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Control of Indoor Pollution in The Bedroom of Tuberculosis Patients Using Cl_2

Pengendalian Polusi Udara dalam Ruangan Kamar Tidur Penderita Tuberkulosis Menggunakan Cl_2

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ABSTRAK

Tuberkulosis (TB) adalah penyakit yang disebabkan oleh Mycobacterium tuberculosis yang ditularkan melalui udara pernapasan. Sumber penularan TBC adalah melalui penderita TBC BTA positif saat batuk atau bersin, menyebarkan kuman ke udara berupa percikan dahak dalam waktu yang lama di udara. Air garam merupakan bahan yang digunakan untuk pengawetan (anti/membunuh kuman). Bahan aktif dalam garam berfungsi sebagai anti bakteri berupa unsur klorin (Cl), karena bersifat diatomik. Proses pelepasan unsur Cl dari molekul garam meja NaCl, kemudian Cl dengan ikatan Cl lainnya membentuk gas Cl_2 dengan metode elektrolisis air garam. Fungsi reaksi elektrolisis air garam merusak ikatan NaCl sehingga logam natrium (Na) dan gas klorin (Cl_2) menyebar ke udara. Penelitian ini dilakukan di rumah pasien TB yang menjadi obyek penelitian di Wilayah Kerja Puskesmas Gamping II Kabupaten Sleman Yogyakarta. Penelitian ini menghasilkan waktu paparan optimal 15 menit menghasilkan gas Cl_2 sebesar 0,2067 ppm dan waktu kontak optimal 15 menit dengan penurunan jumlah kuman 56,22%.

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ABSTRACT

Tuberculosis (TB) is a disease caused by *Mycobacterium tuberculosis* which is transmitted through respiratory air. The source of TB transmission is through smear-positive TB patients when coughing or sneezing, spreading germs into the air in the form of phlegm splashes for a long time in the air. Saltwater is an ingredient used for preservation (anti/kills germs). The active ingredient in salt functions as an anti-bacterial in the form of elemental chlorine (Cl), because it is diatomic. The process of releasing Cl elements from NaCl table salt molecules, then Cl with other Cl bonds to form Cl_2 gas by the salt water electrolysis method. The brine electrolysis reaction function damage the NaCl bond to metallic sodium (Na) and chlorine gas (Cl_2) spread into the air. This research was conducted at the home of TB patients as the object of research in the Gamping II Health Center Work Area, Sleman Regency, Yogyakarta. This study resulted in an optimal exposure time of 15 minutes producing Cl_2 gas of 0.2067 ppm and an optimal contact time of 15 minutes with a reduction in the number of germs of 56.22%.

1. INTRODUCTION

1.1 Background of The Study

Tuberculosis (TB) is a disease caused by *Mycobacterium tuberculosis* and includes diseases transmitted directly through the respiratory air. Based on the Global Report (WHO, 2017), the number of deaths due to pulmonary tuberculosis reached 1.3 million, and Indonesia is among the top three TB countries. Most TB patients are in the productive age group. According to Menteri Kesehatan Republik Indonesia (2011), the source of TB transmission is through TB-BTA positive patients when coughing or sneezing they spread germs into the air in the form of sputum droplets (droplet nuclei). Contagion occurs in a room where sputum splashes are in the air for a long time. Ventilation and sunlight reduce transmission, as sunlight can kill the germ Mycobacterium tuberculosis.

Prevention of TB transmission can be done with environmental management. Saltwater is an ingredient that is widely used in various activities for preservation (anti/kill germs). The active ingredient in salt that serves as an anti-bacterial element is chlorine (Cl), which due to its diatomic nature, the presence of Cl in the air is always in the form of Cl_2 called chlorine. Chlorine is a chemical molecule that has germicidal properties. The process of releasing the element Cl from the NaCl kitchen salt molecule, then Cl with other Cl bonded into Cl_2 gas is by the method of salt water electrolysis. The electrolysis reaction of brine works to break the NaCl bond into sodium metal (Na) and chlorine gas (Cl_2) which diffuses into the air.

According to Ganefati (2013), Cl_2 gas is used as an air disinfectant for TB patients. This is based on laboratory tests obtained results: there is an effect of room air disinfection using Chlorine gas from the electrolysis of brine on the decrease in the number of room air germs. The average decrease in germ number after disinfection of room air with salt water electrolysis method at a concentration of 1, 5, and 10% respectively, namely 15, 32, and 56 CFU/m^3. The concentration of brine that most reduces the number of germs in the air is 10%, which is a solution of 100 gr NaCl in 1 liter of solution in water.

The advantage of chlorine gas as a disinfectant from the electrolysis of NaCl solution compared to disinfectant from other chemicals is that salt is cheap, easy to obtain, people already know every day, simple tools used, and easy operation, and short time. Based on the results of laboratory tests, the use of Cl_2 from the electrolysis of NaCl brine on exposure within 10 minutes of Cl gas content of 0.0216 ppm does not exceed the standard quality ambient air (BMUA) by local regulation.

The innovation of this research is the air disinfection of TB patients using salt water electrolysis, which is expected to be one of the family or community efforts to prevent the transmission of TB disease to family members. However, the application of room air disinfection with Cl_2 from brine electrolysis needs to know the exact exposure time and contact time for the disinfection to run optimally, with Cl_2 gas residue below BMUA. Based on Ganefati (2013), the exposure time and contact time in this study were determined as 5, 10, and 15 minutes, respectively, with a saltwater solution concentration of 100 gr/L solutions in water. Exposure time is the time the electrolysis device is turned on to produce Cl_2 gas, while the contact time is the time since the electrolysis device is turned off, to allow the Cl_2 gas to contact microorganisms in the air, especially *Mycobacterium tuberculosis*.

1.2 Purposes of The Study

This study aims to prevent the transmission of TB disease to the patient's family, through room air disinfection using chlorine gas from salt water electrolysis to reduce germ rates.

2. METHODS

2.1 Research Design

This type of research is a quasi-experiment study with pre-test and post-test design as the following diagram.

	Pre-test	Treatment	Post-test
Experiment 1	O_1	X1	O_2
Experiment 2	O_3	X2	O_4

Description:

X1 : Exposure time (time the electrolysis device is turned on to produce Cl_2 gas), which is 5, 10, and 15 minutes for air disinfection of TB patients' rooms.

X2 : The contact time, the disinfection using Cl_2 gas from the electrolysis of salt water for 5, 10, and 15 minutes from the electrolysis is off.

O_1 : The number of germ air space of TB samples, as data pre-test germ.

O_2 : Cl_2 gas content of room air at the time of emission (5, 10, and 15 minutes), as data pre-test of Cl_2 gas air.

O_3 : Cl_2 gas residue of chamber air at contact time (5, 10, and 15 minutes), as data post-test residue gas Cl_2 air.

O_4 : The number of airborne germs of TB patients in the study sample after contact time (5, 10, and 15 minutes), as data post-test of germ number.

2.2 Population and Sample

The research population is houses of TB BTA-positive patients in the working area of Puskesmas Gamping II Sleman Yogyakarta. Meanwhile, the sample which is then called the research object is the home of TB BTA-positive patients in Puskesmas Gamping II Sleman Yogyakarta, with the criteria: patients are still in the treatment stage, and home occupants ≥5 people, room volume in the range between 15–40 m^3. The sampling technique is purposive sampling quota and obtained the number of research objects from 10 houses.

2.3 Variables

The variables of this research are independent variables and dependent variables. The independent variables consist of time exposure and contact time. The time exposure is the operating time of exposure is the time of electrolysis (for 5, 10, and 15 minutes), to produce gas Cl_2 electrolysis of salt water from the ignition to turn off the device, the unit of minutes. The contact time is the time specified to allow the Cl_2 gas from the brine electrolysis process to contact with microorganisms in the air space of the research object, calculated from the electrolytic device turned off until the measurement of the specified germ number, i.e., 5, 10, and 15 minutes. The dependent variables consist of gas residue Cl_2 and space air germ number. Gas residue Cl_2 is the amount of Cl_2 gas in the air of an object TB patient room measured using the BX176 "Cl_2 Gas Detector" before and after treatment in ppm. The space air germ number is the number of bacterial colonies of CFU/m^3 of air, measured before the time of exposure and after the time and contact.

2.4 Site

This research was conducted in the homes of TB patients as the object of research in the Working Area of Puskesmas Gamping II, Sleman Regency, Yogyakarta.

2.5 Procedures

The procedures of this study are the preparation stage, research implementation, external and measurable indicators at each stage, and data collection techniques. The preparation stage are tool setup (electrolyzer and scissors); preparation of materials (kitchen salt, water, newspapers, and tape); manufacture of brine solution (100 gr of salt is dissolved with 1 liter of tap water then brine is put into the electrolyzer); research implementation (evacuation of TB patients' rooms, closing all doors and windows of the study object room, closing all ventilation holes with used newspapers, taking air samples for examination of germ numbers (pre-test), turn on the Electrolyzer (exposure time) for 5, 10, and 15 minutes, then turn off the Electrolyzer, examination of Cl_2 gas residue (pre-test), implementation of disinfection (providing contact time), for 5, 10, and 15 minutes, air sampling for Cl_2 gas residue inspection (post), and air sampling for air germ number inspection (post), open doors, windows and vents, and the room is ready to use again); external and measurable indicators at each stage (the number of germs in the room air before disinfection, exposure time (salt water electrolysis time) to produce Cl_2 gas residue as an air disinfectant in the room of TB patients, gas levels of Cl_2 (pre-test) after 5, 10, and 15 minutes exposure, contact time, i.e. 5, 10, and 15 minutes after electrolysis was stopped as room air disinfection time, and the number of germs in the room air after disinfection); data collection techniques (secondary data in the form of BTA positive TB patient data, collected from defects in the health center, primary data on the condition of the patient's home was collected by searching the address data of TB patients in the Puskesmas, primary data in the form of environmental health data of the object house was collected by field observation to the object house, primary data of Cl_2 gas residue on brine electrolysis obtained from laboratory examination, primary data on room air germ numbers were obtained from laboratory examination); and data analysis. Data analysis using SPSS with multivariate ANOVA test at a confidence level of 95%.

3. RESULTS AND DISCUSSION

3.1 Research Results

3.1.1 TB Patient Data

In 2016, there were 22 TB cases with positive BTA in the area of Puskesmas Gamping II, with the distribution in the following table.

Table 1. List of Initials and Addresses of TB Patients in Puskesmas Gamping II Year 2016

No	Name (Initial)	Address	Number of Family Members
1	Um Ur	Pudung, Nogotirto	6
2	Alm	Kradenan	3
3	Ist	Jambon	5
4	War	Guyangan	4
5	Murt	Sodomaran	5
6	A Muly	Perum Jongkang	3
7	Skrn	Kajor	6
8	Srj	Modinan	4
9	Nur	Mlangi	5
10	Suk	Gading Sari	3
11	Suw	Modinan	6
12	Sul	Modinan	3
13	Aly	Modinan	5
14	Yul	Patuk	2
15	Arf	Dukuh	6
16	Riy	Kwarasan	3
17	Sul	Modinan	5
18	Msar	Sawahan	4
19	Sddr	Modinan	5
20	Ahm H	Modinan	4
21	Way S	Mlangi	3
22	End K	Tuguran	4

From Table 1 above, it is known that 22 TB patients in Puskesmas Gamping II, epidemiologically spread in 15 villages/sub-districts and the most in Modinan which is 7 people (31.82%).

3.1.2 Data of Research Respondents

According to purposive quota sampling, the criteria for a research respondent whose home is the object of research is the number of family members of five or more people and still in the process of TB treatment, the volume of the room is in the range of 15–40 m^3. From the process of determining the object with purposive quota sampling, obtained 10 respondents whose house is the object of research as in the following table.

Table 2. List of Initial Names and Addresses of Research Respondents in Puskesmas Gamping II Year 2016

No	Name (Initial)	Address	Number of Family Members
1	Um Ur	Nogotirto	6
2	Ist	Jambon	5
3	Murt	Sodomaran	5
4	Skrn	Kajor	6
5	Arf	Dukuh	6
6	Nur	Mlangi	5
7	Suw	Modinan	6
8	Aly	Modinan	5
9	Sur	Modinan	5
10	Sddr	Modinan	5

From Table 2 above, it can be seen the distribution of respondents by village, namely Nogotirto, Jambon, Somodaran, Kajor, Hamlet, and Mlangi 1 person each, and Modinan 4 people.

3.1.3 Respondent's Home Environmental Health Data

Referring to the requirements of a healthy home (Soemirat, 2011), the environmental health data measured in this study include room sanitation, temperature, humidity, lighting, the presence of ceilings, and room size (length, width, and height wall) to calculate the volume of room air. The measurement results are presented in the following table.

Table 3. Results of Monitoring the Sanitation Condition of TB Patient Room

Respondent	Room Sanitation	Temperature (°C)	Humidity (%)	Illumination	Ceiling	Room Volume (m^3)
1	Poor	29	79	Under	Exist	36.75
2	Poor	28.2	84.3	Good	No exist	18.75
3	Good	29.9	76.9	Adequate	Exist	18.75
4	Poor	30.6	79.3	Under	Exist	36.75
5	Poor	29.4	78.5	Under	No exist	18.75
6	Good	29.2	75.1	Under	No exist	27
7	Good	28.5	79.2	Under	Exist	15
8	Poor	29.2	79	Under	No exist	17.5
9	Moderate	30.6	76.3	Under	No exist	31.5
10	Moderate	31	72,8	Under	No exist	17.5
Average		29.56	78.4			23.825

From Table 3 above, it can be described that out of 10 respondent rooms, the results of environmental health monitoring are as follows:

a. Space sanitation
As many as 3 people (30%) of respondents had room sanitation in the good category, as many as 2 people (20%) in the medium category, and as many as 5 people (50%) had a poor level of space sanitation.

b. Respondent's room temperature
According to Peraturan Menteri Kesehatan Republik Indonesia (Permenkes RI) Number 1077/Menkes/Per/V/2011, the air temperature requirement of the house room is 18–30 °C. The data of the lowest temperature measurement results from 28,2 °C, the highest at 31 °C, and an average of 29,56 °C. Compared to the requirements, there are three that are above the standard, namely respondents' number 4 and 9 with a temperature of 30,6 °C with bad and medium category space sanitation, while respondent No.10 temperature of 31 °C with medium category space sanitation.

c. Indoor air humidity
According to Permenkes RI Number 1077/Menkes/Per/V/2011, the requirement of indoor air humidity is 40-60%. Data from the measurement of the entire respondent's room has a humidity >60%, with an average of 78.4% and the highest 84.3% occurred in respondent's room No.2 with poor space sanitation status.

d. Room lighting
According to Permenkes RI Number 1077/Menkes/Per/V/2011 minimum 60 lux lighting requirements, can be easily used for reading and other similar work. Data from the measurement of 8 people (80%) lighting in the room included less. Less light and relatively high humidity make it a good medium for the growth of TB germs.

e. Ceilings
A total of 4 respondents (40%) had their rooms have ceilings, and 6 people (60%) did not have ceilings. The absence of a ceiling is predicted to expand the spread of TB germs to other spaces.

f. Space air volume space air
Volume is obtained by multiplying width x length x height. The results of measurement and calculation of space volume range from 15 to 36.75 m^3, with an average of 23.825 m^3. Respondents with a large room volume or a room that did not have a ceiling were generally occupied by several family members at night.

g. Cl_2 gas residue
Measurement of Cl_2 gas content in room air was done twice, namely pre and post-test. The first measurement was performed when the exposure time was completed, that is when the electrolyzer was switched off after being turned on for 5, 10, and 15 minutes, the result was the level of Cl_2 for the test. The second measurement was performed when the contact time was completed, that is, since the electrolyzer was turned off and waited for 5, 10, and 15 minutes, respectively, the result was the gas residue data Cl_2 post-test. The measurement method, air samples were taken with a tool for analysis of Cl_2 gas, while the examination was performed at the Chem-mix Laboratory Pratama Bantul. Both measurements of Cl_2 gas content are presented in the following table.

Table 4. Results of Examination of TB Respondents' Space Containers Pre and Post-Test Exposure Time 5, 10, and 15 minutes

No	Gas Cl_2 (ppm)								
	5 minutes			10 minutes			15 minutes		
	Pre-test	Post-test	% Down	Pre-test	Post-test	% Down	Pre-test	Post-test	% Down
1	0.167	0.134	19.76	0.217	0.150	30.87	0.200	0.167	16.50
2	0.150	0.117	22.00	0.200	0.167	16.50	0.216	0.183	15.28
3	0.167	0.133	20.36	0.210	0.168	20.00	0.183	0.166	9.29
4	0.133	0.116	12.78	0.167	0.150	10.18	0.201	0.165	17.91

No	Gas Cl_2 (ppm)								
	5 minutes			10 minutes			15 minutes		
	Pre-test	Post-test	% Down	Pre-test	Post-test	% Down	Pre-test	Post-test	% Down
5	0.183	0.150	18.03	0.206	0.152	26.21	0.217	0.182	16.13
6	0.150	0.115	23.33	0.167	0.154	7.78	0.200	0.160	20.00
7	0.167	0.117	29.94	0.183	0.153	16.39	0.215	0.167	22.35
8	0.150	0.131	12.67	0.181	0.151	16.57	0.202	0.181	9.41
9	0.167	0.132	20.96	0.182	0.166	8.79	0.217	0.183	15.67
10	0.150	0.134	10.67	0.184	0.155	15.76	0.216	0.165	23.61
Total	1.585	1.279	190.5	1897	1.566	174.5	2.067	1.719	168.3
Average	0.1584	0.1279	19.05	0.1897	0.1566	17.45	0.2067	0.172	16.83

Table 4 shows, that the average up to Cl_2 pre-test for the exposure time of 5, 10, and 15 minutes were 0.1584, 0.1897, and 0.2067 ppm. These three figures show an increasing trend, that the longer the exposure time (electrolysis time) will produce Cl_2 gas more. If we look at the Cl_2 gas residue after the contact time of 5, 10, and 15 minutes are 0.1279, 0.1566, and 0.1719 ppm. These three numbers are all lower than the Cl_2 gas level at the end of the exposure time (pre-test), which means that there is a decrease in the Cl_2 gas level from pre to post-test. If we look at the average percentage decreases are 19.05, 17.45, and 16.83%, there is a tendency that the longer the contact time, the smaller the percentage decrease. This is because the longer the gas exposure time is produced the more, while the material in the air that reacts with Cl_2 gas is constant, so the longer the reaction contact time slows down because the reacting material is depleted, so the percentage decrease in trend decreases. If associated with BMUA for Cl_2 according to Keputusan Gubernur DIY Nomor 153 Tahun 2002, that is 1 ppm for a maximum contact period of 1 hour, the residue of Cl_2 gas from the electrolysis of salt water for air disinfection of TB patients' room, both post-test and pre-test all treatments are still <1 ppm, so it is safe for humans, especially TB patients as respondents or said this tool is environmentally friendly.

h. Room air germ

The numbers of room air germ numbers were checked twice, namely before disinfection (before exposure time), and after contact time. This means that the time Cl_2 gas reacts with airborne germs since electrolysis begins that reaction time is (5 + 5) = 10 minutes; (10 + 10) = 20 minutes, and (15 + 15) = 30 minutes. The results of the measurement of airborne germ numbers are presented in the following table.

Table 5. Results of Examination of Air Germ Number in Respondent's Room TB Pre-Test and Post-Test Contact Time 5, 10, and 15 minutes

No	Total Airborne Germ Number (CFU/m³)								
	5 minutes			10 minutes			15 minutes		
	Pre-test	Post-test	% Decrease	Pre-test	Post-test	% Decrease	Pre-test	Post-test	% Decrease
1	46	27	41.31	46	23.5	48.91	44	17.5	60.23
2	54.5	31	43.12	41	20.5	50.00	40.5	16	60.49
3	58.5	39	33.33	36	16	55.55	43.5	21.5	50.57
4	56	36	35.71	48	24	50.00	43.5	11.5	73.56
5	62	33.5	45.97	39.5	26.5	32.91	43	20.5	22.32
6	62.5	33.5	46.32	38.5	19.5	49.35	49.5	20	0.59
7	66.5	30	54.89	34.5	14.5	57.97	52	24	530.85
8	56.5	22	61.06	42	22	47.62	38.5	20.5	67.53
9	64	36	43.75	46	22	52.17	43	20.5	63.95
10	66	33.5	49.24	63.5	25.5	59.84	40	13.5	66.25
Total	592.5	321.5	457.4	371.5	214	423.90	394	172.5	562.20
Average	59.25	32.15	45.74	37.15	21.4	42.39	39.4	17.25	56.22

From Table 5 above, it is known that the average number of airborne germs before treatment with disinfection was 59.25, 37.15, and 39.4 CFU/m³. This number is all below the maximum number of germs according to Permenkes RI Number 1077/Menkes/Per/V/2011, i.e., <700 CFU/m³. However, given that the room air is the room air of TB patients with BTA positive, it is very likely that in the low number of germs, there are pathogenic germs of *Mycobacterium tuberculosis*, so the potential for TB transmission to family members remains. After disinfection using chlorine gas from brine electrolysis with an exposure time of 5 minutes and contact time of 5 minutes obtained a germ number of 32.15 CFU/m³ with a decrease of 45.74%, exposure time of 10 minutes and contact time of 10 minutes was obtained germ number 21.4/m³ with a decrease of 42.39%, and an exposure time of 15 minutes and a contact time of 15 minutes obtained a germ count of 17.25 CFU /m³ with a decrease of 56.22%. The number of germs after treatment with this disinfection, the longer the contact time, the average number of germs is smaller and the percentage decrease is greater. This is because the longer the contact time, the more germs react with chlorine gas.

3.2 Data Analysis

3.2.1 Normality Test

Before the differential test, pre-test, and post-test data for Cl_2 gas and airborne germ number, a normality test was performed with $\alpha = 0.05$. The test result obtained $p > 0.05$, which means that the data distribution is normal.

3.2.2 Differential Test

To determine whether the exposure times of 5, 10, and 15 minutes, followed by contact times of 5, 10, and 15 minutes, affect the gas content of Cl_2 pre and post-test, and contact time of 5, 10, and 15 minutes affected the decrease in the number of airborne germs in the respondent's room ANOVA test at α = 0.05. Test results were obtained both p = 0.000 or $p < \alpha = 0.05$. This means:

a. There is an effect of exposure time on the level of Cl_2 gas in the room air of TB patients (Cl_2 gas level pre-test), that is, the longer the exposure time, the higher the level of Cl_2 gas produced.
b. There is an effect of contact time on the decrease in the number of airborne germs in the room of TB patients, that is, the longer the contact time the higher the percentage decrease in the number of airborne germs in the room of TB patients.
c. The optimum exposure time is 15 minutes which produces the Cl_2 gas content of the highest 0.2067 ppm, and the optimum contact time is 15 minutes which produces the highest percentage decrease in germ count, which is 56.22% with a Cl_2 gas residue of 0.1719 ppm (below ambient air quality standards).

3.3 Discussion

3.3.1 Exposure Time and The Level of Cl_2 Gas Produced

Exposure time is the time the electrolyzer is turned on to produce Cl_2 gas from the electrolysis of brine as an air disinfection material in the room of TB patients. Exposure times in this study were 5, 10, and 15 minutes. From Table 1, it can be seen, that the average Cl_2 gas produced is 0.1584, 0.1897, and 0.2067 ppm. From these three figures, it can be seen that there is a tendency for the longer the exposure time, the higher the level of Cl_2 gas produced, and the highest is 0.2067 ppm at 15 minutes of exposure. The content of Cl_2 gas is still below the ambient air quality standard, which is 1 ppm for a maximum contact period of 1 hour (Governor of Yogyakarta, 2002).

In addition to being a disinfectant, Cl_2 gas is also toxic to humans due to its water-soluble nature, including water or mucus from body organs, such as the mucosal cells of the respiratory tract and cornea. Because it is soluble in the water of the body organs, the Cl_2 gas is also irritating to the body organs that are watery or slimy. Therefore, the presence of Cl_2 gas in ambient air needs to be limited to the Ambient Air Quality Standard, which is 1 ppm for a contact time of 1 hour (Governor of Yogyakarta, 2002) because it will be easy contact with the eyes, so there is eye irritation, inhaled by system organs, and breathing with respiratory air. The Cl_2 gas will come into contact with mucosal cells in the upper respiratory tract, namely the nose, pharynx, and larynx, as well as the middle airways, bronchi, and bronchioles. Possible health effects are conjunctivitis in the eyes, upper respiratory tract irritation which supports the high number of cases of upper respiratory tract infections (ARI), as well as irritation of the broccoli and bronchioles which can facilitate the occurrence of bronchitis (Abidin, 2019).

If the exposure to Cl_2 gas is prolonged or occurs repeatedly every day, for example in employees who work with chlorine compounds, then Cl_2 gas can enter the alveoli that will stimulate the alveoli to release fluid, and watery alveoli called emphysema. This condition will reduce the ability of the alveolar wall to transfer oxygen (O_2) into the capillaries to react with Hemoglobin (Hb) into HbO_2 which will be carried to the heart and then distributed throughout the tissues. Oxygen in the tissues is an important ingredient for the occurrence of metabolic reactions in the tissues to produce energy to maintain life and activity (Irfanuddin, 2019).

Thus, if the inhaled ambient air contains Cl_2 gas at high levels and the time is long, it can reduce the rate of metabolic reactions, as a result of reduced energy produced, which eventually people will be easily tired and productivity will decrease.

Due to the impact of Cl_2 gas in the ambient air above, then in the air disinfection of TB patients need to pay attention to the Chlorine gas residue environmentally friendly, that is, the level is still below the standard of ambient air quality. In Permenkes No. 1077/Menkes/Per/V/2011 on Guidelines for Indoor Air Conditioning, chlorine gas parameters maximum that are safe for life were found. However, in the Decree of the Governor of DIY No. 153 of 2002 on Ambient Air Quality Standards in the Special Region of Yogyakarta Province, it is stated that the maximum level of Cl_2 gas in ambient air is 1 ppm for a maximum contact time of 1 hour. Associated with the Cl_2 gas content from the electrolysis of brine for room disinfection of TB patients, the three exposure times (5, 10, and 15 minutes) were all well below 1 ppm, making it safe for home dwellers, or environmentally friendly. In this study, the same content is used for different time variations, namely 100 gr in 1 liter of solution. Given the gas Cl_2 generated by electrolysis is still far below the BMUA, the question arises, what is the level of optimal salt solution electrolyzed so the disinfection chamber of TB patients is more effective, to prevent the transmission of TB to family members better, but produced Cl_2 gas is still under BMUA.

3.3.2 The Contact Time and Residual Cl_2 Gas Air Space

Contact time is the time after the electrolyzer is turned off, meaning the production of Cl_2 stops, until the contact time is completed, which is 5, 10, and 15 minutes. This contact time is intended to provide an opportunity for Cl_2 gas to react with microorganisms in the air, especially the pathogenic Mycobacterium tuberculosis. Chlorine gas levels after the contact time are called residual, because room disinfection has been completed, and the room can be reused by patients with TB. After the contact time, the concentration of Cl_2 gas will decrease because it reacts with microorganisms in the air and other processes that cause Cl_2 gas in the room to decrease. If the chlorine gan level measured when the electrolyzer turned off (pre-test) results were below 1 ppm, then after apparent contact time will be even lower levels, i.e., 0.1719 ppm at 15 minutes contact time so that the residue is environmentally friendly.

There are at least four possibilities related to the percentage decrease in chlorine gas level in the air in the respondent's room, namely:

a. Cl_2 gas reacts with organic matter in the air, including microorganisms, particularly bacteria *Mycobacterium tuberculosis*, as the pathogens which became the target of disinfection. Considering that *Mycobacterium tuberculosis* cannot be cultured from air samples, in this study the total germ number parameter was used, which assumes that present in *Mycobacterium tuberculosis*. Supposedly the larger the total number of bacteria pre-tests, the percentage reduction in chlorine gas levels. Higher. But, in this study does not seem there is a tendency, given the average number of bacteria before treatment between 37.15 to 59.25 CFU / m^3 (Table 5), which means far below BMUA i.e., <700 CFU / m^3 air (Menteri Kesehatan Republik Indonesia, 2011).

b. Chlorine gas is distributed throughout the room, so the larger the volume of the room, the lower the percentage of Cl_2 gas content is higher. The air volume of the respondent's room ranges from 15 m^3 to 36.75 m^3, with an average of 23,825 m^3 (Table 3). If we look closely at the volume of the room from 10 samples (Table 3), there is no tendency for a relationship between the volume of the room and the percentage of chlorine gas content to decrease (Table 4). This indicates that the decrease in the concentration of Cl_2 gas is caused by other factors, possibly airflow velocity.

c. Chlorine gas is distributed to the top because there is no ceiling or to another room because of the airflow in the room and closing the less dense holes. The faster the room's airflow and the room has no ceiling, the higher the drop percentage should be respondent no. 2, 5, 6, 8, 9, and 10, the rooms have no ceilings. It can be seen a decrease in levels of Cl_2 gas has a range between 9.41% and 23.61%, with the average - average of 16.67%, slightly lower than the average of 16.83%, This indicates that the existence of a ceiling does not give a tendency to decrease the percentage of Cl_2 gas content. The limitation of this research is that there is no measurement of indoor airflow velocity.

d. Chlorine gas reacts with water vapor in the air because Cl_2 easily dissolves in water with the reaction $Cl_2 + H_2O$ HCl + HOCl. Actually, according to the toxicity of chlorine compounds, HOCl or hypochlorous acid also reacts with substances that are reducing agents, including germs in the air. This means that the presence of water vapor in the air contributes to the decrease in the Cl_2 gas level in the air. The moisture content in the air is expressed by the humidity parameter (oR). This means that the higher the humidity, the faster the reaction with Cl_2 gas, and the faster the decrease in Cl_2 gas levels in the air. According to Permenkes No. 1077/Menkes/Per/V/2011, the air humidity requirements of the house are between 40–60%. Of the 10 samples, the room has a humidity between 72.8–84.3%, with an average of 78.4%. This shows that the humidity in the respondent's room is generally high. High humidity Cl_2 gas in addition to absorbing more, predicted also be a good medium to live germs in the air, thus increasing the potential for transmission of TB.

3.3.3 The Contact Time and Reduction of Room Air Germ Numbers

Contact time is the time after the electrolyzer is turned off (exposure time is complete) until the specified contact time ends, namely 5, 10, and 15 minutes. This contact time is intended to provide an opportunity for Cl_2 gas to react with microorganisms in the room air, especially the pathogenic bacteria Mycobacterium tuberculosis. The results of the examination of the average number of germs after the contact time was completed (post-test) were 32.15, 21.4, and 17.25 CFU/m^3 with a percentage decrease of 45.74, 42.32, and 56.22%. There is a tendency to decrease the number of germs at post-test, that the longer the contact time, the lower the number of germs that live in the air. There must be a tendency that the longer the contact time, the higher the percentage of the decrease in the number of germs. In this study, the trend exists but is less than perfect, because the numbers start from high, then slightly lower, and finally the highest than the two previous numbers.

3.3.4 Limitations of The Study

Several limitations in this study include a). This study uses only one dose of electrolyzed salt solution, which is 100 g of NaCl in 1 liter of an aqueous solution, which produces Cl_2 gas with levels still far below the Ambient Air Quality Standard (BMUA), which is 1 ppm for a period of time i.e., 1 hour contact (Governor DIY, 2002). The question arises, what is the optimal level of brine solution to produce higher Cl_2 levels, but still below the BMUA, which is 1 ppm for a maximum contact time of 1 hour. This is a matter of thought for other researchers, to conduct research with a higher concentration; b). This study did not measure the velocity of the room air, which is thought to play a major role in the decrease in Cl_2 gas levels in the room air after exposure time.

4. CONCLUSIONS

There is an effect of exposure time (when the electrolyzer is turned on) of 5, 10, and 15 minutes of Cl_2 gas. The highest level is 0.2067 ppm at an exposure time of 15 minutes, and this is still below the ambient air quality standard. There is an effect of contact time (when the electrolyzer is turned off), up to 5, 10, and 15 minutes on the percentage of airborne germ numbers. The biggest decrease was 56.22% occurred at the longest contact time, which was 15 minutes. It is necessary to carry out further research, with levels above 100 g per liter, to obtain the optimum level of electrolyzed NaCl solution which produces Cl_2 gas which is higher but still below 1 ppm. It is necessary to measure the velocity of the room airflow, which is thought to affect the speed of decreasing Cl_2 gas levels in the room air.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

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DECLARATION OF COMPETING INTEREST

The authors declare no conflict of interest.

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