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

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

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Abstract: The aim of this study is to reduce radon gas emanations in indoor environment by incorporating Kenaf and Oil Palm nanocellulose that act as nano-fillers into building materials. Fabrication of composite brick were carried out according to the ASTM Standard. In this the research, 40ml, 80ml, 120ml, 160ml and 200ml of nanocellulose were used to replace the usage of sand, stone and cement materials, respectively. Kenaf and Oil palm nanocellulose were acted 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 bricks were measured within 10 consecutive days in airtight prototype perspex room by using Radon Monitor Sentinel 1030. Compression test also carried out to investigate the physical strength of the fabricated composite bricks. The results have shown 40ml 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 0.93pCi/L, respectively. Meanwhile, brick with no nanocellulose has shown highest radon reading of 3.77 pCi/L. Moreover, Young Modulus for composite brick for both kenaf and oil palm nanocellulose were 28.92N/mm^2 and 27.8N/mm^2 compared to normal brick that was 27N/mm^2. The results have proved the radon gas emanations was reduced by 62.86% for kenaf and 75.3% for oil palm by incorporating the organic nanocellulose which has high potential towards healthy indoor environment.

Keywords: radon, building materials, nanocellulose, healthy environment

1. INTRODUCTION

Recent research have shown that Radon become one of the second leading that cause lung cancer after smoking (Ali, 2013). Naturally, Ra-226 which is one of the primordial radioactive source has continuously decay to Rn-222 and its progenies of alpha particles (Razab et al., 2013) .Alpha particle with its high linear energy transfer property eventually damage human DNA where it will lodge in the lining of the lungs and give off mass radiation energies that damage the lung cells (Sethi, El-ghamry, & Kloecker, 2005). Radon that emits from rock and soil likely to focus in an enclose place like house especially in basement. General population received the higher ionizing radiation that is contribute by the radon. Construction materials that are used for building materials nowadays become one of the major sources of indoor radon concentration where most of the terrestrial materials contain Ra-226 (mostly in gravel) that emit radon gas. There are a few minor factor that effect the concentration of radon gas in an environment that are temperature, pressure, humidity, airflow and ventilation system but it is important to reduce the source that emits radon gas inside the building for residence and work (Kulali, Akkurt & Özgür, 2017). Thus, this research has been 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 replacement to reduce utilization of gravel and other brick material resources. Nanocellulose become one of the phenomena among researchers according to its unique characteristics. One of the advantage is it can be used as fillers in composite to strengthen and harden the material structures (Abraham et al., 2012). This is due to most of hydroxyl group in nanocellulose are usable to form nano-network within intermolecular atomic structures and enhance the strength and stiffness properties off the materials(Shak, Pang, & Mah, 2018).

2. METHODOLOGY

2.1 Chemical Extraction Method

The fibre was blend into smaller size and dried to eliminate the moisture and then, it is immersed in sodium hydroxide 2.5M and sodium sulphate 0.4M. After that, keep boiling for 8-12 hours depend on fibre type to remove the lignin. The residue was washed using hot distilled water to remove the excess acid until a neutral pH is achieved and the next step was bleaching process where fiber will keep boiling in hydrogen peroxide 2.5M to remove the hemicellulose. Lastly, the fibre was wash with cold distilled water until reach neutral pH and dried at room temperature for 24 hours.

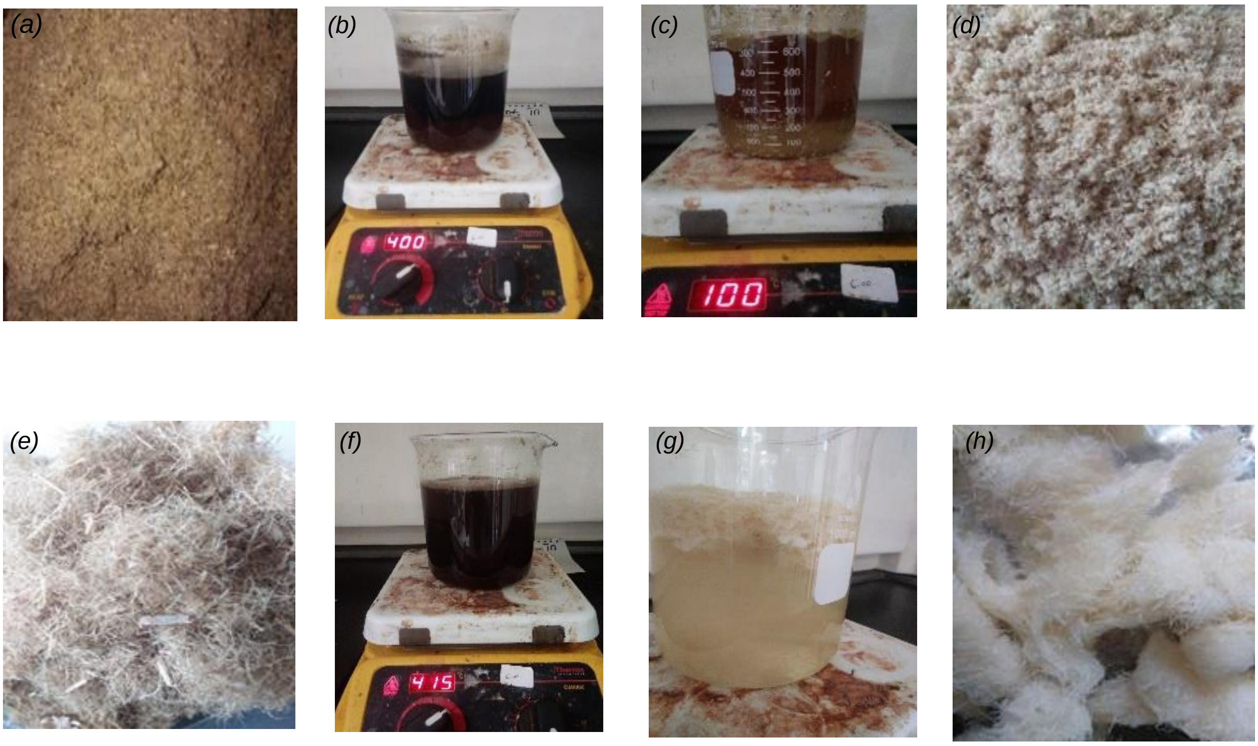

Figure 1: shows that (a) Kenaf that was blend (b) acid hydrolysis process (c) bleaching (d) kenaf cellulose (e) Oil Palm that was blend (f) acid hydrolysis process (g) bleaching and (h) oil palm cellulose

2.2 Mechanical Extraction Method

Mechanical extraction method was the process to produce high nanocellulose yields where 4g kenaf and oil palm cellulose was mixed with 50ml distilled water and sonicate for 30 minutes using sonicator to homogenize the generated nanocellulose to produce high crystallinity nanocellulose in liquid form.

Figure 2: shows (a) 4g kenaf cellulose was mixed with 50ml distilled water and sonicate for 30 minutes using sonicator (b) kenaf nanocellulose (c) 4g oil palm cellulose was mixed with 50ml distilled water and sonicate for 30 minutes using sonicator and (d) oil palm nanocellulose

2.3. Fabricate composite brick

The materials (cement, water, stone, sand, foam and nanocellulose) was prepared and for the brick without nanocellulose, it's acts as a control/commercial brick. The stone: cement: sand was mixed with the ratio of 1:2:3. For the composite brick that consist of cement, sand, stone, foam and nanocellulose was mixed with the ratio shown in table 1 below. The mixture was mixed and poured into the brick mould for the standard brick size 215 x 105.2 x 65 mm ± 7 mm dimension where the control brick and 10 brick with nanocellulose was dried in room temperature for two days. The control brick was put into the perspex box for ten days and continue with the composite brick also for ten days to test the radon concentration using Radon Sentinel Model 1030 and physical testing was test using universal testing machine (compression test).

Figure 3: shows (a) mixing of sand, stone and cement (b) fabricated composite brick (c) radon monitor to detect radon gas (d) compression test

Table 1 below show the ratio to fabricate commercial brick according to the general brick specifications as per Malaysia standard and composite brick that used nanocellulose as the filler. For control brick (commercial) the ratio used was stone: cement: sand 400:800:1200 whereas for composite brick 1 the ratio for stone: cement: sand: nanocellulose was reduced until 100g for each and 40ml of nanocellulose was added. For composite brick 2, only stone was reduced until 100g and 80ml of nanocellulose was added while for brick 3, cement was reduced totally up to 100g and 120ml of nanocellulose was added. 100g of sand was reduced and 160ml of nanocellulose was added to fabricate composite brick as for composite brick 5, each materials like stone, cement and sand was reduce to 100g with 200ml of nanocellulose was added.

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
Brick 1	**300**	**700**	**1100**	40	25	100
Brick 2	**300**	800	1200	80	25	100
Brick 3	400	**700**	1200	120	25	100
Brick 4	400	800	**1100**	160	25	100
Brick 5	**300**	**700**	**1100**	200	25	100

3. CHARACTERIZATION OF NANOCELLULOSE

3.1 Transmission Electron Microscope (TEM)

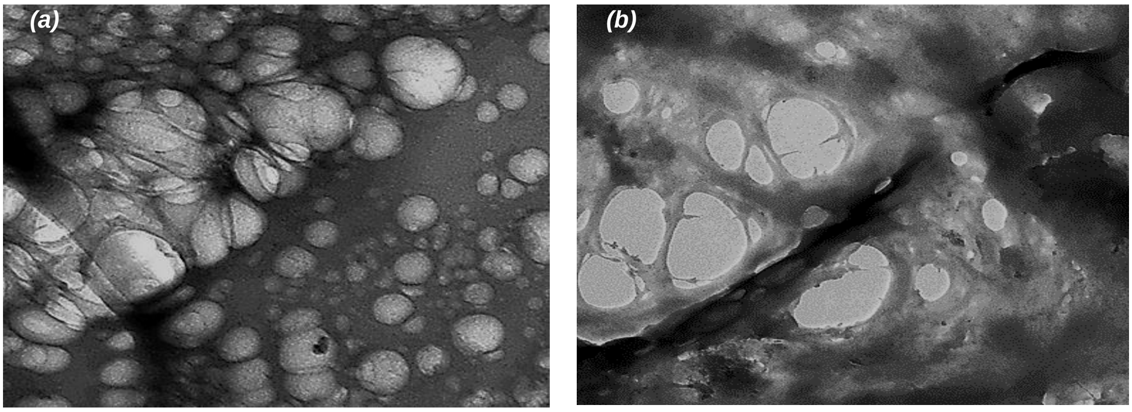

Figure 4: shows structure and morphology of kenaf nanocellulose where (a) under 10k magnification and (b) under 50k magnification

In determining the morphology, particle size and diffraction pattern of nanocellulose, transmission electron microscope (TEM) is used. Figure 4 shows the images where the sonication of kenaf decreasing the degree of polymerization of cellulose and also the measurement of the fibers(V. Barbash, 2017). It can be seen from the result that there is an interaction between the nanocellulose particles where it form a delicate network with diameter range from 30nm to 40nm. So this result prove that the sonication combined with acid hydrolysis produce network between the nanoparticles which will enhance the mechanical strength of nanocellulose. During sonication, the mechanical forces that was exerted on the cellulose was strong which will lead up to the fibrillation of the fibre bundles.

According to (V. A. Barbash et al., 2016) the mechanical properties increase when the acid concentration used during hydrolysis process increase which will influence the properties of tensile and young modulus. The nanoparticles shows the cellular network where this network will strengthen the composite brick structure.

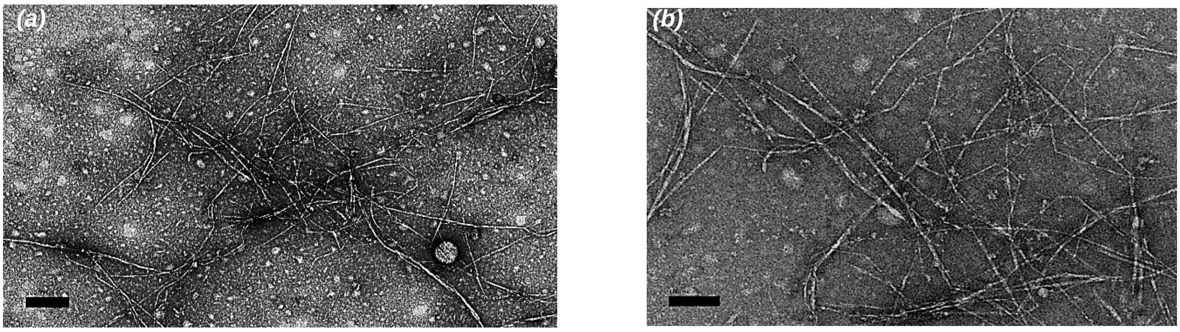

Figure 5: shows the TEM micrograph of an oil palm nanocellulose that was prepared through three steps that are acid hydrolysis, bleaching and sonication under (a) 10k magnification and (b) 50k magnification.

From the analysis of the TEM micrograph, it can be seen that the aqueous suspension of nanocellulose fiber consists of needle-like nanoparticles. Apart from that, there are some of nanocellulose were well separated but there were some of the nanoparticles agglomerated in the form of bundles (Lani et al., 2014). Sonication process caused the cellulose microfiber to separate into several nanofibers because of the breaking down hydrogen bonding. Usually it was difficult to make sure the isolated individual nanofibers in scanning electron microscope due to the agglomeration that occur after acid hydrolysis and bleaching process because of the strong intermolecular hydrogen bonding among them (Nuruddin et al., 2016).

Referring to (Othman et al.,2012), due to the van der walls attraction forces between nanoparticles, agglomeration between particles occur to minimize its surface energy. Moreover, the agglomeration of cellulose that was obtain during acid hydrolysis process produce low quality nanocellulose since the fibrils not distribute well. From the figure 5, it can be obtained that the diameter of the nanocellulose was in the range of 10nm to 30nm analyze by image j software after sonication process.

3.2 Radon Determination

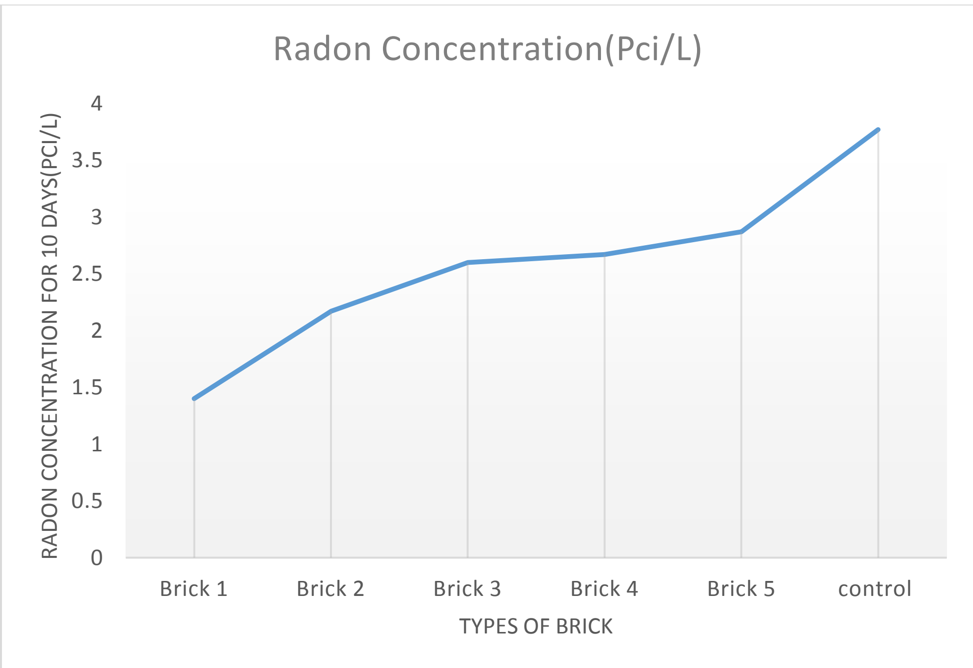

Figure 6: Radon concentration of kenaf nanocellulose composite brick and control brick for 10 consecutive days

From the figure 6, brick 1 has the lowest radon concentration compared to brick 2, 3, 4, 5 and control brick due to the difference in nanocellulose amount, stone, cement and sand. 40ml of nanocellulose was added in brick 1 where 100 g amount of stone, cement and sand was reduced. Foam was added to replace it with water where water also become one of the radon sources. According to (Elzain, 2014), he proposed that different types of water sources contain different amount of radon concentration where well water contain high amount of radon rather than river water and irrigation channel water. For brick 2, 80ml of nanocellulose was used and 100g of stone was reduce but sand and cement used still same with control brick that show the radon concentration of brick 2 is 2.17 Pci/L.

Every 40ml of nanocellulose that was added shows that the increase in radon concentration for each brick. This is because the higher the nanocellulose used, the higher the amount of water used to fabricate the brick since nanocellulose are produced from the sonication of water and cellulose. From the research by (Chami Khazraji & Robert, 2013), cellulose chain and water molecules cause the swelling factor that will increase the volume of cellulose chain due to the liquid uptake that produce bigger porosity and increase in weight.

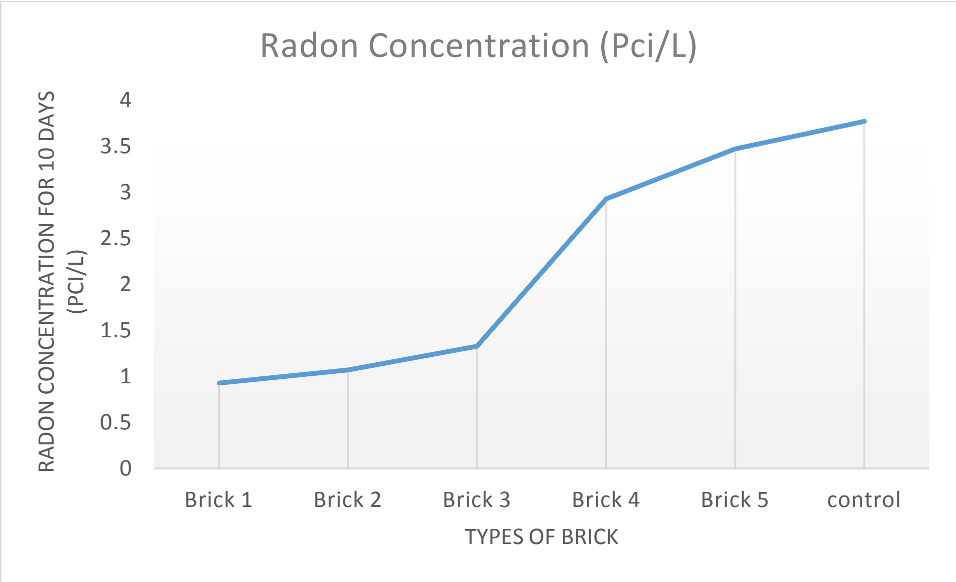

Figure 7: Radon concentration of oil palm composite brick and control brick for 10 consecutive days

Figure 7 shows radon concentration for oil palm nanocellulose composite brick. Brick 1 which use 40ml of nanocellulose as a filler has lower radon concentration reading compare to brick 2, 3, 4, 5 and control brick. From the transmission electron microscope, it can be seen that there are a few network of fibrils which will close the porosity of the composite brick and reduce the percentage of the brick from crack. The differences between commercial brick and brick 1 is almost 2.84Pci/L where this difference is enough to cause lung cancer risk for every 2.7pci/l increase in radon exposure where the lung cancer rises for almost 16 percent per 100 (Bq/m3) indoor air radon (Kurt, 1993).

3.3 compression test

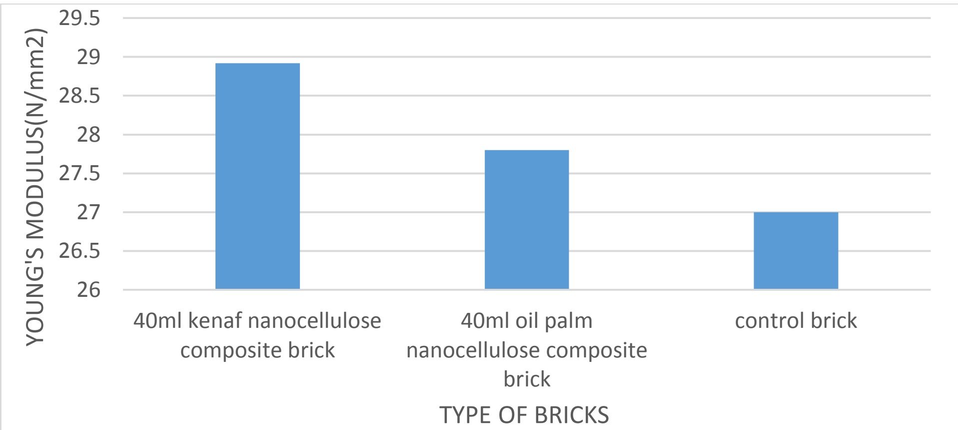

Figure 8: young modulus for 40ml kenaf and oil palm nanocellulose composite brick and control brick after compression testing

According to (Cambridge University Engineering Department, 2003), young modulus for concrete brick mostly range from 27N/mm2 to 38N/mm2 depending on the ratio of the raw material used. From the graph that was obtained from compression test, kenaf nanocellulose composite brick and oil palm nanocellulose composite brick has higher young modulus that was 28.92N/mm2 and 27.8N/mm2 where the higher the young modulus, the stiffer was the material. Compressive strength test was carried out to determine the load that can be bear by the brick where it was an important test to analyze the application for the brick whether it was suitable for the building construction. 40ml kenaf and oil palm nanocellulose composite brick was the optimum amount that can be used in order to produce composite brick which have better properties than control (commercial) brick.

4. CONCLUSION

Incorporating Kenaf and Oil Palm Nanocellulose in Building Materials for Radon Gas Emanation Reduction is one of the way to produce healthy environment and lead to a better life. Transmission electron microscope that was used to analyze the image of the nanocelulose where it shows that there are bonding between each nanocellulose structure which was suitable to be used as a filler in composite brick which will close the composite brick porosity and enhance the composite brick mechanical strength. From the result shown, it can be conclude that 40g of nanocellulose has reach optimum value since less radon emanation was diffuse from the composite brick and can withstand higher load compare to commercial brick.

5. 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

Cambridge University Engineering Department. (2003). Physical Constants in Si Units. https://doi.org/http://www-mdp.eng.cam.ac.uk/web/library/enginfo/cueddatabooks/materials.pdf

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

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 Center of Excellence Geopolymer and Green Technology (CEGeoGTech) School of Materials. *Australian Journal of Basic and Applied Sciences, 7*(5), 315–318.

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

6. ACKNOWLEDGEMENT

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