The effects of magnesium sulphate addition into foaming agents resulted from palm oil fatty acid saponification in the performance of peat fire suppression

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Abstract. The utilization of foaming agents resulted from the saponification of palm oil fatty acids as foam concentrate on peat fire suppression leads to less water use and a shorter time compared to the use of peat water only. The development of foaming agents for a peat fire extinguisher, including the addition of 0.2% magnesium sulfate (MgSO4), was further conducted in order to improve the performance of the liquid foam. This study aims to determine the performance of the developed foaming agent (FAP-MS) applied in peat fire suppression. In order to assess the performance of FAP-MS, two controls namely palm fatty acid-based foaming agent without the addition of magnesium sulfate (FAP) and peat water with no mixture of foaming agents were used. Results showed that the durability of foam produced from the peat water solution mixed with FAP-MS was lower than the foam produced from the peat water solution mixed with FAP. The addition of FAP-MS into peat water solution was found to reduce the use of water by 27% and the addition of FAP reduced it further by 35%. However, compared to peat water with no foaming agent addition, FAP-MS and FAP additions were able to suppression peat fires faster by 79% and 65%, respectively.

Keywords: palm oil, foaming agents, peat fires, suppression, magnesium sulfate

1. Introduction

Fire suppression on peatlands generally requires a large amount of water to extinguish the fires on and below the surface. Water ability to extinguish fires on peatlands is low because of the high surface tension of water and changes in the nature of peatland from hydrophilic to hydrophobic making water penetration to the pores become difficult [1,2]. To overcome this problem, we need a surfactant media
in the form of a foaming agent, in this case, made from palm oil fatty acids so that the surface tension of the water can be reduced and foam formation can be increased [3,4]. Low surface tension will produce a foam that is easy to form, non-volatile, and able to penetrate the pores of the burning peat surface [5,6].

Oil palm fatty acid-based foaming agent (FAP) has been used in peat fire suppression, but its extinguishing performance is still far from optimal. For this reason, efforts to develop this foaming agent, including the addition of MgSO₄ are simultaneously made. The addition of magnesium sulfate into the FAP solution is expected to improve the performance of the foam produced [7]. The application of foaming agent added with magnesium sulfate (FAP-MS) and FAP on the fire suppression on peatland allow the fire to be extinguished faster than using water without foaming agents. In addition to its function as a barrier for oxygen circulation on the surface of burned areas, liquid foam can also penetrate the peat pores to cool down the bottom area [6,8,9]. Aside from making fire extinguishment faster, suppression of peatland fires with foaming agents requires less water [8]. This study was a continuation of works done by [9,10] and aimed to assess the performance from the effects of MgSO₄ addition into foaming agents resulted from palm oil fatty acid saponification on the peat fire suppression. Performance data from the application of foaming agents include time and quantity of foaming agents needed to extinguish the fire.

2. Methods
In this study, the performance evaluation of the foaming agent was carried out for the foaming agent from the saponification of palm oil fatty acids with the addition of 0.2% magnesium sulfate (FAP-MS) and the saponification of palm oil fatty acids (FAP) which is added to peat water for the suppression of peat fire. In addition, fire suppression with peat water only was also carried out. Soil and peat water were taken from Sontang Village, Bonai Darussalam District, Rokan Hulu Regency, Riau Province, Indonesia, with coordinates S: 1° 7’59.50 “; E: 100° 48’4.98” T (Figure 1).

Figure 1. Sampling location of soil and peat water
Peat soil was dried in an oven at 105 °C for 48 hours before it was put into a burner reactor. The water content of dried soil was 12-15 wt% [11]. The application of foaming agents on peat fire suppression was done by using a square-shaped reactor (12 x 12 x 12 cm) [12,13]. Heating in peat burners was conducted by using electricity with 200-250 Watt power, within ± 5 minutes, at a temperature reaching 650 °C. Fire suppression by using foam from FAP-MS, FAP formulas and peat water only were carried out after the burning process of peat soil in the reactor took place for 4 hours at 300-500 °C.

Figure 2. Flow chart for testing of foaming agent applications on peat fire suppression

The foam was produced by putting the extinguishing solution consisting of a foaming agent (3%) and peat water, into a sprayer which acted as a foam-forming regulator [14]. After the sprayer was pumped, the foam was sprayed onto the surface of the burning peat with a foam height of 4-6 cm. All tests were carried out twice by using the same method.

The performance of peat fire suppression was observed by using an infrared camera. The infrared cameras were able to monitor combustion activities in the reactor before and after the extinguishing process. Combustion and extinguishing activities were identified through the movement of peat surface temperature. The combustion working temperature is usually above 50 °C, and to know that the combustion has been extinguished, the temperature should be below 50 °C [8,15]. To analyze the combustion and the extinguishing performance inside the reactor, a thermocouple was used. The thermocouple was connected to the data logger and then connected to the computer so that the temperature data during the combustion and extinguishing process can be obtained. Measurements are conducted to determine the temperature changes as an indicator of whether the fire is extinguished or not in the extinguished reactor [12]. The visualization of the testing flow is presented in Figure 2. Whereas to find out the amount of peat fire extinguishing media used, media weighing was carried out before and after the application. The difference in weight was the amount of media used [11,16].

3. Results and Discussion

The application of foaming agents as fire extinguishers in peat that was burnt in the reactor was effective to reduce the temperature of the peat surface. The condition of the peat surface in the burner reactor is shown in Figure 3 (a) with temperature after spraying reaching 62.3 °C while the initial
temperature at the suppression was 408.74 °C. Figures A-1.1 and A-1.2 show the foam produced from the solution of peat water mixed with FAP-MS and FAP at the initial minute after spraying. Based on the appearance, there was no difference in foam volume. After 20 min, the foam volume changed. The volume difference between the two foams is shown in Figure 3 (b). Figure B-1.1 shows the foam starts to run out due to the pressure and heat from below the surface.

![Figure A-1.1](image1.png)

![Figure A-1.2](image2.png)

**Figure A-1.1 and A-1.2.** Illustration of the foam produced from the solution of peat water mixed with FAP-MS and FAP at the initial minute after spraying. (a) A-1.1: FAP-MS; (b) A-1.2: FAP.

![Figure B-1.1](image3.png)

**Figure B-1.1.** Illustration of foam application from FAP-MS and FAP foaming agent, (a) foam application appearance at the first minute; (b) foam application appearance in the minute 20.

Meanwhile, at the same time, the foam from the mixture of peat water and FAP still covered the peat surface (Figure B-2.1). Reduced foam resistance from liquid added with FAP-MS is suspected to be
caused by the presence of MgSO₄ that can reduce the foam-forming ability in the foaming agent solution [17]. As for the suppression contour using peat water without foaming agents, it can be seen in Figure 4.

![Figure 4. Suppression contour using peat water without the foaming agent, (a) appearance of the contour before suppression; (b) appearance after the first suppression; (c) after the second suppression](image)

Fire suppression by using foam from a mixture of peat water mixed with FAP-MS; and peat water mixed with FAP was carried out with one spraying. Meanwhile, suppression using only peat water was carried out twice. To determine the work process of combustion and suppression of peat, thermal analysis is carried out as temperature control of peat material that is burned at the reactor using a data logger [8,12]. Illustration of the fire suppression performance using foaming agents and peat water is presented in Figure 5. The figure presents the contour graph of temperature in each application of FAP-MS, FAP, and peat water. Likewise, the replicates also had different graphic contour of temperature although the types of peat and fire trigger temperatures were different. This might be
caused by the fact that peat contained various types of organic materials having different calorific values [18] which, in turn, made the burnt peat surface have different temperatures.

![Graphical contour of laboratory scale peat fire suppression performance](image)

**Figure 5.** Graphical contour of laboratory scale peat fire suppression performance: (a) suppression using peat water mixed with FAP-MS foaming agent, (b) suppression using peat water mixed with FAP foaming agents, (c) suppression using peat water only

Figure 5 (a) shows that the suppression using foam from the peat water-FAP-MS mixture was carried out at the fourth hour with an initial suppression temperature of 408.74 °C, then after 1:30:32 hour, the temperature decreased to 47 °C. Fire suppression using foam from peat water mixed with FAP is presented in Figure 5 (b) with suppression time equal to FAP-MS which was at the fourth hour, with an initial suppression temperature of 397.25 °C, then after 2:21:48 hour, the temperature was decreased to 47 °C. For suppression using peat water only, the initial suppression temperature was 488.78 °C but at the eighth hour, a second suppression was needed to be carried out as at the first attempt the fire was not immediately extinguished. This is depicted in Figure 5 (c). The figure shows that in the sixth hour the temperature rises again indicating that the fire has not been extinguished so that the second suppression was performed. After the second suppression, the temperature continued to decrease until it reached a temperature of 47 °C at 6:33:28 hours. The indicator used to ensure that
The fire has been completely extinguished and did not restart was the detection of temperatures below 50 °C in each thermocouple (TC) [14,18].

The amount of peat water used in FAP-MS and FAP foaming agent mixtures was 8.09 L/m² and 7.17 L/m², respectively. When it was used independently without foaming agent mixed, peat water needed was 11.09 L/m². The illustration of the application of solutions in fire suppression on peatland in this study is presented in Figure 6. Mixing peat water with FAP-MS foaming agent for firefighting on peatland could save the use of water by 3.01 L/m² and the use of FAP foaming agent saved water use by 3.93 L/m².

Figure 6. Extinguishing time and solution consumption of peat water with FAP-MS foaming agent, peat water with FAP foaming agent and peat water only, on peat fire suppression

The utilization of peat water mixed with the FAP foaming agent saved more water than the utilization of peat water mixed with a FAP-MS foaming agent with a difference of 0.93 L/m². Meanwhile, results of another study [8], showed that fire suppression on peatlands required 7.02 L/m² of water and the application of water mixed with foaming agents required 3.59 L/m² of water. These differences in the amount of water needed were suspected to be caused by the differences in the depth of peat fire. In this study, the depth of peat was 3-9 cm, whereas the previous study was 2-4 cm. The depth of the peat fire determines the amount of water needed to extinguish. Deeper peat fire is more difficult to extinguish and requires more water [13,19,20].

In addition to the amount of extinguishing solution used, Figure 5 also shows that the use of peat water mixed with FAP-MS and FAP foaming agents could effectively accelerate the peat fire suppression process. Peat fire suppression using unmixed peat water, peat water mixed with FAP-MS foaming agent, and peat water mixed with a FAP foaming agent took about 6.5 hours, 1.5 hours, and 2.4 hours, respectively. Peat water with FAP-MS was able to suppress the peat fires faster by 5.03 hours (79.42%) and peat water with FAP by 4.12 hours (65.03%) compared to the application of peat water independently. Application of a foaming agent as a mixing medium for peat fire suppression can
accelerate the extinguishing process because the foaming agent can reduce the water surface tension and reduce the temperature of the burning surface. Foam liquid can also penetrate the peat pores, cools and closes the pore hole and prevents the oxygen circulation in the burning area [6,10,21].

4. Conclusion
Application of FAP-MS or FAP foaming agents on peat fire suppression at laboratory scale reduced water use. The volume of peat water required was less when it was mixed with FAP foaming agent than when it was mixed with FAP-MS foaming agent. In addition, the application of FAP-MS and FAP foaming agents accelerated suppression compared to the utilization of peat water only. FAP-MS foaming agent was able to extinguish fire faster than the FAP foaming agent.

References
[1] Ambak K and Melling L. 2000. Management Practices for Sustainable Cultivation of Crop Plants on Tropical Peatland; 1999 Nov. 22-24; Bogor, Indonesia. Bogor (ID): Graduate School of Environmental Earth Science Hokkaido University, Sapporo and Research and Development Center for Biology, Indonesian Institute of Sciences. pp: 119-134
[2] Adinugroho WC, Suryadiputra INN, Saharjo BH and Siboro L. 2011. Manual for the Control of Fire in Peatlands and Peatland Forest. Climate Change, Forests and Peatlands in Indonesia Project. Bogor (ID): Wetlands International-Indonesia Programme
[3] Hambali E, Suryani A and Rivai M. 2013. Proses Pengembangan Teknologi Surfactant Mes dari Metil Ester Minyak Sawit untuk Aplikasi Eor/Ior : Dari Skala Lab. ke Skala Pilot. Konferensi Nasional “Inovasi dan Technopreneurship”; 2013 Feb.18-19; Bogor, Indonesia. Bogor (ID): IPB. pp: 18–19
[4] Rivai M, Hambali E, Suryani A, Pramuhadi G, Fitria R and Firmansyah S. 2018. Physico-chemical properties tests of palm oil-based foaming agent using water solvent media from peatland physico-chemical properties tests of palm oil-based foaming agent using water solvent media from peatland. Conf. Ser. Earth Environ. Sci. 2017 Juli 24-25; Bogor, Indonesia: IOP. 209: 012036. DOI:10.1088/1755-1315/209/1/012036
[5] Utami SNH, Maas A, Radjagukguk B, and Purwanto BH. 2009a. Restorasi gambut dengan tiga jenis surfaktan, dan pengaruhnya Terhadap efisiensi penyimpanan kation dan kapasitas memegang air. Agritech 29(1):36–42
[6] Kawahara T, Hate S, Kanyama T, Ishizaki Y and Uezu K. 2016. Development of eco-friendly soap-based firefighting foam for forest fire. Environ. Control Biol. 54(1): 75–78. DOI:10.2525/ecb.54.75
[7] Kurama H. 2016. Fire Retardant Efficiency of Waste Magnesia Powder in Cellulose Insulation. J Aus. Ceramic Soc. 52(2): 143 – 149
[8] Japan International Cooperation Agency. 2016. Standard Operating Procedure concerning Fire-Fighting Techniques against Peat-Land and Forest Fires. Balikpapan (ID): JICA
[9] Rivai M, Hambali E, Suryani A, Fitria R, Firmansyah S and Pradesi J. 2017. Synthesis of palm oil fatty acid as foaming agent for firefighting application. Conf. Ser.: Earth Environ. Sci. 2016 Okt. 10-11; Bogor, Indonesia: IOP 65: 012047. DOI:10.1088/1755-1315/65/1/012047
[10] Subekti P, Hambali E, Suryani A and Suryadarma P. 2017. Potential production of palm oil-based foaming agent as fire extinguisher of peatlands in Indonesia: Literature review. Earth Environ. Sci. 2016 Okt. 10-11; Bogor, Indonesia: IOP:65: 012038. DOI:10.1088/1755-1315/65/1/012038
[11] Subekti P, Hambali E, Suryani A, Suryadarma P, Saharjo BH and Rivai M. 2018. Selection of Peat Firefighting Foam from Palm Oil Fatty Acid Saponification with Simple Additive Weighting (SAW) Method. SNTM-BKSTM. 2018 Okt.03-05; Kupang, Indonesia. Kupang (ID). Dep. Teknik Mesin, Undana. pp. 068–071
[12] Huang X and Rein G. 2014. Smoldering combustion of peat in wildfires : Inverse modeling of the drying and the thermal and oxidative decomposition kinetics. Combustion and Flame
161(6): 1633-1644. doi.org/10.1016/j.combustflame.2013.12.01
[13] Ramadhan ML, Palamba P, Imran FA, Kosasih EA, and Nugroho YS. 2017. Experimental study of the effect of water spray on the spread of smoldering in Indonesian peat fires. Fire Safety J. 91(April):671-679, doi.org/10.1016/j.firesaf.2017.04.01
[14] International Organization for Standardization. 2011. ISO 7076-3:2011. Fire Extinguishing Media Foam Concentrates Specification for Low-Expansion Foam Concentrates for Top Application to Water Miscible Liquids. ISO
[15] Subekti P, Hambali E, Suryani A, Suryadarma P, Saharjo BH, Rivai M. 2019. The Formulation of Foaming Agents from Palm Oil Fatty Acid and Performance Test on Peat Fires. J. Japan Inst. Energy 98: 95-100
[16] Palamba P, Ramadhan ML, Imran FA, Kosasih EA, and Nugroho YS. 2017. Int. Trop. Ren. Energy Conf. (i-TREC). Okt. 26–28, 2016. Bogor, Indonesia. AIP Conf. Proc. 1826, 020017. DOI: 10.1063/1.4979233
[17] Effendi H. 2000. Telaahan Kualitas Air: bagi pengelolaan sumberdaya dan lingkungan perairan. IPB. Bogor. pp. 104-111
[18] Akbar A 2016. Pemahaman dan Solusi Masalah Kebakaran Hutan di Indonesia. Forda Press, Bogor. Pp: 27-70
[19] Huang X, Restuccia F, Rein G and Gramola M. 2016. Experimental study on the surface spread of smoldering peat fires. 5th International Fire Behavior and Fuels Conference: 2016 April 11-15: Portland USA. Missoula (US): IAWF: hlm 1-6
[20] Guitart NP, Rein G, Hadden RM, Belche CM, and Yearsley JM. 2016. Effects of spatial heterogeneity in moisture content on the horizontal spread of peat fires Science of the Total Environment (doi.org/10.1016/j.scitotenv.2016.02.145)
[21] Utami SNH, Maas A, Radjagukguk B, and Purwanto BH. 2009. Sifat fisik, kimia dan FTIR spektrofotometri gambut hidrofobik Kalimantan Tengah. Jurnal Tanah Trop. 14(2) 159-166

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