

An Illumination Study on Floating Storage and Offloading Vessel

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ABSTRACT

There are a few floating storage offshore (FSO) facilities operating in Malaysian waters. This study was executed in one of the facilities, 170 km from the East Coast of Peninsular Malaysia. The objective of this study is to investigate the lighting at the workplace at the FSO and to compare it with the recommended requirements of the Department of Safety and Health (DOSH) Malaysia. Based on the calculated room index for each compartment, a total of fifty-four (54) points were identified for illuminance measurement. Four representative points were selected for specific tasks/activities measurements. A total of forty-eight (48) accessible indoor locations were measured to investigate the adequacy of the lighting (illuminance) inside the accommodation section and a few of the workshops. More than 50% of the measured locations (i.e., twenty-eight (28) out of forty-eight (48)) were found to be recorded with illumination below the recommended levels. The general lighting at three critical areas was found to be low, from 17 to 109 lux. However, all three places use localized light that has more than enough lux. At the same time, it was found that all desktop activities at the studied locations did not manage to achieve the minimum recommended illumination levels. As for activities inside the workshops, specific tasks are supplemented with task lights. Due to this, the specific activities were found to meet the minimum illumination recommendation based on the activities performed, even though the general lighting of each workshop was found to be below the recommended illumination levels.

Keywords: Lighting, Offshore operations, Visual comfort, Human factors, Occupational lighting, Environmental assessment

INTRODUCTION

Inadequate illuminance in workplaces of various backgrounds is common, often below 300-500 lux standards and always associated with discomfort and reduced productivity (Barjoe and Grigorievich, 2024; Osemudiamen and Stanley, 2023; Zhang et al., 2023; Lu et al., 2020). An illumination study was conducted on a Floating & Storage Offshore (FSO) vessel, located approximately 170 km off the east coast of Peninsular Malaysia at the Dulang field, Terengganu, Malaysia. A total of forty-eight (48) accessible indoor locations were measured to assess the adequacy of lighting (illuminance) in the accommodation building and the workshops. This is a good initiative taken by the management to ensure good lighting at the workplace for the occupants.

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The illumination study was conducted during normal working hour with the following objectives; to investigate the illuminance intensity (lux readings) at the workplace as well as the selected indoor locations on the FSO, to identify the potential hazards arising from the work activity under the current lighting condition in the workplace, such as insufficient illumination, glare or flicker and finally to compare the measured lighting levels with the recommended lighting requirement listed in the Guidelines on Occupational Safety and Health for Lighting at Workplace (DOSH, 2018).

WORKPLACE ILLUMINATION

Effective workplace illumination is significant for productivity, and occupational safety and health. Compliance with regulations and standards is also foremost for industries. The most referenced and common regulatory standards for illumination in the literature are the Big Three standards: the International Organization for Standardization (ISO 8995-1/ CIE S 008), (ISO/CIE 2025), IES Lighting Library ANSI/IES RP-7-21 (2021) and EN 12464-1:2021 (2021). Different regions of the world approach regulations, recommended practices, and standards differently (Stefani and Cajochen, 2021). In Malaysia, with the enforcement of the Occupational Safety and Health (Amendment) Act 2022 on June 1, 2024, the prescriptive lighting requirements of the repealed Factory Machinery Act 1967 have been replaced by a risk-based approach under Section 18B (Risk Assessment) of the amended Act. OSHA provides minimum illumination values expressed in foot-candles, typically ranging from 3-30 foot-candles, depending on the task or environment, which can be converted to 32-323 lux (OSHA, 2024). ISO 8995-1/ CIE 008/E adopts a more ergonomically oriented approach, which is based not only on illuminance but also on visual comfort factors such as glare control, luminance distribution, task complexity, and colour rendering quality (ISO, 2025).

Other than that, the Department of Safety and Health, Malaysia (DOSH, 2018)'s Guidelines on Occupational Safety and Health for Lighting at Workplace 2018, emphasizes the need for employers to provide appropriate artificial lighting to prevent accidents, discomfort, and long-term health impacts caused by illumination. It is stipulated that there must be sufficient light in the workplace to ensure the safety and health of every employee. It is also said that the lighting should enable employees to comfortably see what they need to see while performing their tasks. Certain activities, such as office work, industrial tasks, and healthcare settings, require specific illuminance levels ranging commonly between 150 and 500 lux to ensure safety, comfort, and accuracy. In addition, the OSHA (2022) mentioned that compliance is no longer just about "having a lightbulb"; it's about proving through risk assessment that your lighting is suitable and sufficient for the specific task being performed.

Comparing the three documents, DOSH aligns more with ISO principles in emphasizing worker wellbeing and appropriate illuminance levels, while OSHA serves as a regulatory baseline with minimum foot-candle thresholds for safety.

Illumination Study at Floating Storage Offshore, East Coast Malaysia

The assessment for this study was carried out on a Floating Storage Offshore (FSO) that was built in 1991. She has 15 cargo tanks capable of storing at least 134,000 m³ of cargo and is equipped with facilities to tandem moor offtake tankers at her stern. Her designed loading rate is 3,300 m³ per hour. The FSO is designed to accommodate shuttle tankers with a maximum size of 85,000 deadweight tons (DWT) alongside and 150,000 DWT in tandem. She is equipped with the necessary accommodation and life support facilities for 60 persons. Due to operational constraints, the researchers were only able to conduct objective measurements in this study, as the limited time available did not permit the inclusion of subjective evaluations of the workers' perceptions.

The Accommodation Building in the FSO places the offices, control room, radio room, sickbay, bedrooms, galley, kitchen, recreational room, as well as the prayer room. There are also workshops and equipment/chemical storage areas on the lower levels of the accommodation building. The data collection was done focusing on the indoor workplaces (i.e., control room, office, and workshops) as well as the selected indoor spaces. The illumination study was conducted in two approaches: walkthrough inspections and lighting measurement, as suggested by the Guidelines (DOSHS, 2018). There were two types of lighting measurements: general lighting in the general area and specific task or activity lighting at workstations. The room index is used to determine the number of measurement points in particular work areas. Outdoor decks or open-ended corridors, or "non-enclosed areas," were excluded, as the Room Index formula is technically only valid for enclosed rectangular spaces. Table 1 is referred to for the number of measurement points needed.

$$\text{Room Index} = (L+W)/(H_m (L+W)) \quad \text{Eq. 1}$$

Where,

L : Length of room (m) W: Width of room (m)

H_m: Height of lighting above the working plane (m)

From the illumination measurement, the uniformity of illuminance can be established, which is the ratio of the minimum to the average value. Depending on only the average illuminance may result in lower illuminance in certain areas and may be a threat to the safety of the employees in performing specific tasks. Hence, according to the Guidelines (DOSHS, 2018), the uniformity of the illuminance should be no less than 0.5 for general lighting and no less than 0.7 for task or activity lighting. The relationship between the lighting of the work area and adjacent areas is also important. To avoid an unsafe working environment and workers' discomfort, the maximum ratios as listed in Table 2 are used as a reference.

Illumination assessment for individual lighting requires measurement at the task position. Four (4) representative points were selected. The illuminance level at the centre of each area was measured. Lighting measurement was taken at the height of the work plane. For the task position at a computer workstation, two measurement points were taken at the keyboard position, which is 20 cm apart, and two other points on the top of the screen,

10 cm apart. The average of these measurements was then calculated as the average illuminance at the task position and was then compared with the recommended lighting requirement listed in the DOSH Guidelines (DOSH, 2018). The equipment used to measure the illuminance (lux levels) was a calibrated Lux Meter HD450 by Extech Instruments with a capacity of 0 – 400000 Lux and resolution of 0.1, 1, 10, and 100 Lux.

Table 1: Minimum number of measurement points for measuring average illuminance in rooms of different proportion (DOSH, 2018).

Room Index	Number of Measurement Points
Below 1	4
1 and below 2	9
2 and below 3	16
Above 3	25

Table 2: Maximum ratio of illuminance (DOSH, 2018).

Situations to Which Recommendation Applies	Typical Location	Maximum Ratio of Illuminance – Working Area
each task is individually lit & the area around the task is lit to a lower illuminance	Local lighting in an office	5
two working areas are adjacent, but one is lit to a lower illuminance than the other	Localized lighting in a work store	5
two working areas are lit to different illuminances & are separated by a barrier but there is frequent movement between them	A storage area inside a factory & a loading bay outside	10

RESULTS

The first measurement was the general lighting carried out during the walkthrough inspection. Certain area such as in the workshops, have a combination of background lighting and localized/task lighting as shown in Figure 1(a) and (b). The task lights are adjustable and flexible, which allows for more visual comfort to the users while performing the specific detailing tasks. At several locations (i.e., near the boiler control panel as shown in Figure 1(c)), the fluorescent bulb for general lighting was removed and not replaced. Figure 1(d) showed a good practice where curtains were drawn to prevent glare. Figure 1(e) showed that one of the bedrooms (Room T) lacked general illumination due to blown bulbs. Occupants relied on natural lighting from the window for illumination. This can create a safety hazard (i.e., slip, trip, and fall, especially at nighttime). Inside certain bedrooms, as illustrated in Figure 1(f), the reading lights were not installed after being removed. At most of the storage areas, as shown in Figure 1(g), localized lightings were adopted due to the condition of the work areas.

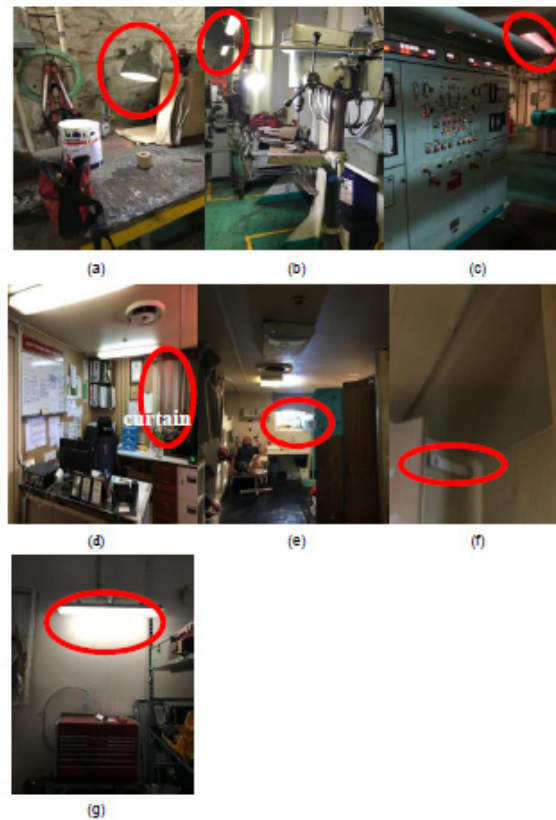


Figure 1: Walkthrough inspection from points (a) to (g) covering the office, reception, and storage.

The detail result of the specific task/ activity are in the Appendix. Twenty (20) out of forty-eight (48) locations meet the average minimum recommended illumination (100 to 843 lux). All desktop activities at the studied locations did not achieve the minimum recommended illumination levels, with the lowest measurement at 51lux from Deck 1 (gaps from the Guidelines' required lux between -70 to -349). As for activities inside the workshops, specific tasks are supplemented with task lights. Due to this, the specific activities were found to meet the minimum illumination recommendation based on the activities performed, even though the general lighting of each workshop was found to be below the recommended illumination level. The gap-to-standard, obtained by subtracting the DOSH (2018) minimum illuminance requirement from the measured average lux. As illustrated in Figure 2, the red bars indicate locations that did not meet the required lighting levels.

From 18 activities identified as critical, such as the Central Control Room, Medical office, Laboratory, Electronic, Electric, and Mechanical Workshops, were found to achieve the uniformity of illuminance as recommended by the Guidelines (DOSHS, 2018), except for the computer workstation at the Camp Boss office, Ward room, and Deck workshop, as depicted in Table 3.

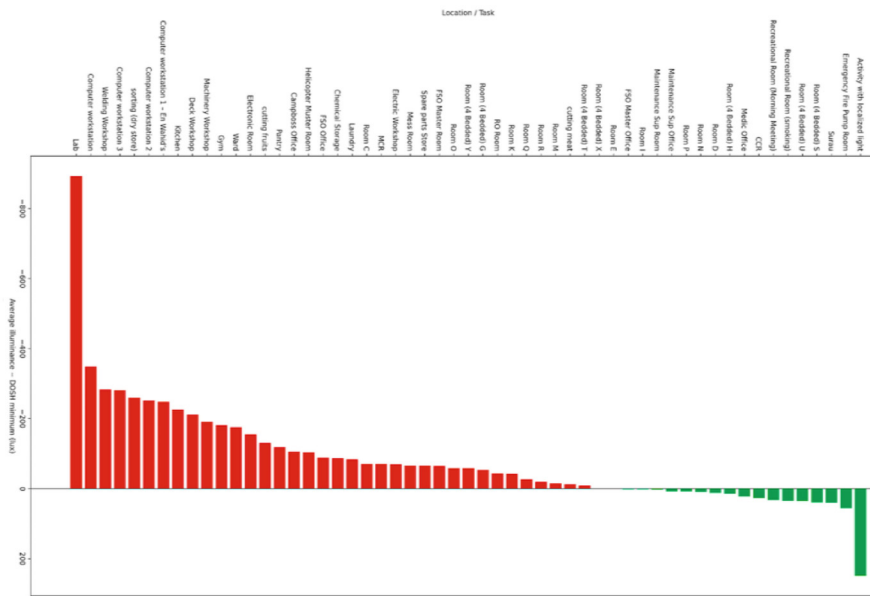


Figure 2: Gap- to-Standard by location/task.

Table 3: Non-compliant uniformity of illuminance for critical activities.

No.	Location / Task	Measured Illumination (Lux), Avg	Measured Illumination (Lux), Min	Uniformity of Illuminance	Recommended Ratio	Compliance Check (Yes/No)
1	Computer workstation	51	38	0.7	Not less than 0.7	No
3	Ward	124	50	0.4	Not less than 0.5	No
3	Deck Workshop	88	14	0.2	Not less than 0.5	No

The relationship between the lighting of the work area/task and adjacent areas is important. For this study, there are three (3) locations applicable, which were identified during the site study as shown in Table 4.

Table 4: Illuminance ratio for locations of critical activities.

No	Task (Where Each Task is Individually Lit and the Area Around the Task is Lit to a Lower Illuminance)	Localized Light Illuminance (Lux)	General Lighting, Avg (Lux)	Calculated Illuminance Ratio	Recommended Maximum ratio of illuminance	Compliance Check (Yes/No)
1	Welding Activity with localized light (welding shop)	549	17	32	5	No
2	Precision machining, grinding, tool inspections etc. inside the machinery workshop	843	109	8		No
3	Deck workshop (workshop area vs surrounding)	154	37	4		Yes

Based on the results, the difference between light intensity during welding and machinery tasks using the task lights compared to the workshop's general lighting was found to be quite significant. This can cause eye discomfort as well as the potential for accidents if the condition is not addressed. Table 5 shows the correlation between the calculated Room Index and the measured average illuminance (lux). Some locations were excluded from the analysis where a Room Index could not be accurately determined due to irregular spatial dimensions. Four locations met the threshold for medium-to-high correlation: Deck 4, Deck 1, the Main Deck, and the Machinery Deck (r values ranging from 0.6 to 0.9, the latter showing a negative correlation).

Generally, burned-out lamps in several low-illumination areas should be replaced promptly, and this should be incorporated into the standard operating or safety procedures of the FSO. Fluorescent lamps with the highest luminous flux are recommended for areas involving desktops and other critical activities. Some locations, such as the deck workshop and ward at the main deck, have poor luminance uniformity, which may indirectly make it difficult to navigate or perform tasks safely. Proper lighting positions are important to ensure optimal lighting at workstations; thoughtful planning and design of lighting layouts should be considered. In summary, the uniformity and illuminance ratio can be improved by implementing technical solutions (e.g., replacing failed lamps, installing higher intensity lighting, and optimizing luminaire spacing and layout), environmental improvements (including wall/ceiling reflectance and glare/contrast control), and systematic management practices such as regular maintenance and periodic lighting audits.

Table 5: Correlation between room index and average Lux.

	Correlation Coefficient (R)	Strength of Correlation
Deck 4	0.85	Strong Positive
Deck 3	0.45	Weak-Moderate
Deck 2	0.23	Weak
Deck 1	0.67	Moderate-Strong Positive
Main Deck	0.75	Strong Positive
Machinery Deck	-0.95	Strong Negative

Comparison of the collected data against MS EN 12464-1:2022 reveals a significant 'performance gap.' While areas like the Maintenance Sup Office (208 lux) meet the DOSH 2018 minimum safety requirement of 200 lux, they fall nearly 60% short of the 500 lux international benchmark (the ISO 8995-1 / CIE S 008) required for sustained clerical work and visual comfort. This suggests that while the facility may be safe by local guidelines, it is suboptimal for visual performance and worker alertness.

Traditional standards focus on visual performance, such as lux and uniformity; however, contemporary approaches include non-visual effects and higher, adjustable illuminance for well-being, especially for aging workers

(Barjoe and Grigorievich, 2024; Stefani and Cajohen, 2021). An empirical study by Lu et al. (2020) suggested that higher illuminance improves comfort, visual performance, some cognitive functions, and perceived productivity, although it is agreed that optimal levels vary by task type. Therefore, future investigations should incorporate workers' perspectives and experiences. The 2024–2026 revisions for ANSI/IES RP-7-21, for example, now place a heavy emphasis on Human-Centric Lighting (HCL), which mimics natural daylight cycles to improve worker alertness and sleep quality.

CONCLUSION

Most locations were found to have low average illumination intensity, as tabulated in the Appendix, with the lowest level at 13 lux. Twenty-eight of forty-eight measured locations were below the recommended values. Based on the illuminance uniformity for the critical activities, three non-compliances were identified, namely, the workstation at Camp Boss office, Ward room, and Deck workshop, with average illumination measured at 51 lux, 124 lux, and 88 lux, respectively. Poor uniformity or bright spots next to dim areas forces the eye to continuously adjust between luminance levels, causing visual strain, reduced sustained attention, faster fatigue, and a likelihood of human error. Whilst high contrast illuminance ratios, such as at the welding shop and machinery workshop, can introduce distracting shadows over work surfaces, glare reduces visibility and veiling luminance, which masks critical visual cues.

To address the 58% non-compliance rate identified, a phased remediation strategy is proposed. Priority 1 (high) focus shall be given to the Welding Shop and Machinery Workshop; despite being critical task zones, current illuminance ratios pose an immediate safety risk through veiling luminance and shadow masking. Implementation should follow a 'Low-Cost/High-Impact' model: first, an immediate maintenance cycle to clean fixtures (potentially recovering 15% of lost output), followed by the installation of localized task lighting at workstations (Priority 1 (high) to bridge the gap between the measured 51–124 lux and the mandated 300+ lux. High-cost capital replacements should be reserved for the Deck Workshop, where structural shadows require a redesign of the luminaire layout to achieve the required uniformity ($U_o \geq 0.40$).

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APPENDIX

No	Location/Task	Room Index	No of Sampling Points	Avg Illumination (Lux)	Recommended Illumination by DOSH (Lux)	Compliance Check (Yes/No)
Deck 4						
1	Helicopter Muster Room	1.49	9	96	200	No
	CCR	2.52	16	227	200	Yes
2	Computer workstation 1	-	4	152	400 – 500	No
	Computer workstation 2	-	4	148	400 – 500	No
	Computer workstation 3	-	4	119	400 – 500	No
3	RO Room	1.53	9	156	200	No
	Computer workstation	-	4	257	400 – 500	No
4	Pantry	0.85	4	108	200	No
5	Gym	1.60	9	118	300	No
Deck 3						
6	Maintenance Sup Office	1.56	9	208	200	Yes
	Computer workstation	-	4	257	400 – 500	No
7	Maintenance Sup Room	1.41	9	103	100	Yes
8	Room E	1.26	9	101	100	Yes

(Continued)

APPENDIX: Continued.

No	Location/Task	Room Index	No of Sampling Points	Avg Illumination (Lux)	Recommended Illumination by DOSH (Lux)	Compliance Check (Yes/No)
9	Room D	1.26	9	112	100	Yes
10	Room C	1.26	9	29	100	No
11	FSO Master Room	1.41	9	35	100	No
12	FSO Master Office	1.56	9	202	200	Yes
	Computer workstation	-	4	217	400 – 500	No
13	FSO Office	1.60	9	111	200	No
	Computer workstation	-	4	65	400 – 500	No
14	Pantry	0.83	4	81	200	No
15	Room I	1.27	9	102	100	Yes
16	Room (4 Bedded) H	1.31	9	114	100	Yes
17	Room (4 Bedded) G	1.36	9	46	100	No
Deck 2						
18	Room (4 Bedded) S	1.33	9	139	100	Yes
19	Room R	1.29	9	80	100	No
20	Room Q	1.24	9	73	100	No
21	Room O	1.18	9	41	100	No
22	Room P	1.26	9	108	100	Yes
23	Room N	1.18	9	109	100	Yes
24	Room M	1.18	9	85	100	No
25	Room K	1.23	9	57	100	No
26	Room (4 Bedded) Y	1.36	9	41	100	No
27	Room (4 Bedded) X	1.31	9	100	100	Yes
28	Room (4 Bedded) U	1.31	9	136	100	Yes
29	Room (4 Bedded) T	1.36	9	91	100	No
Deck 1						
30	Mess Room	2.49	16	134	200	No
	Kitchen	2.59	16	274	500	No
	cutting fruits	-	4	169	300	No
31	cutting meat	-	4	287	300	No
	sorting (dry store)	-	4	40	300	No
32	Recreational Room (Morning Meeting)	2.05	16	232	200	Yes
33	Recreational Room (smoking)	1.85	9	135	100	Yes
34	Camp boss Office	0.83	4	94	200	No
	Computer workstation	-	4	51	400 - 500	No
35	Surau	1.80	9	140	100	Yes
Main Deck						

(Continued)

APPENDIX: Continued.

No	Location/Task	Room Index	No of Sampling Points	Avg Illumination (Lux)	Recommended Illumination by DOSH (Lux)	Compliance Check (Yes/No)
36	Medic Office	1.81	9	222	200	Yes
37	Ward	1.81	9	124	300	No
38	Laundry	2.05	16	216	300	No
39	Lab	1.50	9	107	1000	No
40	Emergency Fire Pump Room	-	16	256	200	Yes
41	Deck Workshop	-	16	88	300	No
Machinery Deck						
42	MCR	-	16	129	200	No
43	Electronic Room	-	16	145	300	No
44	Electric Workshop	-	16	130	200	No
45	Welding Workshop	-	16	17	300	No
	Activity with localized light		4	549	300	Yes
46	Machinery Workshop	-	16	109	300	No
	Activity with localized light		4	843	750	Yes
47	Chemical Storage	-	16	13	100	No
48	Spare parts Store	-	16	34	100	No