

HOSPITAL BUILDING SAFETY: A SYSTEMATIC REVIEW

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ABSTRACT

Safety is the most important aspect that needs to be considered in a hospital. There are several types of safety: patient safety, health personnel safety, building safety, equipment safety, green productivity, and hospital business safety. Building safety is determined to be the third common adverse event that occurred in hospital and affects directly to the safety of patients and health workers. Building safety in hospitals consists of electrical installations, fire and lightning protection, wastewater treatment plants, medical gas systems and medical vacuum, and elevator installation. A systematic review of problems and solutions to improve hospital building safety is expected to become a useful information for any health profession, engineers, and researchers. The purpose of this study is to identify the result of research on the implementation of building safety in the hospital. Some literature on adverse events and solutions from 2000-2019 was reviewed. The result shows various adverse events such as fall of the elevator, fire, damage electrical current which resulted in many victims. The result of this literature review can be a reference for hospitals to conduct evaluation and innovation in the implementation of building safety in hospitals.

Keywords: *Building Safety Hospital, Electrical Installation, Fire, Wastewater Treatment Plants*

1. INTRODUCTION

Hospitals need well-constructed buildings as well as reliable medical devices. Hospital buildings should be capable of resisting various loadings such as dead load, live load, wind load, earthquake load, flooding load, thermal load, fire and others (Chen & Chen, 1995). All of these health activities in hospitals use a large number of Medical Devices or MD, which must be constantly efficient to guarantee their life-saving functions and the continuity of surgical and outpatient procedures for patients. The MD is powered by electric energy and this must be guaranteed without interruption (Stroili, Pavan, Gorela, & Kenda, 2015). If a large earthquake occurs, especially in developing countries, the function of hospitals is very important to save the lives of injured people. On the other hand, hospitals are very dependent on the performance of medical devices, especially critical ones. A Series of adverse events in the hospital (see in table 1).

An adverse event is defined as an injury resulting from a medical intervention, not from the underlying condition of the patient (Edmonds, 2010), or as an unintended injury caused by medical management, rather than by a disease process, which has resulted in death, life threatening illness, disability at time of discharge, admission to hospital, or prolongation of hospital stay (Michel P, Quenon JL, De Sarasqueta AM, n.d.)

Table 1
Adverse Event in Hospital

Time	Location	Cause
August, 08, 2020	Bethesda Hospital Yogyakarta	Fire because short circuit electricity
February, 27, 2019	Saiful Anwar Hospital, Malang	Electrical panel fire

In these above adverse events took a lot of casualties and huge material losses. Most of the victims are patients in hospital, because of their limited walking, resulting in higher probability of casualties than that of healthy people. Therefore, how to design a hospital that has a good installation system, is resistant to fire, earthquake and other adverse events. The purpose of this article is to identify the result of research on the implementation of building safety in the hospital.

2. Materials and Methods

Selection of articles to be reviewed focuses on the type of quantitative and qualitative research. This review is compiled from original studies published online. The literature search results were performed on Google Scholar databases. Keywords used are hospital safety, hospital building safety, hospital fire, and implement hospital building safety.

3. RESULTS AND DISCUSSIONS

There are 30 articles reviewed. All reviewed journals focus to identify the result of research on the implementation of building safety in the hospital. Implementation of building safety in the hospital is divided into four themes: the implementation of electrical installations, fire, wastewater treatment plants, and medical gas systems and medical vacuum.

b. Implementation of Electrical Installation in Hospital

Based on literature review 10 research articles found that the implementation of electrical installations in hospitals based on some reference Indonesia and abroad. The implementation of electricity installation based on PUIL 2011 (Mardiyah, 2016) to know the conformity about electricity installation which installed at a private hospital in East Jakarta with the standard of PUIL 2011 or no, see the significance of electrical installations in hospital. The research result of the quality of electrical installation showed that the installation picture did not correspond to the picture, the presence of instrument of protection against fire and protection against direct touch didn't exist, as well as there was an error of phase installation using the yellow striped green cable. Current and voltage measurements produced the magnitude of losses in the neutral cable that was caused by power imbalance between phases. The magnitude of losses can cause the

electricity bills to swell. The voltage of each phase is always changeable, but still within safe limits.

Another study conducted by Sandi et al (Carnolis & Surapati, 2017) who researched the feasibility of existing electrical installation systems in hospitals, such as electrical distribution systems, electrical installation system, grounding system and shrinkage stress occurs and light intensity on the field work in the operating room. The results of the calculations obtained for qualification In MDP incoming cables of 25.47 A using NYFGBY 4x50 mm² cable types. Value In a cable from the outgoing to the incoming MDP SDP OK obtained at 15.32 A. In the security system at 152.09 incoming MDP A. In the security SDP of 25.47 A. The intensity of illumination on the work plane is measurable range 687- 710 lux, grounding wire using a type BC 50 mm² mounted on MDP and SDP OK. The value of the voltage drop of MDP to SDP accounted for 7,84Volt, and the percentage fall in voltage of 3.6%.

The health and technical legislation has established general principles for guaranteeing the continuous electricity supply necessary for the safety of the people treated in hospitals (Stroili et al., 2015). Another study about implementing electrical installation in hospitals shown in table Table 2.

Table 2
study about implementing electrical installation in hospitals

Title	Result
Evaluation of Electrical Installations in the Multi Center Of Excellent (MCE) Building Sultan Agung Islamic Hospital Semarang (Wahyu Pramon, Karnoto, & Nurhayati, 2018)	The results of the analysis can be concluded that the electrical installation system in the MCE building of the Sultan Agung Islamic Hospital Semarang is in good condition and safe. The MCB security unit is installed in accordance with the PUIL 2000 standard. On the size of the cables that are installed some are not in accordance with the PUIL 2000 standard so that cable replacement is required. For example, the SDP 1 cable for the Floor Divider Panel 1 where the cable installed is 4x35 mm ² replaced with 4x95 mm ²
Feasibility Study of Electrical Installation Systems in the Operating Room of the Kepahiang Regional General Hospital (Carnolis & Surapati, 2017)	This study aimed to evaluate the feasibility of existing electrical installation systems in hospitals, such as electrical distribution systems, electrical installation system, grounding system and shrinkage stress occurs and light intensity on the field work in the operating room. The results of the calculations obtained for qualification In MDP incoming cables of 25.47 A using NYFGBY 4x50 mm ² cable types. Value In a cable from the outgoing to the incoming MDP SDP OK obtained at 15.32 A. In the security system at 152.09 incoming MDP A. In the security SDP of 25.47 A. The intensity of illumination on the work plane is measurable range 687- 710 lux, grounding wire using a type BC 50 mm ² mounted on MDP and SDP OK. The value of the voltage drop of MDP to SDP accounted for 7,84Volt, and the percentage fall in voltage of 3.6%.
Analysis of the Saving of Electrical Energy at the Regional	The electric power distribution network within the dr. Soedarso consists of two groups, namely networks with

<p>General Hospital of Doctor Soedarso Pontianak in terms of installation design (Suharto, 2016)</p>	<p>land cables and air cables. The land cable network uses the NYFGBY type that connects distribution substations with service buildings, embedded in the ground without being equipped with safety signs. The distribution of the electricity network in service buildings in general uses a radial system, adding to the load that occurs when it does not consider the ability to conduct cable currents and the coordination of existing electrical safety. reinstallation</p>
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<p>Mitigation of the Magnetic Field Produces by Low Voltage terminals of Electric Transformation Chamber for Hospital Buildings (Chafla, Garcés, & Quevedo, 2017)</p>	<p>In the present work is analyzed the behavior of the magnetic flow created by the outputs in low voltage of the transformer located in the vicinity of the old hospital buildings, using the method of vortices it is possible to express graphically the dispersion of the magnetic field contemplating a global analysis of affecting the field density generated and not only one point like to study in magneto-static subjects. To mitigate the presence of this physical phenomenon, is simulated the installation of magnetic shielding films of AARONIA company on the walls of the transformation electric center. This mitigation method achieves a shielding efficiency of 57%, this percentage varies depending on the location of the analyzed area.</p>
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c. Implementation of Fire in Hospital

Based on the literature review 10 articles were found on the implementation of Evacuation in Hospital Fire, as stated by Weiling et al (W. Zhang & Yao, 2010) in his research entitled “A Reformed Lattice Gas Model and Its Application in the Simulation of Evacuation in Hospital Fire”. The research simulates the pedestrian evacuation and chases down a plan to solve during rescue. The simulation result indicated that the reformed lattice gas model can simulate the scene of evacuation in hospital fire realistically.

While research conducted by Guoliang et al (G. Zhang, Li, & Lu, 2019) titled “Analysis of Fire Evacuation in High-rise Hospitals from a High-rise Hospital Fire Case”. The paper took the fire caused by the thermal insulation material of the outer wall that took place at a high-rise hospital somewhere as an example to analyze and summarize the fire disposal. Another study about implementation of fire in hospitals shown in table.

Table 3
Study About Implementing Fire in hospitals

Title	Result
<p>Implementation of Fire Safety Using Quality Protocols in Port Said Private Hospital (Heba & Mohamed, 2021)</p>	<p>Hospital management has a prime responsibility toward safety of patients by implementing control measures to fire accidents. Impact of fire could be reduced with proper and ideal safety management in hospital building. Every single employee of a hospital shall follow her/his responsibility during fire emergencies and try to save as many potential victims as possible without waiting for instructions.</p>

<p>Evaluation of Fire Safety Preparedness among Healthcare Providers in Braithwaite Memorial Specialist Hospital (Ikpa, Dienye, P., & Jumbo, 2018)</p>	<p>The methods in this research is cross sectional study of 248 healthcare providers attending a workshop on infection prevention control recruited by purposive sampling technique after stratification according to respondent's cadre. The results show fire safety awareness and training among the respondents is low. Fire safety education and preparedness should be instituted as part of training and retraining of health personnel.</p>
<p>Analysis of Fire Protection System Standard in Hospital: Case Study in Jakarta, Indonesia (Djunaidi & Pratiwi, 2015)</p>	<p>The objects of this study are active fire protection, passive fire protection, and means of evacuation. The data was collected by observation, interviews, and document review. The results showed that from 112 variables of fire protection systems and means of evacuation, 30 variables do not comply with the NFPA standards. Other findings showed that the fire safety standards in the hospital have not been based upon the unique activities and conditions in the hospital. Besides that, the priority and commitment of management toward fire safety in the hospital are very low</p>
<p>Fire Safety Related Challenges Faced by Existing Hospitals: A Review (Hakim Choudhary, Kausar, Satpathy, & Sharma, 2020)</p>	<p>There is poor enforcement of law by agencies. Retrofitting for conformance to fire safety regulations is difficult. Issues like faulty equipment, improperly kept inflammable material, evacuation difficulties due to higher acuity of patients, operational issues like maintenance of all fire safety equipment and installations, and training of staff, etc. are highlighted. Focussed interventions and an all-encompassing fire safety risk management plan is the need of the hour. Significant insights into critical issues of fire safety is of immense benefit to healthcare professionals as a basis to make hospitals safe places.</p>
<p>Fire Safety Management of Public Buildings: A Systematic Review of Hospital Buildings in Asia (Muhamad Salleh, Agus Salim, Jaafar, Sulieman, & Ebekozien, 2020)</p>	<p>This paper recommends a fire safety management plan as one of the practical possible measures for addressing technical, management and legislation factors. Also recommended is training and fire safety education of healthcare staff in collaboration with safety firefighters to address major issues that may arise from management factors. The government should upgrade the safety technology equipment in healthcare facilities as part of measures to mitigate issues concerning technical and legislation factors. Also, the identified factors are part of the theoretical contributions to the advancement of knowledge and this brings to the front burners new opening</p>
<p>Implementation of Fire Safety Management System at DR. Sobirin Hospital District of Musi Rawas 2013 (Arrazy, Sunarsih, & Rahmiwati, 2014)</p>	<p>Management policies have been socialized to all employees through the training. Fire hazard identification hasn't been documented well. Fire prevention and control programme has also been started. The Organization has formed the Committee of safety, fire and disaster precautions with a clear job description. Training hasn't been done routinely. Means of fire protection was still relying on the Fire Extinguisher. Inspection and maintenance processes have been carried out routinely.</p>

<p>Evaluation of the Implementation Fire Emergency response in Hospital of Jombang District (Zurimi, W, & Yudhastuti, 2016)</p>	<p>Fire emergency response was prepared by creating standard operating procedure (SOP) and a special diagram when fires break out. Reporting system hasn't been done although it already has procedure and report formats. Audit fires already done internally and not routine</p>
	<p>This study aims to evaluate the implementation of fire emergency in Jombang Hospitals District on the fulfillment of standards based the decision of Health minister of Indonesia Republic Number.1087/Menkes/SK/VIII/2010 on occupational safety and health standards in hospital. This study is an observational study with cross sectional approach where the sample was determined by using simple random sampling method in which each member of the population being randomly and have equal opportunity to be sampled, so that the number of samples obtained as many as 68 people. The data collected by using questionnaires, observation and inspection of creating checklists in the form of a list. Data processing is performed by means of descriptive analysis and correlation analysis by using the chi-square test. The result of study obtained from 68 respondents to the evaluation of the implementation of the fire emergency response toward on the fulfillment of standards based on the decision of health minister of Indonesia republic number.</p>

d. Implementation Wastewater Treatment Plants in Hospital

In ancient times, hospitals were built in areas far from residential areas, with the consideration that hospital wastewater would not have an impact on settlements. In line with population development, currently the location of the hospital is close to residential areas. So the problem of environmental pollution due to hospital wastewater becomes a problem today. This is because hospital wastewater contains pathogenic compounds that can cause disease if not treated properly.

Combination of biofilter anaerob – aerob technology and ozonation is the effective strategy to manage and process hospital wastewater in Indonesia (Prayitno, 2011). This is because the anaerobic-aerobic biofilter technology has high processing efficiency, is more economical, has a small potential impact and is adaptive to technological developments. By applying this Anaerobic - aerobic biofilter system, the concentrations of COD, BOD and suspended solids can be significantly reduced as well as detergents and ammonia (Hartaja, 2018). The anaerob-aerob biofilter process have some excellence for example its simple operation, yielded a few or little of mud, can be used for the processing of waste water with low concentration and also high concentration, hold up to fluctuation of debit or concentration, and also its cheap operating expenses (Said, 2018).

Hospital wastewater must be treated before it is discharged into the environment. RK Charitas Hospital Wastewater Treatment Plant (WWTP) has not been evaluated. The analysis results of RK Charitas Hospital Palembang's wastewater showed that the wastewater still has high levels of

ammonia (NH₃) and phosphate (PO₄) that are not sufficient to the environmental quality standards and other terms are at the threshold. Phosphate (PO₄) level is 2.134 to 2.213 mg/l which exceeded the environmental quality standards is 2 mg/l and ammonia (NH₃) level is 0.174 to 0.186 that exceeded the environmental quality standards is 0.1 mg/l. This research was conducted to evaluate the process, processing time, material, and costs of WWTP at RK Charitas Hospital Palembang and provide a solution for redesign of a miniature WWTP that will be simulated (Mulyati & Narhadi, 2016).

Most hospital waste is a hazardous medical waste that is infectious. Research carried out in public hospitals WZ John Kupang showed fairly good efficiency. The WWTP used activated sludge has an efficiency of over 60% for all parameters and is relatively efficient. The highest level of efficiency was the parameter of TSS (83.60%) and the lowest was the BOD (62.03%). However, the treatment of wastewater was classified not as effective with an average percentage of 60%, meaning that waste management which carried out was used all available resources but does not meet the expected target, or in other words sewage treatment efficient but not effective (Grez Waang et al., 2016).

5. CONCLUSION

The result of this literature review can be a reference for hospitals to conduct evaluation and innovation in the implementation of building safety in hospitals.

REFERENCES

- Arrazy, (Syafran), Sunarsih, (Elvi), & Rahmiwati, (Anita). (2014). Implementation of Fire Safety Management System at DR. Sobirin Hospital District of Musi Rawas 2013. *Jurnal Ilmu Kesehatan Masyarakat*, 5(2), 103–111. Retrieved from <https://www.neliti.com/publications/57954/implementation-of-fire-safety-management-system-at-dr-sobirin-hospital-district>
- Carnolis, S., & Surapati, A. (2017). Studi Kelayakan Sistem Instalasi Listrik pada Ruang Operasi Rumah Sakit Umum Daerah Kepahiang. 11(1), 31–39.
- Chafla, E. A., Garcés, E. A., & Quevedo, A. M. (2017). Mitigation of the magnetic field produced by low voltage terminals of electric transformer in transformation chambers for hospital buildings. 2017 International Conference on Sustainable and Renewable Energy Engineering, ICSREE 2017, 134–138. <https://doi.org/10.1109/ICSREE.2017.7951527>
- Chen, J., & Chen, K. (1995). The Use of Reliability Index. 36–42.

- Djunaidi, Z., & Pratiwi, F. (2015). Analysis of Fire Protection System Standard in Hospital : Case Study in Jakarta , Indonesia. *Health and Safety, (Ferguson 2005)*, 1–10.
- Edmonds, M. (2010). *Adverse Events, Iatrogenic Injury and Error in Medicine*. University of Adelaide Australia.
- Greza Waang, D., Fernandez, H., Ramang, R., Magister Ilmu Lingkungan, P., Nusa Cendana, U., Jl Adisucipto Penfui Kupang, K., ... Keguruan dan Ilmu Pendidikan, F. (2016). Effectiveness Analysis Of Waste Water Treatment Plant And Assessment Of The Liquid Waste General Hospital John W. *Jurnal Bumi Lestari*, 16(2), 92–99.
- Hakim Choudhary, A., Kausar, M., Satpathy, S., & Sharma, D. K. (2020). Fire safety related challenges faced by existing hospitals: A review. *Medico-Legal Update*, 20(3), 419–425. <https://doi.org/10.37506/mlu.v20i3.1434>
- Hartaja, D. R. K. (2018). Desain Instalasi Pengolahan Air Limbah Rumah Sakit Kapasitas 40 M3/Hari. *Jurnal Rekayasa Lingkungan*, 10(2), 99–113. <https://doi.org/10.29122/jrl.v10i2.2850>
- Heba, P., & Mohamed, Y. (2021). " Implementation of Fire Safety Using Quality Protocols in Port Said Private Hospital ". <https://doi.org/10.21608/muj.2021.61475.1041>
- Ikpae, B. E., Dienye, P., A., & Jumbo, A. D. (2018). Evaluation of Fire Safety Preparedness among Healthcare Providers in Braithwaite Memorial Specialist Hospital. *The Nigerian Health Journal*, 18(1), 14–22.
- Mardiyah, H. (2016). Evaluasi InstalasiI Listrik Pada Rumah Sakit Berdasarkan PUIL 2011. 2011.
- Michelp, Quenon JL, De Sarasqueta AM, S. O. (n.d.). Comparison of three methods for estimating rates of adverse events and rates of preventable adverse events in acute care hospitals.
- Muhamad Salleh, N., Agus Salim, N. A., Jaafar, M., Sulieman, M. Z., & Ebekoziem, A. (2020). Fire safety management of public buildings: a systematic review of hospital buildings in Asia. *Property Management*, 38(4), 497–511. <https://doi.org/10.1108/PM-12-2019-0069>
- Mulyati, M., & Narhadi, J. S. (2016). Evaluasi Instalasi Pengolahan Air Limbah Rumah Sakit Rk Charitas Palembang. *Jurnal Ilmu Lingkungan*, 12(2), 66. <https://doi.org/10.14710/jil.12.2.66-71>

- Prayitno. (2011). Teknologi pengolahan air limbah rumah sakit. *Jurnal Pembangunan Dan Alam Lestari*, 1(2), 72–139.
- Said, N. I. (2018). Paket Teknologi Pengolahan Air Limbah Rumah Sakit Yang Murah Dan Efisien. *Jurnal Air Indonesia*, 2(1), 52–65. <https://doi.org/10.29122/jai.v2i1.2289>
- Stroili, M., Pavan, E. C., Gorela, M., & Kenda, F. (2015). The dimensioning and development of hospital electric installations to guarantee the continuity of use of the therapeutic and diagnostic system. *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS, 2015-Novem*, 1211–1214. <https://doi.org/10.1109/EMBC.2015.7318584>
- Suharto. (2016). Analisis Penghematan Energi Listrik Pada Rumah Sakit Umum Daerah Dokter Soedarso Pontianak Ditinjau Dari Desain Instalasi. *Elkha*, 8(1), 13–19. <https://doi.org/10.26418/elkha.v8i1.16192>
- Wahyu Pramon, E., Karnoto, K., & Nurhayati, T. (2018). Evaluasi Instalasi Listrik Pada Gedung Multi Centre of Excellent (Mce) Rumah Sakit Islam Sultan Agung Semarang. *ELEKTRIKA*, 9(1), 17. <https://doi.org/10.26623/elektrika.v9i1.1110>
- Zhang, G., Li, C., & Lu, S. (2019). Analysis of Fire Evacuation in High-rise Hospitals from a High-rise Hospital Fire Case. *2019 9th International Conference on Fire Science and Fire Protection Engineering, ICFSFPE 2019*. <https://doi.org/10.1109/ICFSFPE48751.2019.9055807>
- Zhang, W., & Yao, Z. (2010). A reformed lattice gas model and its application in the simulation of evacuation in hospital fire. *IEEM2010 - IEEE International Conference on Industrial Engineering and Engineering Management*, 1543–1547. <https://doi.org/10.1109/IEEM.2010.5674167>
- Zurimi, S., W, D. A., & Yudhastuti, R. (2016). Evaluation of the implementation fire emergency response in Hospital of Jombang District. *Engineering, Technology, and Sciences*, 17(1), 15–33.