Incorporating Kenaf and Oil Palm Nanocellulose in Building Materials for Radon Gas Emanation Reduction

Farah Aini Mocktar, Muhammad Khairul Azhar Abdul Razab and An'Amt Mohamed Noor

September 5, 2019

Incorporating Kenaf and Oil Palm Nanocellulose in Building Materials for Indoor Radon Gas Emanation Reduction

Farah Aini MOCKTAR[1], MOHAMMAD Khairul Azhar Abdul RAZAB[2], AN'AMT MOHAMED NOOR[3]

[1]*Medical Radiation Programme, School of Health Science, Universiti Sains Malaysia, 16150 Kubang Kerian Malaysia, farahaini145@yahoo.com*

[2]*Medical Radiation Programme, School of Health Science, Universiti Sains Malaysia, 16150 Kubang Kerian Malaysia, khairul.azhar@usm.my*

[3]*Advanced Materials Research Cluster, Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan, 17600 Jeli, Kelantan, Malaysia, anamt@umk.edu.my*

Abstract: This study aims to reduce radon gas emanations in the indoor environment by incorporating kenaf and oil palm nanocellulose that act as nano-fillers into building materials. Fabrication of composite brick was carried out according to the MS and ASTM standards. In this research, 40 ml, 80 ml, 120 ml, 160 ml, and 200 ml of nanocellulose were used to replace the usage of sand, stone, and cement materials, respectively. Kenaf and oil palm nanocellulose were utilised to reduce the internal and surface porosity as well as to replace the radon resources (stone), which indirectly reduced radon gas emanation. Radon gas emanated from each composite brick was measured within 10 consecutive days in an airtight prototype Perspex room using Radon Monitor Sentinel 1030. A compression test was also carried out to investigate the physical strength of the fabricated composite bricks. The results showed that 40 ml of kenaf and oil palm nanocellulose was the optimum amount in reducing the radon concentration, where the radon readings were 1.4 pCi/L and 0.93 pCi/L, respectively. Meanwhile, the brick with no nanocellulose exhibited the highest radon reading of 3.77 pCi/L. Moreover, the Young modulus for the composite brick of both kenaf and oil palm nanocellulose was 28.92 N/mm^2 and 27.8 N/mm^2 compared to the control brick, which was 27 N/mm^2. The results proved that radon gas emanations were reduced by 62.86% for kenaf and 75.3% for oil palm by incorporating the organic nanocellulose, which has high potential towards a healthy indoor environment.

Keywords: radon, building materials, nanocellulose, healthy environment

1. INTRODUCTION

Radon gas is recognised as the second factor to cause lung cancer after smoking (Ali, 2013; Saidi et al., 2013). Naturally, Ra-226, which is one of the primordial radioactive sources, has continuously decayed to Rn-222 and its progenies of alpha (α) particles (Razab et al., 2017a). Alpha (α) particles, with its high linear energy transfer property, can eventually damage human DNA double bonding, where it will be lodged in the lining of the lung and give-off mass radiation energies (Sethi, El-Ghamry, & Kloecker, 2005). Radon emitted from rock, soil, water, and sand is likely to accumulate in an enclosed space such as the building basement. Generally, the highest background ionising radiation received by humans is contributed by radon gas during the inhalation process. Brick material is one of the significant sources of indoor radon emanation in buildings, where the aggregates contained Ra-226 (mostly in the gravel) that decay to radon gas (Saidi et al., 2016). Some other factors that influence the concentrations of radon gas in building environment are temperature, pressure, humidity, airflow, and ventilation system (Kulali, Akkurt, & Özgür, 2017; Razab et al., 2017b, 2017c). However, it is more important to reduce the radon sources from within the bricks for effective prevention. Thus, this research was conducted to reduce the indoor radon concentration by incorporating organic plant materials of kenaf and oil palm nanocellulose in building materials. The cellulose materials act as liquid fillers to replace the utilisation of radon resources such as gravel, cement, sand, and water (Razab, 2019a). Nanocellulose became one of the phenomena in material industries due to its unique characteristics. One of the advantages is that it can be used as fillers in composite materials to strengthen and harden the structures (Abraham et al., 2012; Razab et al., 2019b). This is due to most hydroxyl groups in nanocellulose are usable to form a nano-network within the intermolecular atomic structures and lead to enhanced material strength and stiffness (Shak, Pang, & Mah, 2018).

2. METHODOLOGY

2.1 Chemical Extraction Method

The fibre was blended into smaller size and dried to eliminate the moisture before immersion into sodium hydroxide 2.5M and sodium sulphate 0.4M solution. The solution was kept boiling for 8–12 hours depending on the fibre types for the removal of lignin. The residues were washed using hot distilled water to remove excess acidic solution until a neutral pH was achieved. The bleaching process follows, where the fibres were kept boiling in hydrogen peroxide 2.5M for hemicellulose removal. Lastly, the fibres were washed with cold distilled water until a neutral pH was reached and dried at room temperature for 24 hours. Figure 1 summarises the chemical processes to obtained cellulose from kenaf and oil palm, respectively.

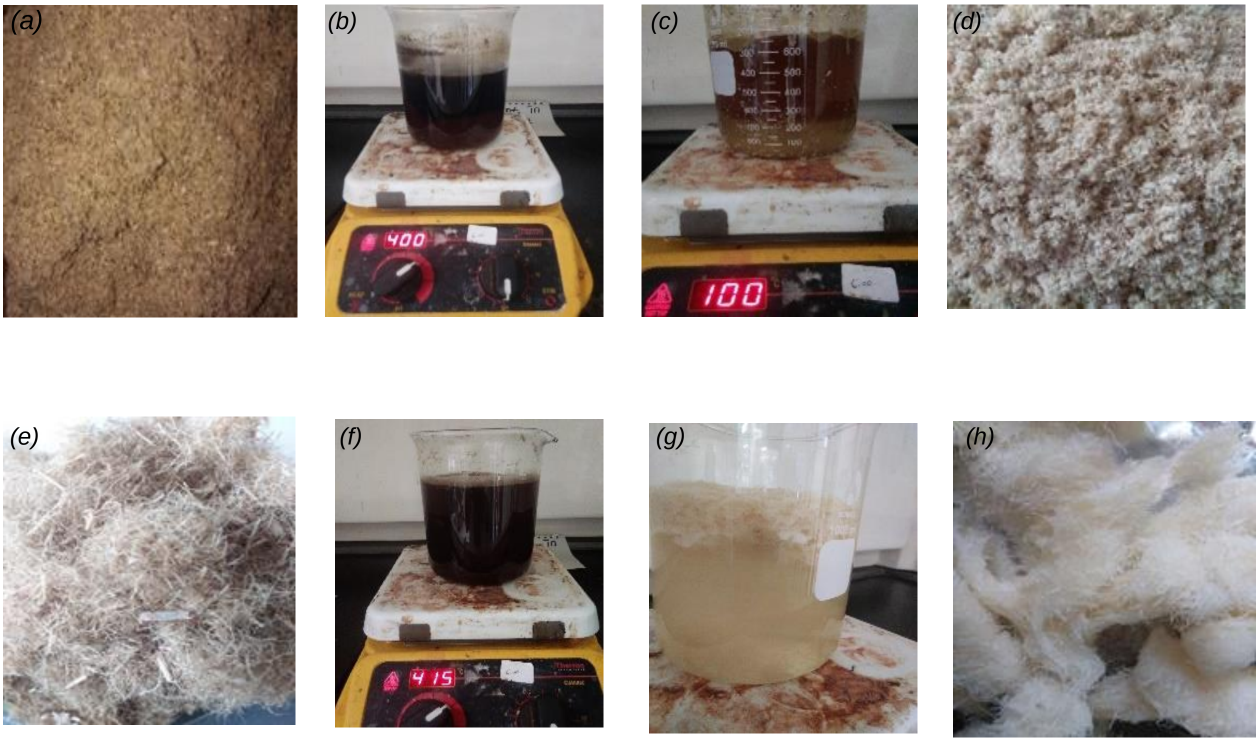

Figure 1: (a) Blended kenaf; (b) Acid hydrolysis process; (c) Bleaching; (d) Kenaf cellulose; (e) Blended oil palm; (f) Acid hydrolysis process; (g) Bleaching; and (h) Oil palm cellulose

2.2 Mechanical Extraction Method

Mechanical extraction method ensued after the extraction of plant cellulose via chemical process to obtain nanocellulose. An amount of 4 g of kenaf and oil palm cellulose were mixed with 50 mL distilled water and sonicated for 30 minutes using a sonicator (Figure 2 [a]) to break the cellulose bonds into nano sizes. Homogenised nanocellulose with high crystallinity was produced in liquid form, as shown in Figure 2 (b).

Figure 2: (a) A total of 4 g kenaf cellulose was mixed with 50 mL distilled water and sonicated for 30 minutes using a sonicator; (b) Kenaf and oil palm nanocellulose.

2.3 Characterisation of Nanocellulose

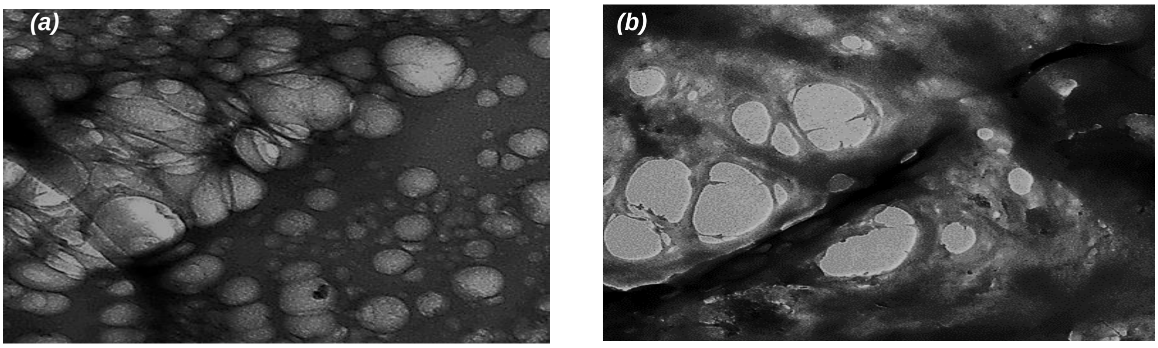

Figure 3: Structure and morphology of kenaf nanocellulose; (a) under 10k magnification; and (b) under 50k magnification

Morphology, particle size, and diffraction pattern of nanocellulose obtained were determined using the Transmission Electron Microscope (TEM). Figure 3 shows that the sonication process decreased the degree of polymerisation of kenaf cellulose fibres (Barbash, 2017). It was shown that the interactions between the nanocellulose fibrils formed delicate networks with a diameter ranging from 30 nm to 40 nm. The results proved that the combination of sonication and acid hydrolysis methods enhanced the mechanical strength of nanocellulose. According to Barbash et al. (2016), the mechanical properties were increased when acid concentration was used during the hydrolysis process, which influenced the properties of tensile and Young modulus. Nanocellulose, with its cellular network, strengthened the internal composite brick structures when incorporated as a liquid filler instead of water.

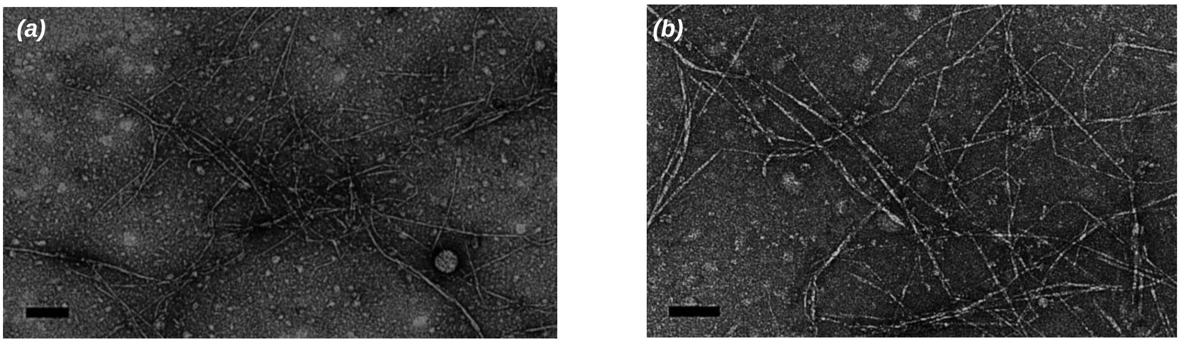

Figure 4: TEM micrograph of an oil palm nanocellulose that was prepared through three steps that are acid hydrolysis, bleaching, and sonication under (a) 10k magnification and (b) 50k magnification.

Figure 4 shows the aqueous suspension of nanocellulose fibre consisting of needle-like nanoparticles, with some separated nanocellulose as well as agglomerated nanoparticles in the form of bundles (Lani et al., 2014). The sonication process caused the cellulose microfiber to separate into several nanofibers due to hydrogen bonding breaking. Usually, it is difficult to observe the isolated individual nanofibers through the scanning electron microscope (SEM) due to the agglomeration that usually occurred after acid hydrolysis and the bleaching process due to strong intermolecular hydrogen bonding among them (Nuruddin et al., 2016). Referring to Othman et al. (2012), agglomeration between particles occurs to minimise its surface energy due to the van der Walls attraction forces between nanoparticles. Moreover, cellulose agglomeration obtained during the acid hydrolysis process produced low-quality nanocellulose, since the fibrils were not well distributed. In this study, the diameter of the nanocellulose was in the range of 10 nm to 30 nm when analysed using the image-J software.

3. RADON GAS EMANATIONS

3.1 Fabrication of Composite Brick

Fabrication of the composite brick was carried out according to the Malaysia Standard and ASTM Standard. A total of 40 g, 80 g, 120 g, 160 g, and 200 g of nanocellulose, as well as a foaming agent, were used to replace the use of sand, stone, and cement materials, respectively. The ratios to fabricate all the bricks are shown in Table 1. The mixtures were mixed and poured into the brick mould for the standard brick size 215 × 105.2 × 65 mm ± 7 mm dimension before dried at room temperature for two days as shown in Figure 5 (a) and (b). Radon emanation concentration for each fabricated brick was determined using Radon Sentinel Model 1030 in a closed-space of a prototype Perspex room for 10 consecutive days, as shown in Figure 5 (c). The compression test was done using a universal testing machine to determine the strength of each brick, as shown in Figure 5 (d).

Figure 5: (a) Mixing of sand, stone, and cement (b) Fabricated composite brick (c) Radon gas measurement (d) Compression test

Table 1: Ratio to fabricate control brick and composite brick

Brick	Stone (g)	Cement (g)	Sand (g)	Nanocellulose (ml)	Foam (ml)	Water (ml)
Control Brick	400	800	1200	0	0	500
Composite Brick 1	**300**	**700**	**1100**	40	25	100
Composite Brick 2	**300**	800	1200	80	25	100
Composite Brick 3	400	**700**	1200	120	25	100
Composite Brick 4	400	800	**1100**	160	25	100
Composite Brick 5	**300**	**700**	**1100**	200	25	100

Table 1 shows the ratio to fabricate commercial brick according to the specifications proposed by Malaysia and ASTM standards. For the control brick, the ratio of stone, cement, sand, and water was 400:800:1200:500. Meanwhile, the ratio of stone, cement, sand, nanocellulose, foam, and water was 300:700:1100:40:25 for composite brick 1, 300:800:1200:80:25:100 for composite brick 2, 400:700:1200:120:25:100 for composite brick 3, 400:800:1100:160:25:100 for composite brick 4, and 300:700:1100:200:25:100 for composite brick 5. The formula has been applied for both kenaf and oil palm nanocellulose.

3.2 Radon Determination

Figure 6 shows that brick 1 has the lowest radon concentration compared to composite bricks 2, 3, 4, 5, and the control brick due to the different ratios of nanocellulose amount, stone, cement, sand, foam, and water.

Composite brick 1 consisted of 40 mL kenaf nanocellulose, while the amount of stone, cement, and sand was reduced. The foam was added to replace water as the mixture agent. According to Elzain (2014), different types of water sources contain different amount of radon concentration, where well water contains a high amount of radon compared to river and irrigation channel water. For brick 2, 80 mL nanocellulose was used, and the stone was reduced, while the amount of sand and cement was kept constant as the control brick. Radon concentration emanated from composite bricks 1 and 2 were 1.4 pCi/L and 2.17 pCi/L, respectively. The increase of kenaf nanocellulose led to increased radon concentration. This is because the amount of water used to fabricate the brick was also increased. From the research by Chami Khazraji & Robert (2013), cellulose chain and water molecules caused swelling factor that increases the liquid uptake and leads to moisturisation. High humidity increased the radon concentration due to interactions of energetic alpha (α) particles with water molecules (Razab et al., 2019a).

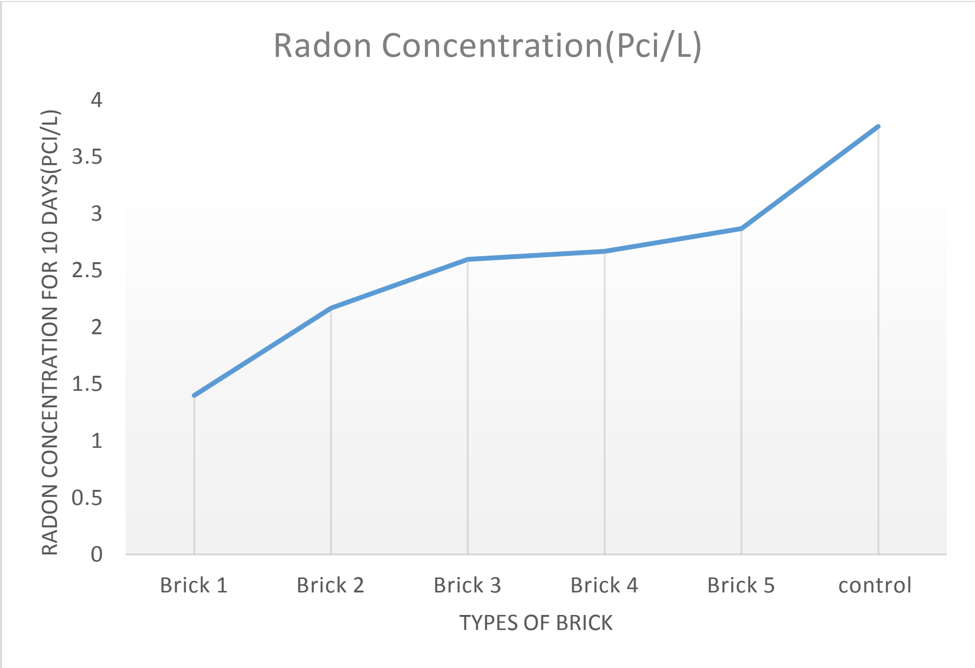

Figure 6: Radon concentration of kenaf nanocellulose composite brick and control brick for 10 consecutive days

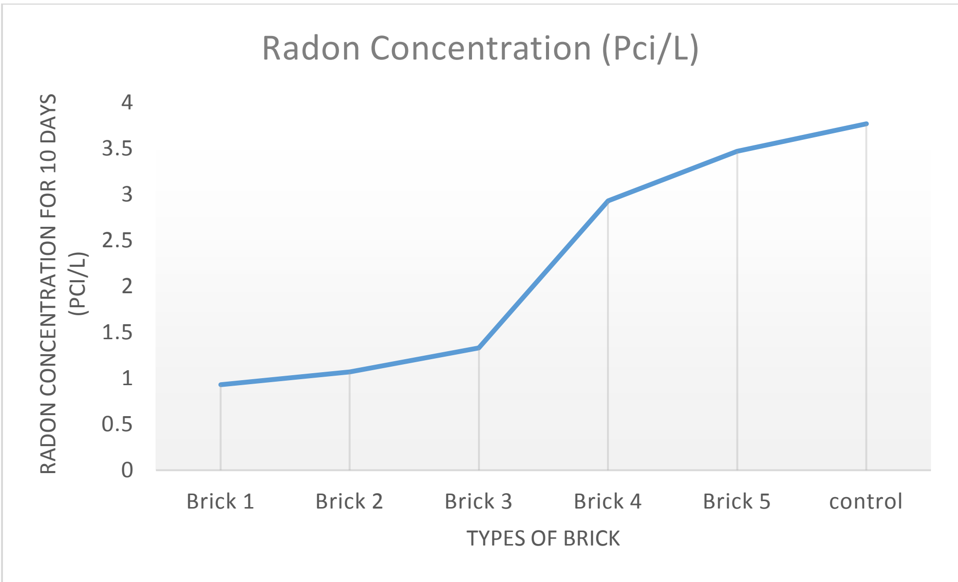

Figure 7: Radon concentration of oil palm composite brick and control brick for 10 consecutive days

Figure 7 shows radon concentration for oil palm nanocellulose composite brick. Brick 1, which used 40 mL of nanocellulose as liquid fillers, has lower radon concentration compared to composite bricks 2, 3, 4, 5, and the control brick. From the TEM micrograph in Figure 4, a few fibril networks are observed, which miniaturised the brick porosity; thus, reducing the potential of a crack. The differences in radon concentrations between control and composite bricks 1 were almost 2.84 pCi/L, which could increase the probability of lung cancer. For every 2.7 pCi/L radon exposure, the probability of lung cancer will be raised for almost 16% per 100 Bq/m^3 in an indoor environment (Kurt, 1993).

3.3 Compression Test

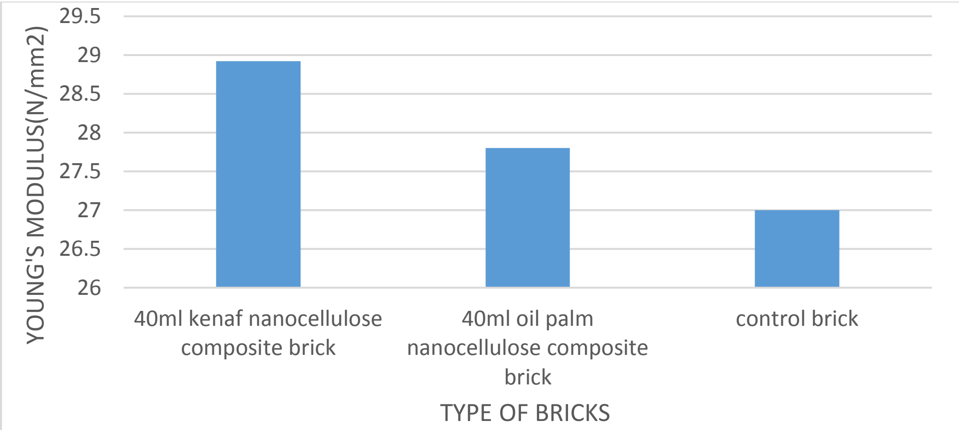

Figure 8: Young modulus for 40 mL kenaf and oil palm nanocellulose composite brick and control brick after compression testing

The compression test was carried out to determine the maximum capacity of the bricks, and it is represented by the Young modulus. High Young modulus indicates the high stiffness of the materials. The Young modulus for concrete bricks mostly ranges from 27 N/mm^2 to 38 N/mm^2, depending on the ratios of the raw materials used. Figure 8 shows that the kenaf nanocellulose composite brick and oil palm nanocellulose composite bricks have higher Young modulus, which are 28.92 N/mm^2 and 27.8 N/mm^2, respectively.

4. CONCLUSION

Incorporating kenaf and oil palm nanocellulose in building materials for radon gas emanation reduction can promote a healthy environment and lead to a better life. The internal bonding between each nanocellulose structures has high potential to be used as liquid fillers in composite brick for porosity miniaturisation and increased mechanical strength. In this research, the composite brick with 40 ml of kenaf and oil palm nanocellulose emanated low radon concentrations and produced an optimum mechanical strength.

5. ACKNOWLEDGEMENT

This research was supported under the Short Term Research Grant (Grant number: 304/PPSK/6315174) awarded by Universiti Sains Malaysia

6. REFERENCES

Abraham, E., Elbi, P. A., Deepa, B., Jyotishkumar, P., Pothen, L. A., Narine, S. S., & Thomas, S. (2012). X-ray diffraction and biodegradation analysis of green composites of natural rubber / nanocellulose. *Polymer Degradation and Stability*, *97*(11), 2378–2387. https://doi.org/10.1016/j.polymdegradstab.2012.07.028

Ali, M. J. (2013). Radon Concentration in Al-Gazalia City , Baghdad , Iraq. *Journal of Al-Nahrain University*, *16*(1), 121–128.

Barbash, V. (2017). Metadata of the chapter that will be visualized online, (September). https://doi.org/10.1007/978-3-319-56422-7

Barbash, V. A., Yaschenko, O. V, Alushkin, S. V, Kondratyuk, A. S., Posudievsky, O. Y., & Koshechko, V. G.

(2016). The Effect of Mechanochemical Treatment of the Cellulose on Characteristics of Nanocellulose Films. *Nanoscale Research Letters*, (November). https://doi.org/10.1186/s11671-016-1632-1

Chami Khazraji, A., & Robert, S. (2013). Interaction effects between cellulose and water in nanocrystalline and amorphous regions: A novel approach using molecular modeling. *Journal of Nanomaterials*, *2013*. https://doi.org/10.1155/2013/409676

Elzain, A. A. (2014). Measurement of Radon-222 concentration levels in water samples in Sudan, *5*(2), 229–234.

Kulali, F., Akkurt, I., & Özgür, N. (2017). The effect of meteorological parameters on radon concentration in soil gas. *Acta Physica Polonica A*, *132*(3), 999–1001. https://doi.org/10.12693/APhysPolA.132.999

Kurt, T. L. (1993). ATSDR Case Studies in Environmental Medicine. 1,1,1-Trichloroethane. *U S Dept of Health & Human Services*, *24*, 1–19.

Lani, N. S., Ngadi, N., Johari, A., & Jusoh, M. (2014). Isolation , Characterization , and Application of Nanocellulose from Oil Palm Empty Fruit Bunch Fiber as Nanocomposites, *2014*.

Nuruddin, M., Hosur, M., Uddin, M. J., Baah, D., & Jeelani, S. (2016). A novel approach for extracting cellulose nanofibers from lignocellulosic biomass by ball milling combined with chemical treatment. *Journal of Applied Polymer Science*, *133*(9). https://doi.org/10.1002/app.42990

Othman, S. H., Rashid, S. A., Idaty, T., Ghazi, M., & Abdullah, N. (2012). Dispersion and Stabilization of Photocatalytic TiO 2 Nanoparticles in Aqueous Suspension for Coatings Applications, *2012*. https://doi.org/10.1155/2012/718214

Razab, M. K. A. A, Azhar, N. E., Hamzah, N. L., Karim, S. F. A., Abdullah, N. H., Noor, A. M., Mohamed, M., Adam, N. (2017a). Investigations of Outdoor and Indoor ^{222}Rn Concentrations Level in Academic Building at Universiti Malaysia Kelantan Jeli Campus. *Materials Science Forum*, 888, 471-476.

Razab, M. K. A. A, Karim, S. F. A., Azhar, N. E., Hamzah, N. L., Abdullah, N. H., Noor, A. M., Mohamed, M., Adam, N. (2017b). The Effects of Altitude Levels on ^{222}Rn Concentration in Academic Building at Universiti Malaysia Kelantan Jeli Campus. *Materials Science Forum*, 888, 466-470.

Razab, M. K. A. A, Hamzah, N. L., Karim, S. F. A., Azhar, N. E., Abdullah, N. H., Noor, A. M., Mohamed, M., Adam, N. (2017c). Determination of Indoor ^{222}Rn Concentrations Level on Different Room Sizes in Academic Building at Universiti Malaysia Kelantan Jeli Campus. Materials Science Forum, 888, 447-452.

Razab M. K. A. A, Noor, A. M., Wong, K. N. S. W. S., Mocktar, N. A., Hikamarhakimi, N. A., Razapi, N. F. M., Mohamed, A. F. M., Taib, N. H. M., Ali, N. K. Y., Mansor, M. S. (2019a). Determination of Rn-222 Emanations from Kenaf Composite Brick. *AIP Conference Proceedings*, 2068, 020047-1 - 020047-6.

Razab, M. K. A. A., Ghani, R. S. M., Noor, A. M., Mocktar, N. A., Zin, F. A. M., Abdullah, N. H., Yusuf, N. A. A. N., Mohamed, M. (2019b). Kenaf Cellulose Nanofibrils as Mechanical Enhancers of Composite Brick. *AIP Conference Proceedings*, 2068, 020071-1 - 020047-5.

Saidi, S. A., Jaafar, M. S., Razab, M. K. A. A., & Zulkepli, N. N. (2013). A Study of Radon-222 Levels In Foamed Light Concrete. *Australian Journal of Basic and Applied Sciences, 7*(5), 315–318.

Saidi, S. A., Jaafar, M. S., Razab, M. K. A. A., Rasat, M. S. M., Ahmad, M. I., Mohamed, M., Mamat, S., Hussin. H. (2016). Potential of Fabricated Light Foamed Concrete in Reducing Radon from Building Material. *Materials Science Forum*, 840, 427-431.

Sethi, T. K., El-ghamry, M. N., & Kloecker, G. H. (2005). Radon and lung cancer risk. *European Journal of Cancer*, *41*(3), 338. https://doi.org/10.1093/jnci/81.10.745

Shak, K. P. Y., Pang, Y. L., & Mah, S. K. (2018). Nanocellulose: Recent advances and its prospects in environmental remediation. *Beilstein Journal of Nanotechnology*, *9*(1), 2479–2498. https://doi.org/10.3762/bjnano.9.232