Research Article

Radon Monitoring in Eco-Friendly Textile Printing of Natural Fabrics

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ABSTRACT

The current work represents the ease to conceive a new method for radon monitoring in natural textile fabrics (wool, silk, and cotton) using solid state nuclear track detectors (SSNTDs) and to investigate the effect of textile printing process on the radon content of these fabrics. Eco-friendly printing pastes containing alkanet natural dye and thickened with biopolymers; namelycarboxymethyl cellulose (CMC) and guar gum have been used in this study. The data show that the radon concentration follow the order wool>cotton>silk for the unprinted fabrics. Alkanet dye was found to have radon concentration equivalent to 7.12 annual effective dose equivalent ($mSvy^{-1}$) compared to 7.17, 3.66 $mSvy^{-1}$ for CMC and Guar gum pastes respectively. The data also show that regardless of the type of thickening agent used; printing process increase the radon concentration of cotton and silk printed fabrics compared to the untreated fabrics, while it has minor effect in case of wool fabric. Also, samples printed using CMC thickener acquire higher radon concentration and colour strength (K/S) values than the samples printed using Guar gum regardless of the type of fabric used.

Keywords: Radon, fabrics, natural dyes, printing.

INTRODUCTION

The effect of pollution has obtained global dimension[1-4]. Textile printing industry represents an important work field for pollution prevention[5-7]. An attempt has been made to assume the various ecological and toxicological properties of the elements of textile printing process[6-8].

During the past few decades, interest in the relationships between ecosystem and human health and the distribution of chemicals specially miners (including uranium, iron, and tin miners) in the environment have established association between radon exposure and the development of cancer[9].

Solid state nuclear track detectors (SSNTDs) are ultrasensitive to charged particle radiation due to its good sensitivity, high degree of optical clarity, and long-term stability against various environmental factors[10]. CR-39 (polyallyldiglycol carbonate) solid state nuclear detector has been used for a variety of applications including radon monitoring in the environment and basic nuclear science studies[11]. The SSNTDs will have damage trails caused by the charged particles when they pass through it. On being treated with appropriate chemical reagents, the material along the damage trails is etched out at a much faster rate (called track etch rate VT) compared to the rate of etching of the undamaged bulk material (called bulk etch rate VB). The subsequent engraving pits can be approximated by geometrical cones with the harm trails as tomahawks and can be effortlessly imaged under an optical microscope.

Calls for the use of natural dyes have been just one of the of the outcomes of expanded natural mindfulness[12-14]. Alkanet (Alkanna tinctoria) roots yield a red dye (C.I. Natural Red 20)[15-17]. Natural fibres refer to all fibres that occur in fibre form in nature. In the classification of textile fibres, the usual major classification of the group into natural and man-made fibres has been followed, as has the usual classification of natural fibres into animal, vegetable and mineral.

The natural cellulosic fibres, usually called "vegetable fibres", of which cotton and linen (flax) are the two most important from the textile view point, in common with other plants are largely cellulosic in structure.

The natural protein fibres obtained from the animal kingdom are fewer in number than the vegetable fibres used for textiles. The two most important are wool and silk[5,18].

In the present work, an attempt was made to monitor radon in natural textile fabrics (wool, silk, and cotton) using CR-39 detector and to investigate the effect of textile printing process on the radon content of these fabrics upon printing with eco-friendly alkanet natural dye. Carboxymethyl cellulose (CMC) and guar gum are unique outstanding representatives of green eco-friendly biopolymers that can be used as thickening agents in this textile printing process.

MATERIALS AND METHODS

Materials

Fabrics

- Mill scoured pure wool fabric (220 g/m^2, 24 yarn/cm warp& 22 $yarn/cm^2$ weft) supplied by Misr Co. for

Spinning and Weaving; Mehalla El-Kubra, Egypt, was used through this study.

- Mill scoured natural silk fabric (140 g/m^2, 32 yarn/cm warp &30 yarn/cm weft) supplied by Hussein M. El-Khatieb Sons Co., Suhag, Egypt, was also used.

- Cotton fabric (165/m^3, 40 yarn/cm warp & 36 yarn/cm weft) used in this study have been produced by Misr/Helwan Co. for Spinning & Weaving, Cairo, Egypt.

Natural Dye

Alkanet[14-17] (AlkannaTinctoria) belongs to the family Borginaceae. Alkanet is known to be both antiseptic and anti-inflammatory. The roots produce a red dye [Colour index: Natural Red 20]. The colouring pigment in alkanet root is Alkanine (Anchusin). Alkanine is soluble in fat/oil and various organic solvents producing a red solution. It is insoluble in water, however it can be extracted with alkaline solution producing a bluish-violet solution, the colour of which can fade with washing or overexposure to sunlight.

Dry alkanet roots were purchased from local market. It was soaked in Castor oil at a concentration of 150 g. plant/L. to extract the beautiful pink colour. Then the extract was filtered and used as the liquid dye.

Thickening agents

- Carboxymethyl cellulose (CMC) sodium salt (high viscosity) was supplied by BDH laboratory supplies (England) and used at a concentration of 1%.

- Guar gum obtained from Sigma-Aldrich, USA as a yellowish white powder that swells in water yielding viscous solution, and used at a concentration of 3%.

Methods

Preparation of printing paste

Recipe of the printing paste is as follows:

Natural Dye ------------------- 40 g

Thickener* --------------------- 940 g

Mordant ------------------------ Xg

Balance ------------------------ Yg

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Total --------------------------- 1000g

*The stock thickener past of Guar gum prepared using 2% of Guar powder.

Printing and Fixation

Fabrics have been printed using silk screen printing technique, then fixation via ironing of the printed fabrics on their back face at the degree appropriate for each fabric.

Washing

After ironing, the fabrics printed were washed as follows: Rinsing with tap water, treatment with hot water, treatment with non-ionic detergent solution at 45°C, then rewashing with hot then cold water, and drying.

Analysis and Measurements

Radon Measurements

Taking sample from each type of textile put in a plastic cup with a plastic cover then fixed the CR-39detector in the bottom of the cover at a distance 4.9 cm from the surface of the sample as shown in (Figure 1), used two samples from each type. When alpha particles from decay of radon strike the CR-39 detector cause damage tracks, after 45 days collected CR-39 from the textile samples then making for the all samples etching process for 8 hours by 6.25 N NaOH at 70°C using water-bath then scanned by an optical microscope for recording the track intensity. Alpha track images were taken by an optical microscope (Olympus BX51M – N35MF) at 50 magnification using Tomoroscope eye 3.5 software with least count of 0.01 lm.

Images were recorded in the JPEG format by a digital camera attached to the microscope. The radon concentration calculated using the following equation[19].

$$C_{Rn} = \frac{N}{TC_f}$$

Where, CRn is the radon concentration [Bq/m3], N is numbers of track [Track/cm2], CF is the calibration factor equal 0.163 ± 0.002 [cm-2 d-1 per Bqm-3] obtained from[20] and T is the time of exposed [hours].

The annual effective dose is given by the following equation:

$$D\left[mSvy^{-1}\right] = \frac{C_{Rn} \times n \times f \times 8760h}{170h \times 3700Bqm^{-3}}$$

Where, D is the annual effective dose in mSy-1, CRn is the radon concentration in Bq/m3, n is the equilibrium factor equal 0.4, f is the ICRP conversion factor equal 3.88 mSv WLM-1.[21] The other factors are take account of house occupancy factor[22].

The exhalation rate of radon is obtained from the expression:

$$E_x = \frac{CV\lambda}{A[T + 1/\lambda(e^{-\lambda T} - 1)]}$$

where Ex= radon exhalation rate (Bq m-2 h-1); C = integrated radon exposure as measured by CR-39 detector (Bq m-3); V = effective volume of the can (m3); λ = decay constant for radon (h-1); A = area of the can (m2) and T = exposure time (h).[21]

Colour Measurements

The colour strength of the printed samples expressed as K/S was evaluated by reflectance technique.[23]

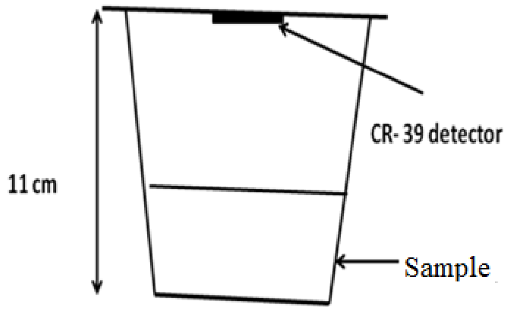

Figure 1: Technique to determine the Radon Concentration in Sample by CR-39.

RESULTS AND DISCUSSION

In the present work, an attempt was made to monitor radon in natural textile fabrics (wool, silk, and cotton) using CR-39 detector and to investigate the effect of textile printing process on the radon content of these fabrics upon printing with eco-friendly alkanet natural dye. The latter is thickened with either CMC or guar gum natural thickeners.

The radon concentration and the calculated annual effective dose received by people from corresponding radon concentration and radon exhalation rate in samples textile are monitored using solid state nuclear track detectors (SSNTDs), namely CR-39. Given below are the results obtained along with the appropriate discussion.

Radon Monitoring before Printing

The data of Table I show the radon concentration monitoring in natural fabrics (wool, silk and cotton), alkanet dye as well as in viscous solutions of CMC and/or Guar gum thickeners. The textile samples were first subjected to washing steps mentioned in the experimental section, then dried and assessed for radon measurement.

The data (Table 1) shows that the radon concentration follow the order wool>cotton>silk for the unprinted fabrics. This order can be explained in light of the number of industrial steps of fabrication.

Effect of Printing Process on Radon Concentration of Fabrics

To investigate the effect of textile printing process on the radon content of wool, silk, and cotton fabrics, different printing pastes were prepared for alkanet natural dye. The latter was thickened with natural thickeners like CMC or Guar gum. The results of investigation of the effect of printing process as well as the effect of type of thickening agent used are represented in Figure 2 and Table 2 respectively.

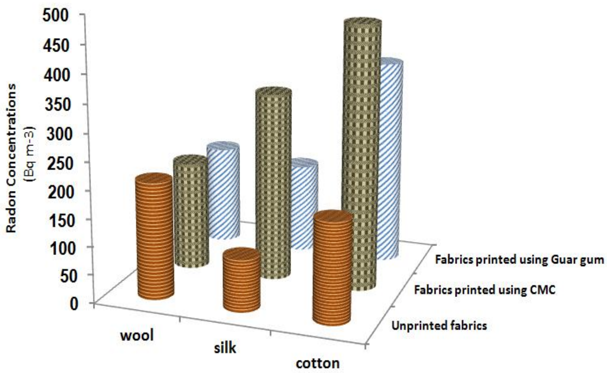

Figure 2: Effect of Printing Process on Radon Concentration of Printed Fabrics

Table 1: The Radon Monitoring for Unprinted Fabrics and Printing Paste Constituents by CR-39

Sample	Radon Concentrations (Bq m^{-3})	Radon Exhalation Rates (Bq$m^{-2}h^{-1}$)	Annual Effective Dose Equivalent (mSvy^{-1})
Wool	208.67	0.00016	4.51
Silk	92.74	0.00007	2.00
Cotton	178.53	0.00014	3.86
Dye	329.24	0.00025	7.12
CMC	331.56	0.00025	7.17
Gaur	169.26	0.00013	3.66

Table 2: Effect of type of Thickener on the Radon Concentration, Annual Effective Dose and Radon Exhalation Rate of Printed Fabrics

Sample		Radon Concentrations (Bq m^{-3})	Radon Exhalation Rates (Bq$m^{-2}h^{-1}$)	Annual Effective Dose Equivalent (mSvy^{-1})
Wool	Printed using CMC	197.08	0.00015	4.26
	Printed using Guar gum	179.69	0.00014	3.88
Silk	Printed using CMC	338.51	0.00026	7.32
	Printed using Guar gum	162.30	0.00012	3.51
Cotton	Printed using CMC	472.99	0.00036	10.22
	Printed using Guar gum	370.97	0.00028	8.018

The data of Figure 2 and Table 2 show that neither the printing process, nor the type of thickener used has an effect on radon concentration of wool fabrics.

The radon concentration in case of wool fabrics remain nearly the same for the unprinted and printed wool fabrics regardless of the type of thickener used (nearly equivalent to annual effective dose of 4 mSvy-1).

However, the effect of printing process on radon concentration of the printed cotton fabric is more clear than in case of silk fabric.

The lowest radon concentration observed for silk fabrics printed using Guar gum (162.30 Bq m-3, equivalent to effective annual dose of 3.51 $mSvy^{-1}$), and the highest concentration observed for cotton fabric printed using CMC (472.99Bq m-3, equivalent to effective annual dose of 10.22 mSvy-1).

The data of Table 2 also show that radon concentration of cotton and/or silk fabrics printed using CMC thickening agent have higher radon concentration than samples printed using Guar gum.

This may be attributed to the higher radon content of CMC pastes (Table 1), that may be transferred to the fabric during the printing process, and not removed during the washing off process.

The higher values obtained in case of using CMC thickeners may be due to the industrial processing steps during carboxymethylation of cellulose, compared to the simple extraction processing of Guar gum from plant sources.

CONCLUSION

- The concentration of radon, and the calculated annual effective dose, and radon exhalation rate in natural fabrics (wool, silk, and cotton) printing process are monitored using CR-39 solid state nuclear track detector.
- Radon concentration follow the order wool>cotton>silk for the unprinted fabrics.
- Radon concentration in case of wool fabrics remain nearly the same for the unprinted and printed wool fabrics regardless of the type of thickener used.
- The effect of printing process on radon concentration of the printed cotton fabric is more clear than in case of silk fabric.
- Radon concentration of cotton and/or silk fabrics printed using CMC thickening agent have higher radon concentration than samples printed using Guar gum.

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