# Chapter 6

# Experimental Results on Effectiveness of Polymeric Dust Suppressants

## 6.1 Introduction

This chapter explains the effectiveness of different polymeric solutions by determining moisture retention capability and its comparison against water-only system. Dust emission rate is estimated using an empirical formula. Finally, the best performing laboratory synthesized polymeric dust suppressant is selected which, in turn, possesses the highest potential in reducing dust emission from haul roads.

## 6.2 Comparison of Moisture Retention Efficiency of Dust Suppressants

Calculation procedure for 'moisture retention efficiency' has been shown in chapter 3.10. In this section, moisture retention efficiency of the dust samples for all the polymers and water-alone as dust suppressant are elaborated at low (25 °C), moderate (35 °C) and high temperature (45 °C) over 8 h duration.

### 6.2.1 Moisture retention efficiency of dust suppressants at 25 °C

Moisture retention efficiency of all the polymers at low temperature (25 °C) are presented in Table 6.1. Figure 6.1 shows the graphical comparison of moisture retention efficiency of haul road dust with the application of all the polymers and only-water working as a dust suppressant.

For the other polymers data have been shown in tabular form, since these values have been used for calculation of dust emission rate later.

Table 6.1 Comparison of moisture retention efficiency (%) of dust at 25 °C with application of all suppressants

| Time (h) | Water | PAM | H-PAM | AP-g-PAM | H-AP-g-PAM | GG-g-PAM | H-GG-g-PAM | PAMPS-co-PAM | H-PAMPS-co-PAM |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 1 | 91.72 | 91.97 | 92.22 | 92.14 | 92.53 | 93.04 | 93.46 | 93.83 | 94.32 |
| 2 | 82.76 | 83.53 | 83.87 | 83.89 | 84.44 | 85.97 | 86.58 | 87.35 | 88.17 |
| 3 | 74.23 | 75.21 | 75.83 | 75.82 | 76.82 | 78.91 | 79.78 | 81.12 | 82.45 |
| 4 | 65.5 | 67.15 | 67.99 | 67.91 | 69.19 | 71.42 | 72.66 | 74.79 | 76.41 |
| 5 | 57.02 | 58.97 | 59.96 | 59.86 | 61.29 | 64.31 | 65.77 | 68.57 | 70.47 |
| 6 | 47.79 | 50.74 | 51.93 | 51.66 | 53.44 | 56.93 | 58.67 | 62.13 | 64.49 |
| 7 | 38.91 | 42.65 | 44.01 | 43.87 | 45.85 | 49.89 | 52.05 | 55.91 | 58.52 |
| 8 | 29.82 | 34.64 | 36.24 | 35.71 | 37.91 | 42.71 | 45.21 | 49.68 | 52.69 |

At this temperature, evaporation of moisture is slow. With the application of only water, 29.82% of moisture is retained by the dust after 8 h of exposures. It is seen from Table-6.1 that moisture retention by the polymers increases in the order of PAM, AP-g-PAM,

H-PAM, H-AP-g-PAM, GG-g-PAM, H-GG-g-PAM, PAMPS-co-PAM and H-PAMPS-co-PAM. The highest moisture retention after 8 h (26%) is by H-PAMPS-co-PAM. It is also apparent from the Table-6.1 that all the hydrolyzed polymers possess more moisture retention efficiency than their counter parts i.e. unhydrolyzed products.

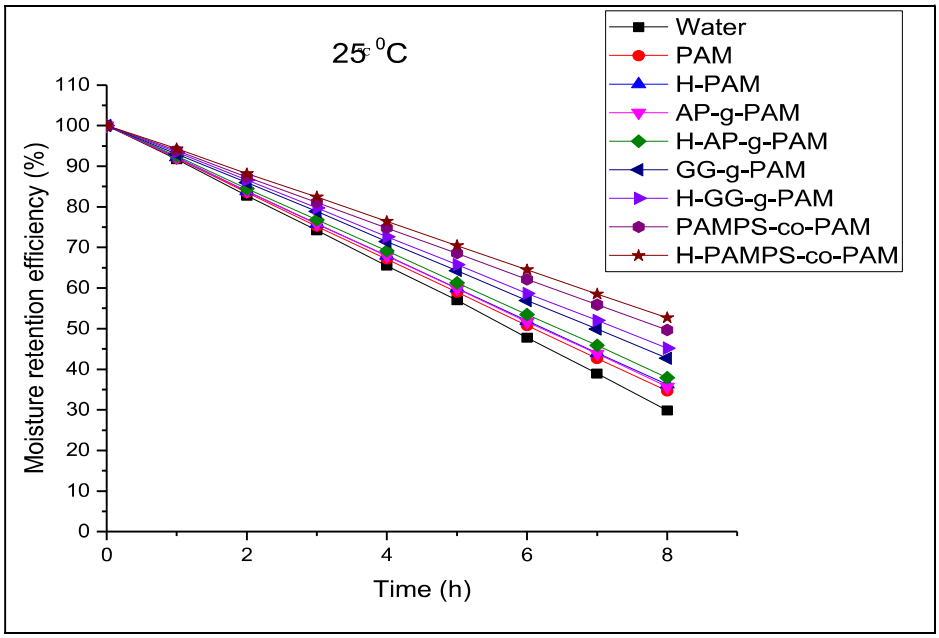


Figure 6.1 Moisture retention efficiency (%) vs time at 25 °C with application of all suppressants

### 6.2.2 Moisture retention efficiency of dust suppressants at 35 °C

At moderate temperature (35 °C), moisture retention efficiency of all the polymers are presented in Table 6.2 and Figure 6.2.

Table 6.2 Comparison of moisture retention efficiency (%) of dust at 35 °C with application of all suppressants

| Time (h) | Water | PAM | H-PAM | AP-g-PAM | H-AP-g-PAM | GG-g-PAM | H-GG-g-PAM | PAMPS-co-PAM | H-PAMPS-co-PAM |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 1 | 88.6 | 89.89 | 90.16 | 90.49 | 90.98 | 90.49 | 91.16 | 92.42 | 92.94 |
| 2 | 76.99 | 78.57 | 79.03 | 79.03 | 79.87 | 80.8 | 81.89 | 83.8 | 84.98 |
| 3 | 63.83 | 67.08 | 68.01 | 67.87 | 69.09 | 70.21 | 72.01 | 75.28 | 76.87 |
| 4 | 51.62 | 55.55 | 56.71 | 56.21 | 57.97 | 59.81 | 61.89 | 65.82 | 67.73 |
| 5 | 39.98 | 43.67 | 45.12 | 44.88 | 46.95 | 48.03 | 50.44 | 55.83 | 58.21 |
| 6 | 26.22 | 31.84 | 33.47 | 32.16 | 34.69 | 36.9 | 39.79 | 46.41 | 49.17 |
| 7 | 12.32 | 19.97 | 21.86 | 20.75 | 23.7 | 25.71 | 28.96 | 36.9 | 40.3 |
| 8 | 0.92 | 8.82 | 11.02 | 10.7 | 13.98 | 15.62 | 19.24 | 27.82 | 31.81 |

At this temperature, evaporation of moisture is faster than the 25°C. At the end of 8 h, moisture retained by water treated dust is almost negligible (0.92%), whereas other polymers give better results. Like 25 °C, at 35 °C also moisture retention after 8 hrs increases in the order of PAM, AP-g-PAM, H-PAM, , H-AP-g-PAM, GG-g-PAM, H-GG-g-PAM, PAMPS-co-PAM and H-PAMPS-co-PAM. Maximum moisture retention is 31.81% by H-PAMPS-co-PAM. Again, like 25 °C, at 35 °C also efficiency of hydrolyzed polymers are more than their counter parts i.e. unhydrolyzed products.

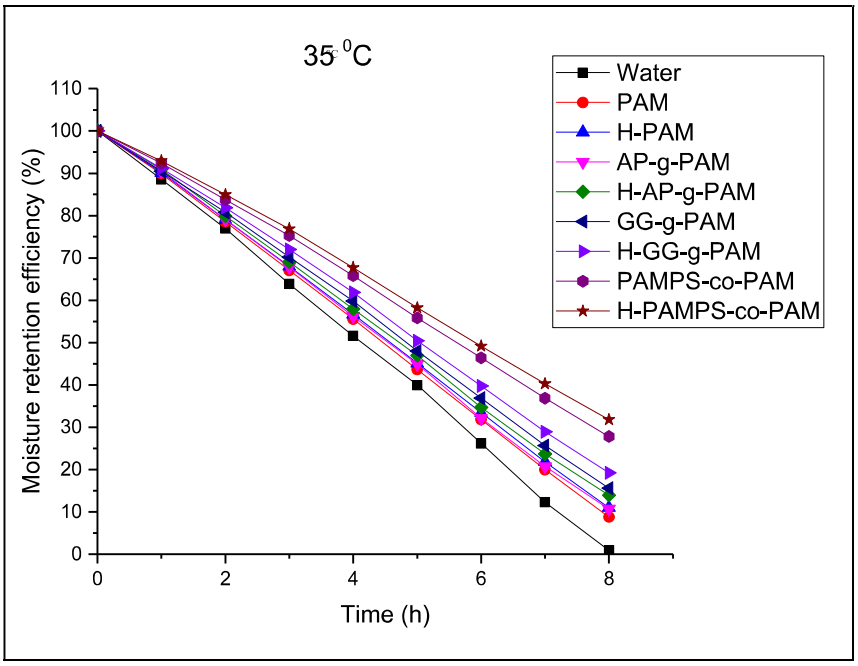


Figure 6.2 Moisture retention efficiency (%) vs time at 35 °C with application of all suppressants

### 6.2.3 Moisture retention efficiency of dust suppressants at 45 °C

Moisture retention efficiency of all the polymers at high temperature of 45 °C, are shown in Table 6.3 and Figure 6.3.

At this high temperature of 45 °C, evaporation of moisture is very fast compared to 25 °C and 35 °C. At the end of 2 h, moisture retained by only-water treated dust drastically falls to 15.82%, and after 3 h, the dust sample becomes almost dry (moisture retention is 0.45 %). It is seen from Table 6.3 that after 2 h, moisture retention by the polymers increases in the order of PAM, H-PAM, AP-g-PAM, H-AP-g-PAM, GG-g-PAM, H-GG-g-PAM, PAMPS-co-PAM and H-PAMPS-co-PAM. Here again, efficiency of hydrolyzed polymers are more than their counterparts i.e. unhydrolyzed products, as was observed at 25 °C and 35 °C.

After 2 h, moisture retention by H-PAMPS-co-PAM is 51.26% and that for water-alone system is 15.82%. Therefore, after 2 h of application, efficiency of H-PAMPS-co-PAM is 3.24 times higher in comparison to water-alone system.

Table 6.3 Comparison of moisture retention efficiency (%) of dust at 45 °C with application of all suppressants

| **Time (h)** | **Water** | **PAM** | **H-PAM** | **AP-g-PAM** | **H-AP-g-PAM** | **GG-g-PAM** | **H-GG-g-PAM** | **PAMPS-co-PAM** | **H-PAMPS-co-PAM** |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 1 | 58.4 | 63.98 | 65.44 | 67.12 | 68.61 | 68.71 | 70.54 | 73.17 | 75.35 |
| 2 | 15.82 | 26.55 | 29.05 | 32.34 | 35.94 | 36.79 | 40.81 | 46.11 | 51.26 |
| 3 | 0.45 | 0.81 | 0.88 | 1.75 | 3.26 | 4.59 | 11.41 | 19.58 | 27.03 |
| 4 | 0.01 | 0.03 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 | 0.3 | 2.52 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

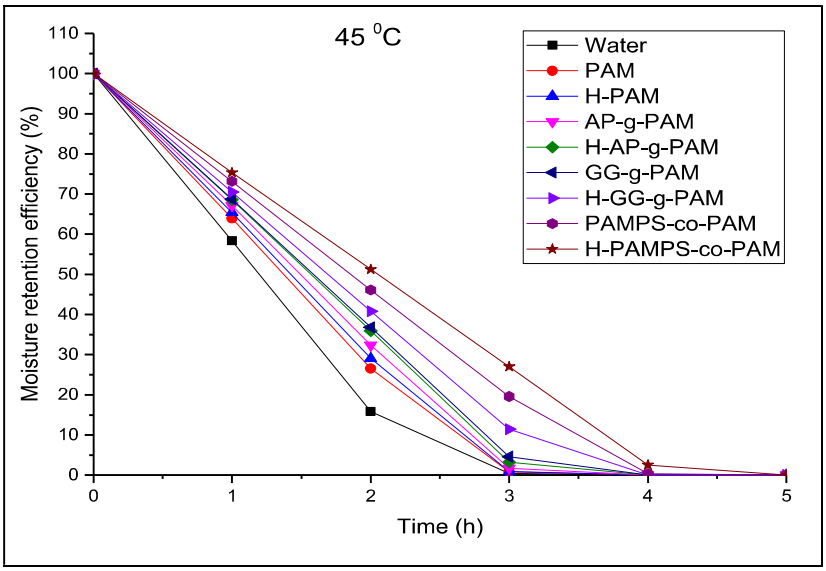


Figure 6.3 Moisture retention efficiency (%) vs time at 45 °C with application of all suppressants

## 6.3 Comparison of Dust Emission Rates for Different Dust Suppressants

In this section, we discuss the emission rate of haul road dust over the period of 8 h at the temperature of 25 °C, 35 °C and 45 °C on application of various synthesized dust suppressants and water-alone system.

### 6.3.1 Estimation of dust emission rate

A detailed discussion has been presented in Chapter-3.11 for the estimation of haul road dust emission rate. It is mentioned that the Empirical Equation-3.8 as proposed by Chaulya et al. (2002) will be used in the present work [92]. The values for the parameters to be used in the calculation, namely, (i) silt content, (ii) wind speed, (iii) average vehicle speed, (iv) frequency of vehicle movement, and (v) capacity of dumper, have been

presented in Table-3.3 of Chapter-3.11. The value of the moisture content of dust samples at different temperatures will be taken from the Tables of the experimental results presented in previous Section-6.2.

### 6.3.2 Dust emission rate for different dust suppressants at 25 °C

Emission rates of haul road dust after application of all the polymer solutions at low temperature (25 °C) are given in Table 6.4. Figure 6.4 shows graphical comparison of the estimated dust emission rates with the application of all the developed polymers and also water-alone system as a dust suppressant.

Table 6.4 Comparison of dust emission rate (mg $m^{-1}$ $s^{-1}$) at 25 °C with application of all dust suppressants

| Time (h) | Water | PAM | H-PAM | AP-g-PAM | H-AP-g-PAM | GG-g-PAM | H-GG-g-PAM | PAMPS-co-PAM | H-PAMPS-co-PAM |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0.48 | 0.46 | 0.45 | 0.46 | 0.44 | 0.41 | 0.39 | 0.37 | 0.35 |
| 2 | 0.93 | 0.89 | 0.87 | 0.87 | 0.85 | 0.77 | 0.74 | 0.70 | 0.66 |
| 3 | 1.40 | 1.35 | 1.31 | 1.31 | 1.25 | 1.14 | 1.09 | 1.02 | 0.95 |
| 4 | 1.96 | 1.85 | 1.79 | 1.80 | 1.71 | 1.57 | 1.50 | 1.37 | 1.28 |
| 5 | 2.61 | 2.45 | 2.37 | 2.38 | 2.26 | 2.04 | 1.94 | 1.75 | 1.63 |
| 6 | 3.51 | 3.19 | 3.07 | 3.10 | 2.93 | 2.62 | 2.47 | 2.20 | 2.03 |
| 7 | 4.69 | 4.14 | 3.96 | 3.98 | 3.74 | 3.28 | 3.06 | 2.70 | 2.48 |
| 8 | 6.49 | 5.43 | 5.14 | 5.23 | 4.85 | 4.14 | 3.81 | 3.30 | 3.00 |

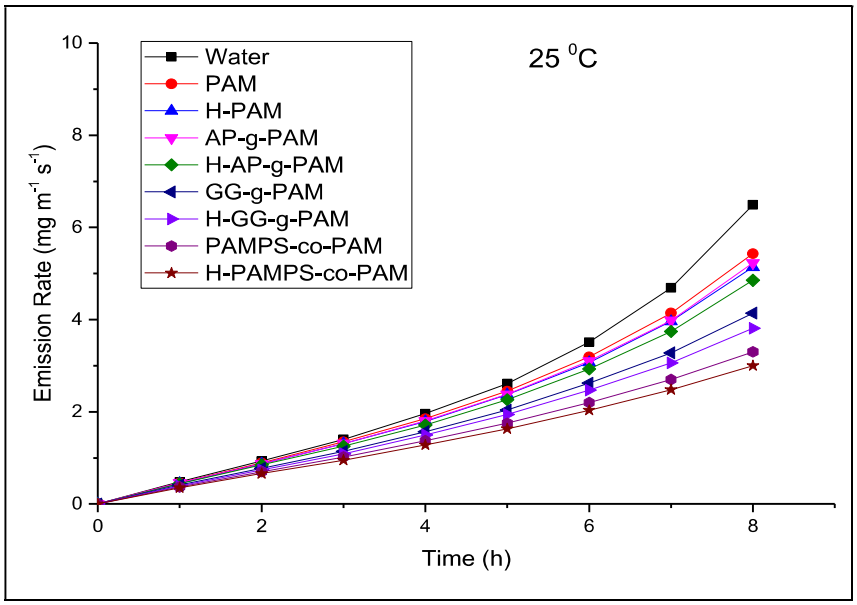


Figure 6.4 Dust emission rate vs time at 25 °C with application of all dust suppressants

At this low temperature (25 °C), evaporation rate of moisture is very slow. Therefore, the emission of dust from the haul road is also very low. When water is applied, estimated dust emission rate is 6.49 mg $m^{-1}$ $s^{-1}$after 8 h of application. The best performing polymer is H-PAMPS-co-PAM, for which the emission rate is 3.00 mg $m^{-1}$ $s^{-1}$.

It is also seen from Table 6.4 that after 8 h of application, dust emission rate by the polymers decreases in the order of PAM, H-PAM, AP-g-PAM, H-AP-g-PAM, GG-g-PAM, H-GG-g-PAM, PAMPS-co-PAM and H-PAMPS-co-PAM. Efficiency of hydrolyzed polymers is better than their counter parts i.e. unhydrolyzed products.

### 6.3.3 Dust emission rate for dust suppressants at 35 °C

Emission rate of haul road dust for all the polymers at moderate temperature (35 °C) are presented in Table 6.5 and Figure 6.5.

Table 6.5 Comparison of dust emission rate (mg $m^{-1}$ $s^{-1}$) at 35 °C with application of all dust suppressants

| Time (h) | Water | PAM | H-PAM | AP-g-PAM | H-AP-g-PAM | GG-g-PAM | H-GG-g-PAM | PAMPS-co-PAM | H-PAMPS-co-PAM |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0.63 | 0.57 | 0.56 | 0.54 | 0.51 | 0.54 | 0.51 | 0.44 | 0.42 |
| 2 | 1.24 | 1.16 | 1.13 | 1.13 | 1.09 | 1.04 | 0.98 | 0.88 | 0.82 |
| 3 | 2.08 | 1.85 | 1.79 | 1.80 | 1.72 | 1.65 | 1.54 | 1.34 | 1.25 |
| 4 | 3.10 | 2.74 | 2.63 | 2.68 | 2.53 | 2.38 | 2.22 | 1.94 | 1.81 |
| 5 | 4.53 | 4.01 | 3.82 | 3.85 | 3.61 | 3.48 | 3.22 | 2.71 | 2.51 |
| 6 | 7.48 | 6.01 | 5.67 | 5.94 | 5.42 | 5.02 | 4.55 | 3.67 | 3.36 |
| 7 | 15.72 | 9.93 | 9.06 | 9.55 | 8.33 | 7.64 | 6.70 | 5.02 | 4.48 |
| 8 | - | 21.19 | 17.39 | 17.85 | 13.99 | 12.61 | 10.30 | 7.01 | 6.02 |

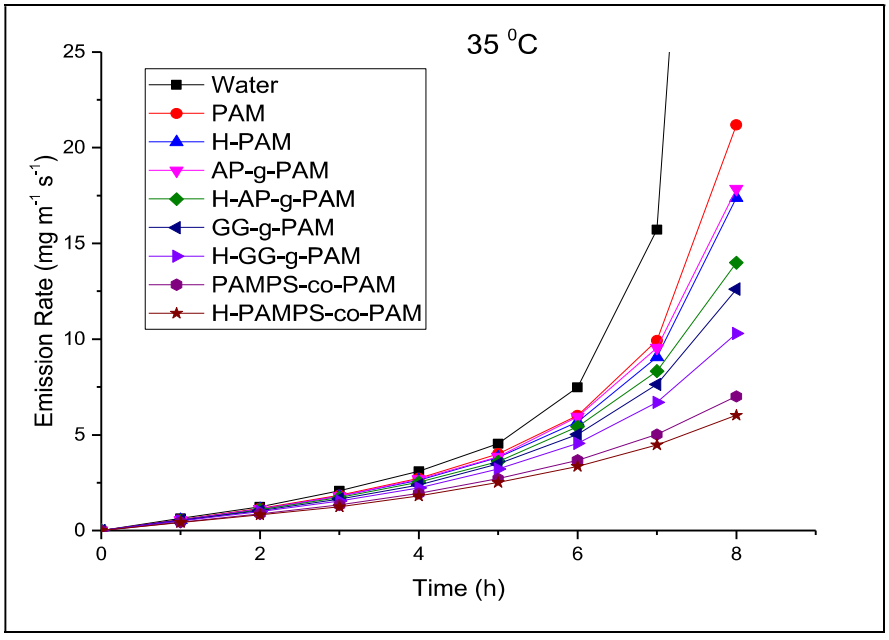


Figure 6.5 Dust emission rate vs time at 35 °C with application of all dust suppressants

The evaporation rate of moisture is slightly higher due to increase in the temperature. Therefore, the emission of dust from the haul road is also high which increases gradually as time passes. In case of water application, estimated dust emission rate is 15.72 mg $m^{-1}$ $s^{-1}$ after 7 h of exposures. After 8 h, almost no more moisture is left in the water treated sample, and hence, dust emission rate increases exponentially which can't be estimated.

After 7 h of exposure of treated samples, dust emission rate is minimum for H-PAMPS-co-PAM. Hydrolyzed polymers performed better than the corresponding unhydrolyzed polymers.

### 6.3.4 Dust emission rate for dust suppressants at 45 °C

Emission rate of haul road dust of all the polymers solution treated at high temperature (45 °C) are presented in Table 6.6 and Figure 6.6.

Table 6.6 Comparison of dust emission rate (mg $m^{-1}$ $s^{-1}$) at 45 °C with application of all dust suppressants

| Time (h) | Water | PAM | H-PAM | AP-g-PAM | H-AP-g-PAM | GG-g-PAM | H-GG-g-PAM | PAMPS-co-PAM | H-PAMPS-co-PAM |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 0 |
| 1 | 2.49 | 2.07 | 1.96 | 1.85 | 1.75 | 1.74 | 1.63 | 1.47 | 1.34 |
| 2 | 12.46 | 7.38 | 6.68 | 5.90 | 5.19 | 5.04 | 4.40 | 3.70 | 3.14 |
| 3 | - | - | - | - | 49.26 | 37.05 | 16.85 | 10.12 | 7.24 |
| 4 | - | - | - | - | - | - | - | - | 60.89 |
| 5 | - | - | - | - | - | - | - | - | - |

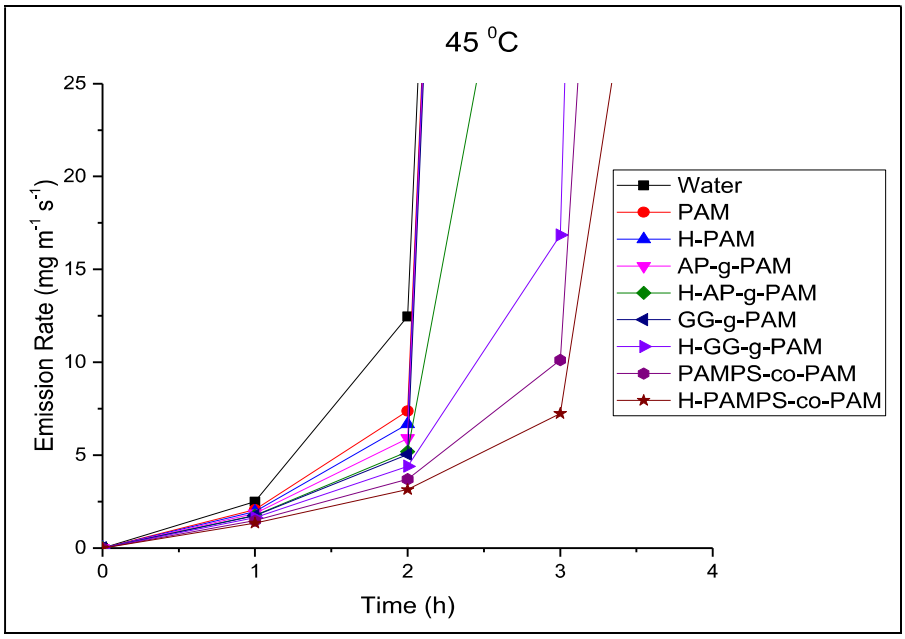


Figure 6.6 Dust emission rate vs time at 45 °C with application of all dust suppressants

At high temperature (45 °C), the evaporation of moisture is very fast. Therefore, the emission of dust from the haul road is very high which increases exponentially as time passes. In case of water application, estimated dust emission rate is 12.46mg $m^{-1}$ $s^{-1}$after2 h of exposures. After 3 h onward, no moisture is left for the water-alone treated sample, therefore dust emission rates could not be estimated. After 2 h of exposure of polymer treated samples, dust emission rate decreases in the order of PAM, H-PAM, AP-g-PAM, H-AP-g-PAM, GG-g-PAM, H-GG-g-PAM, PAMPS-co-PAM and H-PAMPS-co-PAM. It is observed that like low (25 °C) and moderate (35 °C) temperatures, at high (45 °C) temperature also hydrolyzed polymers performed better than the corresponding unhydrolyzed polymers with respect to dust emission.

## 6.4 Selection of Best Performing Polymer

The polymer solution that can hold more moisture compared to only-water application in haul road dust samples, is said to be the *best performing polymer*. From the above analysis, it is seen that at all the three temperatures under study i.e. 25 °C,35 °C & 45 °C, H-PAMPS-co-PAM polymer is able to retain the highest moisture level than the other polymers.

### 6.4.1 At low Temperature (25 °C) & after 8 hour of application

**(i) Moisture retention efficiency of H-PAMPS-co-PAM (from Table 6.1)**

Moisture retained for only-water application = 29.82%

Moisture retained for H-PAMPS-co-PAM application = 52.69%

∴ Moisture retention by H-PAMPS-co-PAM is (52.69 ÷ 29.82) i.e. 1.77 times better than only-water system.

**(ii) Dust emission rate of H-PAMPS-co-PAM (from Table 6.4)**

Emission rate for only-water application = 6.49 mg $m^{-1}$ $s^{-1}$

Emission rate for H-PAMPS-co-PAM application = 3.0 mg $m^{-1}$ $s^{-1}$

∴ Dust emission rate of H-PAMPS-co-PAM is (6.49 ÷ 3.0) i.e. 2.16 times lower than only-water system.

### 6.4.2 At moderate Temperature (35 °C) & after 7 hour of application

**(i) Moisture retention efficiency of H-PAMPS-co-PAM (from Table 6.2)**

Moisture retained for only-water application = 12.32%

Moisture retained for H-PAMPS-co-PAM application = 40.3%

∴ Moisture retention by H-PAMPS-co-PAM is (40.3÷ 12.32) i.e. 3.27 times better than only-water system.

**(ii) Dust emission rate of H-PAMPS-co-PAM (from Table 6.5)**

Emission rate for only-water application = 15.72mg $m^{-1}$ $s^{-1}$

Emission rate for H-PAMPS-co-PAM application = 4.48mg $m^{-1}$ $s^{-1}$

∴ Dust emission rate of H-PAMPS-co-PAM is (15.72 ÷ 4.48) i.e. 3.51 times lower than only-water system.

### 6.4.3 At high Temperature (45 °C) & after 2 hour of application

**(i) Moisture retention efficiency of H-PAMPS-co-PAM (from Table 6.3)**

Moisture retained for only-water application = 15.82%

Moisture retained for H-PAMPS-co-PAM application = 51.26%

∴ Moisture retention by H-PAMPS-co-PAM is (51.26 ÷ 15.82) i.e. 3.24 times performed better than only-water system.

**(ii) Dust emission rate of H-PAMPS-co-PAM (from Table 6.6)**

Emission rate for only-water application = 12.46 mg $m^{-1}$ $s^{-1}$

Emission rate for H-PAMPS-co-PAM application = 3.14 mg $m^{-1}$ $s^{-1}$

∴ Dust emission rate of H-PAMPS-co-PAM is (12.46 ÷ 3.14) i.e. 3.97 times lower than only-water system.

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