

Fast fingerprinting of arson accelerants by proton transfer reaction time-of-flight mass spectrometry

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Abstract

Current techniques for the forensic analysis of fire debris as a means to detect the presence of arson accelerants normally use off-line sampling with the collection of accelerant vapours on activated charcoal strips and further pre-chemistry prior to analysis. An alternative method for the direct detection of arson accelerants that requires no sample pre-treatment is described here. The analysis uses proton transfer reaction mass spectrometry (PTR-MS), incorporating a time-of-flight mass spectrometer for rapid multichannel compound detection. It is demonstrated that using PTR-MS volatile organic compound (VOC) fingerprints of a given fire accelerant can be collected by simple head space analysis of accelerant burned materials. Using a set of the four most common arson accelerants and four common household building materials, characteristic VOC fingerprints are shown to provide successful identification of the accelerant used to burn each material. There is the potential to develop this methodology for the rapid screening of large numbers of samples.

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1. Introduction

The cost of arson fires to society in the UK has now reached over £1.3 billion a year and it is estimated that arson attacks result in insurance claims of around £550 million per year. In 2004 over 91,000 fires (approximately 1750 per week) were recorded as being deliberately started [1], with the cost to the UK Government estimated to be nearly £1.4 billion [2]. Between 2002 and 2004 deliberate fires were the cause of 316 fatalities and 9345 injuries, and each year 20,000–30,000 homes and businesses are affected by arson [1]. Malicious arson is often started by the use of accelerants such as petrol, diesel, paraffin, kerosene, paint thinner and lighter fluid, all of which consist of mixtures of volatile organic compounds (VOCs).

The characterisation of arson accelerants has been reported previously [3–16], with particular focus on petrol (gasoline) [6–8,13–15]. The principal mode of analysis uses gas chromatography–mass spectrometry (GC–MS), with sample extraction performed mostly by the use of activated charcoal strips (ACS) and solid phase microextraction (SPME) [10,17].

ACS methods normally require the use of several stages of chemical processing before analysis on the test sample can begin; a time-consuming process that may introduce sources of contamination during the analysis process. SPME is a simpler method that uses no pre-chemistry or solvents in which a phase-coated fused silica fibre is exposed to the headspace of the sample [18,19]. The analytes adsorb onto the phase and are thermally desorbed for analysis by GC–MS. This method has removed the possibility of cross contamination and is quicker to run, taking approximately 20 min. However, not all of the analyte molecules within a sample will be adsorbed onto the phase with equal efficiency, and so different phases may need to be used on blind samples [10].

The forensic science community has reached a general consensus for standards of analysis and interpretation of arson samples by using ACS and SPE methods that has been approved by the American Society for Testing and Materials (ASTM) [3,20]. However, it is recognised that for a number of cases a more rapid screening for particular accelerants would reduce laboratory time and may allow teams more time to focus on other issues relating to a particular case.

One possible solution is to utilise the recently established method of proton transfer reaction mass spectrometry, or PTR-MS for short, for detecting the presence of arson accelerants. In

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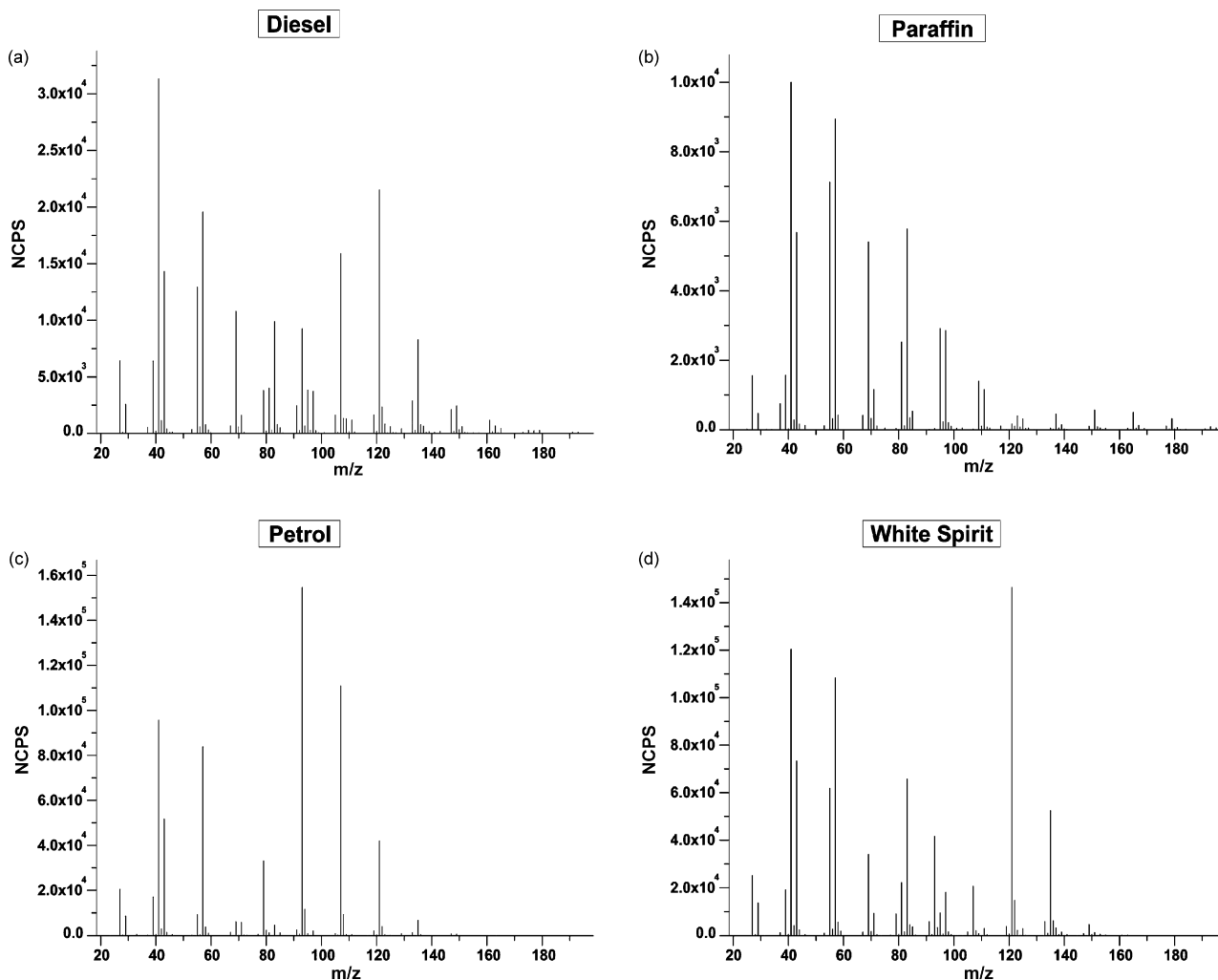


Fig. 1. Reference spectra for the accelerants (a) diesel, (b) paraffin, (c) petrol and (d) white spirit. Normalised counts per second (NCPS) refers to the ion count rate when normalised against a H_3O^+ count rate of 10^6 counts per second.

our laboratory, we have developed a PTR-MS based on a time-of-flight mass spectrometer (PTR-TOF-MS), which is particularly well-suited for detecting a wide range of VOCs owing to its multichannel detection capability. While common accelerants share a similar chemical composition of aliphatic and alicyclic compounds, the relative abundances are different, which should potentially allow a specific accelerant to be identified from the VOC profile. In other words, the VOC profile might provide a kind of ‘fingerprint’ for one or more specific fire accelerants without the need for any sample pre-treatment. In addition, the PTR-TOF-MS instrument has a typical sensitivity of the order of part per billion (ppbV) [21] (on a 1 min measurement), whereas typical GC-MS instruments are of the order of part per million (ppmV) or better [18]. While current GC-MS techniques have reduced the analysis time to less than 30 min, PTR-TOF-MS could provide a rapid screening of samples, with a typical sample analysed in less than 5 min. Using debris collected from a fire scene, the VOC fingerprint of the sample could be quickly compared against a library of pre-determined fingerprints for a variety of accelerants, identifying whether the debris warrants further in-depth analysis. This would give forensic teams the

ability to easily establish and focus on those samples most important to a case. The analysis is performed in one step, minimising any possibly sample contamination, with no need for sample pre-concentration.

The work described in this paper investigates the viability of PTR-TOF-MS for the detection and identification of arson accelerants from burned materials. This demonstration is based on the combination of the four most common arson accelerants, namely diesel, paraffin, petrol and white spirit, with several common building materials.

2. Experimental

2.1. Sample preparation and handling

The chosen substrate materials for the experiments were brick, carpet, vinyl flooring and wood. These were collected from internal sources from within the University of Leicester. The accelerants diesel, paraffin, petrol and white spirit, were purchased as standard items from local stores (diesel and petrol purchased from a nationwide supermarket chain while paraffin

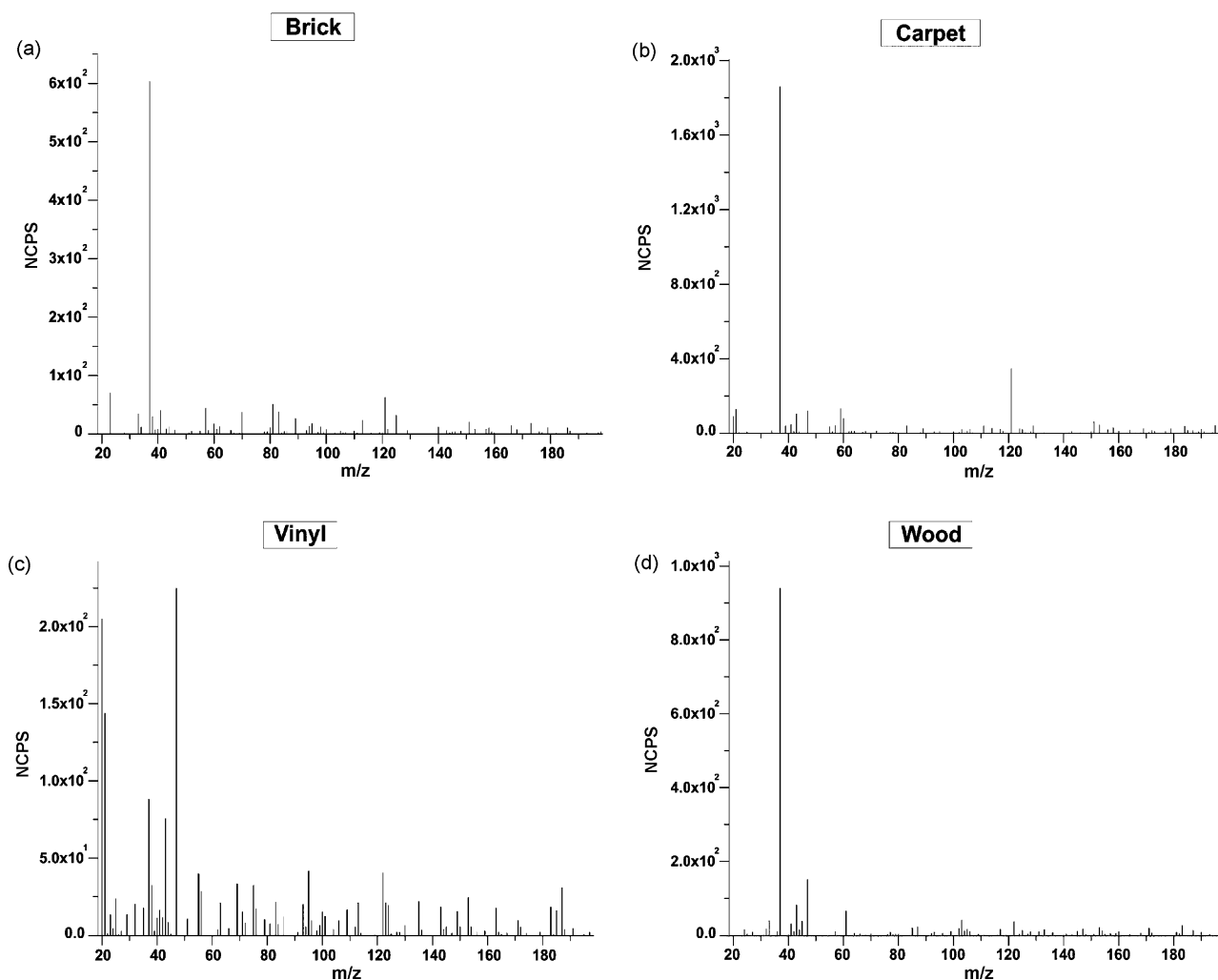


Fig. 2. Reference spectra for vapour above the substrates (a) brick, (b) carpet, (c) vinyl and (d) wood.

and white spirit were purchased from a nationwide hardware chain).

Each of the chosen substrate materials was separated into pieces with a surface area on one plane of around 2 cm^2 . A single piece was placed into a ceramic crucible and then covered with 1 ml of one of the four accelerants. The doused material was set alight in the open air with a match and left to burn until all the accelerant had been spent. Most of the accelerants ignited relatively easily, but paraffin generally required several attempts to start burning. For the first set of experimental data, the burned material was transferred from the crucible to a storage vessel attached to the PTR-TOF-MS instrument for headspace analysis immediately after burning.

To provide some information on the effect of delays to the measurements, some burnt samples were also subjected to a period of storage prior to analysis. In one series of experiments the substrate materials were burned with diesel as the accelerant, and after burning the samples were allowed to cool and were then placed into individual sealable nylon bags. The bags were stored in a cupboard in an air conditioned room for 24 h before analysis. A third set of material samples were burned with petrol, and after burning the samples were placed in fresh crucibles and placed in

a clean, well ventilated room for 3 days, before being deposited in individual nylon bags and placed in a cupboard for analysis 1 week after the burning.

To obtain suitable reference ‘fingerprints’, mass spectra were recorded of the head-space vapour above each of the pure accelerant samples and material substrates. Finally, to ensure that any VOCs detected from the accelerant burned samples would not be naturally produced from the material when burned ‘dry’, each substrate material was also burned with a match and the head-space vapour extracted.

2.2. Instrument details

The Leicester PTR-MS instrument used in this work has been described in detail previously [22,23]. In brief, the instrument comprises an in-house designed and built radioactive ion source, a differentially pumped drift tube, and a reflectron time-of-flight mass spectrometer. The radioactive source is a strip of ^{241}Am (NRD LCC, Grand Island, New York), which emits alpha particles with an energy of approximately 5 MeV. In all the experiments reported here the reagent gas is water vapour, which generates the hydronium ion, H_3O^+ , in high yield when

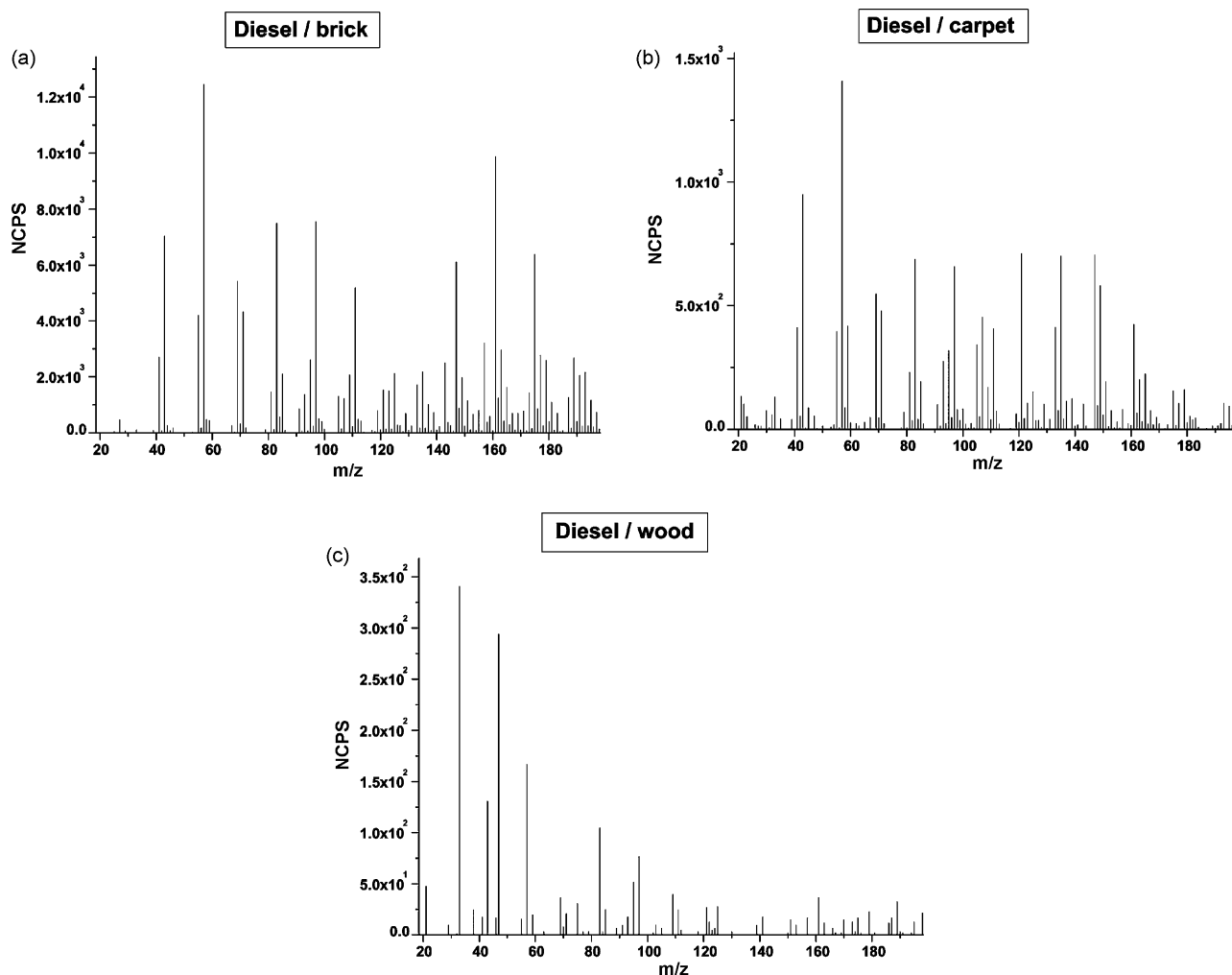


Fig. 3. Mass spectra from the vapour above (a) brick, (b) carpet and (c) wood after being doused with diesel and burned.

subjected to alpha irradiation in the radioactive source region of the instrument. The water vapour is delivered by bubbling zero-grade N₂ carrier gas (99.998%, BOC special gases) through a glass vessel containing high purity deionized water (15 MΩ) at a flow rate of 52 sccm. The samples were placed in a sealed glass vessel through which zero-grade nitrogen was passed to transport headspace VOCs into the drift tube at a controlled rate of 252 sccm. The combined flow from sample and water vapour maintains a pressure within the drift tube of 8 mbar. An electric field along the drift tube draws any ions into the mass spectrometer. The strength of the electric field, E , and the pressure, which can be correlated to the gas number density, N , dictate the fragmentation/clustering conditions within the ion source. All data reported here were recorded with an E/N value of 147 Td, where 1 Td (Townsend unit) is equal to 10^{-17} V cm². While typical PTR-MS instruments run at lower E/N ratios in the range of 100–140 Td, we find that this value provides a good balance between the obstruction of water cluster formation and the minimisation of fragmentation products for our current instrument configuration.

Mass spectra were recorded over a mass range of 0–200 amu for an averaging period of 60 s and successive 1-min mass spec-

tra were collected over a variable period of time. Before any real samples were investigated, an instrument background spectrum was recorded by passing nitrogen through the instrument over a time period that varied from 5 to 10 min. The sample was analysed directly afterwards. In each case reported here the first acquired scan for each sample was used for data analysis.

All mass scans recorded were normalised to 10^6 H₃O⁺ ion counts [24] and were processed by subtracting an appropriate normalised background scan.

3. Results and discussion

3.1. Reference data

Reference spectra recorded from each of the accelerants are shown in Fig. 1. For each accelerant there is an abundant VOC profile. Table 1 lists the most prominent mass channels and a probable chemical identity for that channel alongside the relative abundance (with respect to the most abundant ion) recorded for each accelerant. In general, PTR-MS is unable to detect low mass alkanes, owing to the proton affinities being lower than that of water, and under the thermal conditions within the ion source

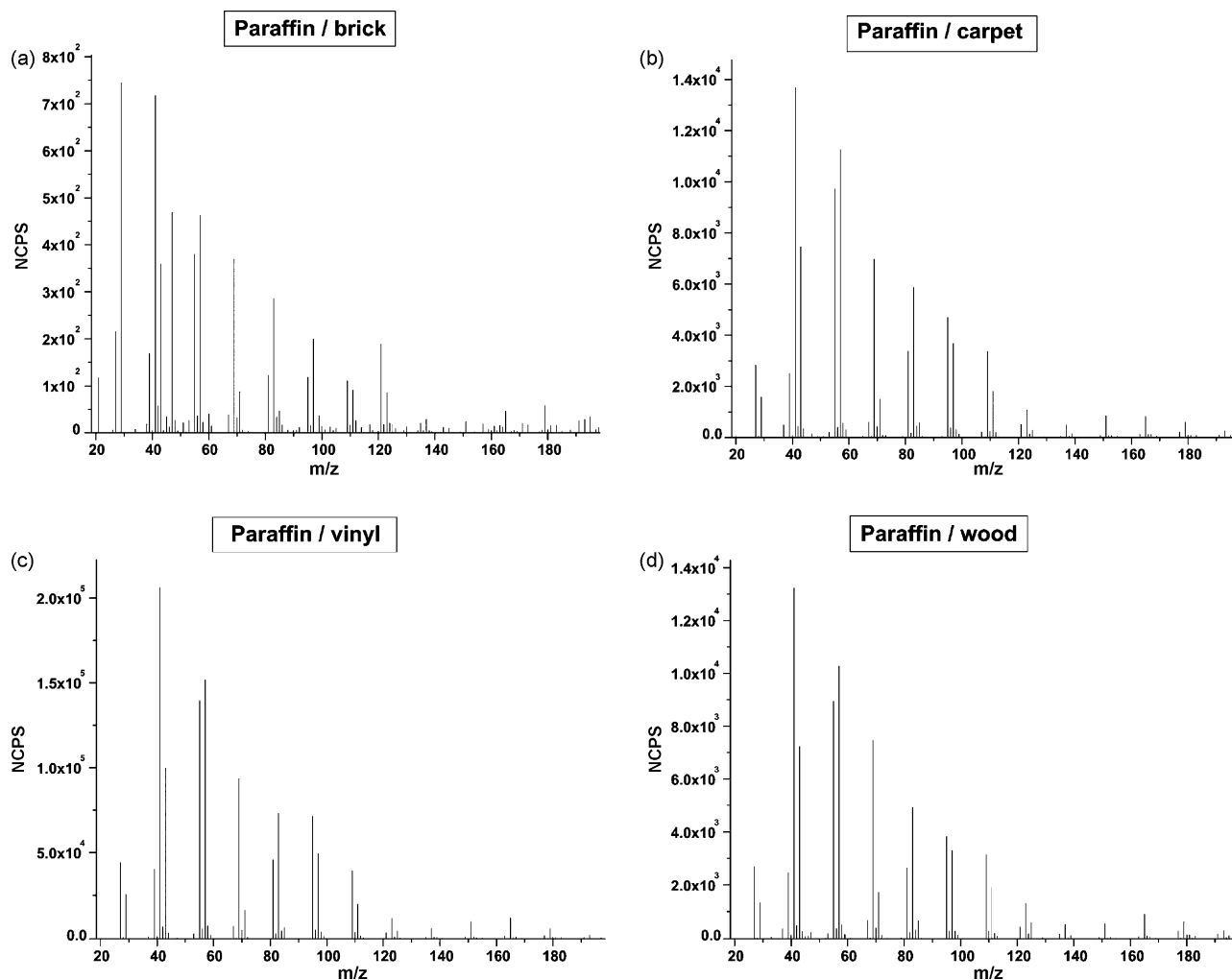


Fig. 4. Mass spectra of the vapour above the substrates (a) brick, (b) carpet, (c) vinyl and (d) wood after being doused in paraffin and burned.

Table 1
Summary of the main mass peaks in the PTR-MS spectra of the vapour above diesel, paraffin, petrol and white spirit

Mass channel	Most probable chemical identity	Percent relative abundance (relative to most abundant ion)			
		Diesel	Paraffin	Petrol	White spirit
27	Fragment	21	16	13	17
39	Fragment	20	16	11	13
41	C3 aromatic or cyclic	100	100	62	82
43	C3 aromatic or cyclic	46	57	33	50
55	C4 aromatic or cyclic	41	71	6	42
57	C4 aromatic or cyclic	63	89	54	74
69	Furan, C5 aromatic or cyclic	34	54	4	23
71	2,3-Dihydrofuran	5	12	4	6
79	Benzene	12	0	21	6
81	C6 aromatic or cyclic	13	25	1	15
83	Methyl furan	32	58	3	45
93	Toluene	30	0	100	28
95	C7 aromatic or cyclic	12	29	1	6
97	C7 aromatic or cyclic	12	29	1	12
107	<i>m</i> -, <i>o</i> -, <i>p</i> -Xylene, ethyl benzene	51	0	72	14
109	C8 aromatic or cyclic	4	14	0	1
121	Tri methyl benzene, <i>n</i> -propyl benzene	69	2	27	100
135	<i>n</i> -Butyl benzene	27	0	4	36
147	C11 aromatic or cyclic	7	0	1	1
149	C11 aromatic or cyclic	8	1	0	3

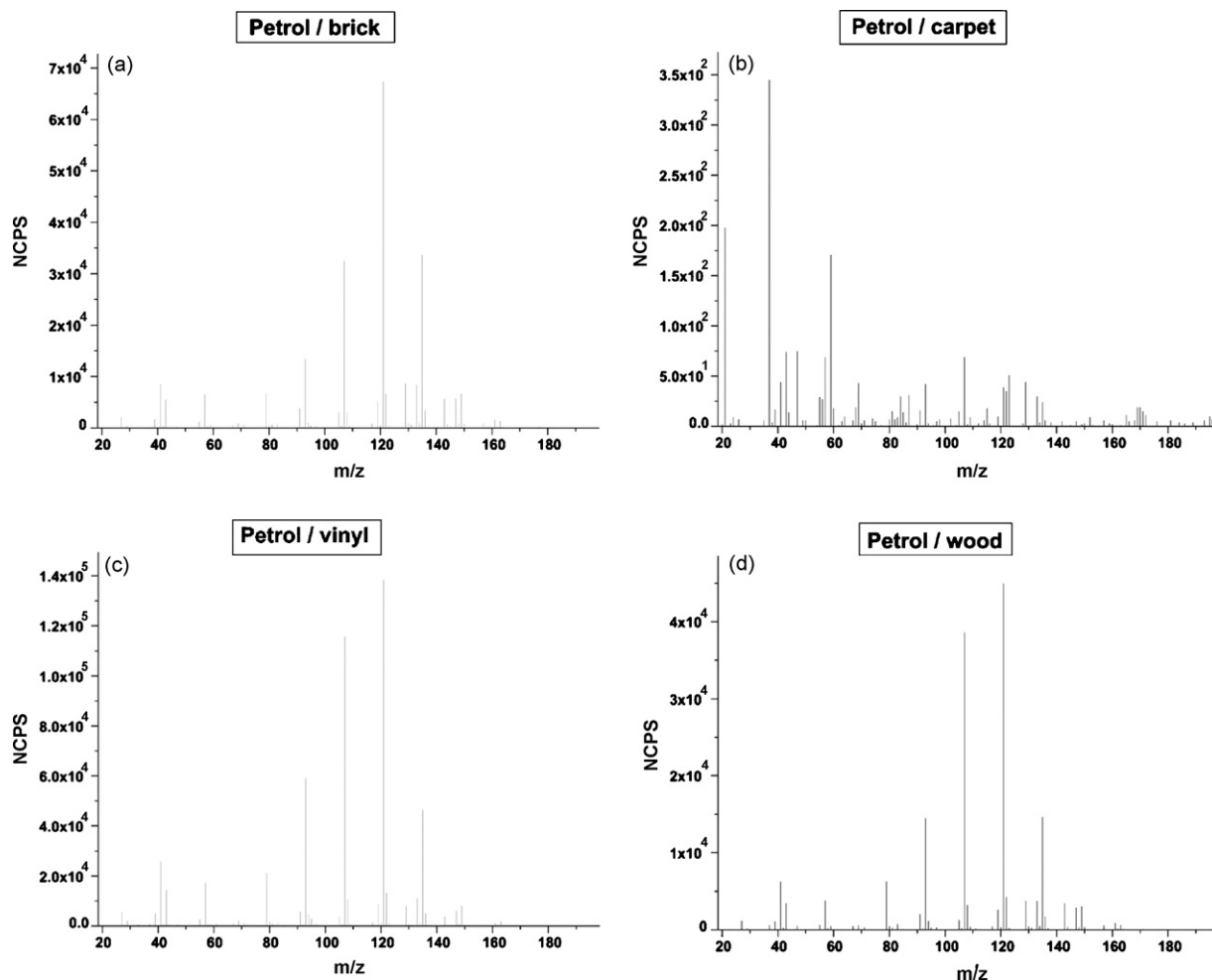


Fig. 5. Mass spectra from the vapour above substrates (a) brick, (b) carpet, (c) vinyl and (d) wood after dousing with petrol and being burned.

the reactions are too endothermic to occur [25]. However, work by Španěl and Smith has shown that larger *n*-alkanes can undergo ion–molecule association reactions to form $\text{H}_3\text{O}^+\cdot\text{M}$, recording such complexes for hexane, octane, decane and dodecane [25]. Examination of the data reveals that the diesel background spectrum does show some clear peaks at masses 105 ($\text{H}_3\text{O}^+\cdot\text{C}_6\text{H}_{14}$), 133 ($\text{H}_3\text{O}^+\cdot\text{C}_8\text{H}_{18}$), and 161 ($\text{H}_3\text{O}^+\cdot\text{C}_{10}\text{H}_{22}$) at 5, 9, and 4% relative abundance. Unfortunately it is not possible to unequivocally identify such species in this mixture, but their presence can be tentatively ascribed to these compounds.

It is possible that some of the lighter masses observed under $m/z < 60$ are the products of the fragmentation of the larger aromatic species. However, under our current aim of providing characteristic fingerprints for each accelerant/substrate mixture this should not prove to be too problematic as the proportion of fragments produced should remain constant over repeated experiments with different samples.

The mass spectra recorded from the substrate materials are shown in Fig. 2. Few VOCs were emitted by the substrate materials, even those with a high plastic content such as the vinyl and carpet, as evidenced by the low recorded normalised intensity which is one to two orders of magnitude lower in intensity

than that recorded for the accelerants. For all materials, bar vinyl the most intense peak detected at $m/z > 20$ is at mass 37, which arises from the cluster $\text{H}_3\text{O}(\cdot\text{H}_2\text{O})^+$. Any vapour emitted by the unburned substrate is at such low levels as to be negligible under these conditions.

After burning the bare substrate materials with a match, with the obvious exception of brick, the overall intensity of the VOCs detected is generally an order of magnitude higher than that for the unburned substrate. However, aside from the increase in signal in almost all mass channels, there is little difference between the burned and unburned substrate spectra, except for the increase of mass channel 121 in the burnt wood spectrum.

3.2. Simulated arson data—analysis of accelerant-doped burnt samples

In burning the substrate materials doused with accelerants, most burned with few problems. However, the diesel/vinyl mixture failed to ignite even after numerous attempts. The exact reason for this is unknown, but this mixture will consequently not be considered any further. All of the accelerants except white spirit produced very sooty flames and left a large soot deposit

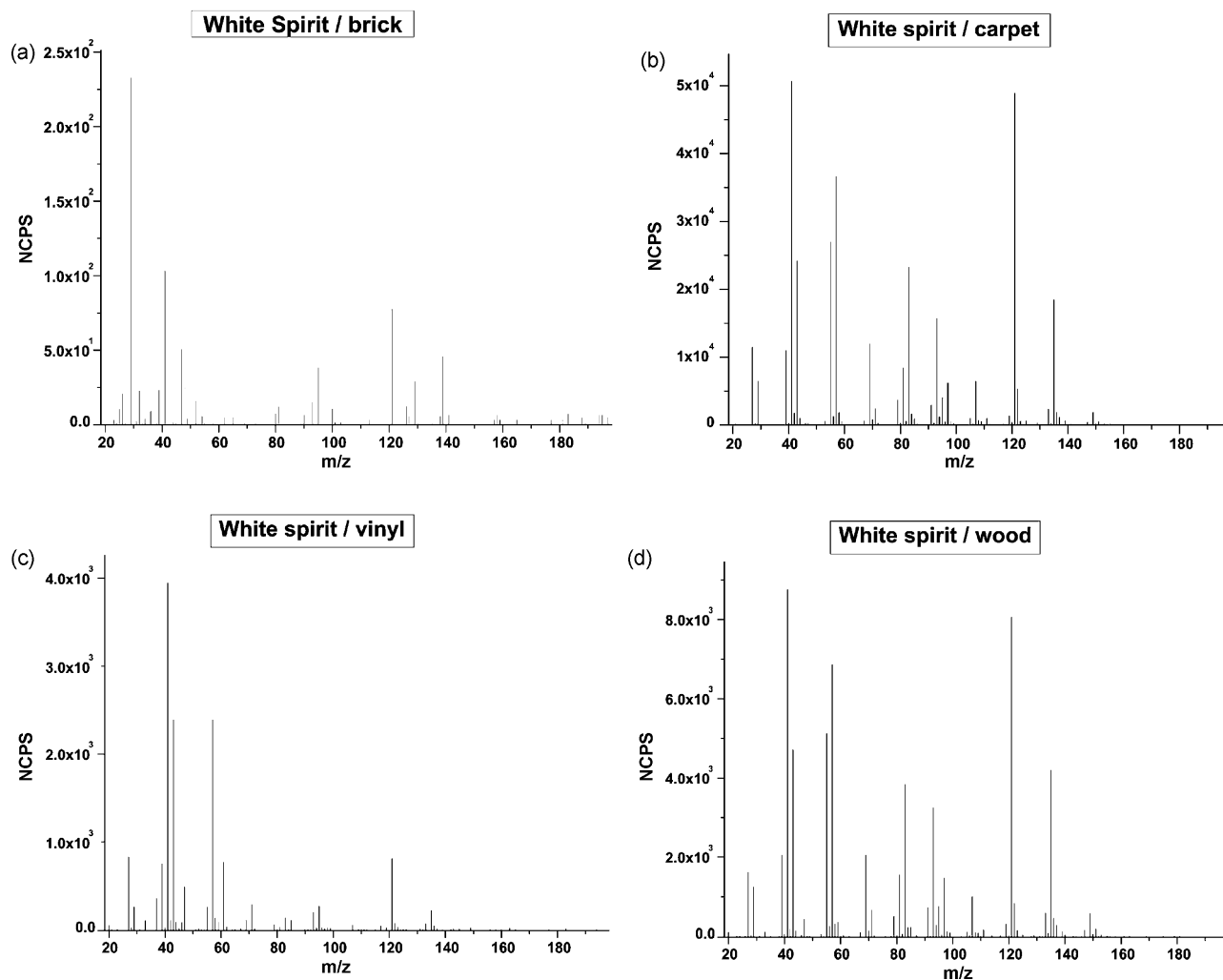


Fig. 6. Mass spectra from the vapour above substrates (a) brick, (b) carpet, (c) vinyl and (d) wood after dousing with white spirit and being burned.

on the crucibles used for the test burning. The substrate material was charred but generally free of any soot. The soot was discarded from the analysis. The brick and wood substrates were observed to ignite but remain substantially intact, whereas the carpet and vinyl were affected more by the burning process. The vinyl and backing of the carpet warped substantially owing to the heat, and the fibres of the carpet were either consumed entirely or melted onto the backing. The behaviour of the accelerant with the material would depend chiefly on the viscosity of the accelerant and how readily it is absorbed into the material. Paraffin and diesel were the most viscous of the accelerants used, and white spirit the least.

The spectra produced by the burned diesel–substrate mixtures shortly after the fires had burned out are shown in Fig. 3. In the case of brick and carpet substrates the spectra differ considerably from the burnt sample of diesel alone. In particular, there is a greater prevalence of higher mass VOCs (>100 amu) in the spectra of the former mixtures. This is most likely because the burning process removes more of the lighter, more volatile VOCs, increasing the relative abundance of the lower volatility higher mass VOCs. The diesel/wood combination produces few VOC species in general. This may be attributable to a more

efficient burning of the diesel on the wood than on other source materials, with most of the diesel being removed in the burning process. Thus, the viscosity of the accelerant, the porosity of the substrate and the way in which the two interact play a role in how the material burns and the residues that remain. Brick and carpet must interact in a similar way with diesel, judging from the similarity in the spectra. Although the wood spectrum produces less VOC species there are a number of high mass species (between 100 and 200 amu) present that correlate to those seen in the carpet and brick spectra, albeit at much lower relative concentrations. Furthermore, examination of the mass channels 105, 133, 161 and 189, which could possibly contain species ionised by ion–molecule association reactions as described earlier, show an increased relative abundance from the reference spectrum. The diesel–brick mixture features peaks for all four of these masses at relative abundances of 10, 13, 79 and 21% respectively. The diesel–carpet mixture shows peaks at 105, 133 and 161 with 24, 30 and 30% relative abundances, respectively. The wood data show only peaks at the higher masses of 161 and 189, with values of 10 and 9%, respectively.

Fig. 4 shows the mass spectra recorded for burned paraffin–substrate mixtures. The paraffin data are unique in

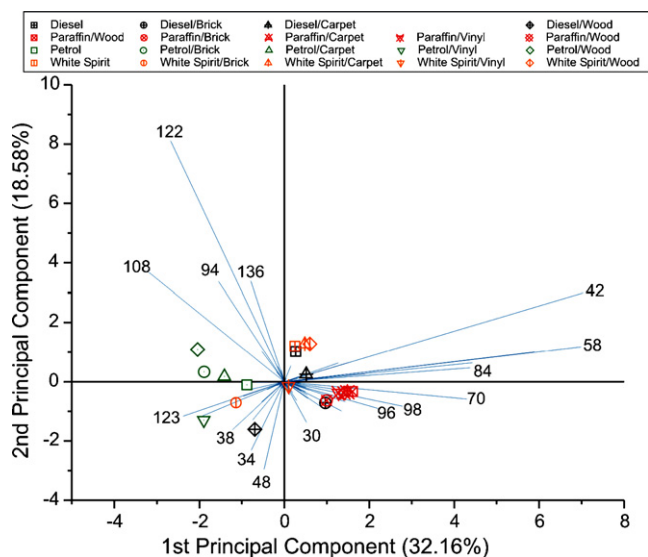


Fig. 7. Principal component analysis of the test mixtures and reference compounds 1st and 2nd components.

the analysis in that the spectra from the various burned paraffin–substrate mixtures are almost identical to the original reference spectrum recorded for paraffin vapour alone. The only variation is in the overall concentration of the VOCs recorded, with the carpet, vinyl and wood mixtures seeing an increase in the concentration recorded over that for the reference. Only brick shows a decrease in the overall concentration, suggesting that more of the accelerant has been consumed in the burning on this material. However, despite this effect of the burning process the VOC profile of the paraffin–brick mixture remains largely unchanged from that of paraffin.

The spectra recorded for the petrol–substrate mixtures are shown in Fig. 5. The petrol–substrate spectra retain the characteristic simplicity of the petrol reference spectrum over the observed mass range for all but one of the substrates tested. However, higher mass VOCs become more prominent on burn-

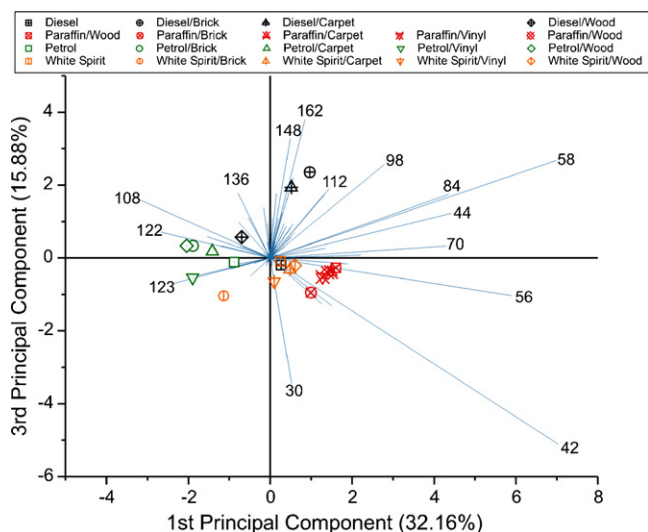


Fig. 8. Principal component analysis of the test mixtures and reference compounds 1st and 3rd components.

ing, which again can be attributed to the greater rate of losses of the lighter VOCs versus the heavier VOCs on burning. The one substrate that does not follow this pattern is carpet, which is dominated by the presence of the first water cluster, $\text{H}_3\text{O}(\cdot\text{H}_2\text{O})^+$, and the overall intensity for all mass channels is some two orders of magnitude lower than that recorded in the other spectra. There are a greater number of species observed in the carpet spectrum, but only some of the peaks observed correlate to the principle characteristic peaks observed in the other spectra in the appropriate relative ratios. It would appear that given the very low concentrations of the VOCs and the dominance of the first water cluster that very few VOCs have been emitted by the remains of the burned sample.

Fig. 6 shows the data recorded for white spirit as the accelerant. Once again there are different burning patterns for the different substrates, and it is the wood and carpet substrates that produce VOC profiles different to the other substrates. This time the spectra for these mixtures are very similar to the white spirit VOC profile, whereas vinyl shares many of the light VOCs of the white spirit profile but the heavier VOCs are oddly absent. The same is true of the brick sample which shares many of the key species as the white spirit profile but with different relative ratios and a much lower overall intensity. The reason for these patterns is not at first clear as white spirit is just as thin as petrol, and therefore one would expect the white spirit to absorb just as readily into the carpet fibres and burn in a similar way.

The PTR-TOF-MS instrument has a real time (1 min scan time) sensitivity of around 1 ppbV or better for a range of VOCs [21]. As an illustration, the quantification that can be achieved for toluene in each of the sample mixtures is given in Table 2.

During this part of the work there are several key factors that must be considered. For the vast majority of the example mixtures studied here the burned spectra are either almost identical to that of the accelerant used, e.g., paraffin, or are in some way very similar to that profile, e.g., petrol. However, there are a number of key cases where the resultant VOC profile is substantially different, and the reasons for this should be explored.

It is clear that the viscosity of the accelerant, the porosity of the substrate, and the interaction between these two is a key factor in deciding the resultant VOC profile after burning, as will be the temperature the materials reach on burning. The quantity of accelerant used was sufficient to completely douse the substrate and saturate it. It is therefore possible that the accelerants, particularly the viscous accelerants such as paraffin and diesel, may linger within the heart of the material and not be fully spent during the burning or be affected so adversely by the rising tem-

Table 2
Concentrations for toluene in each of the sample sets

Accelerant	Toluene concentration (ppbV)				
	Accelerant only	Brick	Carpet	Vinyl	Wood
Diesel	356	59	5	ND	1
Paraffin	1	7	2	139	17
Petrol	5946	2592	2	5324	1729
White spirit	1601	3	1881	31	310

ND: not detectable.

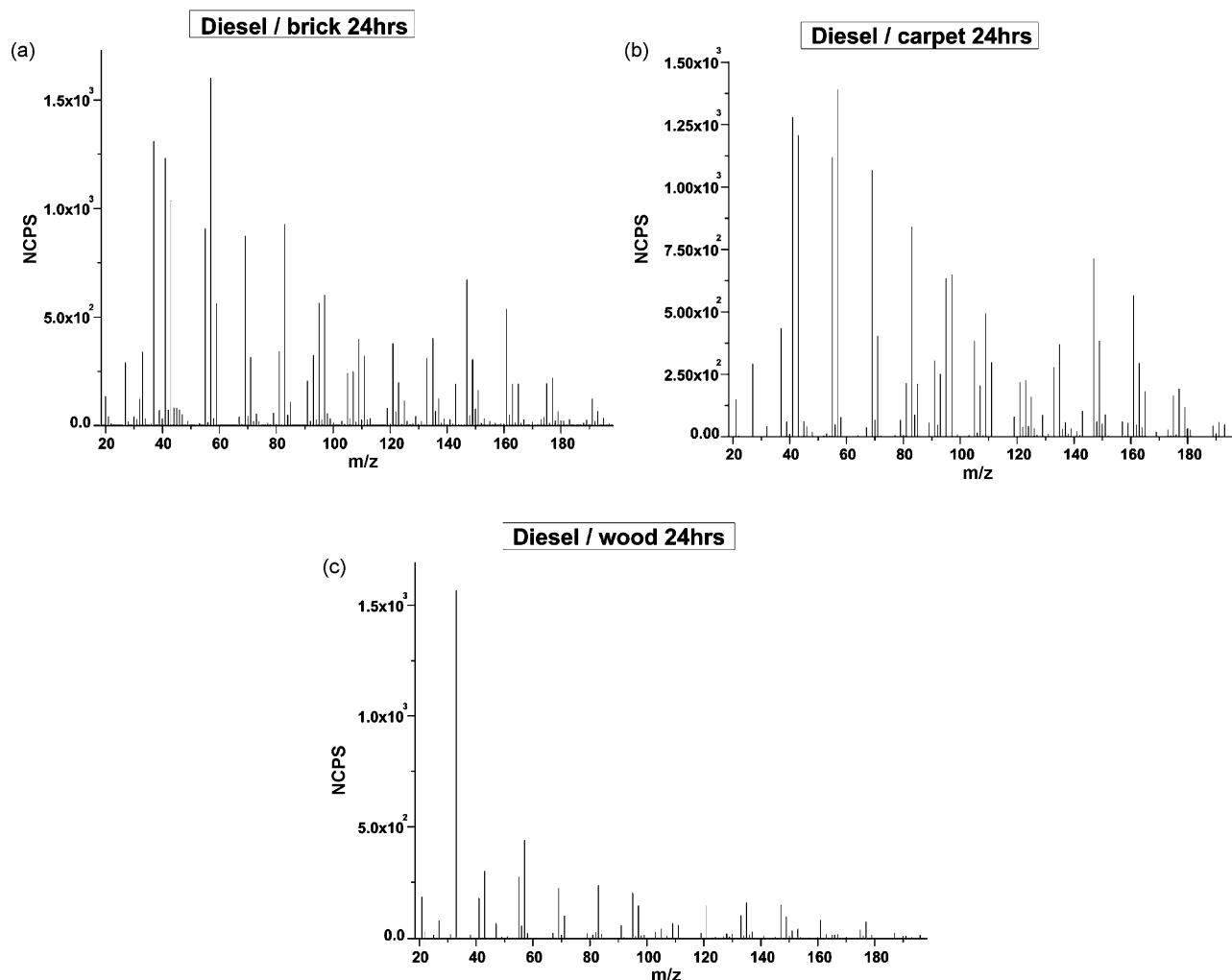


Fig. 9. Mass spectra from the vapour above substrates (a) brick, (b) carpet, (c) vinyl and (d) wood after dousing with diesel and being burnt. These data were obtained 24 h after the sample was burnt and extinguished.

perature as they are protected by what remains of the burned substrate. Therefore, after burning the VOCs emitted would be very similar to those of the accelerant, as observed for all of the paraffin spectra and the majority of the diesel spectra.

In those cases where the VOC profile is substantially different from that of the accelerant, the burning conditions must be different for these mixtures. The burning of diesel and wood for example could burn hotter and/or consume more of the substrate during burning, providing less protection for the accelerant within the centre of the material. In each of the carpet burnings the fibres were completely burned away from the substrate, therefore any traces of the accelerant detected after burning would have to be stored within the plastic backing or left as a residue on the backing material from the melting of the carpet fibres. Petrol was the only accelerant to not produce a substantial quantity of VOCs, suggesting that either the petrol was not so readily absorbed into the plastic backing, or was more fully removed during the burning of the fibres. In the case of white spirit it is the brick and vinyl substrates that produce fewer VOCs in a pattern completely dissimilar to the accelerant's profile. It would therefore appear that in these cases the white spirit that

was absorbed by these materials was affected more by the burning. One could hypothesise that perhaps the heat produced by the burning evaporated more of the solvent than was observed in other cases such as the petrol–brick combination. However, if this were the case one would expect that the lower mass volatiles would be lost first, but it is these species below 100 amu that are detected.

One should perhaps consider that these accelerants are also solvents, and as such may react with the plastic content of some of the materials, such as carpet and vinyl. A reaction between the accelerant and these materials may alter the VOC profile detected and may have some contribution to the results observed.

A key principle for this analysis is to establish whether the recorded spectra provide unambiguous VOC fingerprints for the identification of the accelerants from burnt materials. For analysis, all the data was normalised to the most intense peak in each spectrum. This procedure will allow us to qualitatively compare each spectrum purely in terms of the VOC profile. Principal Component Analysis was performed on the normalised mass spectra using MATLAB coupled with the PLS Toolbox from Eigenvector Research Inc. The PCA was mean-centred and has

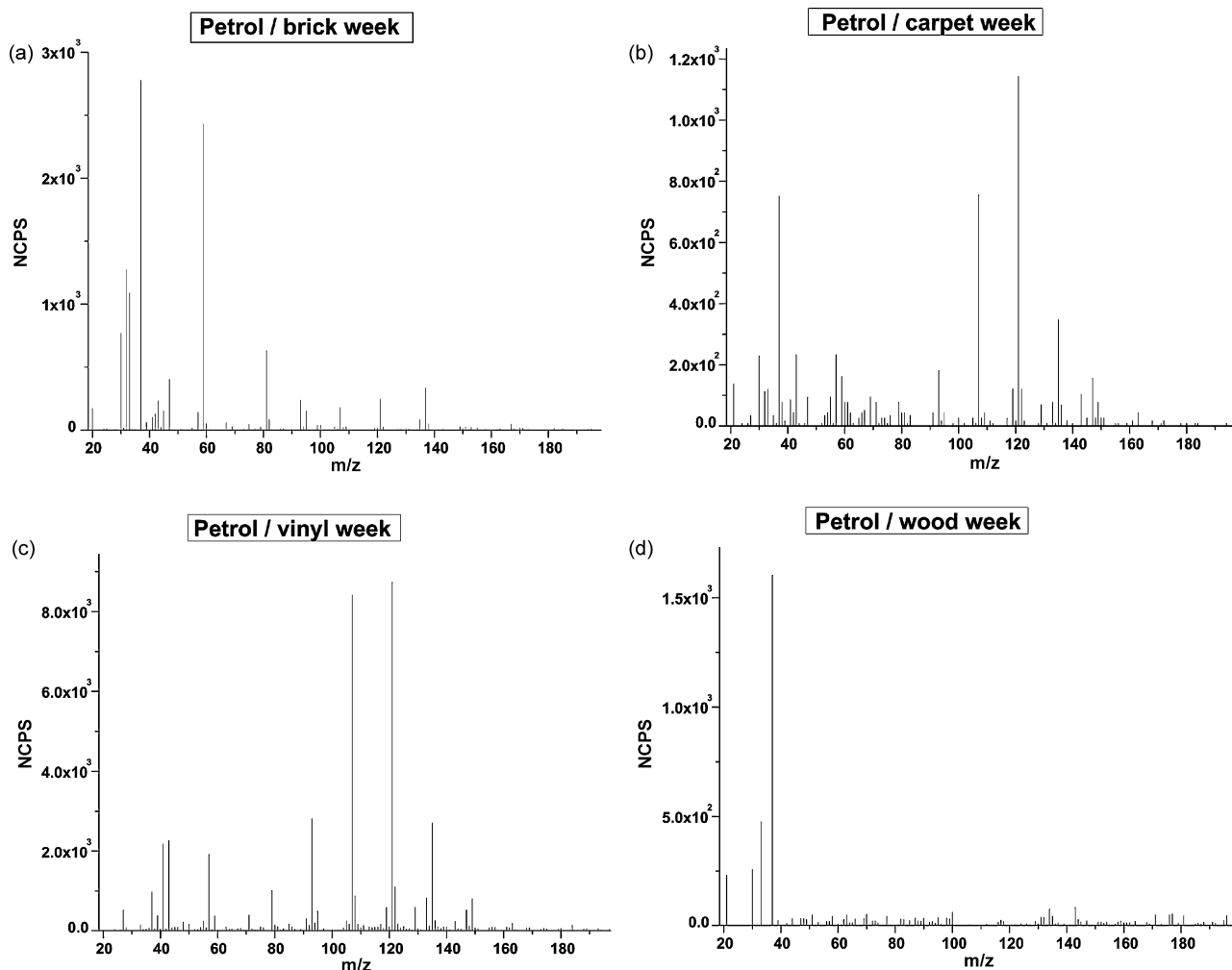


Fig. 10. Mass spectra from the vapour above substrates (a) brick, (b) carpet, (c) vinyl and (d) wood after dousing with petrol and being burnt. These data were obtained 1 week after the sample was burnt and extinguished.

95% confidence. Figs. 7 and 8 show biplots determined for the first three principal components, detailing the principal component coefficients for each mass channel (the blue vectors) and the principal component scores for each experimental mixture (the individually labelled data points). Fig. 7 shows the plot for the first and second components, while Fig. 8 is for the first and third components. The first principal component includes 32% of the variance occurring in the spectra, the second includes nearly 19%, while the third includes nearly 16%. The magnitude of the principal component coefficient vectors give an indication of the mass channels that are responsible for the most variance in the mass spectra between each sample set. From Figs. 7 and 8, we can see which mass channels hold the most variance between each accelerant mixture. For instance mass channels 98, 112 and 136 are strongly correlated with diesel, 94, 108, and 122 for petrol. It is difficult to determine which species are relevant for paraffin and white spirit as they occupy similar regions in both spaces.

Looking at the scores for each sample set in the first, second and third principal components, it can be seen that paraffin is the best grouped and separated from the other accelerants, with

the notable exception that in Fig. 7 the diesel/brick and paraffin/brick mixtures are very similar. The petrol sample set is also quite well separated through a little more scattered. In the first and second component space the white spirit and diesel samples are mixed together quite badly, but in moving to first and third component space they are better separated. Only the white spirit/brick mixture sits away from this group, but this mixture has been noted for being quite different from the spectra of the other white spirit mixtures. Unfortunately, the diesel samples do not group clearly and are not fully resolved when looking at any of the first three components. However, the principal component analysis has shown that there is sufficient difference between the majority of the VOC fingerprints for each of arson accelerants to be able to separate them unambiguously.

3.3. Delayed analysis after burning

The spectra for the diesel samples analysed after a period of 24 h are shown in Fig. 9. Overall the spectra show strong similarities with those obtained immediately after burning. The overall concentration of species was found to be reduced by an

order of magnitude, which is unsurprising. There is little indication of additional peaks within any of the spectra that may be attributable to plasticizers from the containment bags, so this method of storage should not yield any contaminants which might confuse the accelerant identification.

Alternatively, the petrol samples that were analysed a week after ignition give mixed results, as can be seen in Fig. 10. Brick and especially wood yielded a low VOC output such that the spectra are dominated by $[\text{H}_3\text{O}-\text{H}_2\text{O}]^+$. Unexpectedly, given prior results, it is the petrol–carpet and petrol–vinyl mixtures that have produced a VOC fingerprint that more closely matches the reference spectrum. It is possible that for the carpet data here, an additional quantity of petrol was used, or that the burning was not as thorough, causing the difference between this data set and that of the immediate analysis.

This data is promising in that it shows that samples need not be analysed “fresh” in order to reveal useful information. Packaging the material in a standard nylon bag seems to produce no contaminants and is a simple and affordable way to collect samples from a crime scene. While the sample spectra do not produce as many VOCs as in the immediate analysis it is reasonable to expect that if the sample substrate was heated gently it could release more VOCs into the headspace, which could be detected.

4. Conclusions

The technique of proton transfer time-of-flight mass spectrometry has been shown to be a simple method for the rapid detection and screening of trace VOCs from materials burned by common arson accelerants. By removing the use of solid extraction and activated charcoal strips a number of chemical treatment steps have been removed, and the time required for analysis and the possibility of contamination entering into the samples during these processes has been reduced.

Each of these accelerants was shown to have an unambiguous VOC profile, or fingerprint, and while these fingerprints may alter after the burning process, the majority have consistent patterns that are independent of the material burned. In such cases where there is a dependence upon the material, the VOC profile detected is significantly greater than the ambient VOC profile produced from the material itself after burning and could thus suggest the presence of an external substance. In addition, it is possible that all of the recorded fingerprints could be collated into a database that could be used for comparison against other external and “blind” samples, for use as part of a rapid screening process for arson detection. Additional work is required to meet this goal, for instance using multiple sources of accelerant and

material and conducting blind sample tests. Furthermore, it is important to test samples that have been extinguished by water and fire retardants such as foams. It is samples of this type that are more likely to be recovered by fire crews and a mechanism for heating and extracting the accelerants from the headspace of the doused burned materials could be developed. However, the proof of principle for the viability of this technique has been ably shown and therefore may be of application in arson investigation.

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