

## **Environmental Health Condition and Community Healthy Behavior in the Radon Radiation Exposure Area**

Bintarsih Sekarningrum\*  
Faculty of Social and Political Sciences Padjadjaran  
University, Indonesia

Suhardjo Sitam  
Faculty of Dentistry Padjadjaran University, Indonesia

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### **ABSTRACT**

Radon is a natural radioactive gas, which is colorless, odorless, and tasteless. Radon rises to the earth's surface through a natural decaying process of uranium found in all environments. Exposure to radon has an effect on health. The research approach is qualitative and supported by a certified air and water test sampling method. The population is the community located in an area exposed to radon radiation with low, normal, or high categories. The research result corroborates that the water coming from springs and wells remains safe for use, as it remains below the standard of the radon contamination level for drinking water. The radon concentration in the spring is higher than in the well because the soil's geological structure is limestone rock. The air conditions inside and outside the room remain safe for the people because it is below the standard of radon contamination level. Lime dust is detected as a limestone mining impact, which is prone to noise and landslides. Moreover, the community's poor health behavior could affect their health. In conclusion, the studied area is categorized as low radon exposure. However, if community health behavior remains poor, radon radiation exposure will affect the community's health.

Keywords: Radiation Exposure, Radon, Environmental Health, Health Behavior

### **1. INTRODUCTION**

Radon is a natural radioactive, colorless, odorless, and tasteless gas that can only be detected using specific equipment. Radon is generated from the radioactive decay of radium, whereas radium is generated from the radioactive decay of uranium. Uranium is the first element in a long series of decay, which produces radium and radon. Uranium is called the parent element, whereas radium and radon are called daughters. Uranium occurs in a natural environment, especially in soil and rocks. Through the uranium decay, radon presented in the soil can rise to the earth's surfaces either in the air, soil, water, or indoors. The radon in the air and water, especially in the river water, is low because it can quickly vanish in the atmosphere. By contrast, the presence of radon indoors, especially in an enclosed or unventilated space, will have high concentration and will be dangerous for human health.

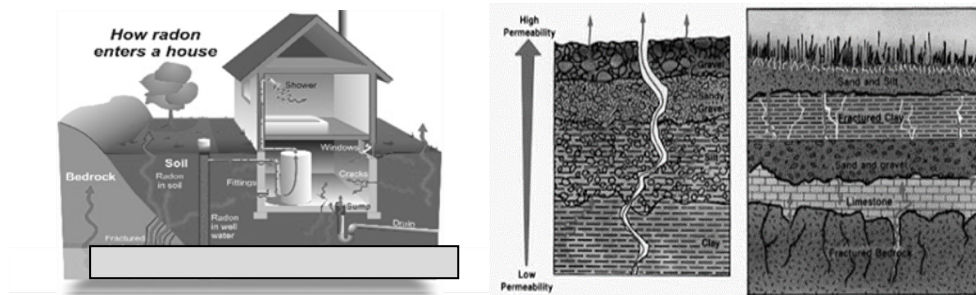


Figure1. Process of Radon Rising to the Earth's Surface

Radon enters houses through the water system. In Indonesia, directly using groundwater for daily needs is a common practice, such as bathing, washing of clothes or household appliances, cooking, and drinking. The use of radon-contaminated water, especially in enclosed spaces, can increase the radon level. Exposure to this gas can affect health. Moreover, the condition, shape, and material type of the building can affect the presence and concentration of radon. A building with closed air circulation provides a higher radon level than a house with open-air circulation. These facts have been examined by several studies.

Musriadi S. Lamanda, Syamsir Dewang, and Bualkar Abdullah (2014) on their “Analysis of Radon and Thoron Concentration on Makassar” propose that radon in a few settlements exceeds the limits set by the International Commission on Radiological Protection (ICRP). The factors affecting this matter include air circulation, topography, geological structure, and the building material used (cited from URL: <http://repository.unhas.ac.id/handle/123456789/11045>, 26 January 2018). Sutarman and Wahyudi (2003) present in their writing entitled “Radon Concentration in Outdoors and Indoors around the Flames in Oil Mineral Cites of Cepu, Cirebon and Prabumulih” that the radon concentration outdoors is higher than that recommended by the International Atomic Energy Agency (IAEP). Furthermore, a study entitled “Determination of Radon in Dwelling in Aceh” (Wahyudi, Dadong Iskandar, Rini Safitri, and Kusdiana, 2017) suggests that the concentration level of radon indoors is determined by the geological structure of the area, building quality, and air circulation.

Radon exposure causes certain health issues to people through inhalation, ingestion, dermal contact, and other exposures. The health effects of radon can be death, systemic disorder; effects on the immune system, nervous system, growth and development, and reproduction system; genotoxicity; and cancer (US EPA, 1990). A few studies corroborate that radon affects health. “The Study of Environmental Radioactivity Level and Environmental Epidemiology on Tin Mining Area of Bangka Island, Bangka Belitung Island Province” (Bambang Wahyudi, 2003) affirms that radon concentration on the residential area, especially in bedrooms, is higher than the concentration in the living rooms. Radon radiation can cause health problems, such as asthma and lung cancer. However, a study entitled “Health Effect of Exposure to Low Dose of Radiation” (Zubaedah Alatas, 2003) presents that the metabolism system of the human body can tolerate the radiation and radioactivity exposure from nature. Unfortunately, certain industries, which utilize the natural resources in their chosen environments, can increase the natural radionuclides (isotope from radioactive compounds can naturally emit radiation). Moreover, it can approach the limit, which can potentially cause health issues

for humans and the environment. Sri Widayati (2001) in her study entitled “Radon in Our Life” also validates that radon can bring negative health effects, especially for lungs.

Previous research describes radon as a colorless and odorless gas, which can seep from the soil and diffuse in the air. Radon is nearly everywhere from groundwater, rocks, soils around the residential area, and even indoors. It will accumulate in the air, especially in rooms with poor ventilations. Consequently, it will cause several health effects, especially to the respiration system.

Considering the dangerous effects of radon to health, this research investigates the environmental health and public’s health behavior on a radon natural ionizing radiation exposure area in Padalarang Regency, particularly in Gunung Masigit Village. Prior research entitled “Social-Economy Condition of the People in Radon Natural Ionizing Radiation Exposure Area in Padalarang” (Bintarsih, 2015) asserts that most of the people in this area have low levels of education, thereby limiting their choice of work and causing low income. The effects of this low income to the people include limited access to job security, nutritious food, and clean environment and residents. Such restriction will further create an impact to health. For instance, people are frequently suffering from upper respiratory tract infection (URI). URI is a highly recurring health problem for people living near limestone quarries, which regularly create thick smoke and ash as well as noise.

The current research discusses the environmental health and people’s health behavior at the radon radiation exposure area in Padalarang. This research is different from the previous studies in that the former relates the environmental condition with the people’s health behavior. Performing this research is necessary given that radon will rise to the earth’s surface owing to geological factors and human behavior. Therefore, human behavior, particularly the health behavior, is very important in determining radon’s concentration level in an area.

## 2. METHODOLOGY

The research follows a quantitative approach to present the phenomena concerning the health condition of the environment and the health behavior of communities in the area exposed to radon radiation. This study also employs the sampling method to obtain reliable specimens for water and air quality testing certified by the National Nuclear Energy Agency (BATAN).

The population is the community living in areas with low, normal, or high radon radiation exposure. The sample of the research is subjected to a purposive sampling technique to acquire further representative data. The criteria for consideration include the (1) local residents; (2) willingness to join as a research participant; (3) adult age according to the 2013 WHO; and (4) living in the test area.

The data collection technique employed in the research includes (1) water and air quality test technique—to test water and air condition in radon radiation exposure areas (low, normal, or high) inside and outside the home; (2) in-depth interview technique—to explore data on the health behavior of community related to environmental health, including behavior toward sanitation (toilet), drinking water supply, housing, garbage disposal, and solid waste disposal; (3) observation technique—to observe directly the environment condition in radon radiation exposure (low, normal, and high), including water and air condition as well as residential condition (e.g., ventilation and lighting); and (4) documentation study—to analyze radon-related documents and literature.

Direct measurement with RAD7 Electronic Radon Detector SOP 031.003/KN 05 02/KMR 2.1 is the analytical technique utilized for the measurement result of well water, river water, and air samples. Moreover, descriptive analysis was employed to the data gathered from the interviews to determine its relation to people's health behavior in the area by considering the internal coherence degree and relation to factual events.

The research was conducted at Gunung Masigit Village, Padalarang. The location is determined by considering that Gunung Masigit Village belongs to one of the areas mapped with low, normal, and high radon levels. In addition, Gunung Masigit Village is one of limestone mining areas with 81 limestone mining companies.

### **3. RESEARCH FINDINGS AND DISCUSSION**

#### **3.1. General Description of the Research Site**

The research is conducted in Gunung Masigit Village, which has an area of 1,053 ha; it is divided into 547,100 ha of residential areas, 141,200 ha of cultivation areas, 100,600 ha of plantation areas, 92,800 ha of yards, 31,700 ha of office areas, and 136,000 ha of other public infrastructure areas. The population of this area as of 2017 is 15,694 people: 7,945 are male and 7,749 are female, which are spread into 4,867 householders. Most of the people are Junior High School graduates (2,812 people), and only a few of the people (approximately 62 people) continue their study until the university level.

This area has mining potential, such as limestone and sand. The ownership and management of 81 businesses for these mining goods, especially the limestone, are characterized as a private ownership, namely, *Comanditaire Venotschap* (CV) and Private Company/Limited Liability company. The ownership and management of the sand are handled by private ownership and CV. Furthermore, the marketing of these goods is through direct selling, either through retailers or sold to the companies.

The clean water, which comes from 553 dug wells is used by 1,287 households. Other sources for clean water are six springs used by 1,511 households and five pump wells used by 736 households. For the people with no water sources at their houses, they will use 30 public facilities around this region. Unfortunately, not all households have their private toilets at their houses; only 2,618 households have their own toilets.

In relation to the air quality of Gunung Masigit Village, this region is indicated to suffer air pollution from limestone factories and stone refining. Thus, it has a mid-category effect on health in nine regions. In addition, other pollutions occurring in 19 regions come from vehicles in the form of air pollution and dust, which are categorized as medium. Noises from vehicles and limestone factories range from light to medium noises. These noises negatively affect the people's health, including health issues, noisiness, and discomfort.

On the basis of those facts, people generally encounter respiratory problems. In 2017, 27 people suffered from URI, and 27 people suffered from asthma. These diseases are linked to the air pollution created by the limestone factories and stone mining. The latter triggers health problems, especially related to the respiratory system.

#### **3.2. Result of Radon Sampling Measurement in Air, River Water, and Well Water**

Radon is a radioactive, odorless, colorless, and tasteless gas. It is constantly being released to the surface and can enter the houses through the pores of soil, water, and the material of the buildings. Given that radon in air is the source of radiation, a need arises

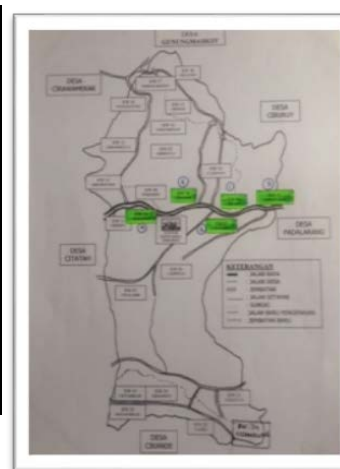
to create a protection from this gas. According to Article 22 Verse (3) from the Law of Republic of Indonesia No. 23 of 1992 concerning the Environmental Health, a radiation protection linked to environmental health is needed.

Given the radiation protection, especially radon radiation for environmental health, the measurements of radon in air (indoors and outdoors) and water sources (rivers and spring water) are performed. The sample measurements are conducted in five regions, which are determined on the basis of their proximity to limestone mining (outdoors) and high-density residential areas (indoors). The result remains below the quality standard of radon contamination level (<4 Bq/m<sup>3</sup>) for indoors and outdoors. The radon contamination level remains safe for the people in these regions.

Table 1. Result of Radon Sampling Indoors and Outdoors

No.	Location	Position (GPS)	Radioactivity concentration (Bq/m <sup>3</sup> )
1	Region 1	S 06°-49,841 <sup>1</sup> E 107°-27,007 <sup>1</sup>	<4,00
2	Region 2	S 06°-50,024 <sup>1</sup> E 107°-26,493 <sup>1</sup>	<4,00
3	Region 3	S 06°-49,894 <sup>1</sup> E 107°-27,067 <sup>1</sup>	<4,00
4	Region 4	S 06°-50,034 <sup>1</sup> E 107°-26,092 <sup>1</sup>	<4,00
5	Region 5	S 06°-49,686 <sup>1</sup> E 107°-26,520 <sup>1</sup>	<4,00

**Notes:** Quality standard of radon-222 contamination in air and indoors: 300 Bq/m<sup>3</sup> (Source: Result of sample measurement, 2017)



Apart from its presence on the surface of the Earth, radon can enter the house through the water system. In Indonesia, people frequently use groundwater for their daily needs, such as bathing, washing clothes/dishes, and drinking and for the lavatories. Radon can enter the rooms if we use this groundwater.

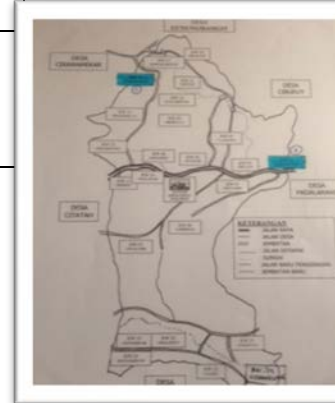
Protection against radiation for environmental health can also be examined through the water, either the river water or groundwater used daily by the people. In this research, the sample measurement of water is performed in two regions, namely, upstream and downstream. The water in the upstream and downstream is affirmed to remain under the quality standard of the radon contamination level. Particularly, the river water remains safe for people's consumption.

Table 2. Result of Radon Sample Measurement in River Water

No.	Location	Position (GPS)	Radioactivity concentration (Bq/m <sup>3</sup> )
1	Region 1	S 06°-48,477 <sup>1</sup> E 107°-26,078 <sup>1</sup>	<4,00
2	Region 2	S 06°-49,876 <sup>1</sup> E 107°-27,072 <sup>1</sup>	<4,00

**Notes:** Quality standard of the radon-222 contamination level in drinking water (EPA's Contamination): 11,100 Bq/m<sup>3</sup>.

(Source: Result of sample measurement, 2017)

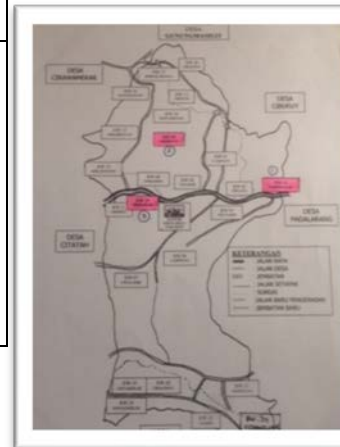


Henceforth, groundwater becomes the main water source of the people's daily requirements in compliance with their substantial need. The sample measurements of groundwater are conducted in several regions, which have springs and wells. Water from the springs and wells is affirmed to remain under the quality standard of the radon contamination level in drinking water (11,100 Bq/m<sup>3</sup>). Thus, water from springs and wells remains safe for use to satisfy the people's daily needs.

Table 3. Result of Radon Sample Measurement in Springs and Wells

No.	Location	Position (GPS)	Sample type	Radioactivity concentration (Bq/m <sup>3</sup> )
1	Region 1	S 06°-49,809 <sup>1</sup> E 107°-27,014 <sup>1</sup>	Spring water	750 ± 322
2	Region 2	S 06°-49,622 <sup>1</sup> E 107°-26,320 <sup>1</sup>	Well water	1,140 ± 393
3	Region 3	S 06°-50,034 <sup>1</sup> E 107°-26,092 <sup>1</sup>	Spring water	2,030 ± 509

**Notes:** Quality standard of the radon-222 contamination level in water (EPA's Contamination) is 11,100 Bq/m<sup>3</sup>  
(Source: Result of sample measurement, 2017)



This sample measurement result of water from springs and wells essentially finds that the water from the springs has a higher concentration than the one from wells. The radon concentration of well water is between undetectable, from <4 Bq/m<sup>3</sup> to 1,140 Bq/m<sup>3</sup>. Radon concentration in spring water is between undetectable, from <4 Bq/m<sup>3</sup> to 2,030 Bq/m<sup>3</sup>. Thus, radon concentration varies in different water sources; some are low and some are high. This phenomenon happens because the geological structures of the soil in each region are different from one another. The radon concentration level in springs is fairly high because the surrounding area consists of rocks, particularly limestones.

### 3.3. Environmental Health Condition

#### 3.3.1. Water Condition

The Law of Republic of Indonesia No. 32 of 1992 states that the scope of environmental health includes water and air sanitation; management of liquid waste, solid waste and gas; protection of waste; and noise protection. In connection with this statement, the health behavior of society is determined by the environment, such as water condition, residential neighborhood condition, and house condition.

Nonetheless, water plays an important role in human life for drinking, cooking, bathing, or washing. Among those roles, water for drinking is the most important. Thus, clean potable water should be clear or not cloudy. It should also be colorless or pellucid, tasteless, odorless, and without sediments.

In the target area of the research, the water usually comes from three different sources, namely, springs, dug wells, and pump wells. Spring water is the water from groundwater, which naturally flows or comes to the surface. If this water has not been contaminated, it only requires boiling before it becomes potable. By contrast, well water is shallow groundwater coming to the surface through the digging or drilling process. The depth of this groundwater from the surface is different from one place to another. The depth of the wells is approximately 5 to 15 m deep from the surface. The cleanliness of well water is uncertain given that contamination occurs from the ground. Thus, boiling before drinking is a must. Water from pump well, especially the deep pump well, has previously met the health requirement. Unfortunately, using the pump well in Gunung Masigit Village is very costly because the soil is constructed from limestone. Thus, only a few families can afford the pump well water.

On the basis of the interviews and observations in the residential areas of 36 households, the water condition in 33 households is mostly clear, while 35 households have pellucid water. Furthermore, the water in 36 households is tasteless and odorless. However, in certain regions, particularly in 12 households, the water has sediments in it. Nonetheless, it is very common in a limestone mountain area. Although the water is clear, pellucid, tasteless, and odorless, it still contains limestone sediments.

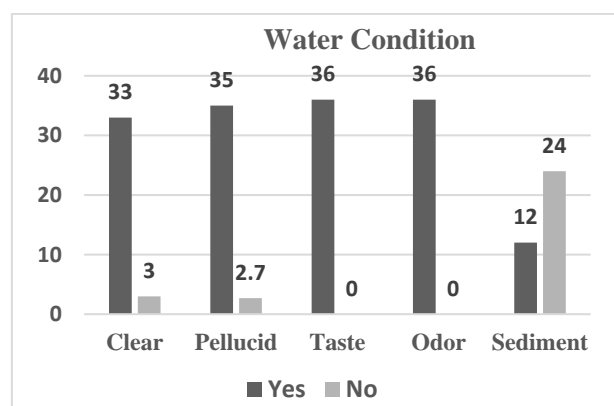


Chart 1. Water Condition  
(Source: Research result, 2017)

#### 3.3.2. Residential Neighborhood Condition

Location should be considered when building a house. In reference to the Decree of Minister of Health No. 829/Menkes/SK/VII/1999 on the requirement for Residential Health and Residential Neighborhood Health, the residential area should not be located in disaster-prone areas, such as those prone to landslides, former mines, or an accident-prone area. On the basis of the interviews and observations of 36 households, most of their houses, particularly in 26 family houses, were built in the area prone to landslides. This vulnerability to landslides is caused by the limestone quarries. Moreover, four households even built their houses on former mines/quarries, while the other eight households built their houses on an accident-prone area.

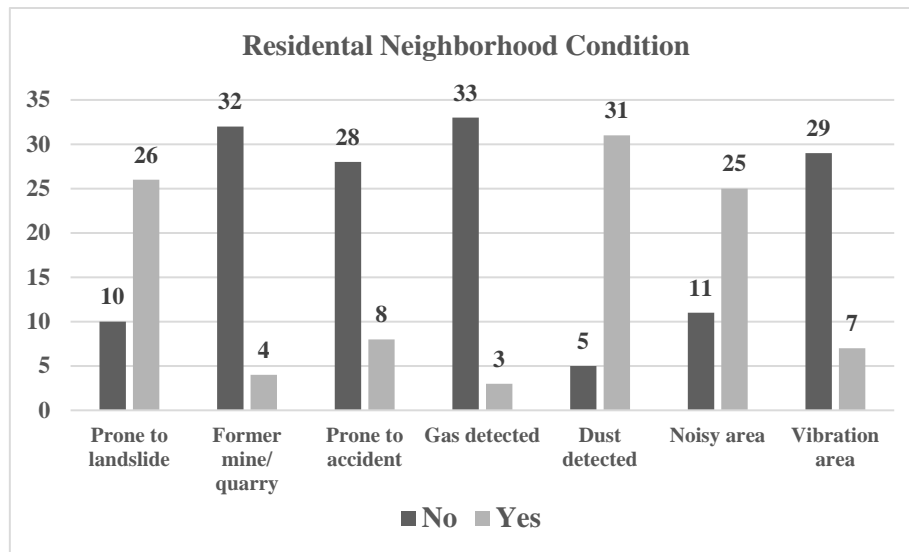


Chart 2. Residential Neighborhood Condition  
(Source: Research result, 2017)

In relation to the air condition, noise, and vibration, a healthy environment should meet several health requirements. The Decree of Minister of Health No. 829/Menkes/SK/VII/1999 declares the following requirements of a healthy environment: (1) any gas should not be detected (especially H<sub>2</sub>S [sulphide] and NH<sub>3</sub> [ammonia]), which can cause certain health problems; (2) dust must have a diameter of less than 10 µg and a maximum diameter of 150 µg/m<sup>3</sup>; and (3) the maximum dust is 350 mm<sup>3</sup>/m<sup>2</sup> a day. The current research has conducted a specific test on air quality, noise, and vibration not on the basis of health requirement but on the observations and interviews. Nonetheless, no gas was detected in nearly all of the observed households (i.e., in 33 households), which can cause a health issue. By contrast, certain gases were detected in the other three households. It can happen because most of the regions are located in an area with limestone quarries. Notably, limestone serves as the economic resources for companies (total of 81 companies), the private and self-owned companies, which manage and manufacture it. With these numbers of companies or ownership, the noise from the processing machines causes noise disturbances to 25 households. Despite the noise disturbance that these machines generate, the latter does not cause vibration disturbance.

### 3.3.3. House Condition



Henceforth, environmental health is focusing not only on the optimum condition or situation of the residential neighborhood but also on the environmental health of the house, namely, house ventilation, air flow and movement space, noise, clean water supply, feces and household waste managements, housing density, and adequate morning sunray. All of these aspects provide positive influences to health.

The studies on 36 households verify that most of them are in poor conditions: 33 households have poor house ventilation, 26 households lack air flow and movement space, 22 households suffer from noise disturbance, all of the households (36 households) have poor clean water supplies, 32 households have poor feces and household waste management, 32 households live in a highly dense house, and 30 households have no adequate morning sunray. These unhealthy house conditions can happen because the houses are located near the limestone quarries.

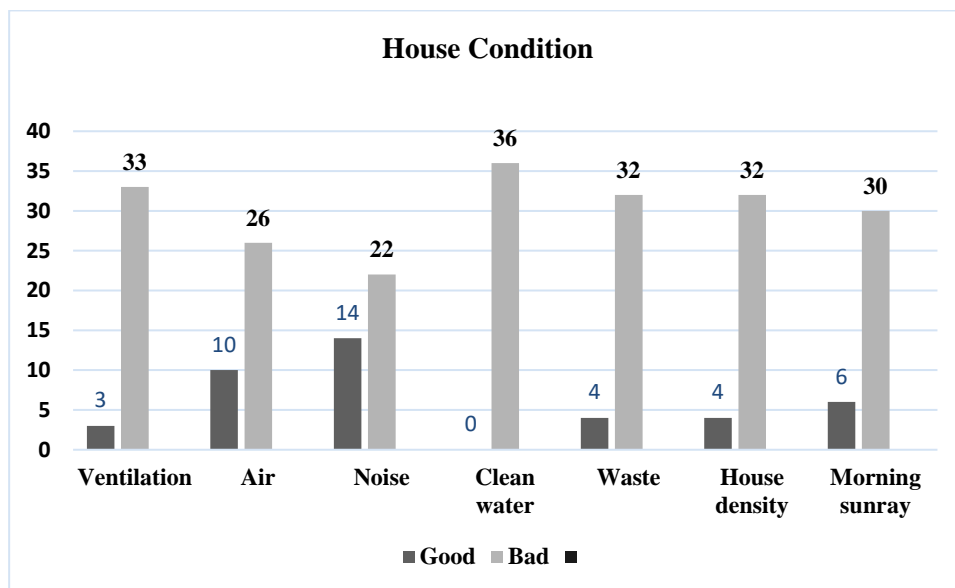


Chart 3. House Condition  
(Source: Research result, 2017)

### 3.4. Health Behavior of the People

Notoatmodjo (2007) proposes that the scope of environmental health in developing countries covers sanitation (toilets), drinking water supplies, housing, and garbage and wastewater disposal. Hence, the study on the behavior of environmental health encloses the behaviors in using water for health purposes; sanitary condition; liquid and solid waste disposal; garbage disposal; and attitudes related to a healthy house, such as the existence of ventilation and light in the house.

The research on people's health behavior related to the behavior in utilizing and using clean water for health purposes confirms that 32 households have shown good behavior in using the clean water. The water from springs or wells is only used for bathing and washing household utensils and clothes. Most of the households choose to buy bottled waters for drinking considering that water from springs and wells contains limestone sediments.

Furthermore, 21 households show good attitudes in maintaining and using toilets because these households have their own toilets as well as cleaning routine of the latter

for two to three times a week. Conversely, 15 households exhibit less health behaviors as the bathroom is not really clean. The bathroom is dark and humid because the floor is made of cement or merely a soil/ground floor. Moreover, a few households do not have their own bathrooms, thereby prompting them to use the public bathrooms located around their residential areas.

With respect to the people’s habit of disposing waste, a total of 32 households who own a private bathroom dispose their solid waste into the septic tank. Unfortunately, for the habit related to garbage disposal, 29 households continue demonstrating poor behavior by burning the garbage in front or behind the house after collecting it. This behavior persists because no operators collect the garbage and send it to the junkyard.

The requirements of a healthy house, including the existence of ventilations and adequate lighting, must be fulfilled. The ventilations serve to control the airflow inside the house, enabling a balance between the indoor air and outdoor air. The lack of ventilation will reduce the amount of oxygen (O<sub>2</sub>) inside the room and increase the amount of carbon dioxide (CO<sub>2</sub>) in the house. In addition, poor ventilations cause damp and humid rooms as the humidity increases. The lack of sunray indoors will trigger the proliferation of diseases. From 36 households, 25 households lack ventilation and light, which cause the houses to become dark and the air to be hot and humid. Moreover, as the houses are located in the slope of a limestone mountain or near limestone quarries, a considerable amount of dust exists indoors. This condition will affect the health of the people, especially to the respiratory system. On the basis of the assessment of the health condition of the people based on 10 Major Diseases in 2014 (one year), URI is the most suffered disease by the people (a total of 2,124 individuals). The latest data of people’s health condition in December 2016 (one month) proved that URI remained the most suffered disease by the people (a total of 26 individuals).

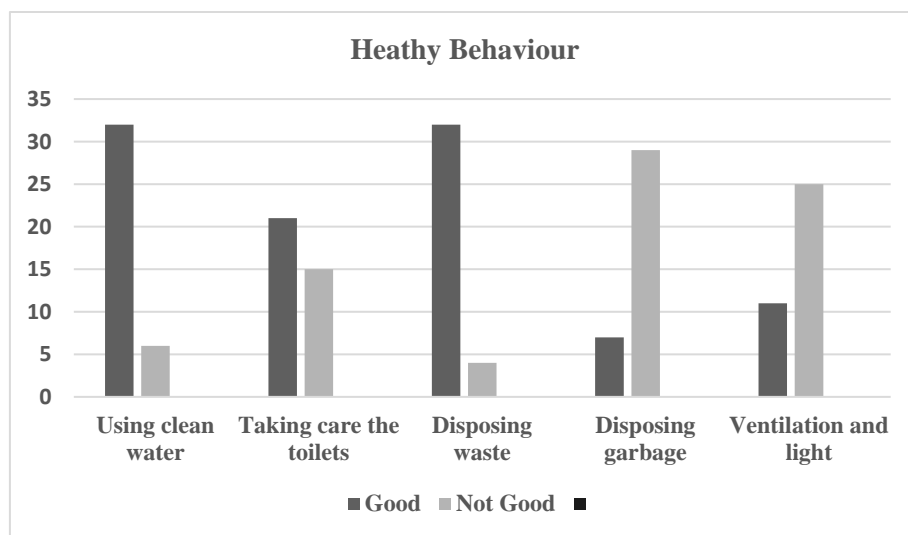


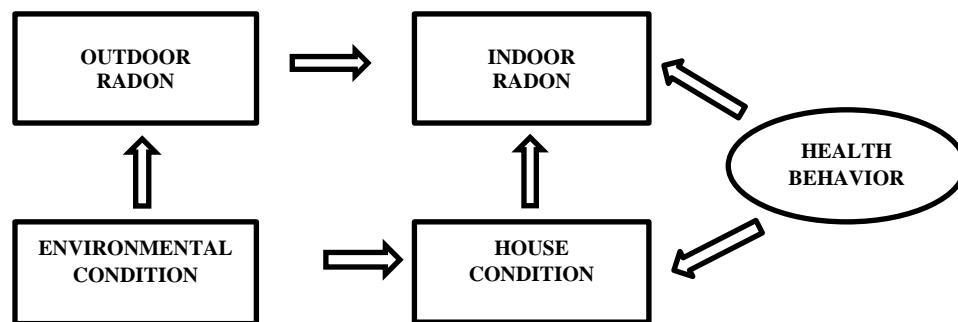
Chart 4. Health Behavior of the People  
(Source: Research result, 2017)

The water condition in the residential area on radon radiation exposure regions, whether from springs or wells, remains safe for consumption because it remains under the quality standard of the radon contamination level for drinking water (11,100 Bq/m<sup>3</sup>). However, the radon concentration in springs is higher than in wells because of its

geological structure, which is constructed from rocks, especially limestone. It causes the water in those regions to contain limestone sediments although the water seems clear, pellucid, tasteless, and odorless. The indoor and outdoor air conditions remain safe for the people in those regions because the concentration remains under the quality standard of the radon contamination level ( $<4 \text{ Bq/m}^3$ ). Nevertheless, limestone dust is detected in the indoor and outdoor air. The dust found indoors and outdoors is the effect of limestone mining in those regions, which also increases the risk of noises and landslides.

Unfortunately, the health behavior related to environmental health results in an unhealthy house condition that lacks ventilations and sunlight and dark and humid rooms, which then cause inadequate oxygen inside the house. A significant amount of dust indoors will affect the health of the people inside that house. Moreover, the people's habit of disposing garbage by burning will cause air pollution if the burning process is inappropriately done.

Finally, the current research confirms that radon can rise to the surface, depending on the geological structure of the region. The outdoor radon can enter indoors through several entry points, namely, through the pores of the soil, water, and building materials. Radon levels indoors can be high if the room has insufficient air circulation, thereby affecting the health of the people. The amount of radon indoors is determined by the health behaviors.



Environmental Health Condition and Community Health Behavior

#### 4. CONCLUSIONS

The environment's condition, especially water coming from the spring, actually has a risk on health as it is contaminated with radon and thus is unsafe for drinking. If such condition is supported by an unhealthy societal behavior, then the radon radiation exposure will have an effect on health, either through the skin, oral cavity, or other exposure pathways.

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