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Analysis of Building Electrical Lighting System Tomohon City Regional Drink Water Company

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Abstract— This study aims to see whether the electrical lighting installation at the Regional Drinking Water Company (Indonesian, abbreviated as PDAM) of Tomohon City follows the General Requirements for Electrical Installations (abbreviated as PUIL) or vice versa. Using the analysis approach, direct observation was performed at the research site, and after performing the study, it was discovered that many electrical lighting installation requirements did not satisfy PUIL. Following the measurements and calculations, it was found that none of the lighting in building A met PUIL standards, while for building B, there was only 1 room whose lighting met PUIL standards. Furthermore, there were several rooms where the lights were not installed. Of course, this can affect the daily activities in the room. From the results of the study, it is inevitable that the electrical lighting installation in the PDAM building in Tomohon City must be repaired immediately and should follow the applicable PUIL.

Keywords: Lighting Installation, PUIL.

I. INTRODUCTION

Lighting is one of the components that workers can use to observe the work being done quickly, comfortably, and safely. From this, good lighting will provide a good view and a refreshing environment. A light will look like it reflects light, either from the light itself or in the form of reflections coming from other light sources, with the aim of lighting so that the light looks clear. The lighting can be adjusted according to a customized image and the accuracy or clarity of the work to ensure eye health and work enthusiasm (Nazari & Matusiak, 2024; Pratiwi, 2020).

Humans can carry out their activities well and achieve optimal results if their work environment supports them. One of them is good lighting. In several workplaces, lighting has been proven to have a positive impact, such as increasing maximum production, availability of goods and services, and expanding the work environment (DiLouie, 2021).

Laboratories, lecture halls, and work rooms enable activities that require good lighting so that they can run smoothly. An institution's workers, employees, and students need a comfortable atmosphere so that their activities run smoothly. One of them is lighting. Good lighting is lighting that allows us to see the object being worked on clearly, quickly and without unnecessary effort. The following are things that determine good lighting (Darnoto, 2021), among others: i) distribution of illumination in the field of view; ii) prevention of glare; iii) heat of lighting to the surrounding conditions; iv) direction of light; v) color.

Poor lighting is where it is not possible to see objects being worked on clearly and may be assisted by visual aids. The effects that result from poor lighting (Boyce, 2021) include i) eye fatigue, ii) mental fatigue, iii) damage to the visual apparatus, iv) complaints of soreness around the eyes, and v) increased accidents. Furthermore, the effects of eye fatigue will lead to decreased work performance, including loss of productivity, low work quality, many errors, and increased work accidents. One problematic factor that disrupts the workforce's comfort is the problem of inadequate lighting (Putri Sampurno et al., 2024).

Attention must also be paid to the installation of electrical sockets, switches, and lamps in the electrical lighting installation system, whether they are in accordance with PUIL standards or not. This greatly affects an agency's quality of work and will impact its employees. Based on the surveyor's observation, the Tomohon City PDAM Building still needs to reduce the lighting in its workspace. Rooms still need to be improved in light, which can affect vision. There are still broken lamps and several sockets and switches whose installations still need to follow PUIL standards.

The lighting system affects every indoor and outdoor area of the building. The location and characteristics of the lighting affect the color and shape of the building (Jaglarz, 2023). This is an optical characteristic that affects the appearance of the walls and roofs of office buildings. Energy use in the lighting system of commercial buildings ranges from 10% - 30% of the total electricity consumption (D'Oca et al., 2018). Although it does not consume much electricity, the impact of energy efficiency on the lighting system is quite influential. The lighting system is one of the critical factors in creating comfort and safety in the company environment related to the level of productivity of the company's employees. The lighting system is categorized as good when the objects being worked on can be known or seen by employees correctly and accurately (Indriyani et al., 2021). The design and mechanism of the building lighting system are made so that the building area looks bright and active people can see clearly in the building area. The tool used to determine the intensity of lighting is a lux meter. The tool uses a photoelectric cell to convert light energy into electrical energy. Intensity is expressed in illumination in Lux (Sammarco, 2020; Treese, 2018). Lighting intensity is measured in 2 ways (Purwaningtyas, 2021), namely:

a. General lighting is a measurement carried out on every square meter of floor area, with a measurement height of approximately 85 cm from the floor (waist height).
   Determination of general measurement points: the intersection point of the horizontal line of the length and width of the room at every certain distance of one meter from the floor (Karlen & Spangler, 2023).

b. Local lighting is measured at the workplace or work desk on an object seen by the workforce (e.g., a study lamp). Measure local measurement points: work objects like work desks or equipment (Karlen & Spangler, 2023).
   Measurements can be done on the existing table if it is a work desk. According to SNI 16-7062-2004, certain distances can be distinguished based on the room's area as follows: Room area less than 10 square meters: The horizontal intersection point of the room's length and width is at a distance of every one meter (Hangga et al., 2024; Putri & Sudarti, 2022; Rasa & Sativa, 2024).

The need for lighting intensity depends on the type of work being done (Suryatman & Hermawan, 2021). Precision work is difficult if the workplace lighting conditions are inadequate. For more details, see Table 1.

Table 1. Lighting Levels Based on Job Type

Type of work	Example of work	Required lighting level (Lux)
Not careful	Storing goods	80 – 170
Somewhat careful	Installation (not careful)	170-350
Careful	Reading, Drawing	350-700
Very careful	Installation	700-1000

It is listed in Table 2 according to the Decree of the Minister of Health of the Republic of Indonesia number *1405/MENKES/SK/XI/2002* concerning the requirements for office and industrial work environment education (Pramono et al., 2023). Then, based on the Illuminating Engineering Society (IES) (Chen, 2017), it is listed in Table 3.

Table 2. Lighting Level Standards
According to the Decree of the Minister of Health

Type of Work	Minimum Lighting Level (Lux)	Descriptions
Rough and irregular work	100	Storage and equipment/ installation rooms require continuous work.
Rough and continuous work	200	Machine work and rough assembly.
Routine work	300	Administration rooms, control rooms, machine work & assembly/ composers.
Somewhat fine work	500	Drawing or working with office machines, inspection, or machine work.
Fine work	1000	Color selection, textile processing, fine machine work, and exemplary assembly.
Very fine work	1500 Does not cast shadows	Hand engraving and inspection of excellent machine work and assembly.
Detailed work	3000 Does not cast shadows	Inspection of work: excellent assembly.

Table 3. Standards Based on IES
(Illuminating Engineering Society)

Place	Type of work	Illumination level rating	
		Very Good	Good
Regular office	Book keeping, typing, reading, writing, servicing office machines	1000	500
	Archive room, stairs, hallways, waiting rooms	250	150
	Classrooms	500	250

School	Drawing rooms	1000	500
	Sewing rooms	1000	500
	Watchmaking, small and fine instruments, engraving	500	2500
Industry	Fine fitting work, setting up automatic lathes, fine lathes, polishing	2000	1000
	Drilling work, rough lathes, general work	1000	500
	Forging and grinding	500	250
Shop	Large store displays	2000	1000
	Other stores	1000	500
House of worship		250	125
Residential house	Bedroom, bathroom, dressing room, kitchen	500	250
	General lighting	250	125

The design of an electrical installation system must meet the general requirements for electrical installations (PUIL 2011) and other regulations such as:

a) Law Number 1 of 1970 concerning occupational safety and its implementing regulations.
b) Law Number 30 of 2009 concerning Electricity
c) Government Regulation No. 14 of 2012 concerning the provision and utilization of electricity.
d) Government Regulation No. 62 of 2012 concerning Electricity Supporting Businesses.
e) Regulation of the Minister of Mining and Energy Number 01.P/40/M.PE/1990 concerning electrical installations.
f) Other regulations concerning electricity that apply and do not conflict with PUIL 2011 (for example, standards of the state electricity company, PLN).

In designing an electrical installation system, attention must be paid to the safety of humans, other living creatures, and property from dangers and damage that can be caused by electrical installations. In addition, electrical installations must function in good condition and in accordance with their intended use (Mamahit & Pangestu, 2024; Pangestu et al., 2023).

In PUIL 2011 (Saputra et al., 2023), it is called KKB (Ordinary Contact Box) and KKK (Special Contact Box). KKB is a regular contact box installed for use at any time (not permanently) for any electrical device that requires it, as long as its use does not exceed its capacity. KKB is spread throughout the building with non-permanent loads and is usually one with a group for lighting.

A switch is a component or device that disconnects or connects an electric current. Wall switches are usually placed approximately 120 cm above the floor on a commonly used path. If it must be used by opening the door first, then the switch is placed near and on the side of the door leaf that opens. The switches used are series switches and single switches (Koloway & Kattie, 2023; Lembong & Tatali, 2023).

For electrical installations, the distribution of electric current from the panel to the load or as a safety (grounding) uses electrical conductors that are appropriate for their use(Abast et al., 2023; Rahmat et al., 2024). Installation cables that are commonly used in lighting installations and the types of cables that are widely used in residential installations for permanent installations are NYA and NYM. In its use, NYA cables use pipes to protect mechanically or protect from water and moisture that can damage the cable. The types of cables used are NYM Cable and NYY Cable.

II. METHOD

This type of research is descriptive research, which will describe the results of measuring the lighting intensity in rooms in the Tomohon City Regional Drinking Water Company (PDAM) Building. This research will be conducted in the Tomohon City Regional Drinking Water Company (PDAM) Building, with a research period of approximately one month, namely in July 2023. The data collection technique used in this study uses documentation, observation, and interview methods. The data analysis technique used by the researcher is conclusion drawing. Then, after that, several calculations were done by the researcher, starting from the lighting flux and lighting intensity if there are some standards in the field.

This analytical calculation employs a formula to determine measurements and light intensity and to calculate lumen size and standard lux units, presuming that the lamps utilized in the Tomohon City PDAM building are 18-watt CFLs. Lighting Intensity Calculation Formula (Simons & Bean, 2000):

$$I = \frac{\Phi}{\omega} \quad (1)$$

Descriptions:

I : light intensity (Cd)
Φ : luminous flux (Lumen)
ω : angular magnitude
r : $\sqrt{(a+b)^2}$
$\cos a$: $\frac{y}{r}$

E : $\frac{I.cos\ a}{r^2}$

Formula for finding the lumen size:

$$\Phi = \text{I.A} \tag{2}$$

Descriptions:

A : room size

$$\Phi_{TIAP\ LAMPU} = \frac{\Phi}{N} \tag{3}$$

N : number of lights

III. RESULT AND DISCUSSIONS

The PDAM (Regional Drinking Water Company) office in Tomohon City, North Sulawesi, operates under the authority of the PDAM Tomohon City corporate entity. This office addresses diverse community requirements for water services, including utility registration, bill inquiries, payment processing, and Internet transactions. PDAM Tomohon City was founded on 4 August 2006, as sanctioned by Tomohon City Regional Regulation Number 11 of 2006 on the Establishment of the Tomohon City Regional Drinking Water Company. The Duties and Responsibilities of Structural Officials are governed by Tomohon Mayor Regulation Number 13 of 2006, which pertains to the Organizational Structure and Work Procedures of the Tomohon City Regional Drinking Water Company, PDAM Tomohon City, an extension of PDAM Minahasa.

This corporation is also equipped with a Supervisory Board, which was subsequently modified to a Supervisory Board following Permendagri Number 2 of 2007. On 26 November 1980, the Minister of Public Works of the Republic of Indonesia issued Decree Number 109/KPTS/CK/XI/1980, establishing the Minahasa Regency Drinking Water Management Agency (BPAM). In 1990, the PERDA (local regulation) was enacted to establish the Minahasa Regency Regional Drinking Water Company (PDAM). Perwako (mayor's regulation) No. 13 of 2006 was issued to establish the Tomohon City Regional Drinking Water Company. On 9 May 2007, the Minutes of Asset Handover & Management were recorded from PDAM Minahasa to PDAM Tomohon.

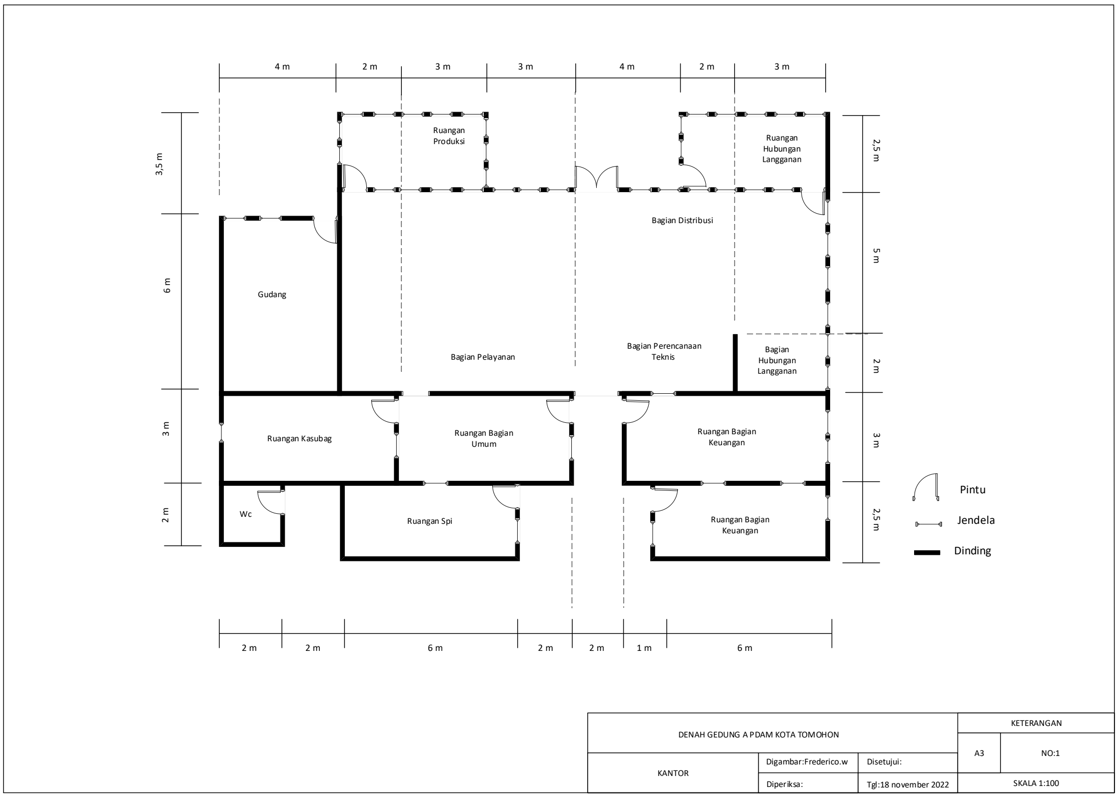

Figure 1. Floor Plan of Building A

The study was executed at the PDAM facility in Tomohon City, which comprises two structures. Through the observations conducted, the researcher acquired significant data. The researcher employed local metrics for data collection or measurement, specifically calculations performed directly within the work area. Measurements were taken using a lux meter. The procedures for data collection or measurement are outlined as follows:

a. Activate the lux meter and calibrate it after that.
b. Position the lux meter in the designated area for measurement.
c. Allow it to rest for a period to achieve optimal outcomes.

d. Document the measurement outcomes on the measurement sheet.
e. Deactivate the lux meter upon its completion.

Following local measurements and observations within the Tomohon City PDAM building. The acquired data is illustrated in Figures 1, 2, 3, 4, 5, and 6.

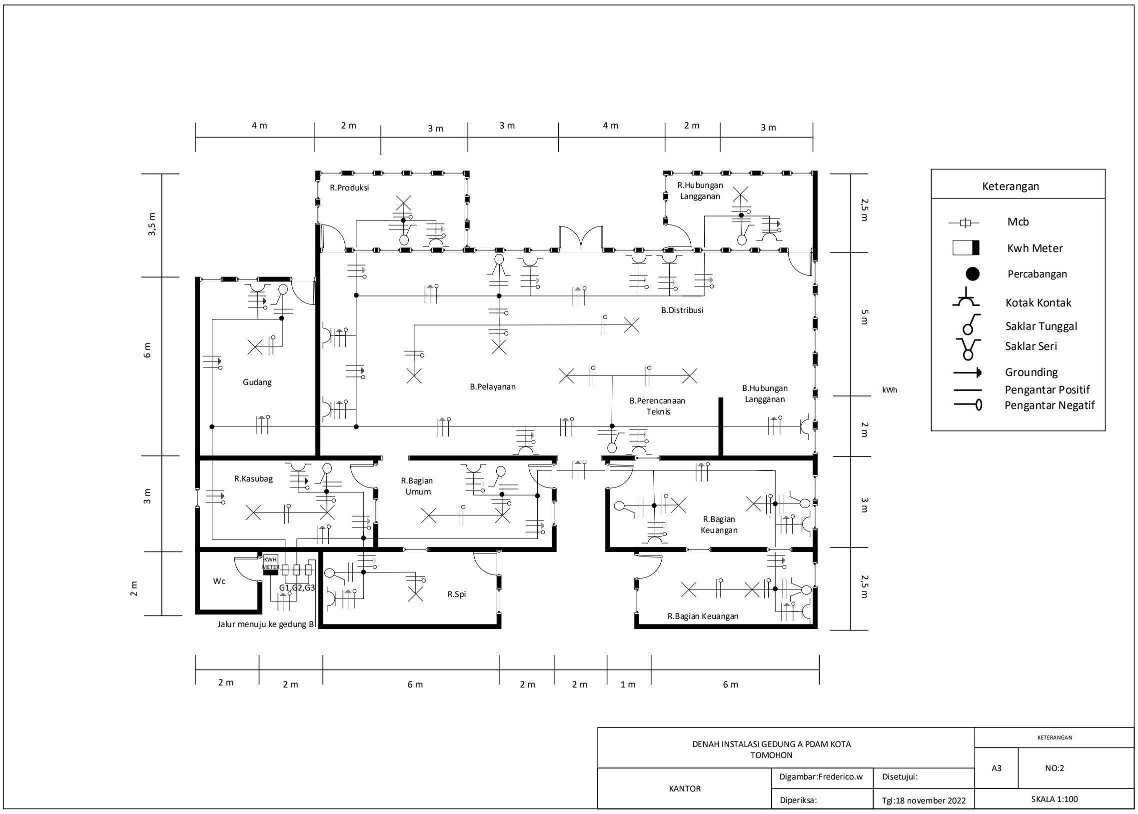

Figure 2. One Line Diagram of Building A

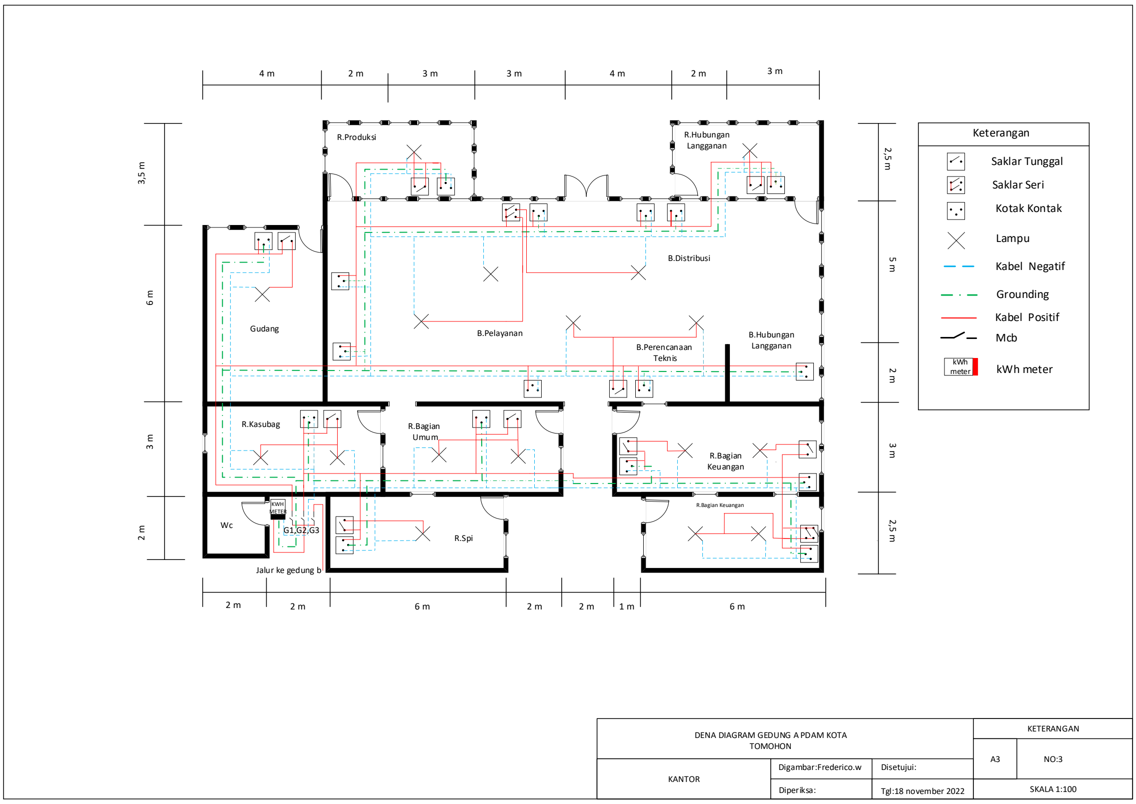

Figure 3. Wiring Plan of Building A

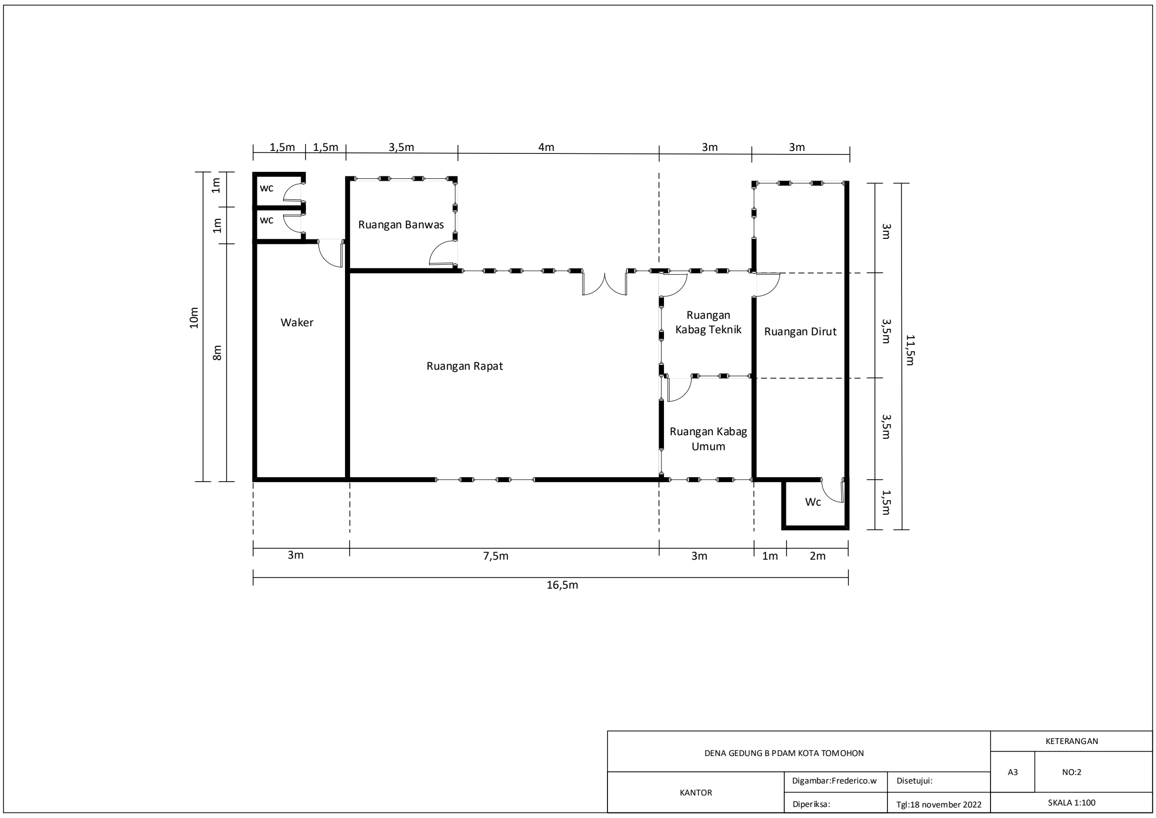

Figure 4. Floor plan of building B

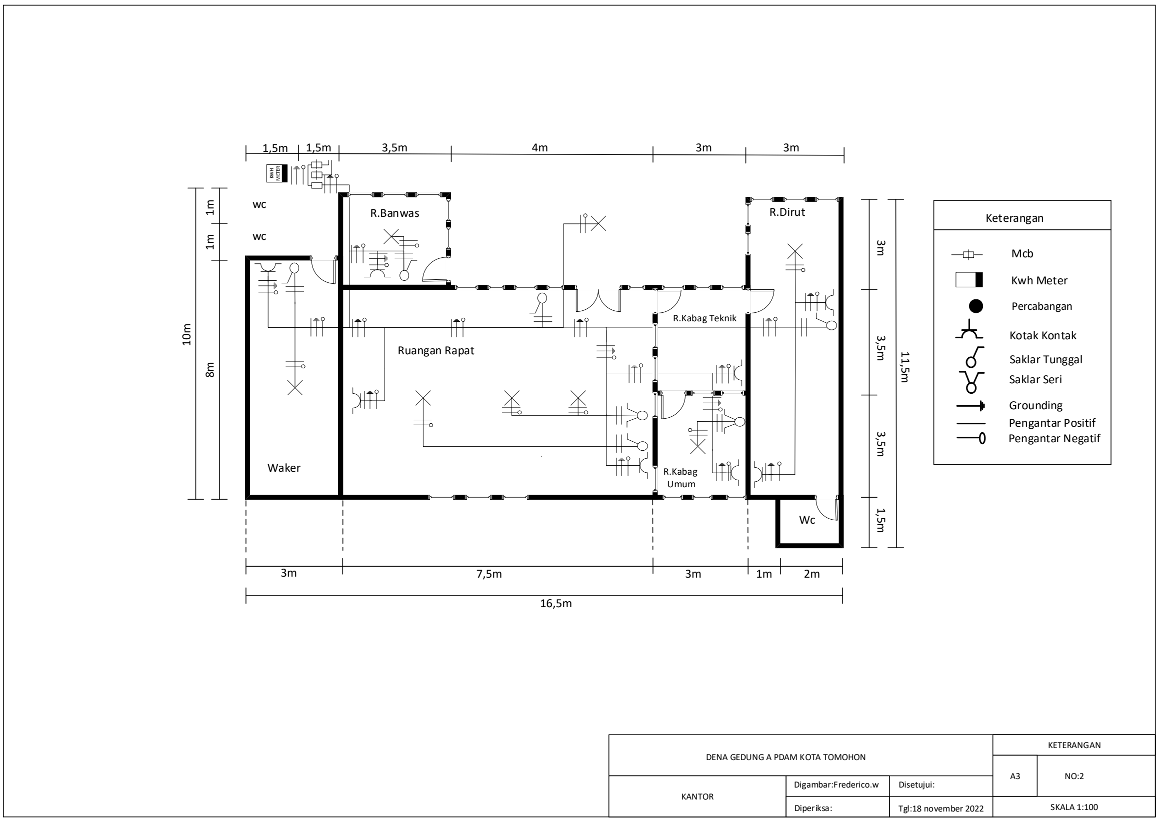

Figure 5. One Line Diagram Plan of Building B

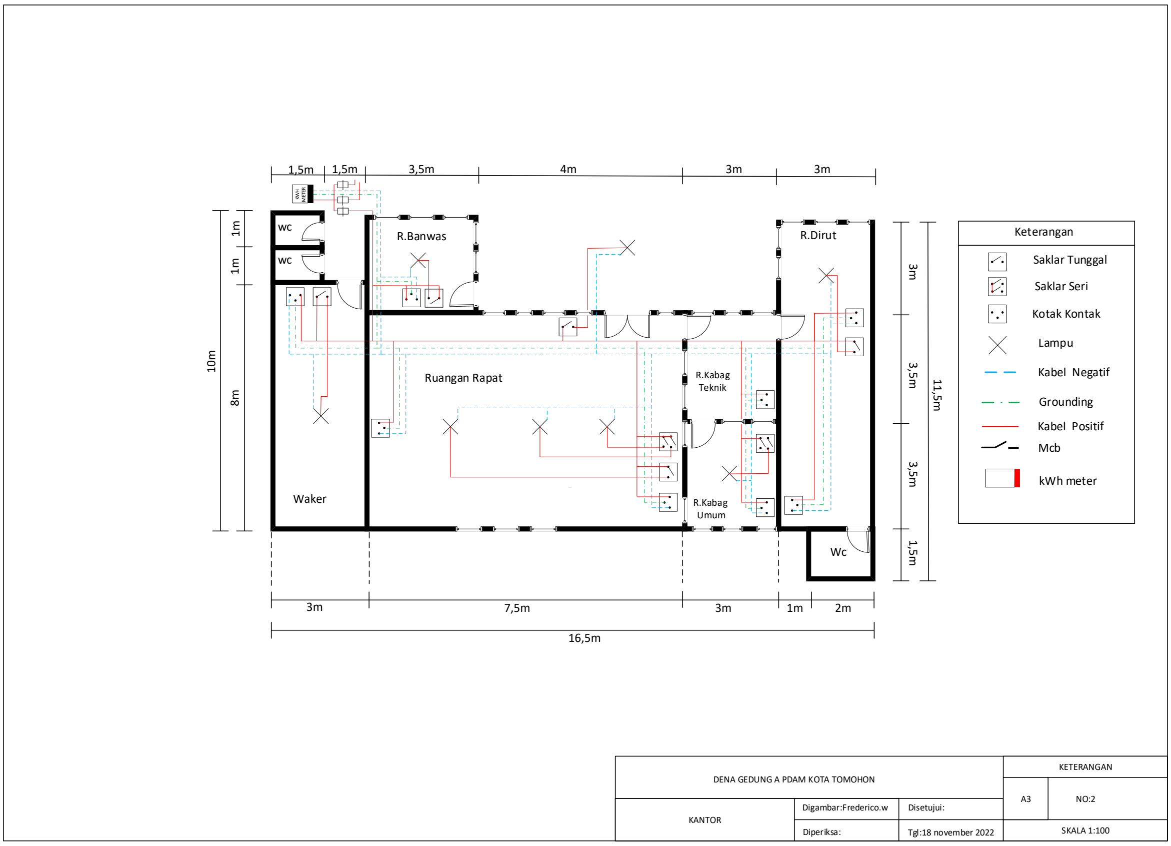

Figure 6. Wiring Diagram of Building B

Table 4. Results of illumination measurements at PDAM Building A

No.	Room name	Measurement results (Lux)
1.	Warehouse	215
2.	General section 1	235
3.	Relationship and subscription	202
4.	Head of sub-section room	12
5.	SPI room	280
6.	Finance section room 1	165
7.	Finance section room 2	215
8.	Production room	185
9.	General section room 2	98
10.	Public toilet	9

According to Table 4, the illumination measurements indicate that the warehouse has 215 lux, general section 1 has 235 lux, the relationship and subscription room has 202 lux, the sub-section headroom has 12 lux, the SPI room has 280 lux, finance section 1 has 165 lux, finance section 2 has 215 lux, the production room has 185 lux, general section 2 has 98 lux, and the public toilet has no lighting.

Table 5 shows the results of the illumination measurements obtained: 233 lux in the Banwas room, 304 lux in the director's room, no lights in the Head of Engineering room, 143 lux in the Head of General and Finance room, 151 lux in the meeting room, 85 lux in the guard room, no lights in the director's toilet, and no lights in the public toilet.

Table 5. Results of illumination measurements at PDAM Building B

No.	Room name	Measurement results (Lux)
1.	Banwas Room	233
2.	Director's Room	304
3.	Head of Engineering Room	0
4.	Head of General and Finance Room	143
5.	Meeting Room	151
6.	Guard Room	85
7.	Director's Toilet	0
8.	Public Toilet	0

According to Table 6, the measurements and calculations of light intensity in each room of PDAM Building A indicate that during sunny weather, data was collected from 10 rooms, each exhibiting varying light intensity levels. The calculated and measured lighting lux in PDAM Building A does not comply with PUIL regulations.

Table 7 explains that the measurement and calculation results of light intensity in each room in PDAM Building A show that data is produced when the weather is sunny. There are eight rooms, each with a different light intensity. Based on the calculation and measurement data, the lighting lux in PDAM Building B does not meet PUIL standards.

Table 6. Results of comparison of lighting standards and measurements of Building A

No.	Room Name	Lighting Standards (Lux)	Room Size			Measurement results (Lux)	Calculation Results (Lux)	Types of Lights
			L(m)	W(m)	A(m^2)			
1.	Warehouse	300	4	6	24	215	0.047	CFL
2.	General section 1	300	17	7	119	235	0.005	CFL
3.	Relationship and subscription	300	5	2.5	12.5	202	0.062	CFL
4.	Head of sub-section room	300	6	3	18	12	0.043	CFL
5.	SPI room	300	6	2.5	15	280	11.710	CFL
6.	Finance section room 1	300	7	3	21	165	0.043	CFL
7.	Finance section room 2	300	6	2.5	15	215	0.037	CFL
8.	Production room	300	5	2.5	12.5	185	0.062	CFL
9.	General section room 2	300	6	3	18	98	0.043	CFL
10.	Public toilet	300	2	2	4	0	0.000	CFL

Table 7. Results of comparison of lighting standards and measurements of Building B

No.	Room Name	Lighting Standards (Lux)	Room Size			Measurement results (Lux)	Calculation Results (Lux)	Types of Lights
			L(m)	W(m)	A(m^2)			
1.	Banwas room	300	3.5	3	10.5	233	132.000	CFL
2.	Director's room	300	10	3	30	304	460.700	CFL
3.	Head of Engineering room	300	3.5	3	10.5	0	0.000	CFL
4.	Head of General and Finance room	300	3.5	3	10.5	143	0.132	CFL
5.	Meeting room	300	7.5	6	45	161	2.781	CFL
6.	Guard room	300	8	3	24	85	1.563	CFL
7.	Director's toilet	300	1.5	2	3	0	0.000	CFL
8.	Public toilet	300	1.5	1	1.5	0	0.000	CFL

IV. CONCLUSIONS

The study's results showed that in Building B, just one room complies with PUIL lighting criteria while Building A has no rooms that fulfill these standards. Several rooms lack installed lighting, which significantly impacts the everyday operations of PDAM Tomohon City personnel.

Based on this study's findings, I recommend that PDAM Tomohon City prioritize areas lacking lighting installations and ensure adherence to lighting regulations for all utilized spaces prior to constructing or remodeling structures. The quantity of fixtures and lamp types in each room must be accurately determined based on their function, following established standards. Additionally, ensure the light source remains unobstructed and maintain the room's cleanliness by addressing dust accumulation and performing regular maintenance.

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