

Analisis Pengukuran Fisik Ruang Isolasi Pasien COVID-19 Sebelum Dipergunakan: Studi Kasus Rumah Sakit Universitas Mataram

Physical Measurement Analysis in Pre-Utility Covid-19 Isolation Room: A Case Study Universitas Mataram Teaching Hospital

Eustachius Hagni Wardoyo¹, Ida Bagus Alit², Monalisa Nasrul³, Didit Yudhanto⁴, Prima Belia Fathana⁵, Rini Srikus Saptaningtyas⁶

¹Microbiology Department, Faculty of Medicine Universitas Mataram, ²Mechanical Engineering, Faculty of Engineering, Universitas Mataram, ³Ophthalmology Department, Faculty of Medicine Universitas Mataram, ⁴ENT Department, Faculty of Medicine Universitas Mataram, ⁵Pulmonology Department, Faculty of Medicine Universitas Mataram, ⁶Architecture Engineering, Faculty of Engineering, Universitas Mataram

Korespondensi Penulis :
Eustachius Hagni Wardoyo
Email: wardoyo.eh@unram.ac.id

Abstrak

Latar belakang: Ruang bertekanan negatif direkomendasikan untuk perawatan pasien COVID-19. Tujuan study untuk mendeskripsikan analisis pengukuran fisik ruang isolasi Rumah Sakit Pendidikan Universitas Mataram. **Metode:** Ruang isolasi tekanan negatif yang baru dikembangkan adalah pengukuran fisik menggunakan instrumen berikut: anemometer, pengukur kelembaban, higrometer dan pengukur tekanan. **Hasil:** Penelitian ini menunjukkan pengukuran fisik sebagai berikut: 1) ACH- air change per hour (pergantian udara per jam) 23,3 / jam [minimum: 12+ ACH]; 2) perbedaan gradien tekanan antara ruang rawat inap dan anteroom -30 Pa [minimum -15 Pa]; 3) rata-rata suhu udara 24,8°C [21-24]; 4) kelembaban udara 58% [maksimum 65%] dan 5) kelembaban beton 22,45%. **Kesimpulan:** Ruang isolasi COVID-19 di Rumah Sakit Pendidikan Universitas Mataram memenuhi kriteria standar

Kata Kunci: Ruang Isolasi Bertekanan Negatif; COVID-19; Analisis Pengukuran Fisik

Abstract

Background: Negative pressure room is recommended for the treatment of COVID-19 patients. Aim this study to describe physical measurement analysis of isolation room Universitas Mataram Teaching Hospital. **Methods:** Newly developed negative pressure isolation room was physical measure using following instruments: anemometer, moisture meter, hygrometer and pressure gauge. **Results:** This study showed physical measurement as follow: 1) ACH (air change per hour) 23.3 / hour [minimum: 12+ ACH]; 2) the difference in pressure gradient between the inpatient room and anteroom -30 Pa [minimum -15 Pa]; 3) the mean of air temperature 24.8°C [21-24]; 4) air humidity 58% [maximum 65%] and 5) concrete moisture 22.45%. **Conclusion:** The COVID-19 isolation room at the Universitas Mataram Teaching Hospital meets the standard criteria

Keywords: Negative Pressure Isolation Rooms (NPIRs); COVID-19; Physical Measurement Analysis

Background

COVID-19 patients with moderate to severe symptoms are advised to be treated at the hospital. Negative pressure rooms are recommended for procedures that induce aerosolization or for patients with prominent respiratory symptoms.¹ NPIRs apply several conditions: 1) to contain airborne pathogen contaminant within room, by a prevention of air leak to the environment, 2) negatively pressure is determined to let air streamed via outlet duct to be filtered before let it lose to the environment or to be re-circulated.^{2,3} This well-engineered room is designed to prevent of COVID-19 spread to other patients, staff and visitors and to the environment. Based on above it is highly recommended that each hospital to develop a negative pressure isolation rooms (NPIRs) for the treatment of symptomatic COVID-19 patients.

Develop NPIRs is a complex task, even for developed countries, with additional climate challenge, with separated HVAC (heating, ventilation and air conditioning) system from regular room. The development of

NPIRs at the Mataram University Hospital is the development of a previously existing room, to be developed into a negative pressure isolation room. In the study newly developed negative pressure isolation room was physically analyzed. Due to limitation of resources and time, the parameter measured were: 1) ACH (air change per hour); 2) pressure gradients; 3) the mean of air temperature; 4) air humidity and 5) concrete moisture.

Methods

After development of NPIRs was complete in early April 2020, we took physical analysis of isolation room in April 17, 2020. Instruments that we use are as follow: 1. Anemometer (GM8902 Benetech®), measuring the speed of air movement; 2. Moisture meter for concrete and wood (MS-7003, Lutron), measuring moisture of the concrete; 3. Digital hygrometer (HTC-1) and 4. Implanted pressure gauge (magnehelic®). Analysis of the material and monitoring system that is support for the effectiveness of isolation room is gathered through observation.

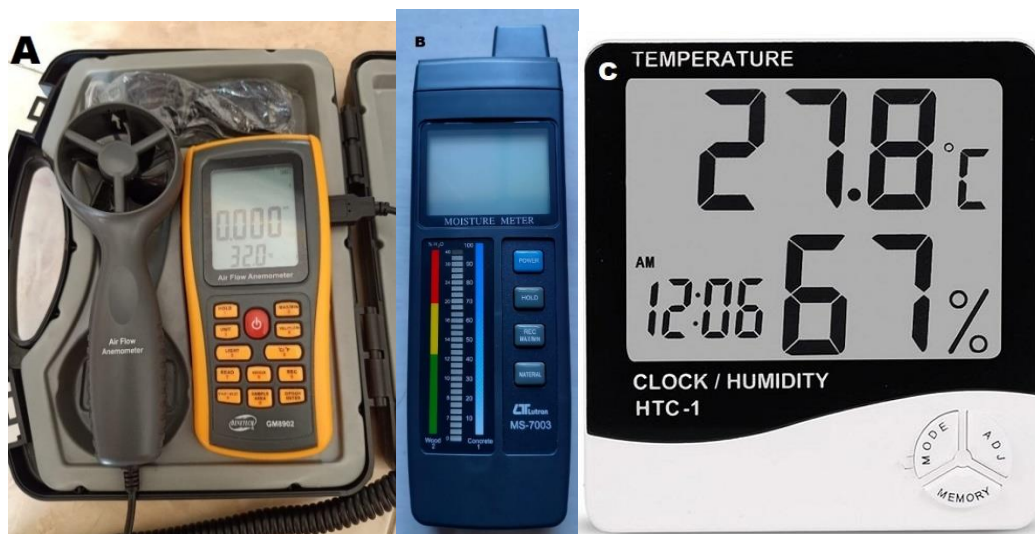


Figure 1. Instruments used in the study. A=anemometer (GM8902 Benetech®); B=moisture meter (MS-7003, Lutron); C=hygrometer (HTC-1®)

$$ACH = 3.600 \text{ sec} \times \frac{[\text{mean air velocity outlet } (\frac{m}{s}) \times \text{outlet duct wide (m2)}] - [\text{mean air velocity inlet } (\frac{m}{s}) \times \text{inlet duct wide (m2)}]}{\text{Room Volume (m3)}}$$

Air change per hour for negative pressure room is measured the difference between outlet and inlet flow times to the wide of ductus divide by room volume in one hour and describe it as following formula.⁴

Results

Negative pressure isolation rooms (NPIRs) Universitas Mataram Teaching Hospital is located in C building Ground Floor. It has 5 patient rooms with 1 designated as high care unit (HCU) (Figure 2).

Parameter measurement as follow: mean patient room volume is 53.799 m³. In each room there are 2 outlet duct with circle exhaust, each with diameter of 25 cm (Figure 3) and one inlet duct Air

conditioning with area of (0.62x0.08) m². Mean air velocity outlet was 1.4558 m/s and inlet 4.5 m/s. Include all known measurement in the formula: 3600x[(1,4558x3,14x0,25²x2)-(4.5x0.62x0.08)]/53,798 m³ and ACH was measured 23.3/hour.

Pressure gradient was observe in 5 patient rooms (Figure 4) with mean of -30Pa (28-32). Mean air humidity from 5 patient rooms was observed 58% (56-60%). Mean of concrete moisture 22.45% (21.8-23.1). On material observation we found that there is no airlock system in the patient door. The door material is aluminum framed glass. On one side of the wall was calcium board material that is not airlock ability.

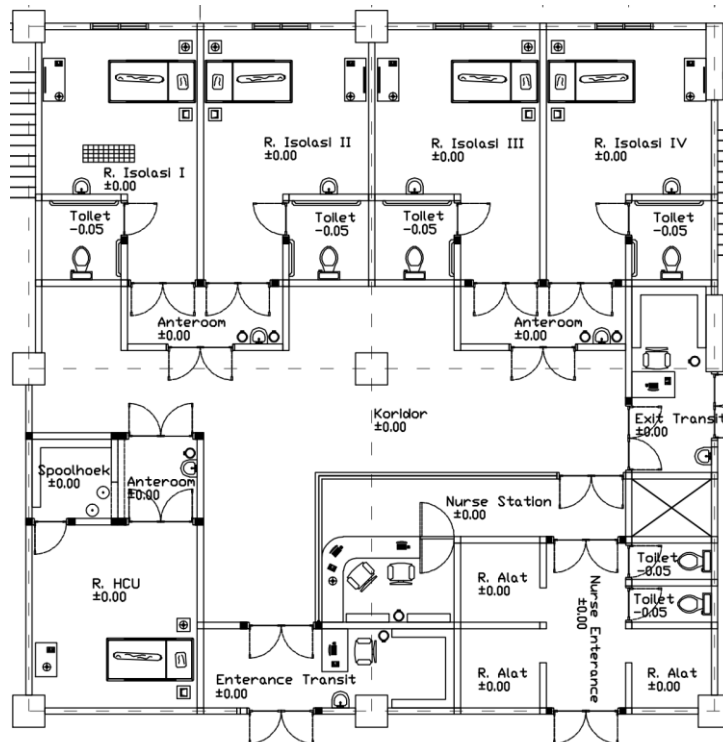


Figure 2. Schematic diagram of NPIRs. There are 5 designated patient rooms (4 regular rooms and 1 HCU room).

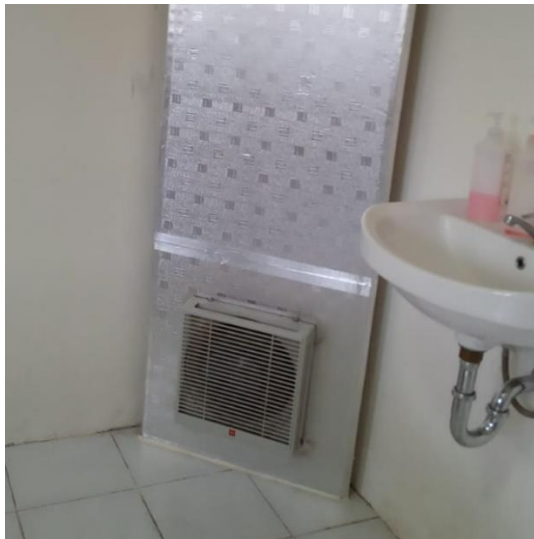


Figure 3. Outlet duct with 25cm in diameter. There are two outlet ducts in each NPIR



Figure 4. Implanted pressure gauge (magnehelic®)

Discussion

Infection prevention and control recommendation from WHO in facing SARS-CoV-1 is still relevant to SARS-CoV-2 especially in isolation room role.¹⁷

Several physical parameters need to be analyzed to assess the effectiveness of NPIRs, air change per hour (ACH) is an important parameter in ensuring that the overall air in the room added, remove, exchanges several times in one hour. ACH parameters are important in measuring whether: decreases the risk of pathogens being inhaled again by patients or inhaled by health workers and reduces the risk of environmental contamination. CDC describe ACH as time required in removing 99% and 99.9% airborne contaminant. ACH standard used in this study is $12^{+6,7}$ that mean will effectively remove 99% and 99.9% airborne contaminant 23 and 35 minutes, respectively. In this study, our finding ACH of 23.3 is 99 and 99.9% remove less than 14 and less than 21 minutes, respectively.⁶ Even the ACH parameter showed a high calculation, it did not entirely describe IPC efficiency. Over power of negative pressure is not ideal for effective air change in the hotspots of the whole of the room. In figure 5 there are other factor to contribute in IPC beside engineering and environmental control.

Pressure gradient between patient room to anteroom is important to be maintain negative >-15 Pa is believed to be minimum pressure to contain the virus to flow through outlet duct, not to anteroom or to the corridor. In this study showed -30 Pa has fulfill the minimum requirement.

In order to increase performance and sustainability of NPIRs to contain SARS-CoV-2 should provide: 1). the airlock system in doors/ hermetic door.⁸ 2). air-tight wall and ceiling material⁹ 3). open and close automatic door alternately between two doors of patient room and anteroom¹⁰ and 4). Smart setting to maintain efficient pressure gradient and ACH.¹¹ Those 4 aspects we are not found in our study setting.

In this study air humidity was 58%, that is stil in optimal range of maximum humidity 65% (ASHRAE, 2019) or in range 40-60%.^{12,13} This study is accordance to Tungjai et al (2017) Ahlawat et al (2020) reviewed there were three different scenarios how humidity affects virus transmission in indoor setting: evaporation kinetics modulating survival microorganisms inside the viral droplets, survival rate of SARS-CoV-2 on surfaces, role of dry indoor air in airborne transmission of the virus.^{14,15} Those scenarios imply that low humidity ($<40\%$) is tend to increase its transmission rate while higher humidity

tend to decrease transmission rate of the virus. The reasons are, the humid air will increase the weight of the droplets or aerosols that increase the speed of settling to the ground, while moisture-free air yields optimal route for long

distance transmission from smaller droplets and aerosols. Also, moisture-free air our mucosa become dry and viscous and reduce our cilia capability to expel viral aerosols.¹⁶

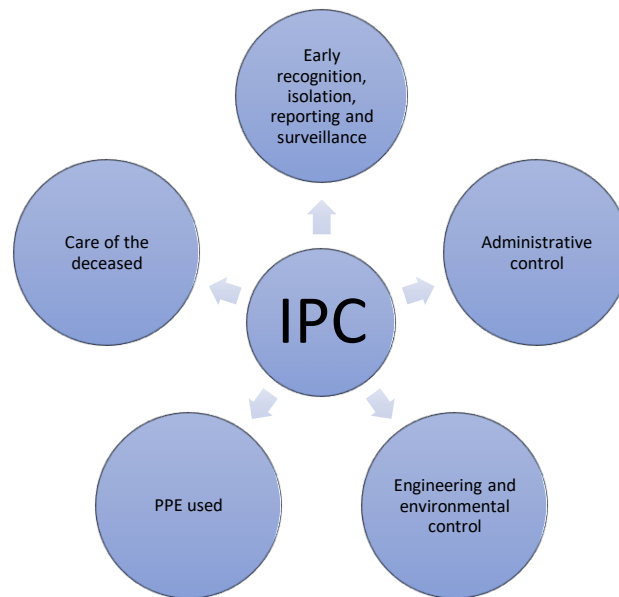


Figure 5. Position negative pressure isolation room in infection prevention and control: engineering and environmental control. IPC=infection prevention and control recommendation; PPE=personal protective equipment. Developed according to ref.⁵

Although air humidity and concrete moisture slightly contribute to the measurement of the risk of virus transmission, it is suspected that these parameters contribute to the persistence of the virus in the environment.^{17,18}

Concrete moisture will affect in respiratory health. Dampness of concrete promotes the growth of bacteria and molds and release chemical. Too much moisture may

cause toxic chemicals to be released from building materials and furnishings. The health effect after exposure to the dampness of moisture are: upper respiratory tract (nasal and throat) symptoms, cough, wheeze asthma symptoms in sensitized asthmatic persons.¹⁹ No documented standard for normal value of concrete moisture, but relatively dynamic to temperature variation. In 29°C indoor temperature,

indoor concrete humidity around 60%⁽²⁰⁾⁽⁷⁾ in this study temperature of 24.8°C correlate with concrete moisture of 22.45%.

Limitation of the study. Physical measurement analysis during utility is unable to perform due to continuously use of isolation room. It takes 48 hours operational shut down before take evaluation measurement. Effectiveness to contain virus was not evaluated.²

Conclusion

We conclude that physical measurement analysis of negative pressure isolation room Universitas Mataram Teaching Hospital meets standard criteria. Further periodic monitoring is recommended.

Acknowledgement

We acknowledge to dr. Ahmad Taufik, SpOT, director of Universitas Mataram Teaching Hospital.

Conflict of interest

There is no conflict of interest stated.

References

1. Ministry of Health Republic Indonesia. Manual of prevention and control Coronavirus Disease (COVID-19) Revisi-5. 2020.
2. Kim SC, Kong SY, Park GJ, Lee JH, Lee JK, Lee MS, et al. Effectiveness of negative pressure isolation stretcher and rooms for SARS-CoV-2 nosocomial infection control and maintenance of South Korean emergency department capacity. *Am J Emerg Med.* 2021;
3. Al-Benna S. Negative pressure rooms and COVID-19. *Journal of Perioperative Practice.* 2021.
4. Brouwer M, Katamba A, Katabira ET, van Leth F. An easy tool to assess ventilation in health facilities as part of air-borne transmission prevention: A cross-sectional survey from Uganda. *BMC Infect Dis.* 2017;
5. Guidelines WI. Infection prevention and control of epidemic- and pandemic-prone acute respiratory diseases in health care WHO. Infection prevention and control of epidemic- and pandemic-prone acute respiratory diseases in health care. 2007.
6. CDC. Healthcare Infection Control Practices Advisory Committee (HICPAC): Guidelines for Environmental Infection Control in Health-Care Facilities. US Dep Heal Hum Serv Centers Dis Control Prev Atlanta, GA 30329. 2003;
7. Holt M. Health care facilities. *EC M Electr Constr Maint.* 2009;108(10).
8. Tahpi ©. Isolation Rooms - Guideline Section - International

- Health Facility Guidelines. 2017;19–28. Available from: http://healthfacilityguidelines.com/Guidelines/ViewPDF/iHFG/iHFG_part_d_isolation_rooms
9. Herrick M. Planning and maintaining hospital air isolation rooms. *Hfm Magazine*. 2017.
 10. VACIC. Guidelines for the classification and design of isolation rooms in health care facilities. Victorian Advisory Committee on Infection Control. 2007.
 11. Wang Y, Li Y, Zhou L. Pressure Gradient Control and Energy-saving Operation Strategy Study on a Multi-zone Cleanroom. In: *Procedia Engineering*. 2015.
 12. Nortec. HEALTHY AIR HUMIDITY - The importance of air humidification in hospitals and in outpatient settings *We Love Humidity*. 2017;
 13. PMK No. 24. Permenkes No 24 tahun 2016 tentang Persyaratan Teknis Bangunan dan Prasarana Rumah Sakit. Menteri Kesehatan Republik Indonesia Peraturan Menteri Kesehatan Republik Indonesia. 2016;
 14. Tungjai A, Kubaha K. Indoor Air Quality Evaluation of Isolation Room for Hospital in Thailand. In: *Energy Procedia*. 2017.
 15. Ahlawat A, Wiedensohler A, Mishra SK. An overview on the role of relative humidity in airborne transmission of sars-cov-2 in indoor environments. *Aerosol Air Qual Res*. 2020;
 16. Taylor S. Why the fight against COVID-19 must include indoor air humidity. *Building* [Internet]. 2020; Available from: <https://building.ca/feature/why-the-fight-against-covid-19-must-include-indoor-air-humidity/>
 17. WHO. WHO guidelines for indoor air quality: Dampness and mould. Copenhagen: WHO Regional Office for Europe. *J Biomed Semantics*. 2009;
 18. Mecenas P, da Rosa Moreira Bastos RT, Rosário Vallinoto AC, Normando D. Effects of temperature and humidity on the spread of COVID-19: A systematic review. *PLoS One*. 2020;
 19. CDC/ IOM 2004. Summary of 2004 IOM Report: Damp Indoor Spaces and Health.
 20. U.S. Environmental Protection Agency. *Moisture Control Guidance for Building Design , Construction and Maintenance*. 2013;(December):144.