An Overview of Radon Concentrations and Risk Factors in Elementary School Classrooms: Systematic Literature Review 2010 – 2020

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Abstract

Managing indoor air quality in elementary schools is very important since children are more vulnerable than adults and unique characteristics of schools such as higher level of occupancy than other buildings, containing a variety of pollutant sources, poorly designed ventilation systems, etc. EPA found that more than 70,000 classrooms in the US that in use today have short-term radon levels above 4 pCi/L. Thus, this study aimed to describe radon levels in elementary schools and its associated factors. This is a systematic literature review which collects and evaluates published papers regarding radon concentration assessments in classrooms from various countries between 2010-2020. A Center for Reviews and Dissemination (CRD) research protocol was used. 23 literatures were selected. It shows that radon activity ranged from 26.65 – 480 Bq/m^3, median: 119 Bq/m^3, arithmetic mean: 133.43 ± 95.14Bq/m^3, geometric mean: 109.06 ± 1.87 Bq/m^3. Numerous factors are associated with indoor radon levels, which can be classified into building, building location; and meteorological factors.

Keywords
Radon, Indoor Air Quality, Elementary School, Radon Concentrations, Risk Factors

1. Introduction

Most people spend about 90% of their time indoors such as in homes or public spaces (e.g., schools, workplaces, vehicles, and others) (EPA, 1989). However, people often do not realize that the concentration of indoor air pollutants may be higher than outdoor air, which can pose variety of health risk. According to the National Survey which was conducted by EPA in the United States (1987), indoor air pollutant levels may be two to five times, even 100 times higher than outdoor levels, because pollutants can be accumulated indoors.

Indoor air quality (IAQ) issues must be considered in elementary schools because children tend to be more vulnerable than adults due to the development of tissues and organs in children. Exposure to pollutants in the early stages of a child development can cause permanent damage (WHO, 2018). Schools generally have unique characteristics such as having a high level of occupancy than other public settings such as general offices, having a variety of pollutant sources (e.g., from arts and science activities and school bus exhaust), short break periods, and poorly designed ventilation systems (EPA, 2009).

Radon is a type of indoor air pollutant that can be found in schools. Radon is a radioactive natural gas produced from uranium and thorium decay which can enter the room through building's gaps (CDC, 2018; ATSDR, 2012). (ATSDR, 2012). Radon deposits in the soil, building structure, and type of HVAC (Heating, Ventilation, and Air-Conditioning) system contributes to radon concentrations in the room (EPA, 1993).

Several studies have shown the data of radon concentration in school spaces. According to the National Survey for Radon in Schools which was conducted in the United States by EPA (1993), nearly 19.3% of US elementary schools have at least one room with a short-term radon level above 4 pCi/L. Based on the EPA estimation, the short-term radon levels in over 70,000 classrooms in the US today is more than 4 pCi/L (EPA, 1993).

The risk of lung cancer in elementary school children caused by radon exposure is higher than adults because children have faster breathing rates and different lung size and shape (ATSDR, 2012). EPA stated that Radon is the second leading cause of lung cancer in the United States, with approximately 21.000 deaths per year. DNA in body cells is damaged due to exposure to the radon & radon progeny (e.g. ^{210}PO, ^{214}PO, and ^{214}Pb) which decomposes in the air and is inhaled into the body (American Cancer Society, 2015).

Based on the explanation above, this study aimed to describe exposure to radon concentrations and its associated factors in elementary school classrooms using the 2010-2020 systematic literature review method.

2. Methods

This study is a systematic literature review which collects and evaluates published papers regarding radon concentration assessments in classrooms from various countries that were conducted between 2010-2020. A research protocol from the Center for Reviews and Dissemination (CRD) guidelines was used. Google Scholar and Portal Garuda were used as the international and national studies databases for this study, respectively.

This study used combination of some words using an "AND" and "OR" strategy. The keywords were "Radon, Indoor Air Quality, Indoor, Classrooms, and Elementary School." Literatures that were selected in this study have passed the selection based on the author's inclusion criteria. The inclusion criteria in this study were literatures that were published from 2010-2020, literatures that were written in English and/or Indonesian, full access from Universitas Indonesia library, and answers the research questions. Quality of the selected literatures were appraised by RoBANS (Risk of Bias Assessment Tools for Non-Randomized Study). Each stage carried out in the literature selection process is documented by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyzes).

This study uses a narrative approach that involves collecting, combining, and summarizing each literature's findings in a systematic review. Radon activity measurement results from each literature were also collected to describe the distribution of radon activity.

3. Results

From the Google Scholar and Portal Garuda database, a total of 2.581 literatures were found. The subsequent phase of study was selection based on the year and language, which resulted in 1.429 articles. This selection was narrowed down to 1.274 after abstract and titles screening. All articles went through results screening, which then generated 45 articles. From 45 articles, 15 studies were excluded based on the accessibility and completeness, and 8 studies were eliminated after the selection of objective, method, and results. Twenty two literatures were selected after the selection process according to the inclusion criteria. The author obtained 4 additional literatures from the hand searching process, so the total literature selected was 26 literatures. However, there were 3 literatures that had a high risk of bias according to RoBANS that documented in **Table 1**, so that the total 23 literature were finally selected. The literature selection process is presented in **Figure 1**.

Table 1. Quality Appraisals of Literature Using RoBANS

No.	Author	Selection of Participants	Confounding Variables	Measurement of Exposure	Blinding of Outcome Assessments	Incomplete Outcome Data	Selective Outcome Reporting	Overall
1.	Vaupotič, J. and Kávási, N, 2010	+	?	+	+	+	+	**Low Risk**
2.	Shawar, A. S. S, 2010	+	+	+	+	+	+	**Low Risk**
3.	Labidi et al, 2010	+	+	+	?	+	+	**Low Risk**
4.	Kumar, A, 2011	+	-	?	?	-	-	**High Risk**
5.	Trevisi et al, 2012	+	+	+	+	+	+	**Low Risk**
6.	Poulin, P. et al, 2012	+	+	+	+	+	+	**Low Risk**
7.	Vaupotič, J. et al, 2012	+	?	+	+	-	+	**High Risk**
8.	Lee, J. M. et al, 2013	+	+	+	+	+	+	**Low Risk**
9.	Kosovo, P, 2014	?	?	+	?	-	-	**High Risk**
10.	Damla, N. and Aldemir, K, 2014	+	?	+	+	+	+	**Low Risk**
11.	Bochicchio et al, 2014	+	+	+	+	+	?	**Low Risk**
12.	Stajic, J. M., Milenkovic, B. and Nikezic, D, 2015	+	+	+	+	+	+	**Low Risk**
13.	Zabadi, H. Al, Mallah, K. and G.Saffarini, 2015	+	+	+	+	+	+	**Low Risk**
14.	Sousa, S. I. V. et al, 2015	?	+	+	+	+	+	**Low Risk**
15.	Madureira et al, 2015	+	+	+	+	+	+	**Low Risk**
16.	Branco, P. T. B. S. et al, 2016	+	+	+	+	+	+	**Low Risk**
17.	Kurt, A. et al, 2016	+	+	+	+	+	?	**Low Risk**
18.	Soteriades, E. S., Talias, M. A. and Zissimos, A, 2016	?	+	+	+	+	+	**Low Risk**
19.	Sogut and Avshar, 2016	+	+	+	+	+	+	**Low Risk**
20.	Habtamu, 2016	?	+	+	+	+	+	**Low Risk**
21.	Azara, A. et al, 2018	?	+	+	+	+	+	**Low Risk**
22.	Le, H. V, 2018	?	+	+	+	+	+	**Low Risk**

23.	Obed, R. I., Oyelade, E. A. and Lateef, H. T, 2018	+	+	+	+	+	+	**Low Risk**
24.	Al-Awadi, L. and Khan, A. R, 2019	+	+	+	+	+	+	**Low Risk**
25.	Neri, Giammanco and Leonardi, 2019	**?**	**?**	+	+	+	+	**Low Risk**
26.	Manic et al, 2019	+	+	+	+	+	+	**Low Risk**

Notes: (+) indicates low risk of bias; (?) Indicates unclear risk of bias; (-) Indicates high risk of bias

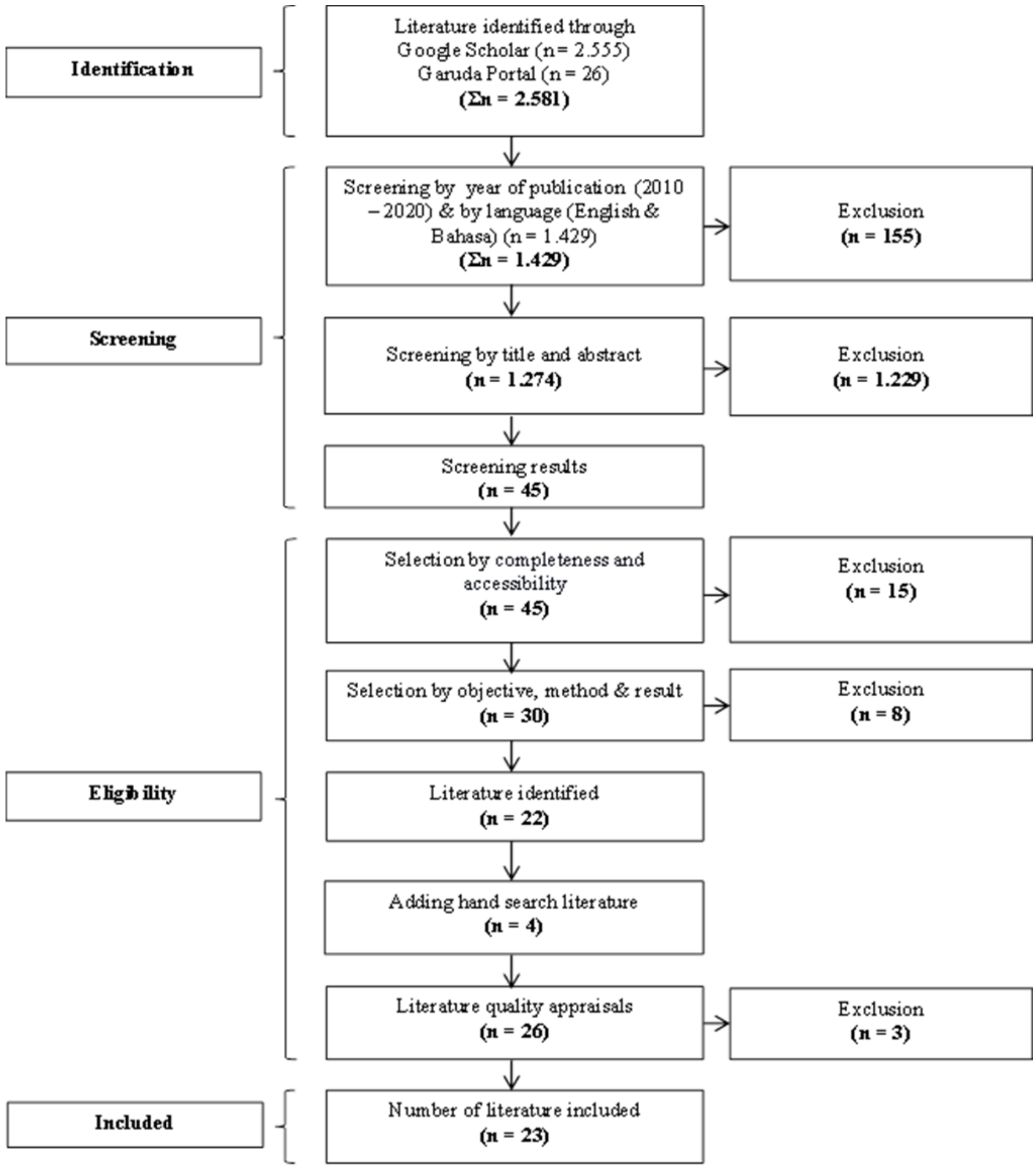

Figure 1. PRISMA Flow Chart Diagram

22 out of 23 selected literatures present the data of radon activity measurements in elementary schools in various countries. Those results are provided in **Table 2.** It was found that radon activity ranged from 26.65 Bq/m^3 - 480 Bq/m^3, median 119 Bq/m^3, arithmetic mean 133.43 Bq/m^3 ± 95.14 Bq/m^3, geometric mean 109.06 Bq/m^3 ± 1.87 Bq/m^3. Data from each country was compared with exposure standard that is applied in that particular region. Israel Guideline, EPA, TAEK (Turkish Atomic Energy Authority), WHO, ICRP, Slovenian Guideline, EURATOM and Canadian Guideline were used for comparison. 6 out of 22 studies found that the exposure of radon exceeded standard level.

Table 2. Data of Radon Activity Measurement from 22 Literatures

Lit. #	Author (s)	Country	Continent	Climate	Sample (n)	Measurement Method	Radon activity (Bq/m^3)	Reference	Standard (Bq/m^3)	Remark
1	Shawar, A. S.S	Israel	Asia	Sub-Tropical	7	Active & Passive	69.9	Israel Guidelines	200	Below Standard
2	Lee, J.M.et al.	Korea	Asia	Sub-Tropical	21	Active	65.04	EPA	148	Below Standard
3	Damla, N. and Aldemir, K	Turkey	Asia	Sub-Tropical	42	Passive	49	TAEK	300	Below Standard
4	Zabadi, H. et al.	Palestine	Asia	Sub-Tropical	20	Passive	40.42	ICRP	200	Below Standard
5	Kurt, A. et al.	Turkey	Asia	Sub-Tropical	25	Passive	125	TAEK	300	Below Standard
6	Sogut and Avshar	Turkey	Asia	Sub-Tropical	12	Passive	55.45	TAEK	300	Below Standard
7	Le, H. V	Vietnam	Asia	Tropical	1	Active	26.65	WHO	100	Below Standard
8	Al-Awadi, L. and Khan, A. R	Kuwait	Asia	Sub-Tropical	5	Passive	66.33	ICRP	200	Below Standard
9	Vaupotic, J. And Kavasi	Slovenia	Europe	Sub-Tropical	35	Passive	480	Slovenian Guidelines	300	Above Standard
10	Trevisi et al.	Italy	Europe	Sub-Tropical	113	Passive	218	ICRP	200	Above Standard
11	Bochicchio et al.	Serbia	Europe	Sub-Tropical	327	Passive	119	ICRP	200	Below Standard
12	Stajic, J. et al.	Serbia	Europe	Sub-Tropical	21	Passive	52.09	ICRP	200	Below Standard
13	Sousa, S. I. V et al.	Portugal	Europe	Sub-Tropical	1	Active	339.26	EURATOM	300	Above Standard
14	Madureira et al.	Portugal	Europe	Sub-Tropical	13	Passive	197	EURATOM	300	Below Standard
15	Branco, P. T. B. S. et al.	Portugal	Europe	Sub-Tropical	8	Active	166	EURATOM	300	Below Standard
16	Soteriades, E. et al.	Cyprus	Europe	Sub-Tropical	1	Passive	429	EURATOM	300	Above Standard
17	Neri, M. et al.	Italy	Europe	Sub-Tropical	1	Active	31	ICRP	200	Below Standard
18	Manic et al.	Serbia	Europe	Sub-Tropical	10	Active	105.7	ICRP	200	Below Standard
19	Labidi et al.	Tunisia	Africa	Tropical	28	Passive	26.9	ICRP	200	Below Standard
20	Habtamu	Ethiopia	Africa	Tropical	2	Active	225.5	ICRP	200	Above Standard
21	Obed, R. et al.	Nigeria	Africa	Tropical	3	Passive	214.08	ICRP	200	Above Standard
22	Poulin, P, et al.	Canada	America	Sub-Tropical	65	Passive	56	Canadian Guidelines	200	Below Standard

Table 3. Factors Affecting Indoor Radon Concentration

Author(s)	**Factors Affecting Indoor Radon Concentration/Activities**																			
	Building cracks	**Floor level**	**Building age**	**Ventilation**	**Geological location**	**Building construction material**	**Radioactivity in the soil**	**Area of the building**	**Soil composition**	**Indoor materials**	**Season**	**Indoor heating**	**Water resources**	**Temperature**	**Pressure within the building**	**Room density**	**Time**	**Permeability & soil moisture**	**Radium substancein the soil**	**Meteorological conditions**
Shawar, A. S.S	✓	✓																		
Labidi et al.		✓																		
Trevisi et al.		✓	✓																	
Poulin, P, et al.				✓																
Lee, J.M.et al.	✓		✓	✓	✓															
Damla, N. and Aldemir, K		✓		✓	✓	✓	✓													
Bochicchio et al.		✓			✓															
Zabadi, H. et al.	✓	✓	✓		✓	✓														
Sousa, S. I. V. et al.	✓			✓																
Madureira et al.		✓	✓					✓												
Branco, P. T. B. S. et al.	✓	✓	✓						✓											
Kurt, A. et al.		✓								✓										
Sogut and Avshar	✓	✓	✓	✓					✓		✓	✓	✓	✓	✓					
Habtamu				✓												✓				
Azara, A. et al.		✓		✓		✓									✓	✓				
Le, H. V	✓			✓		✓									✓		✓			
Neri, M. et al.				✓	✓	✓					✓									
Manic et al.				✓		✓						✓						✓	✓	✓
Total	**7**	**11**	**6**	**10**	**5**	**6**	**1**	**1**	**2**	**1**	**2**	**2**	**1**	**1**	**3**	**2**	**1**	**1**	**1**	**1**

Based on **Table 3**, it was found that there are at least 20 factors that are associated with radon concentrations in elementary school classrooms. These factors include cracks in the building's wall (7/18), floor level (11/18), building age (6/18), ventilation (10/18), geological location (5/18), building materials (6/18), radioactivity in the ground (1/18), the area of the building (1/18), soil composition (2/18), indoor material (1/18), seasons (2/18), indoor heating (2/18), water sources (1/18), temperature (1/18), indoor pressure (3/18), room density (2/18), time (1/18), permeability and soil moisture (1/18), radium substance in the soil (1/18), and meteorological conditions (1/18).

4. Discussion

4.1 Overview of Radon Concentration in Elementary Schools

Twenty-two literatures were selected for this study. It was found that the radon activites measured from 22 schools ranged from 26.65 Bq/m^3 - 480 Bq/m^3, median 119 Bq/m^3, arithmetic mean 133.43 Bq/m^3 ± 95.14 Bq/m^3, geometric mean 109.06 Bq/m^3 ± 1.87 Bq/m^3. The average value used to describe the overall measurement results is geometric mean (109.06 Bq/m^3). The geometric mean is not influenced by extreme values and has a small difference in data variation, as proven by the standard deviation value of 1.87 Bq/m^3. In comparison with several indoor radon standards from various institutions, the mean value (109.06 Bq/m^3) exceeds the WHO's standard (100 Bq/m^3). However, the average value is still below the standard recommended by EPA (148 Bq/m^3), ICRP (200 Bq/m^3), and IAEA (300 Bq/m^3).

Furthermore, radon concentrations from each literature are also compared with the standards that is imposed in each country. From 22 literatures, six studies found the radon activities exceeded the related standard. Those six studies were conducted at Ethiopia (225.5 Bq/m^3), Nigeria (214.08 Bq/m^3), Slovenia (480 Bq/m^3), Portugal (339.26 Bq/m^3), Cyprus (429 Bq/m^3), and Italy (218 Bq/m^3).

In this study, although the number of studies is still limited, we found that the radon exposure level in Europe and Africa's were higher than in Asia and America area. The relationship between radon concentrations and continental areas can be explained based on the geological conditions related to the soil's structure and composition of the region. A research from Otton (1992) showed that the soil composition of an area containing high uranium levels could increase radon exposure in that area. In Europe, uranium deposits can be found in several countries, such as Russia with 2.983 tons, Ukraine with 801 tons in 2019 as well as in Brazil, France, Germany, and Rome. In Africa, areas with high level of uranium can be found in some countries such as Namibia (5.476 tons), Nigeria (2.983 tons), South Africa (346 tons in 2019), and Malawi (369 tons in 2014) (World Nuclear Association, 2020). Zielinski, J (2014) also found the evidence of the high radon exposure in Europe and Africa, which states that the maximum value of radon exposure in Europe is 84.000 Bq/m^3, and in Africa is 15,400 Bq/m^3. Those two values are far higher compared to the radon exposure in Asia (5.000 Bq/m^3), South America (346 Bq/m^3), North America (1.720 Bq/m^3), and Australia (420 Bq/m^3).

If we compare the radon activity in sub-tropical and tropical countries, school at sub-tropical countries have higher radon concentrations due to the winter season. The research from Szabó et al. (2013) found that the radon concentration in the soil during winter can be 2.5 higher (median 7.0 kBq/m^3) than summer (2.8 kBq/m^3). High levels of radon gas in the soil during winter can contribute to high level of indoor radon concentration. Moreover, the building style in sub-tropical countries which is more tightly closed and the windows design covered with three layers glass to maintain room temperature in winter, can accumulates indoor radon concentration (BATAN, no date).

4.2 Overview of Factors Affecting Radon Concentration in Elementary Schools

Risk factors associated with radon exposure at schools can be grouped into building, building location and meteorological factors as follow.

4.2.1 Building Factors

The building factors consist of building cracks, indoor pressure, building age, building construction materials, water resources, indoor materials, indoor heating, ventilation, building area, and room density. Several studies suggest that relatively higher radon concentrations are found in classrooms with cracks, either in the wall area or on the floor of the building (Shawar, A. S.S, 2010; Lee, J.M.et al., 2013; Zabadi, H. et al., 2015; Sousa, S. I. V. et al*.,* 2015*;* Branco, P. T. B. S. et al*.,* 2016; and Sogut and Avshar, 2016). This statement was obtained from each researcher's identification results in a room or school building with a higher radon concentration than other buildings. Cracks in buildings are radon's pathways into the room because radon can diffuse and move up into the air through these gaps (ATSRD, 2012; and Zabadi, H. et al., 2015). Cracks in buildings can also be triggered by increased pressure in the building (Lee, J. M et al., 2013; and Sogut and Avshar, 2016).

The building age can affect the radon concentration in the room. Based on the research from Lee, J.M et al. (2013), Zabadi, H. et al. (2015), and Madureira et al. (2015), older buildings usually have more cracks on the foundation, so it increases the radon concentration in the room. This possibility can also be affected by differences in building materials and low paint quality in the old building than the new building. Research from Trevisi et al. (2012), Zabadi, H. et al. (2015), and Branco, PTBS et al. (2016) also showed a significant difference between the building ages with radon concentrations measured from each school ($p<0.05$).

The building materials used to build schools can affect indoor radon concentrations. Based on the research from Azara, A. et al. (2018) showed that there is a significant difference between each school's radon concentration and the type of building material ($p<0.021$). School building materials can affect radon concentrations in the room due to the decay of radium produces radon, and these radioactive elements can be found in building materials (Damla, N. and Aldemir, K, 2014). Building materials can contain different radium depending on the type (Zabadi, H. et al., 2015; Neri, M. et al., 2019; and Manic et al., 2019). Le, H. V (2018) also showed that radon concentrations were relatively high in rooms with gypsum building materials.

Indoor resources, such as water resources and materials can also affect radon concentrations. Water resources containing high radium levels can increase the indoor radon concentration (Sogut and Avshar, 2016). Typically, the radon concentration in the groundwater is higher than the surface water because groundwater or well water is in direct contact with rocks and soil that contains more derivative of uranium and thorium chains (ATSDR, 2012). Indoor materials such as classroom furniture containing high radium can also increase indoor radon concentrations. Research from Kurt A. et al. (2016) showed that radon concentrations in classrooms that had granite table furniture, which naturally contains radioactive elements, were found to be higher than other classrooms.

Furthermore, ventilation can affect indoor radon concentrations. Poulin, P, et al. (2012) showed a significant relationship between the use of a ventilation system and indoor radon concentration ($p=0.038$). Based on several studies, radon was found to be higher in classrooms that do not use a ventilation system or use an inadequate ventilation system, so that radon can accumulate inside the room (Poulin, P et al., 2012; Lee, J.M et al., 2013; Damla, N. and Aldemir, K, 2014; Sogut and Avshar, 2016; Habtamu, 2016; Neri, M. et al., 2019; and Manic et al., 2019). Azara, A. et al. (2018) also showed a decrease in radon concentrations after increasing the school room's ventilation system. Thus, the ventilation system must be used in every room, especially on the building's ground floor, which is in direct contact with the ground with a primary source of radon presence. The effectiveness of the ventilation system in each room also needs further attention. This effectiveness can be affected by the room density (Habtamu, 2016) and building area (Madureira et al., 2015). Then, the ventilation system must still be used in every room, even though room heater has been installed(Sogut and Avshar, 2016). If possible, the classroom can use a type of room heater, which can also be a mechanical ventilation system.

4.2.2 Building Location Factors

Building location factors include floor level, geological location, radioactivity in the soil, radium substance in the soil, soil composition, and permeability and moisture in the soil. The floor level of a room can affect the radon concentration in the room. Based on the research from Zabadi, H. et al. (2015) and Branco, PTBS et al. (2016), there is a significant difference between floor level and radon concentration in the room ($p<0.05$). Several studies also stated a negative correlation between radon concentration and floor level (Zabadi, H. et al., 2015; Azara, A. et al., 2018). However, this is a subjective statement from the researcher by looking at the distribution of radon concentrations on each floor without performing statistical analysis. The negative correlation is the decrease in radon concentration as the floor level increases. Based on the measurement and analysis data obtained from the literature review, it can be concluded that the radon concentration was found to be higher on the lower floor (ground floor) than the upper floor.

Geological factors can affect each elementary school's geological location, affecting radiation exposure in the room. In the research of Lee, J.M.et al (2013), high concentrations of radon were found in elementary schools, which are 4.5 meters from the mountain with limestone granite. Neri, M. et al. (2019) showed that high radon concentrations were found in elementary schools closer to the earth's active fault area (40 - 150 m). Bochicchio et al. (2014) stated that radon concentrations were found to be higher in rural schools (96 Bq/m^3) than in urban area schools (58 Bq/m^3). This is because schools in rural areas are generally closer to mountainous area, which increase the soil layer's risk of radium substance. Thus, the location of the school can affect the concentration of radon in the room. The influence of the geological location is related to the composition of the soil at that location. The research of Branco, P. T. B. S. et al. (2016) showed that there was a significant difference ($P <0.05$) between the soil composition of school buildings and the concentration of radon. This study found that the soil's composition with magmatic rocks was higher than that of other rocks.

The radioactivity level of each type of rock can vary, depending on the uranium composition. In the research by Damla, N., and Aldemir, K (2014), the level of radioactivity in the soil can affect radon concentration in the room. However, a study from Manic et al. (2019) stated the opposite, that the relationship between the level of radioactivity in the soil and the indoor radon concentration showed no significant difference ($p = 0.149$) and had a negative correlation ($r = -0.196$). The negative correlation in this study can be explained by the fact that radon's concentration in the room can be influenced by other things such as permeability and soil moisture, which are essential factors in releasing radon from the soil into the air (Manic et al., 2019).

4.2.3 Meteorological Factors

Based on the systematic review results, it was found that three meteorological parameters can affect radon concentrations, such as season, temperature, and time (morning and evening). Research from 22 literature shows that radon concentrations that exceed the standard are found more in countries with sub-tropical climates than in tropical countries. The measurement results of radon concentration during winter are relatively higher than in other seasons. During winter, classrooms will be closed to maintain room temperature, but the ventilation system in these classrooms is not adequate to increase radon concentrations (Sogut and Avshar, 2016).

The research from Sogut and Avshar (2016) also stated that room temperature can affect radon concentrations. The temperature factor may be related to the time factor. The time factor is the division of periods in one day, which are the morning and evening periods. Based on the research by Le, H. V (2018), overall radon concentrations continue to decline from the peak levels in the morning to lower levels in the afternoon. This behavior can occur due to the natural effects from the sun. When the sun goes down, the indoor temperature is higher than outdoors, which cause the pressure inside the room to increase. When the pressure increases, radon can enter the room through the building's cracks. Thus, meteorological factors can participate in affecting the concentration of radon in the room.

5. Conclusion

Based on the literature from 2010 - 2020, the radon activities in elementary schools from 22 studies ranged from 26.65 – 480 Bq/m^3, median 119 Bq/m^3, arithmetic mean 133.43 ± 95.14 Bq/m^3, geometric mean 109.06 ± 1.87 Bq/m^3. The geometric mean value (109.06 Bq/m^3) of radon exceeds the WHO standard (100 Bq/m^3). However, it is still below the EPA (148 Bq/m^3), ICRP (200 Bq/m^3), and IAEA (300 Bq/m3) standards. The results showed that building factors (10/20), building location (6/20), and meteorology (4/20) could affect the concentration of radon in the room. Building factors include building cracks, building age, ventilation, building construction materials, building area, room density, indoor materials, room heating, water resources, and indoor pressure. Building location factors include floor level, geological location, radioactivity in the soil, soil composition, soil permeability and moisture, and radium substance. Meteorological factors include season, temperature, meteorological conditions, and time. Based on the systematic literature review results, this study suggests that the factors influencing the increase in radon concentrations in the room can be controlled. However, more comprehensive studies on radon exposure at school are required.

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