Thermal spectrum characteristics of blue light flare irradiation and its impact on surroundings biotic and abiotic environment

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Abstract. A recent modification of flare light irradiation with a high-pressure system in blue light color has been causing performance improvement of the flare light so that it is more invisible at the daylight time and in the night as well. It has been reducing social complaints. Field observation was conducted in 2011 in Jambi. Blue light showed very low irradiation, illumination, quantum value and ultraviolet at the soil surface. Its surrounding thermal spectrum was recorded with an infrared thermal imager and its impact on ambient and soil temperature was found as insignificant. There was also found that latex production and understory vegetation biodiversity at the distance of 225-800 m from the radiation source was not affected by the irradiation.

Keywords: understory biodiversity, blue flare light, latex production, thermal spectrum, weed population

1. Introduction
Most of the flare stacks of oil and gas industries were installed with a reddish-yellowish light color for environmental and safety reasons. Despite the impact on its microclimate circumstances, this unmodified natural fire color attracts birds and insects approaching the glare object. Unmodified flare light color shew its negative impact production on soybean [1]. Since the effect on plant growth, physiology, development and biomass yield are more related to light spectral quality [2], the phenomenon of blue light flare irradiation would support and contribute additional information about the role of an additional light source on the vegetation life and surroundings environmental quality as well.

Since negative socio-economics and cultural impact due to complaints of surrounding living people were exposed in a few regions in Indonesia, blue light flare technology was expected to improve existing gas flaring systems. Besides to oxygenize power blowing system, additional certain metal fuel in pyrotechnic compositions can intensify and improve the quality of the blue flare standard [3].

Despite the more invisible color of flare light in the daylight time even in the night time, the quantitative impact on the surroundings ecosystem should be confirmed. The purpose of this study was to identify the impact of blue light flare irradiation on surrounding environmental exposures consisting

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of understory or lower vegetation strata, rubber plantation and soil properties. Beside them, the contribution of blue light flare irradiation to the existing sunlight irradiation was to be characterized.

2. Methodology
Field assessment was completed in the oil and gas industry and surrounding in Jambi at the surroundings of the location coordinate 324,158 m Easting 9,876,709 m Northing under the reference of WGS-84 at the altitude of approximately 15 m above sea level. The height of the flare stack was approaching 40 m. The observation was conducted from February-June 2011 at a distance of 225 m, 275 m, 325 m, 375 m, 425 m, 475 m, 525 m, 600 m, 700 m and 800 m from the flare stack. All of them were replicated 4 times. S/2-rubber tapping system at the 10 years old rubber for harvest was adapted for sampling, where it was also applied by the farmer regularly. The rubber clones consisted of GT, Avros and LCB. Infrared Thermal Imager FLIR-i3 was used for a thermal spectrum of blue light flare observation at the location of vegetation. For light measurement, quantum sensor, pyranometric sensor, and photometric sensor of Li-190R, Li-200R and Li-210R respectively were connected to Licor Lightmeter Li-250. Lutron YK-35UV was applied for UVA and UVB measurement. To differentiate blue light flare irradiation with sunlight irradiation, the light measurements were conducted in the daylight time and the night. In the night the contribution of sunlight was supposed to be omitted, and the irradiation and illumination source is mainly only from the flare stack. The recorded light data was adjusted by local light sources for possible interference. Internal unpublished data showed that flared gas daily during the observation ranged from 3-4 MMSCFD with 5times spots peak until 28-48 MMSCFD.

3. Results and discussion
The blue light color of fire from the upper side of the flare stack was more invisible compared to mostly oil and gas flare stack in Indonesia. For this reason, a complaint from local people is supposed to be more insignificant compared to the other fire color of the flaring technique. The supporting occurrence, that the flaring intensity during the observation was relatively low at the level of 3-4 MMSCFD, the risk of negative impact was supposed to be more inconsequential. Moreover, the contribution of the flare blue light emission to the environmental or ambient parameter was very low. There was no significant increase in measured parameter values due to the flare blue light at daytime and night time. Contrasted to the sunlight at the surface at the distance of 150 from flare stack at 12.00 daytime, PAR parameter contributed less than 0.05 μmol m⁻² s⁻¹, illumination less than 0.05 lux, irradiation less than 0.002 watts/m², and ultraviolet light less than 0.002 mW cm⁻². The contribution to the increase of ambient ground temperature and ambient temperature at the same distance was undetected. All of the contribution values were less than 0.2% of the magnitude of the relevant measurement values at 12.00. Measurement results of microclimate measurements were presented in table 1.

To find the relation between blue light flaring and the vegetation biodiversity, the result of simple regression analyses show, that the dominance of each species of understory vegetation at rubber plantation consisting of Cyclosorus sp., Clidemia hirta, Cyperus sp., and Axonopus sp. had no relation to the distance to the flare stack. The very low contribution of flare blue light emission to the environment was not enough to promote nor inhibit the growth, dominance, and biomass production as well. The average dominance of Cyclosorus sp., Clidemia hirta, Cyperus sp., and Axonopus sp was at the value of 35.47%, 34.55%, 13.82%, 10.03%, and 45.31% respectively with weighed biomass production at the value of 45.31 g m⁻². At the distance of 225-800 m from the flare stack point, the absolute regression slope magnitudes were less than 0.09 and with a determination coefficient value R² less than 37%. The data about the dominance and dry weight of understory vegetation of rubber plantation related to the distance to the flare stack position is presented in table 2. In this cultivated area, there was no understory vegetation categorized as invasive plant species [4].
Table 1. Contribution of the blue light source to ambient light characterization, air, and ground temperature

| Light parameter/temperature | Light source | Unit       | Measurement time at 7.00 | Measurement time at 12.00 | Measurement time at 17.00 | Measurement time at 23.00 |
|-----------------------------|--------------|------------|--------------------------|---------------------------|--------------------------|---------------------------|
| PAR                         | Sunlight     | µmol m\(^{-2}\) s\(^{-1}\) | 31                       | 1050                      | 261                      | 0                         |
| PAR                         | Blue flare light* | µmol m\(^{-2}\) s\(^{-1}\) | <0.05                    | <0.05                     | <0.05                    | <0.05                     |
| Illumination                | Sunlight     | Lux        | 2.703                    | 38.846                    | 2511                     | 0                         |
| Illumination                | Blue flare light* | Lux        | <0.05                    | <0.05                     | <0.05                    | <0.05                     |
| Irradiation                | Sunlight     | Watt m\(^{2}\) | 11                       | 999                       | 36                       | 0                         |
| Irradiation                | Blue flare light* | Watt m\(^{2}\) | <0.00                    | <0.002                    | <0.002                   | <0.002                    |
| Ultraviolet                | Sunlight     | mW cm\(^{-2}\) | 0.08                     | 3.39                      | 0.02                     | 0.00                      |
| Ultraviolet                | Blue flare light* | mW cm\(^{-2}\) | <0.00                   | <0.002                    | <0.002                   | <0.002                    |
| Air Temperature            | Sunlight     | °C         | 27.0                     | 31.8                      | 30.2                     | 27.3                      |
| Air Temperature**          | Blue flare light* | °C          | 0                        | 0                         | 0                        | 0                         |
| Ground Temperature         | Sunlight     | °C         | 25.8                     | 36.2                      | 30.0                     | 26.0                      |
| Ground Temperature**       | Blue flare light* | °C        | 0                        | 0                         | 0                        | 0                         |

*Contribution value from measurement in the night
**Measured at 130 cm height on the ground and the distance of 150 m from the flare stack

Table 2. Dominance and dry weight of understory vegetation of rubber plantation related to the distance to flare stack position

| Distance to flare stack position (m) | The dominance of main understory vegetation (%) | Dry weight of understory vegetation (g m\(^{-2}\)) |
|--------------------------------------|-----------------------------------------------|-----------------------------------------------|
|                                      | Cyclosorus sp. | Clidemia hirta | Cyperus sp. | Axonopus sp. |                                |                              |
|                                      | 42.87 | 57.13 | 0.00 | 0.00 | 73.98 |
| 225                                  | 47.49 | 17.26 | 31.19 | 0.00 | 82.64 |
| 275                                  | 47.54 | 14.86 | 18.41 | 45.19 | 32.76 |
| 325                                  | 34.53 | 9.82  | 12.87 | 0.00 | 27.55 |
| 375                                  | 67.59 | 19.55 | 12.87 | 0.00 | 30.34 |
| 425                                  | 36.28 | 47.78 | 15.94 | 0.00 | 74.45 |
| 475                                  | 56.08 | 34.14 | 5.67  | 0.00 | 45.14 |
| 525                                  | 27.86 | 34.14 | 24.56 | 13.44 | 62.09 |
| 600                                  | 20.44 | 27.59 | 0.00  | 41.64 | 16.79 |
| 700                                  | 0.00  | 83.27 | 16.73 | 0.00 | 7.31  |
| Intercept                            | 63.51 | 7.00  | 16.54 | 3.18 | 86.07 |
| Slope                                | -0.06\(^{ns}\) | 0.06\(^{ns}\) | -0.01\(^{ns}\) | 0.01\(^{ns}\) | -0.09\(^{ns}\) |
| R\(^2\)                              | 0.32\(^{ns}\) | 0.23\(^{ns}\) | 0.01\(^{ns}\) | 0.02\(^{ns}\) | 0.37\(^{ns}\) |

\(^{ns}\)Not significant at p<0.05

The growth of rubber plantation was not influenced by the blue light flare transmission to the plant. Similar to the analyzing method at understory vegetation parameters, the regression analyses procedure was applied to find the relation between the blue light and performance of the rubber plantation. The results also showed that the blue light flare transmission to the canopy had no effect on plant height, trees circle measurement at 130 cm BH (Breast Height), tapping zone height for harvest, and average latex production either, where its average value amounted to 73.91 cm, 3.79 m, 41.28 cm, and 17.93 g/tree respectively. The very low measurement result of the blue light transmission was associated with this neglected effect. At the distance of 225-800 m from the flare stack point, the absolute regression regression slope
magnitudes were less than 0.02 and with a determination coefficient value $R^2$ less than 39%. The data about the growth performance of rubber plants related to the distance to the flare stack is displayed in table 3.

**Table 3. Relationship between rubber growth performance and the distance to flare stack position.**

| Distance to flare stack position (m) | Plant circle at 130 cm BH (cm) | Free branch height (m) | Tapping zone height (cm) | Average latex production per harvest time (g/tree) |
|------------------------------------|--------------------------------|------------------------|--------------------------|-----------------------------------------------|
| 225                                | 60.95                          | 2.64                   | 34.73                    | 16.41                                         |
| 275                                | 70.25                          | 3.61                   | 56.95                    | 7.88                                          |
| 325                                | 65.85                          | 3.57                   | 53.25                    | 8.84                                          |
| 375                                | 58.65                          | 3.31                   | 38.13                    | 12.51                                         |
| 425                                | 66.58                          | 1.22                   | 43.75                    | 11.39                                         |
| 475                                | 69.95                          | 4.73                   | 12.23                    | 13.77                                         |
| 525                                | 72.45                          | 2.76                   | 56.88                    | 14.33                                         |
| 600                                | 60.75                          | 3.00                   | 23.75                    | 12.05                                         |
| 700                                | 49.15                          | 2.20                   | 43.25                    | 2.23                                          |
| 800                                | 52.73                          | 1.99                   | 54.75                    | 2.23                                          |
| Intercept                          | 73.91                          | 3.79                   | 41.28                    | 17.93                                         |
| Slope                              | $-0.02^{ns}$                   | $0.00^{ns}$            | $0.00^{ns}$              | $-0.02^{ns}$                                  |
| $R^2$                              | $0.33^{ns}$                    | $0.12^{ns}$            | $0.00^{ns}$              | $0.39^{ns}$                                   |

$^{ns}$Not significant at $p<0.05$

The dynamics of plant growth and performance are very closely related to water status and availability in the soil. Since there was no significant influence on the microclimate and soil temperature, there was no substantial effect on water status in the soil, so that there was no expected effect on plant performance. More dominance of understory vegetation had no significant relation to water uptake at the plantation ecosystem [5,6]. The occurring more understory vegetation in this people's plantation compared to a corporate plantation could improve environmental performance in the sense of biodiversity abundance [7,8,9]. All of this impact and phenomena would support the previous discussion, that the blue color light of flare fire was capable to minimize negative environmental impact.

4. Conclusion

Blue light flare emitted very low irradiation, illumination, quantum value and ultraviolet measured at the soil surface. The microclimate of surroundings rubber plantation, ground temperature, understory vegetation biodiversity, rubber plant performance and its production at the distance of 225-800 m from the radiation source were not affected by the blue light exposures.

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