

# Screening and investigation on inhibition of sediment formation in a Kuwait light crude oil by commercial additives with some guidelines for field applications

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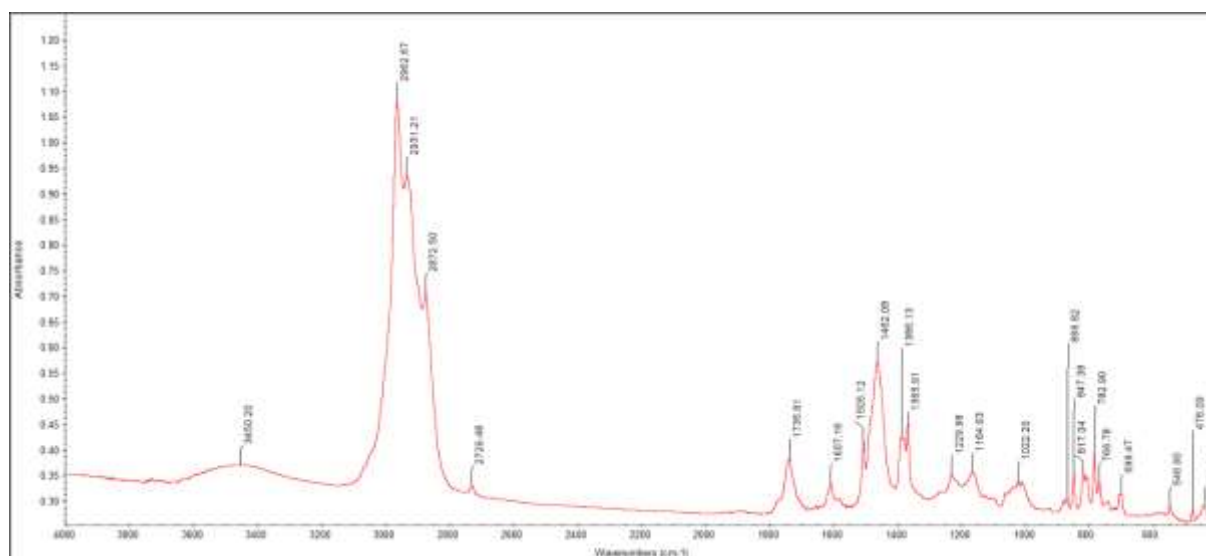
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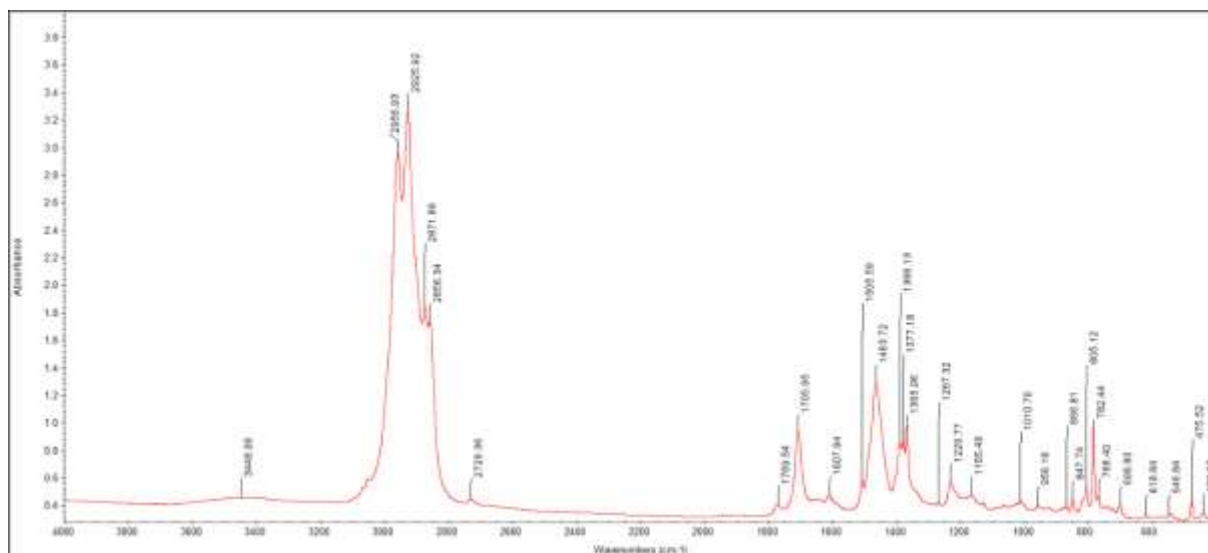
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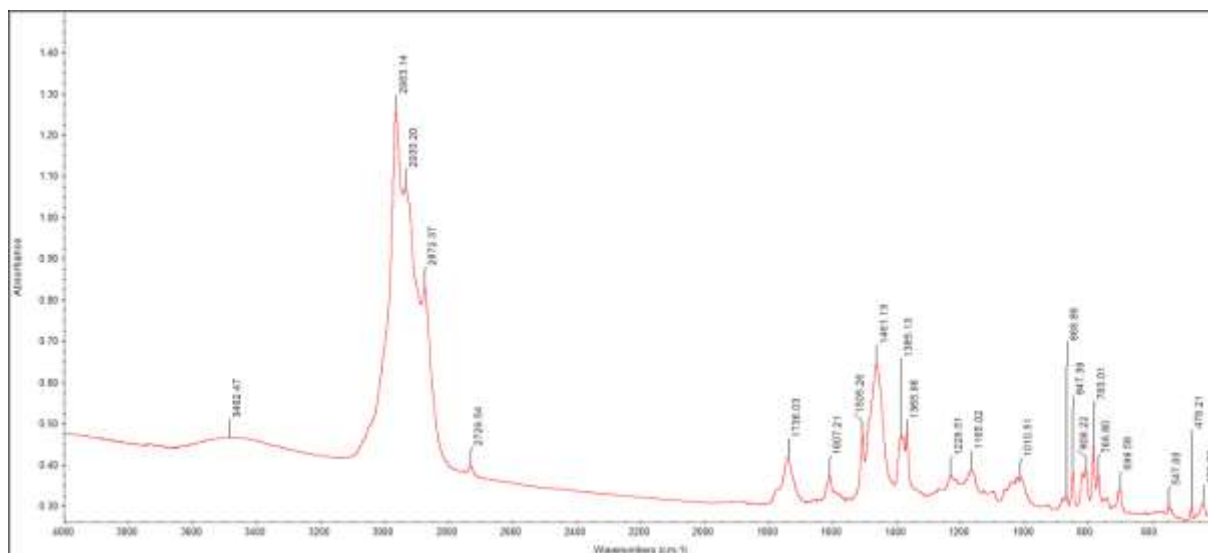
**Figure S1.** IR-spectra of additive A1

FTIR spectrum of additive A1 indicates that it consists of aliphatic and aromatic hydrocarbons. The IR-spectra of the additive A1 showed that it contains bands in the region 3000-2800  $\text{cm}^{-1}$  and at 1462  $\text{cm}^{-1}$ , and at 1386/1366  $\text{cm}^{-1}$ , typical for presence of aliphatic groups. The band at 1736  $\text{cm}^{-1}$  is due to the stretching vibration of the C=O bond participating in ester. The absorption intensities at 1607  $\text{cm}^{-1}$  and 1505  $\text{cm}^{-1}$  corresponded to carbon - carbon stretching vibrations in the aromatic ring. The bands in the region 900 - 700  $\text{cm}^{-1}$  are due to out of plane bending of aromatic C - H bonds, used in distinguishing different types of aromatic ring substitution.



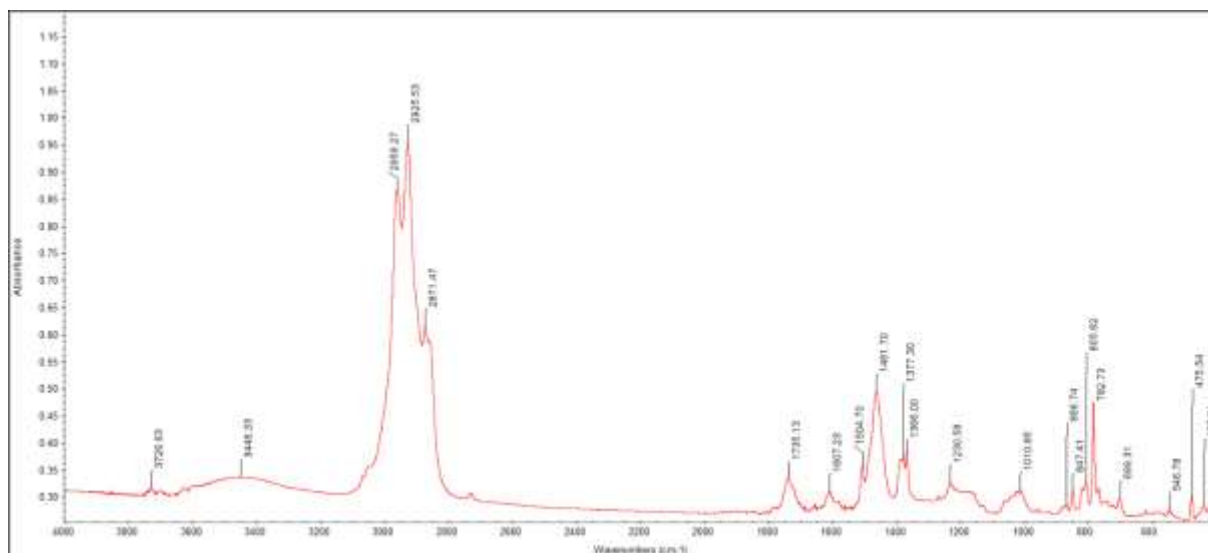
**Figure S2.** IR-spectra of additive A2

FTIR spectrum of additive A2 indicates that it consists of aliphatic and aromatic hydrocarbons. The IR-spectra of the additive A2 showed that it contains bands in the region 3000-2800  $\text{cm}^{-1}$  and at 1464  $\text{cm}^{-1}$ , and at 1388/1377/1366  $\text{cm}^{-1}$ , typical for presence of aliphatic groups. The band at about 1770  $\text{cm}^{-1}$  is due to the stretching vibration of the C=O bond. The band at about 1706  $\text{cm}^{-1}$  is due to the stretching vibration of the C=O bond probably participating in ketone. The absorption intensities at 1608  $\text{cm}^{-1}$  and 1506  $\text{cm}^{-1}$  corresponded to carbon - carbon stretching vibrations in the aromatic ring. The bands in the region 900 - 700  $\text{cm}^{-1}$  are due to out of plane bending of aromatic C - H bonds, used in distinguishing different types of aromatic ring substitution.



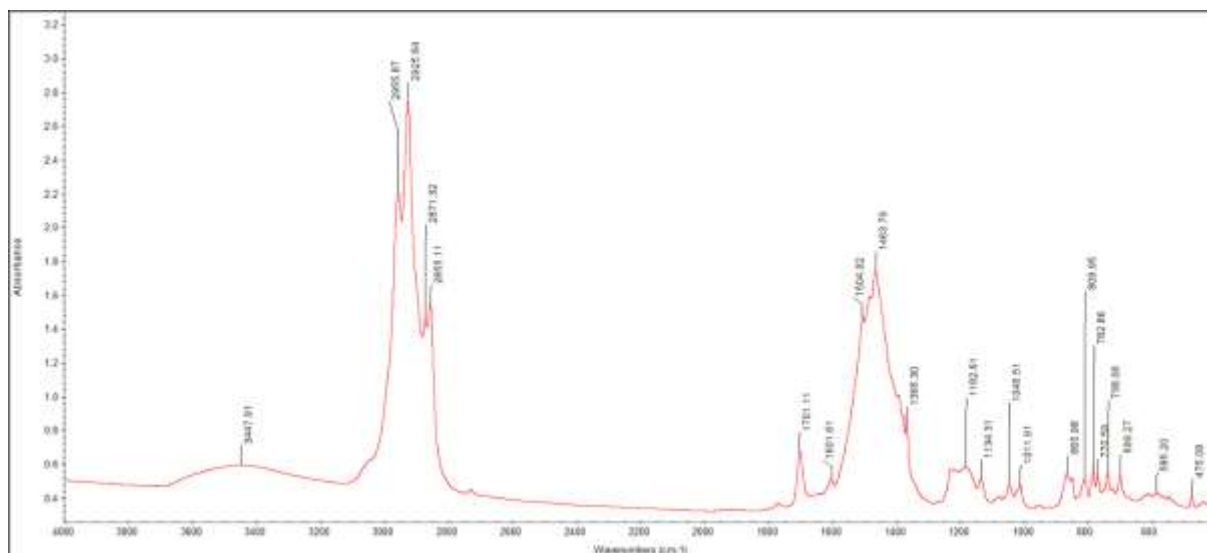
**Figure S3.** IR-spectra of additive A3

FTIR spectrum of additive A3 indicates that it consists of aliphatic and aromatic hydrocarbons. The IR-spectra of the additive A3 showed that it contains bands in the region  $3000\text{--}2800\text{ cm}^{-1}$  and at  $1461\text{ cm}^{-1}$ , and at  $1385/1366\text{ cm}^{-1}$ , typical for presence of aliphatic groups. The band at  $1736\text{ cm}^{-1}$  is due to the stretching vibration of the  $\text{C}=\text{O}$  bond participating in ester. The absorption intensities at  $1607\text{ cm}^{-1}$  and  $1505\text{ cm}^{-1}$  corresponded to carbon - carbon stretching vibrations in the aromatic ring. The bands in the region  $900\text{--}700\text{ cm}^{-1}$  are due to out of plane bending of aromatic C - H bonds, used in distinguishing different types of aromatic ring substitution.



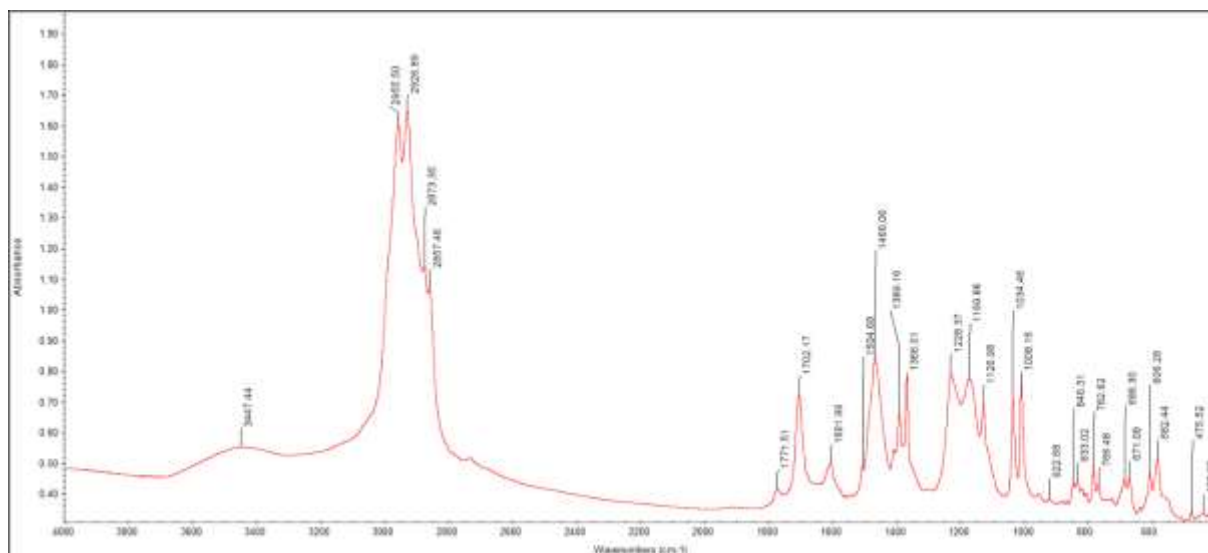
**Figure S4.** IR-spectra of additive A4

FTIR spectrum of additive A4 indicates that it consists of aliphatic and aromatic hydrocarbons. The IR-spectra of the additive A4 showed that it contains bands in the region 3000-2800  $\text{cm}^{-1}$  and at 1462  $\text{cm}^{-1}$ , and at 1385/1377/1366  $\text{cm}^{-1}$ , typical for presence of aliphatic groups. The band at 1735  $\text{cm}^{-1}$  is due to the stretching vibration of the C=O bond participating in ester. The absorption intensities at 1607  $\text{cm}^{-1}$  and 1505  $\text{cm}^{-1}$  corresponded to carbon - carbon stretching vibrations in the aromatic ring. The bands in the region 900 - 700  $\text{cm}^{-1}$  are due to out of plane bending of aromatic C - H bonds, used in distinguishing different types of aromatic ring substitution.



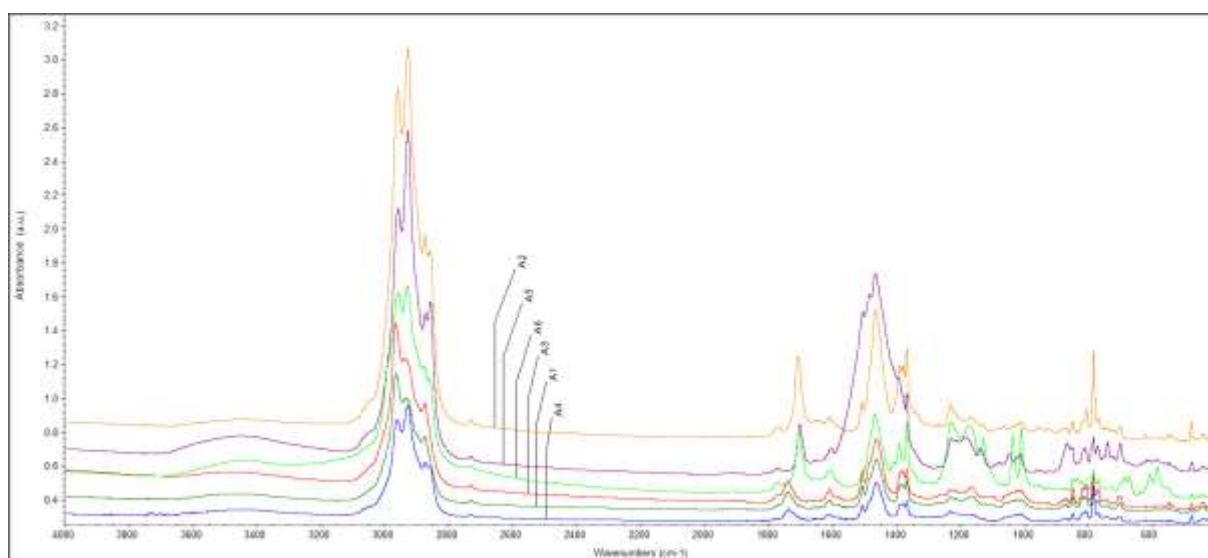
**Figure S5.** IR-spectra of additive A5

FTIR spectrum of additive A5 indicates that it consists of aliphatic and aromatic hydrocarbons. The IR-spectra of the additive A5 showed that it contains bands in the region 3000-2800  $\text{cm}^{-1}$  and at 1464  $\text{cm}^{-1}$ , and at 1366  $\text{cm}^{-1}$ , typical for presence of aliphatic groups. The band at 1701  $\text{cm}^{-1}$  is due to the stretching vibration of the C=O bond participating in carboxylic group. The absorption intensities at 1602  $\text{cm}^{-1}$  and 1502  $\text{cm}^{-1}$  corresponded to carbon - carbon stretching vibrations in the aromatic ring. The bands in the region 900 - 700  $\text{cm}^{-1}$  are due to out of plane bending of aromatic C - H bonds, used in distinguishing different types of aromatic ring substitution. The absorption intensity with maximum at 1480  $\text{cm}^{-1}$  is probably due to presence of inorganic compound.

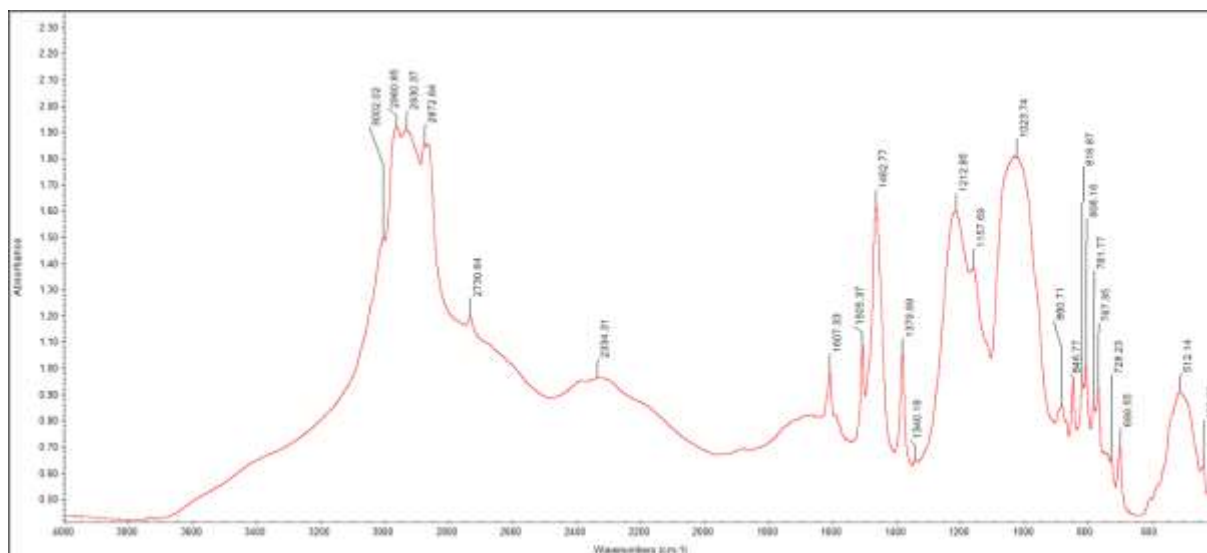


**Figure S6.** IR-spectra of additive A6

FTIR spectrum of additive A6 indicates that it consists of aliphatic and aromatic hydrocarbons. The IR-spectra of the additive A6 showed that it contains bands in the region 3000-2800  $\text{cm}^{-1}$  and at 1466  $\text{cm}^{-1}$ , and at 1389/1366  $\text{cm}^{-1}$ , typical for presence of aliphatic groups. The band at 1702  $\text{cm}^{-1}$  is due to the stretching vibration of the C=O bond probably participating in ketone. The absorption intensities at 1602  $\text{cm}^{-1}$  corresponded to carbon - carbon stretching vibrations in the aromatic ring.

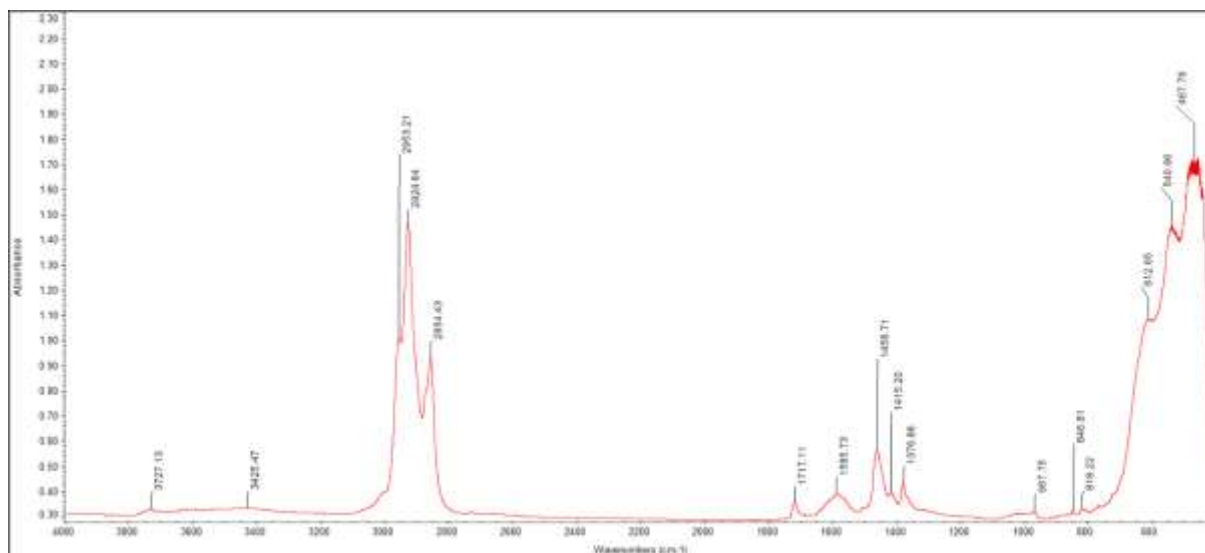


**Figure S7.** Combined IR-spectra of the additives A1, A2, A3, A4, A5, and A6.



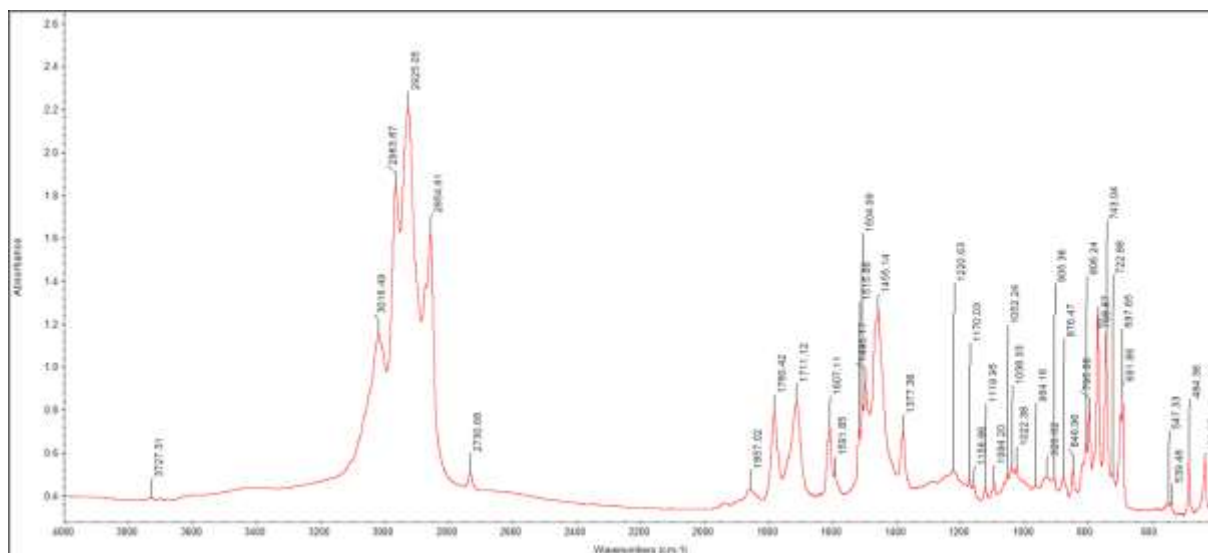
**Figure S8.** IR-spectra of additive A7

The IR-spectra of the additive A7 showed that it contains bands in the region 3000-2800  $\text{cm}^{-1}$  and at 1463  $\text{cm}^{-1}$ , and at 1380  $\text{cm}^{-1}$ , typical for presence of aliphatic groups. Three broad bands at about 2700-2500  $\text{cm}^{-1}$ , 2400-2100  $\text{cm}^{-1}$ , and 1800-1600  $\text{cm}^{-1}$  are due to presence of hydroxyl groups that are strongly involved in hydrogen bonding to phosphoryl oxygen atoms in acidic organophosphorus acids. The very strong and broad band at 1213  $\text{cm}^{-1}$  is due to the P=O stretching vibration. The strongest and also very broad absorption at  $\sim 1024 \text{ cm}^{-1}$  is attributed to the P-O stretching vibrations. Several weak bands between 881-650  $\text{cm}^{-1}$  are characteristic of the ethylhexyl groups. The absorption intensities at 1607  $\text{cm}^{-1}$  and 1505  $\text{cm}^{-1}$  corresponded to carbon - carbon stretching vibrations in the aromatic ring, indicating presence of aromatic compound.



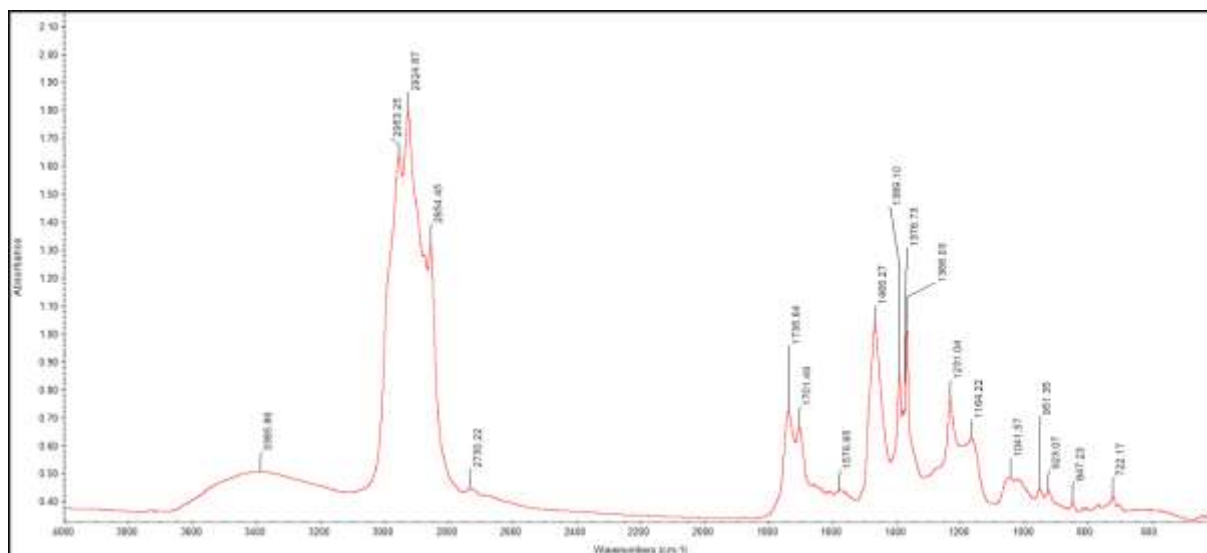
**Figure S9.** IR-spectra of additive A8

The IR-spectra of the additive A8 showed that it contains bands in the region 3000-2800  $\text{cm}^{-1}$  and at 1459  $\text{cm}^{-1}$ , and at 1377  $\text{cm}^{-1}$ , typical for presence of aliphatic groups. The band at 1717  $\text{cm}^{-1}$  is due to the stretching vibration of the C=O bond. The strong absorption in the region 750-400  $\text{cm}^{-1}$  probably is due to presence of inorganic compound.



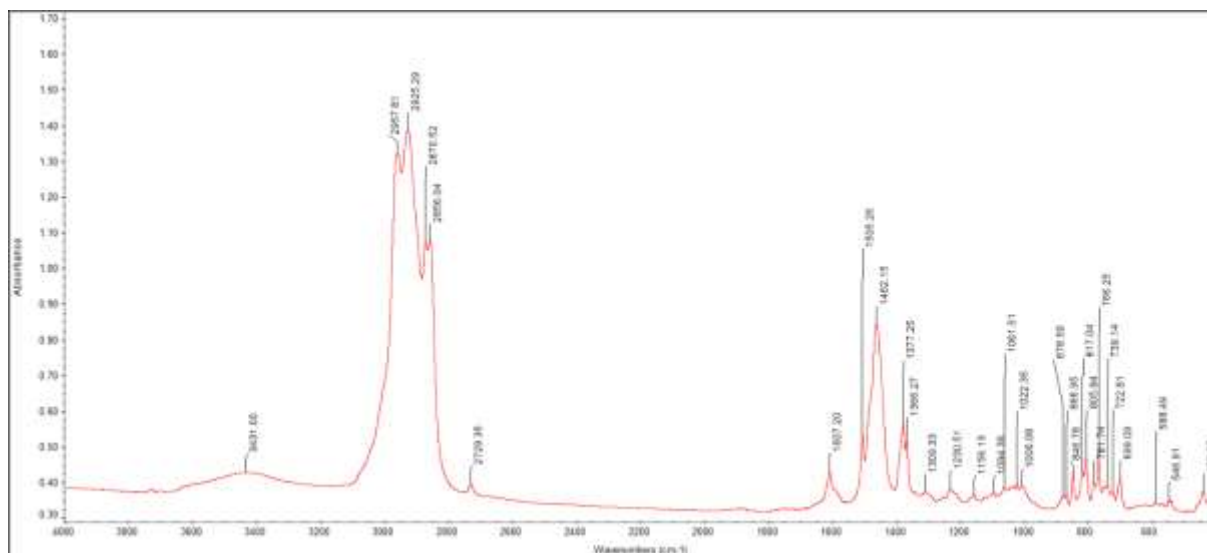
**Figure S10.** IR-spectra of additive A9

FTIR spectrum of additive A9 indicates that it mainly consists of aromatic hydrocarbons. The absorption band at  $3016\text{ cm}^{-1}$  is assigned to the unsaturated C-H stretching vibrations in aromatic compounds. The IR-spectra contains bands in the region  $3000\text{--}2800\text{ cm}^{-1}$  and at  $1455\text{ cm}^{-1}$ , and at  $1377\text{ cm}^{-1}$ , typical for presence of aliphatic groups. The bands at  $1780\text{ cm}^{-1}$  and  $1711\text{ cm}^{-1}$  is due to the stretching vibration of the C=O bond. The bands that at  $1607$ ,  $1592$ ,  $1516$  and  $1495\text{ cm}^{-1}$  are due to stretching of the carbon-carbon bonds in the benzene ring. The bands in the region  $900\text{--}700\text{ cm}^{-1}$  are due to out of plane bending of aromatic C - H bonds, used in distinguishing different types of aromatic ring substitution.



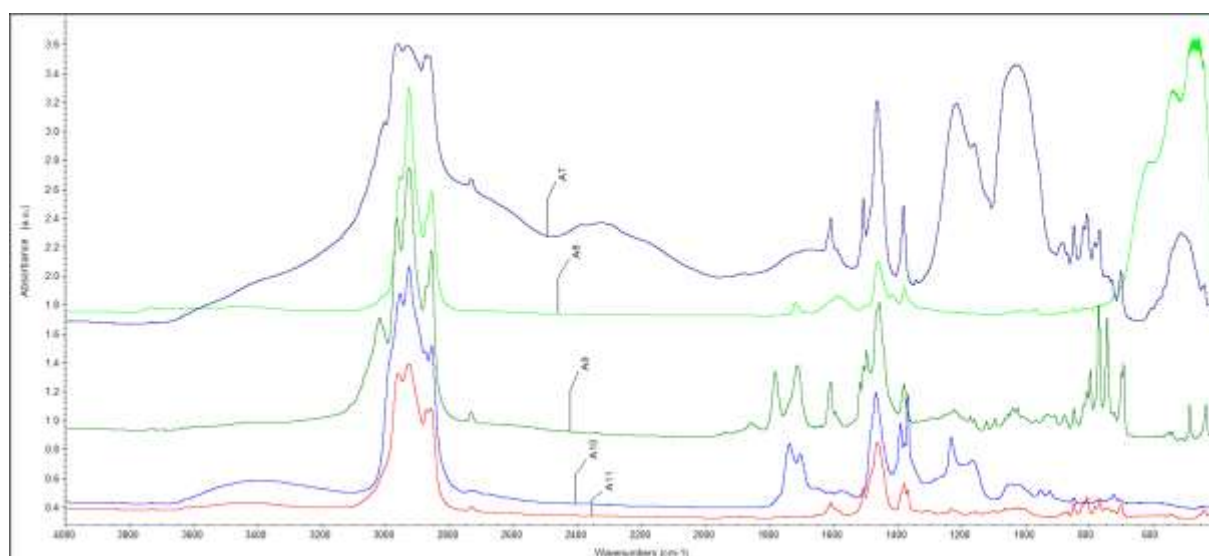
**Figure S11.** IR-spectra of additive A10

The IR spectrum of additive A10 contains bands at 2953  $\text{cm}^{-1}$  ( $\text{CH}_3$  asymmetric stretching), 2925  $\text{cm}^{-1}$  ( $\text{CH}_2$  asymmetric stretching), 2855  $\text{cm}^{-1}$  ( $\text{CH}_2$  symmetric stretching;  $\text{CH}_2$  asymmetric stretching), 1466  $\text{cm}^{-1}$  ( $\text{CH}_2$  symmetric bending;  $\text{CH}_3$  asymmetric bending). The band of the deformation vibrations of the methyl group appears as a triplet with maxima at 1366  $\text{cm}^{-1}$ , 1377  $\text{cm}^{-1}$  and 1389  $\text{cm}^{-1}$ . In this triplet the maxima at 1366  $\text{cm}^{-1}$  and 1389  $\text{cm}^{-1}$  relate to the vibrations of the gem-dimethyl group and at 1377  $\text{cm}^{-1}$  to isolated methyl groups. The band at 1230  $\text{cm}^{-1}$  and the weaker doublet with maxima at 923  $\text{cm}^{-1}$  and 951  $\text{cm}^{-1}$  are assigned to the skeletal vibrations. The aforementioned band positions in the spectrum prove the presence of polyisobutylene structure. The peak at 3386  $\text{cm}^{-1}$  is assigned to the stretching vibrations of N-H groups. The band at 1702  $\text{cm}^{-1}$  originates from carbonyl group vibrations in imides with a five-membered ring.



**Figure S12.** IR-spectra of additive A11

FTIR spectrum of additive A11 indicates that the sample consists of aliphatic and aromatic hydrocarbons. The IR-spectra of the additive A11 showed that it contains bands in the region 3000-2800  $\text{cm}^{-1}$  and at 1462  $\text{cm}^{-1}$ , and at 1377/1366  $\text{cm}^{-1}$ , typical for presence of aliphatic groups. The absorption intensities at 1607  $\text{cm}^{-1}$  and 1505  $\text{cm}^{-1}$  corresponded to carbon - carbon stretching vibrations in the aromatic ring. The bands in the region 900 - 700  $\text{cm}^{-1}$  are due to out of plane bending of aromatic C - H bonds, used in distinguishing different types of aromatic ring substitution.



**Figure S13.** Combined IR-spectra of the additives A7, A8, A9, A10, and A11