EFFECT OF CHLORINE GAS DERIVED FROM SALT WATER ELECTROLYSIS ON THE DECREASE OF AIR MICROBE NUMBER OF HOSPITAL CARE-ROOMS (NOSOCOMIAL INFECTIONS PREVENTION THROUGH THE CONTROL OF AIR MICROBE POLLUTION)

[1]Sri Puji Ganefati, [2]Hartono, [3]Adi Heru Sutomo, [4]Prabang Setyono

ABSTRACT--*Nosocomial infection is a new disease in patients who are treated for 48 hours. Cases of 40% nosocomial infection are caused by Staphylococcus aureus and 50% gram-negative microorganisms. This case is the main cause of patientsdeath in the hospital. Control efforts through disinfection of hospital care-rooms with* Cl_2 *gas from salt water electrolysis. The purpose of this study was to determine: the effect of* Cl_2 *gas on decreasing microbe number; the influence of salt levels on the decrease in the microbe number and electrolyzers which most reduced the micorbe number in the hospital care-rooms. This research was Quasi Experiment (quantitative) with Pre Test and Post Test Group Design. Location is determined by quota sampling. The population of the study was 42 rooms, 32 rooms sample, Stratified Random Sampling technique, and calculation used the Slovin formula. The results showed that there was an effect of chlorine gas (*Cl_2*) from salt water electrolysis ondecrease in microbe number, there was an influence of ferocious levels on the decrease in microbe number, and* Cl_2 *of the 13 voltage electrolyzer with a salt content of 200 gr/L reduced the mostmicrobe number. There are effectedthe various electrolyzer models on decreasedto the number of germs which mean that there was an influence of electrolyzer voltage variations and salt content on decreasing bacterial numbers*.

Keywords-- *air microbe pollution,* Cl_2 *gas, electrolysis, hospital care-rooms,.*

I. INTRODUCTION

Nosocomial infection is a disease caused after a person is hospitalized for 48 hours, by the presence of microorganisms originating from outside the care-rooms of the patient. Factors that influence the occurrence of nosocomial infections include: enteric bacteria that are usually involved in hospital-acquired nosocomial infections, the presence of disease agents (viruses, microbe number, and fungi), resistance to drugs, and equipment including rooms contaminated with disease agents. This infection is an important public health problem, but few is known about its contribution to antibiotic resistance[1]. According to Ginting[2], the incidence of

[1] *Doctoral Program in Environmental Science, Sebelas Maret University, Surakarta 57126, Central java, ,Health Polytechnic, Ministry of Health of Yogyakarta, Indonesia, sripuji_ganefati@yahoo.com, Telp/Fax: (0274) 617601.*
[2] *Faculty of Medicine, Sebelas Maret University, Surakarta 57126, Central Java, Indonesia.*
[3] *Faculty of Medicine, Gadjah Mada University, Yogyakarta 55284, Indonesia.*
[4] *Environmental Science Program, Sebelas Maret University, Surakarta 57126, Central Java, Indonesia.*

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nosocomial infections as much as 40% is caused by *Staphylococcus aureus* and 50% is caused by gram-negative species of stem microbe.

According to WHO[3] and Cottter[4] that nosocomial infections are a major caused of death and illness in hospitalized patients, with a minimum death rate of 175,000 annually in industrialized countries, and there is an increase in cases each year. Increased nosocomial infections in Europe and America by 1% each year, while in Asia by 40% each year. Nosocomial infections in the United States from 100 patient who visits in hospitals there were 5-6 cases, each year there are estimated to be 2 million cases of nosocomial infections[5]. According to Samuel[6], that nosocomial infection is recognized a public health problem worldwide with a prevalence rate of 3.0-20.7% and an incidence rate of 5-10%. The prevalence of nosocomial infections in high-income countries is smaller when compared to low and middle-income countries. The prevalence of nosocomial infections in high-income countries was between 3.5% -12%, while the prevalence of nosocomial infections in low and middle-income countries was between 5.7% -19.1% [7]. The prevalence of nosocomial infections in North Iran is 4.13%, consisting of 49.1% of respiratory tract diseases, wound infections 26.3%, and blood infections 7.9%. Among diseases caused by nosocomial infections that caused by uncontrolled use of antibiotics by doctors, resulting in resistance to antibiotics[8]. Evolution of bacterial resistance occurs due to the excessive used of antibiotics in patients. Weak utilization of antibiotics at various levels causes a major threat to public health[9].

Based on the studyresults of Schelz[10] and Wach[11], that nosocomial infections are caused by the use of medical devices and the emergence of bacterial resistance to drugs. Resistance to drugs is an inevitable effect of the microbial survival process. Drug resistance is a major problem in handling bacterial infections.

Based on preliminary tests of room germ examination in the Department of Environmental Health of the Health Ministry in Yogyakarta on September 28, 2015, out of 5 rooms, the average total number of care-roomsmicrobe count was 1,207.8 CFU/m^3 not in accordance with the air germ number standard stated in Health Ministry Decree[12] concerning Health of the Office and Industrial Work Environment, which air microbe number was<700 CFU/m^3. Based on the research of Suwarni and Sutomo[13], it showed that the results of air microbe measurement and the incidence of nosocomial infections in government and private hospitals in the Special Region of Yogyakarta averaged 3,758 CFU/m^3 with thenosocomial infections average incidence of 4.26%. The number of microbes exceeds the standard of the Health Ministry Decree of the Republic of Indonesia[14] regarding Hospital Environmental Health Requirements, where the airmicrobe number of care-rooms is less than 200-500 CFU/m^3.

Control of air microbe pollution numbers according to Ulrich[15], that disease caused by microbe and virus numbers can be transmitted through air, prevention of disease transmission through indoor air disinfecting using chemicals and ultraviolet light (SUV). Taking into account the number of cases and the strength of the effects of all cardiovascular diseases, mitigation measures must address all pollutants, especially CO, NO_2, and PM_{10}. Another alternative for disinfecting room air is to kill the microbe numbers with Cl_2 gas from salt water electrolysis. The electrolysis reaction of kitchen salt (NaCl) using an electric current produces 2Na in the form of solids and Cl_2 in the form of gas. The use of Cl_2 gas from kitchen salt water electrolysis to recycle used batteries in order to reduce energy consumption using the principle of electrolysis proved to be efficient enough to be used[16]. This study aimed to determine: the effect of chlorine gas (Cl_2) from salt water electrolysis on decreasing germ count; the effect of salt levels from electrolysis of deep brine on decreasing the microbe number; and Electrolyzer which had the highest microbe number.

II. METHODS

Research Design

This type of research is Quasi Experiment (quantitative) with Pre Test and Post Test Group Design.

Population dan Sample

This study was conducted in an air-conditioned care-room at Panembahan Senopati Bantul Regional Hospital which requirements met the 47 rooms, then 32 rooms were taken using the Slovin Formula[17]. The application of Cl_2 gas disinfection from salt water electrolysis was carried out 192 times, while the examination of microbe numbers was carried out before application (pre test) 192 times and after application (post test) 192 times.

Research Variable

This study used independent variables as temperature (unit: °C, scale: continuous); humidity (unit:%, scale: continuous), electrolyzer (unit: volt, scale: continuous), and salt content (unit: gr/L, scale: continuous) while the dependent variable was a decrease in microbe number (unit: CFU/m^3, scale: continuous).

Operational definition

a. Room temperature was the temperature of the hospital care-room measured before treatment, used a thermometer with an °C unit.
b. Room humidity was the temperature of the hospital care-room temperature measured before treatment, used a hygrometer with the% unit.
c. Electrolyzer was a tool for the electrolysis of salt water which produced Cl_2 gas for disinfection of hospital care-rooms, in this study used 5 volts, 9 volts and 13 volts.
d. Salt content was the weight of salt per liter of water for electrolysis, in this study using 100 g/L, 150 g/L, and 200 g/L.

Tools and Materials

The instrument used a Single Gas Detector of Cl_2; Thermometer; hygrometer, and Midget Impingers (Microbiology Air Sampler). The materials used are aquades and table salt (NaCl). Measurement of Cl_2 Gas used the Single Gas Detector Cl2 has been confirmed with the results of laboratory tests using a Spectrophotometer. The results of the calculation of Cl_2 gas regression used a Single Gas Detector with R_{square} of 0.032; and used a R_{square} Spectrophotometer of 0.033. The results of regression analysis between Cl_2 gas measurements used a Single Gas Detector with a Spectrophotometer showed an R_{square} difference of 0.001 or <0.05. This situation can be said that the measurement of Cl_2 gas used a Single Gas Detector is declared valid.

Ethical Clearence

This research has been declared ethical by the Health Ethics Commission of Moewardi Hospital/Sebelas Maret University Faculty of Medicine Surakarta Number 213/V/HREC/2019 dated July 30, 2019 (Ethical Eligibility Attached).

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Data Analysis

Data analysis used the statistical tests T-test, Multivariate ANOVA, and Quadratic Regression, the significance level of 95% (α = 0.05).

III. RESULTS

Sample Characteristic

Care-rooms temperature

Care-rooms temperature in this study in the application of Cl_2 gas disinfection from Electrolyzer (5 volts, 9 volts and 13 volts) with a salt content (100gr/L, 150 gr/L and 200gr/L) between 25.3°C to 27,7°C. The complete data can be seen in Table 1 as follows.

Table 1: average of thecare-room temperature (°C) in the Cl_2 gas disinfection application from electrolyzer and salt content

Electrolyzer Salt Content	n	5 volt	9 volt	13 volt
100 gr/L	192	26.8	25.3	26.2
150 gr/L	192	27.1	26.2	27.1
200g/L	192	27.7	25.7	25.8

Care-rooms humidity

The data of care-rooms humidity can be seen in Table 2 as follows.

Table 2: average care-rooms humidity (%) in Cl_2 gas disinfection application from electrolyzer and salt content

Electrolyzer Salt Content	N	5 volt	9 volt	13 volt
100 gr/L	192	75.6	72.3	76.4
150 gr/L	192	69.7	74.4	73.8
200g/L	192	73.7	69.8	69.9

Cl_2Gas

The results of Cl_2 gas measurements in disinfection care-rooms of electrolyzers (5 volts, 9 volts and 13 volts) with the highest salt content (100 gr/L, 150 gr/L and 200 gr/L) on the 13 volt Electrolyzer with salinity 200 gr/L that was same to 0.251 ppm, while the lowest was a 5 volt Electrolyzer with a salt content of 100 gr/L that was same to 0.156 ppm. The complete data can be seen in Figure 1 as follows.

Decrease in microbe number

The care-rooms microbe number decrease in Cl_2 gas disinfection applications from Electrolyzer (5 volts, 9 volts and 13 volts) with salt content (100 gr/L, 150 gr/L, and 200 gr/L) between the highest in 13 volt Electrolyzer with a salt content of 200 gr/L was same to 6,754 CFU/m^3 while the lowest was in 9 volt

Electrolyzer with a salt content of 100 gr/L that was same to 4,799 CFU/m^3. The complete data can be seen in Figure 2 as follows.

Univariate Analysis

The average ofcare-rooms temperature was 27.73°C, while the average of the humidity was 61.93%. Complete data can be seen in Table 3 as follows.

Table 3: Results of Descriptive Analysis of Temperature and Humidity of Care-Room in Panembahan Senopati Hospital

Variable	N	Mean	SD	Minimum	Maximum
Temperature (ºC)	192	27.7	1.1	26.2	30.6
Humidity (%)	192	61.9	3.8	55.2	69.2

Multivariate Analysis

Double linear regression

The results of the Double Linear regression test obtained beta values (b) between -0.020 to -0.270 can be said to be the temperature, humidity, salt content and electrolyzer have influenced with a decrease the bacterianumber. Complete data can be seen in Table 4 as follows.

Table 4: Results of Double Linear Regression Analysis of Humidity, Temperature, Electrolyzer and Salt Content

Independent Variable	B*	p	β**
Constant			
Temperature (°C)	-21.574	.788	-0.25
Humidity (%)	-4.857	.834	-0.20
Electrolyzer (Volt)	-5.986	.004	-0.270
Salt Content (mg/L)	-5.986	.004	-0.270

* B: Unstandardized Coefficients

** p: Standardized Coefficients

Interpretation:

a. Temperature had a negative effect on the microbe number, the higher the temperature than the number of bacteriadecreased, but it was not statistically significant (B = -21,574; p = 0.788).

b. Temperature had a negative effect on the microbe number, the higherthe temperature than the number of bacteria decreased, but it was not statistically significant (B = -21,574; p = 0.788).

c. Electrolyzer had a negative effect on the microbe number, the higher the voltage than the electrolyzer would further reduce the microbe number, statistically significant (B-5,986; p = 0.004).

d. Salt content had a negative effect on the microbe number, the higher the salt level than the lower the microbe number, statistically significant (B-5,986; p = 0.004).

Multivariate of anova

Anova multivariate test results obtained p = 0,000, it can be said there was an influence of the electrolyzer model and the salt content in the Cl_2 gas disinfection process to decrease the microbe number.

IV. DISCUSSION

Nosocomial infection is a disease caused after a person is hospitalized for 48 hours, by the presence of microorganisms originating from outside of the patient. Factors that influence the occurrence of nosocomial infections include: enteric bacteria that are usually involved in hospital-acquired nosocomial infections, the presence of disease agents (viruses, microbe number, and fungi), resistance to drugs, and equipment including rooms contaminated with disease agents. This infection is an important public health problem, but just few is known about its contribution to antibiotic resistance[1]. According to Matteo[18], that high rated of nosocomial infections caused by *Staphylococcus aureus* bacteria are known to some degree of disease severity and methicillin resistance is a factor that causes premature death and late treatment. For patients with bacterial infection with *Staphylococcus aureus*, consultation of infectious diseases is an invaluable measure to improve clinical treatment outcomes.

According to WHO[3] and Cotter[4] that nosocomial infections are a major cause of death and illness in hospitalized patients, with a minimum mortality rate of 175,000/year. Increased nosocomial infections in Europe and America by 1% per year, in Asia by 40% per year [5]. According to Hasan[19], infection control committees should control transmission of infection, practice appropriate and healthy methods for providing patient care, using appropriate methods for antimicrobial use, staff training, proper waste management and service reform health.

The incidence rate of nosocomial infection is 7.4 per 1,000 patient days, with a significant difference between 3 annual infection rates. The highest prevalence of infection was found in the Internal Medicine Unit (41.3%), followed by the Intensive Care Unit (12.4%), the Surgical Unit (9.0%,) and Cardiology (7.1%) (Allesio M, et al., 2016)[20]. The prevalence of nosocomial infection in North Iran is 4.13%, consisting of 49.1% of respiratory tract diseases, wound infections 26.3%, urinary tract infections 16.7%, and blood infections 7.9%. Among diseases caused by nosocomial infections caused by the use of antibiotics[8,9].

According to Podha[21], in Thailand it is estimated that every year there will be at least 1,121,995 cases of anti-microbial resistant nosocomial infections which 48,258 cases caused death. The results of the study by Suwarni and Sutomo[13] showed the incidence of Nosocomial infections in Government and Private Hospitals in Yogyakarta Province with an average of 4.26% of patients. According to WHO[3], stated that world death rate due to nosocomial infection is 1.4 million people or 10%, thus increased the length of treatment to 4-12 days.

Hassan[19] said that the use of antibiotics is not appropriate and caused of resistance in organisms to drugs often, making it difficult to treat. The organization must develop an infection control program which infection rates can be compared and controlled. A well-managed monitoring methodology is needed. According to Mhealth Ministri Decree in Republic of Indonesia No. 1405/MENKES/SK/XI/2011, incare-rooms maximum microbe pollution number is 200-500 CFU/m^3 [22].

Efforts to rehabilitate the care-rooms air through disinfection of ultraviolet (SUV) and 3 chemicals[23,24]. Based on the results of Suwarni and Sutomo [13] the number of care-rooms microbe number in government and private hospitals in Yogyakarta with an average of 3,758 CFU/m^3 exceeds the Standard of (200-500 CFU/m^3).

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According to Aaron[25], virus play an important role in microbial ecology and some infectious diseases, but relatively just a little is known about the concentration, sources, transformation, and life cycle of viruses in the atmosphere.Diseases caused by microorganisms are transmitted through the air, preventing transmission through disinfecting indoor air using the Ulraviolet (UV) rays and chemicals Other alternatives can be Cl_2 gas from salt water electrolysis[26]. Laboratory test results proved that Cl_2 gas can be used as an air disinfectant.

According to Roseno[27] and Kiros[28], electrolysis of edible salt produces Cl_2 gas. The results of Ganefati's research[29], Cl_2 gas from electrolysis of edible salt at 5 volts voltage of exposure time within 10 minutes of Cl_2 gas content of 0.0216 ppm and did not more than the standard. Roseno[27] said that statistically there was no difference in chlorine gas production voltage between 9 volts and 13 volts. Suwarni and Sutomo[13] said there was a relationship between the air microbe number (an average of 3,758 CFU/m^3) with the nosocomial infections (an average of 4.26%). The purpose of this study was to determine the effect of chlorine gas (Cl_2) from salt water electrolysis with various concentrations and stressed to decrease the microbe number and residual chlorine gas.

The remaining chlorine gas in the room air as a disinfectant functions fororiginating microorganisms from the air conditioner.The use of air conditioners can increase the microorganismsproliferation by the presence of low temperatures and high humidity. Theroom air is sucked into the air conditioner, then released again. Air circulation allowed microorganisms trapped in the room, then die by addingthe Cl_2 gas. In the presence of air circulation, Cl_2 gas also functions as a disinfectant for microorganisms trapped in the air conditioner.

Based on the description, mostof nosocomial infectionscausedby microorganisms in the patient's environment, so care-rooms air disinfection studies used the Cl_2 gas disinfectant from salt water electrolysis. The results showed the highest decrease in the average microbe number by 6.754 CFU/m^3 and the lowest at 4.799 CFU/m^3. The research variables will be fully explained as follows.

Effect of Temperature on Microbe Numbers

The growth and propagation of microorganisms is influenced by air temperature. Based on the results of the study showed the higher the temperature, than decrease the microorganisms, but not statistically significant. This situation can be said to be related to the good temperature for microorganisms to developed, but the decrease in microorganisms was not influenced by air temperature. Based on air temperature, microorganisms are grouped into 3 (three), namely psychophyl, mesophyl and thermophyl. The changes of air temperature made microorganisms grow and multiply.

According to Ewa and Josef[30], the most common microorganisms found outdoors are gram-positive rods that made up the endospores. Statistically, the most important meteorological factors associated with the survival of bacteria in the air are temperature and UV radiation. Mesophyl microorganisms will optimally live and breed at 25-55°C, while thermophyl bacteria will optimally live and multiply at 50-65°C. Based on these conditions, it can be said that air microbe number in the treatment room of Panembahan Senopati Hospital with an average room temperature of 50.6°C is possible for microorganisms of mesophyl and thermophyl groups to multiply optimally.

The results of room temperature measurements in Table 1 showed temperatures between 25.3°C-27.7°C; the univariate analysis results in Table 3 showed an average temperature of 27.7°C; and the results of the multiple regression analysis in Table 4 showed the results the higher the temperature, made the higher the number of germs, but not statistically significant. This situation was possible to the existence of microorganisms that live at temperatures higher than 25-50°C, namely microorganisms, mesophyll and thermophyl groups.

Effect of Humidity on Microbe Number

Growth and propagation of microorganisms is also influenced by air humidity. High humidity also affects the growth of microorganisms in the room. Based on the results of the study showed the higher the humidity affected to decreased the air microorganisms, but not statistically significant. This situation can be said that humidity is related to the propagation of microorganisms, the decrease in microorganisms wass not influenced by air humidity. Martin[31] explained that the propagation of microorganisms can reach 80% humidity.

Humidity that was suitable with the environment of microorganisms, the microorganisms can grow and multiply quickly. This situation is proven from the results of research showing high rates of care-rooms microbe number from pre-test data with a average between 8094-11,063 CFU/m^3.

Room humidity measurement results in Table 2 showed an average of 69.7%-76.4%; The results of the univariate analysis in Table 3 showed an average humidity of 61.9%, and the results of the multiple regression analysis in Table 4 showed the higher the humidity the higher the microbe number, but not statistically significant. This situation was possible at humidity up to 80%, microorganisms were able to multiply faster.

Effect of Eelectolyzer on Cl2 Gas

Salt water electrolysis produces Cl_2 gas which functioned as a disinfectant for care-rooms hospital air microorganisms. Disinfection using Cl_2 gas from salt water electrolysis used materials that were easily found, can even use sea water, and the type of microorganisms that die is quite extensive. Disinfection of care-rooms using Cl_2 gas from salt water electrolysis did not exceed specified standards or did not exceed 1 ppm. The purpose of controlling the air microbe numbers pollutionwas an effort to prevent the occurrence of nosocomial infections. This situation is also supported by the measurement of the remaining Cl_2 gas in the room <0.3 ppm or not exceeding the standard quality of immovable sources. Safe spaces are used by patients, families and visitors[32].

The mechanism of chlorine compounds as a disinfectant by inhibiting enzymes involved in carbohydrate metabolism in microorganisms. Cl_2 disinfectant was easy to do and the type of microorganisms that killed with this compound was quite extensive (Roseno, 2013)[29]. Cl_2 gas is toxic, so it can be used as a material for disinfection of air space (deadly microorganisms) of an average of 0.238 (<0.3), below the international microbe standard[32].

Based on the description, the results of the study showed that there are effectedthe various electrolyzer models on Cl_2 gas produced from salt water electrolysis. This situation is proven by the results of the study in Figure 1 showed the higher the electrolyzer voltage and salt content, the higher the Cl_2 gas produced.

Effect of Salt Content on Microbe Number

Edible salt is a bond between sodium (Na) and chloride (Cl). The electrolysis reaction of edible salt (NaCl) using an electric current produces 2Na in the form of solids and Cl_2 in the form of gas. The weight of salt in the electrolysis process affects the Cl_2gas. The heavier the salt, the more Cl element contained in the NaCl bond. This situation is strengthened by the research results showed the electrolysis of salt water the higher the salt content, the higher the Cl_2 gas produced. Cl_2 gas in salt water electrolysis produced from salt of 100g/L, 150g/L and 200g/L showed an increase in Cl_2 gas. The higher the salt content, the higher the Cl_2 gas produced.

Based on these descriptions, the results of the study found that there are effectedthe various electrolyzer models on decreasedto the number of germs. This situation is shown by the results of the studies in Figure 1 and Figure 2 and the results of the anova multivariate test ($p = 0.00$ / $p < 0.05$), which mean that there was an influence of electrolyzer voltage variations and salt content on decreasing bacterial numbers.

V. CONCLUSIONS

1. There was an effect of chlorine gas (Cl_2) from salt water electrolysis in disinfection of hospital care-rooms on microbe number reduction, based on multivariate analysis p = 0,000 <0.05.
2. There was an influence of salt levels from electrolysis of salt water in disinfection of hospital care-roomson decreasing the microbe number rates, based on multivariate analysis p = 0,000 <0.05.
3. A 13 volt electrolyzer with a salt content of 200 gr/L reduced the microbe number in the care room air, based on multivariate analysis p = 0,000 <0.05.

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