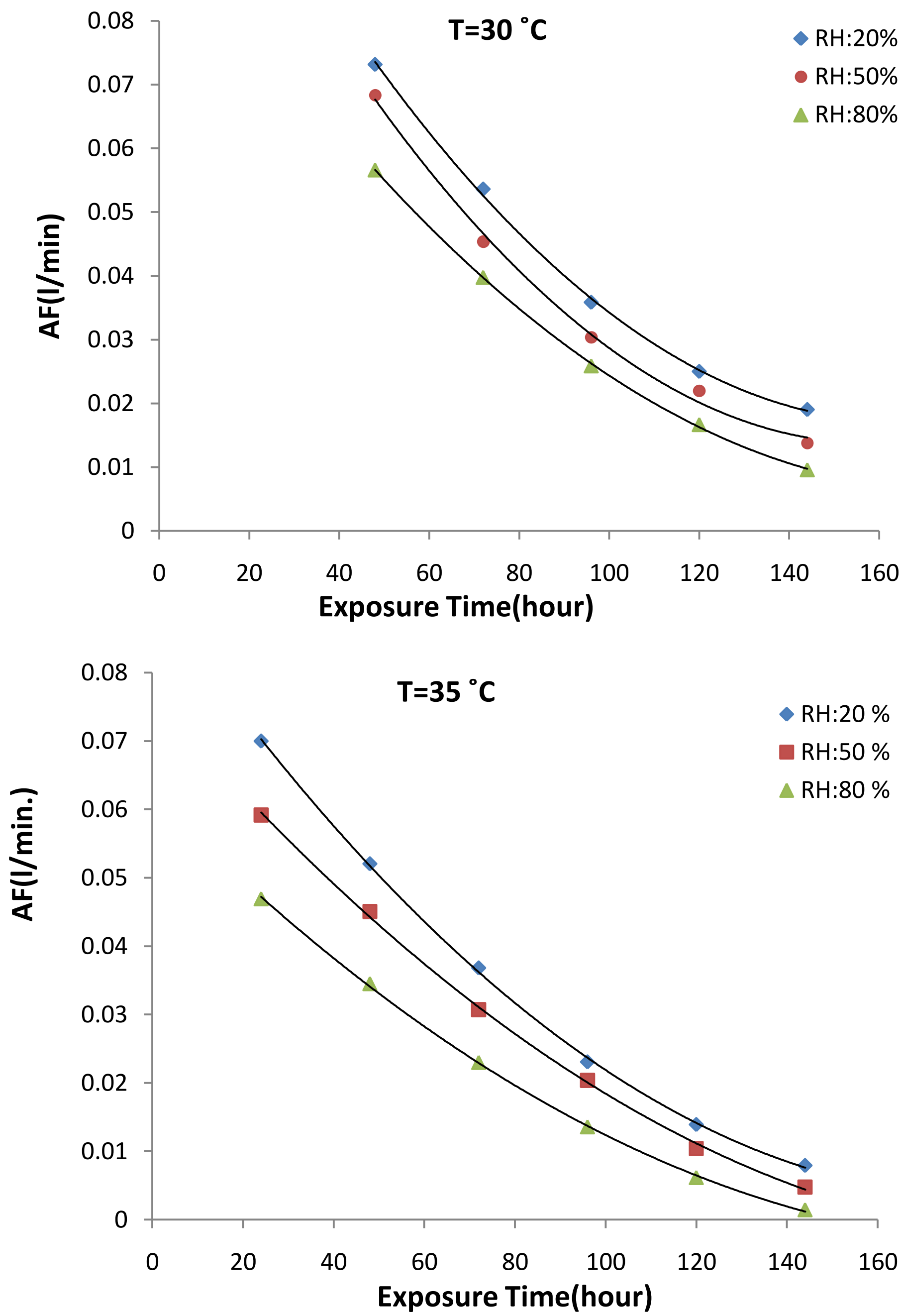



**Figure (5)** Exposure time versus adjustment factor (AF) at different RH% for 4″ OF charcoal canister at T =20, 25, 30 and35 ºC.

From Fig. 5, one can conclude that at fixed exposure time the value of AF decreases as the humidity increases, while for the same humidity the value of AF decreases as the temperature increases.

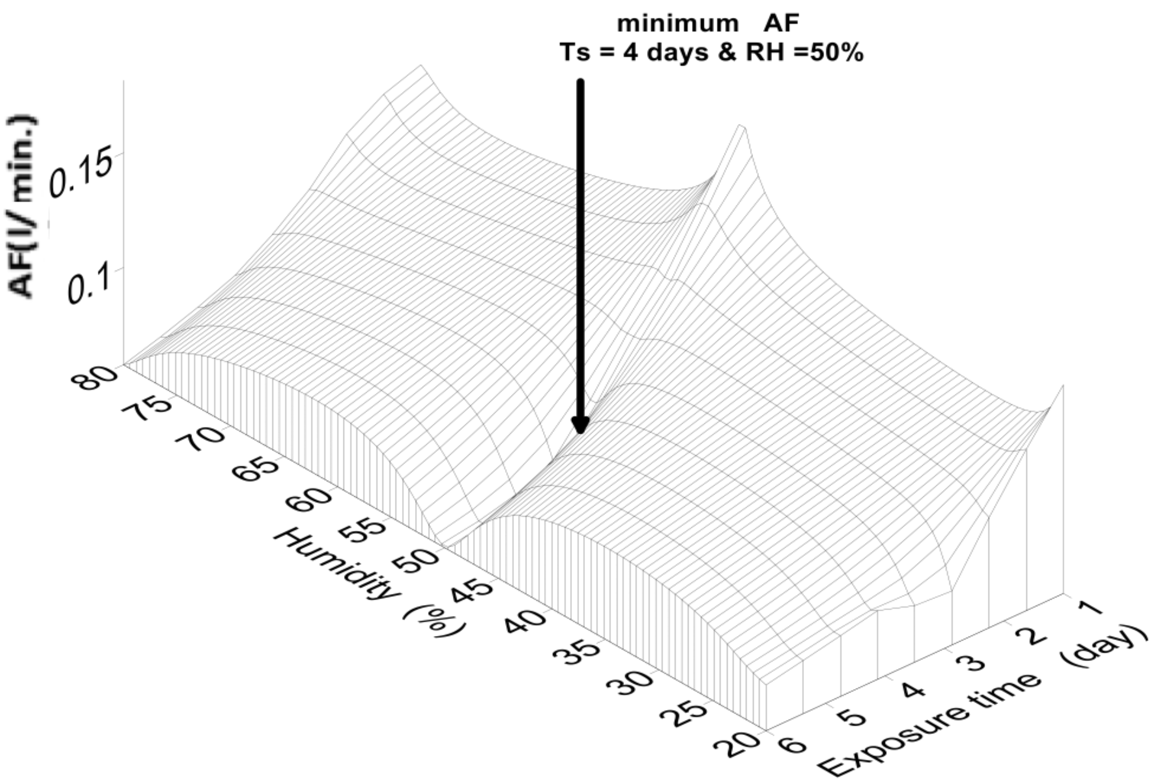



**Fig. (6):** 3-dimentions plot represent the dependence of the AF on the relative humidity and exposure time.

Figure 6, shows the dependence of AF on exposure time and the relative humidity. This figure shows that the appropriate exposure time is around 4 days at moderate humidity 50% and at 20-25 °C where the adjustment factor has a minimum value and the charcoal has maximum efficiency.

## 4.Conclusion

The use of charcoal canister was extended up to 35 °C and can be applied in hot country.

The calibration factor as well as the adjusting factor curves were established using previously constructed radon chamber.

The effect of temperature on the adsorption of radon concentration at different humidity was examined. The open face canister has better efficiency at low temperature. The calibration factor decreases exponentially with increasing the water gain. The values of adjustment factor decrease with increasing the temperature and with increasing the exposure time for different percentages of the humidity. The recommended exposure time for open-faced canister is around 4 days when the humidity is around 50%.

## Acknowledgments

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**الملخص باللغةالعربية**

# تأثير درجة الحرارة والرطوبة على أداء كواشف الكربون النشط السالبه

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تمت دراسة اعتماد امتصاص غاز الرادون على درجة الحرارة في المدى من ٢٠ إلى ٣٥ درجة مئوية على كواشف الكربون المنشط المكشوفة ذاتلقطر ٤ بوصة باستخدام غرفة غاز الرادون للمعايرة مع التحكم في تغيير تركيز غاز الرادون عند درجات رطوبه مختلفة (٢٠-٥٠-٨٠٪) . وقد تم بناء منحنيات المعايرة لكواشف الكربون المنشط المكشوفةCF, AF عند درجات الحرارة و الرطوبة المختلفة و زمن تعرض (١-٦ ايام) . وتستخدم هذه المنحنيات لتعميم استخدام كواشف الكربون النشط المكشوفة في مناطق ذات درجات حرارة و رطوبة عالية تختلف عن أوروبا و شمال أمريكا.