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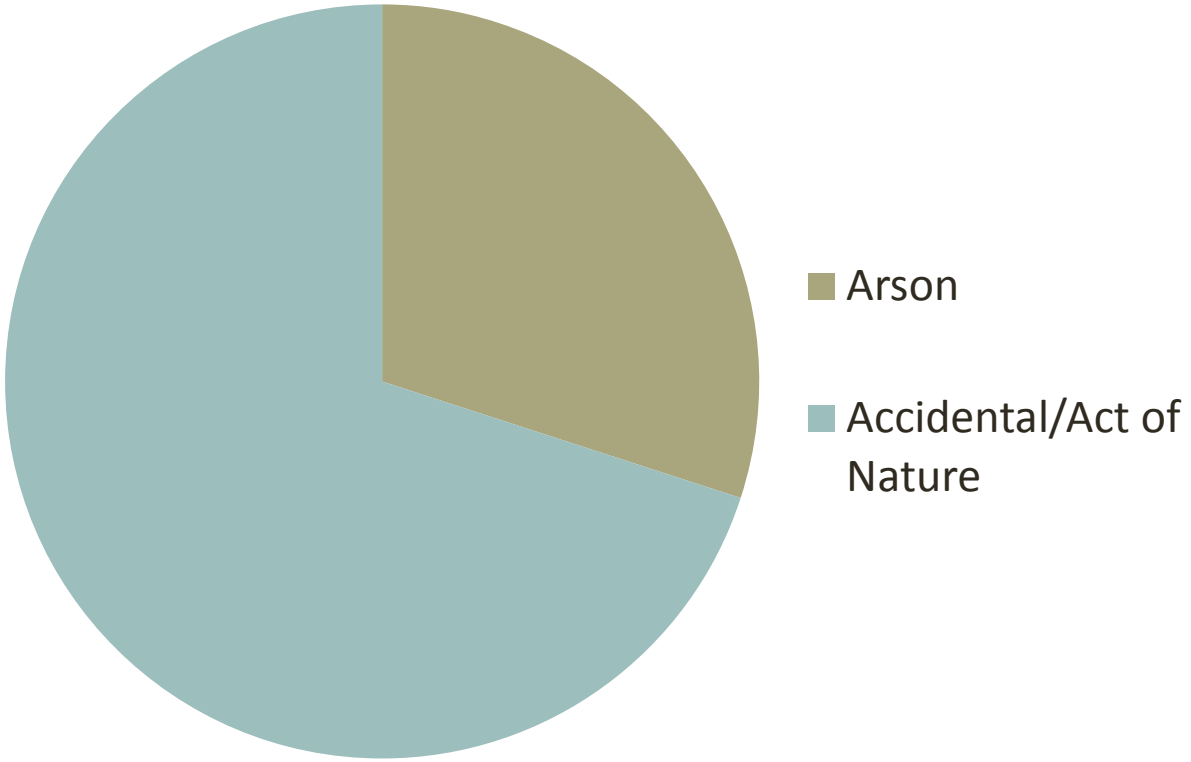
The Use of Localised Thermal Desorption for Extraction of Volatile Hydrocarbons from within a Fire Scene: A Multi-Study Analysis

Tom Smale, Bsci(Psy), BFor

The Cost of Fire

- In Australia, the average cost of damages caused by bush fires per year is AUD$80-100 million [1]
- The cost of arson-related fires in the United States was US$551 million in 2010 [2]
- There are over 100 fire-related deaths and 3,000 fire-related injuries in Australia each year [3]

Causes of Fire In Australia



Evidence and Fire Scenes

- Conviction rates for arson are exceedingly low
  - 9% for Australia [4]
  - 5% for the United States [5]

- This is partly due to the nature of fire scene evidence
  - The presence of an *accelerant* in a scene indicates a likelihood of deliberate fire-setting
  - Unfortunately the accelerants used in arson are mostly consumed in the fire itself
  - However, small amounts of accelerant can still be present within a scene post-burn

Collecting Trace Accelerants

- Trace amounts of liquid accelerants, known as *Ignitable Liquid Residue* (ILR), can remain on surfaces and debris within the scene
- This ILR is a valuable source of evidence as it can be extracted and analysed using Gas Chromatography Mass Spectrometry (GC-MS)
- Specialised *extraction techniques* must be used to remove the ILR from debris or surfaces

The Challenge

- Most extraction techniques require the substrate be moved to a laboratory for testing
- However, ILR may be present on large, fixed surfaces within a scene, such as concrete
- It can be impractical or unsafe to try and remove sections of these fixed surfaces for transport and laboratory-based analysis

Extraction Methods

- Numerous methods are possible, including distillation and dichloromethane rinsing

- A common method involves *thermal desorption*
  - The sample is heated in a container, evaporating the ILR from the substrate
  - The evaporated ILR forms a gaseous cloud in the top of the container, known as a *headspace*
  - This headspace can be sampled using either activated charcoal or a solid-phase microextraction needle

Research at CIT has focused on finding a way to perform these procedures directly at the scene

Recent Research at CIT

- Recent research has focused on using thermal desorption as a scene-based technique, rather than a lab-based technique

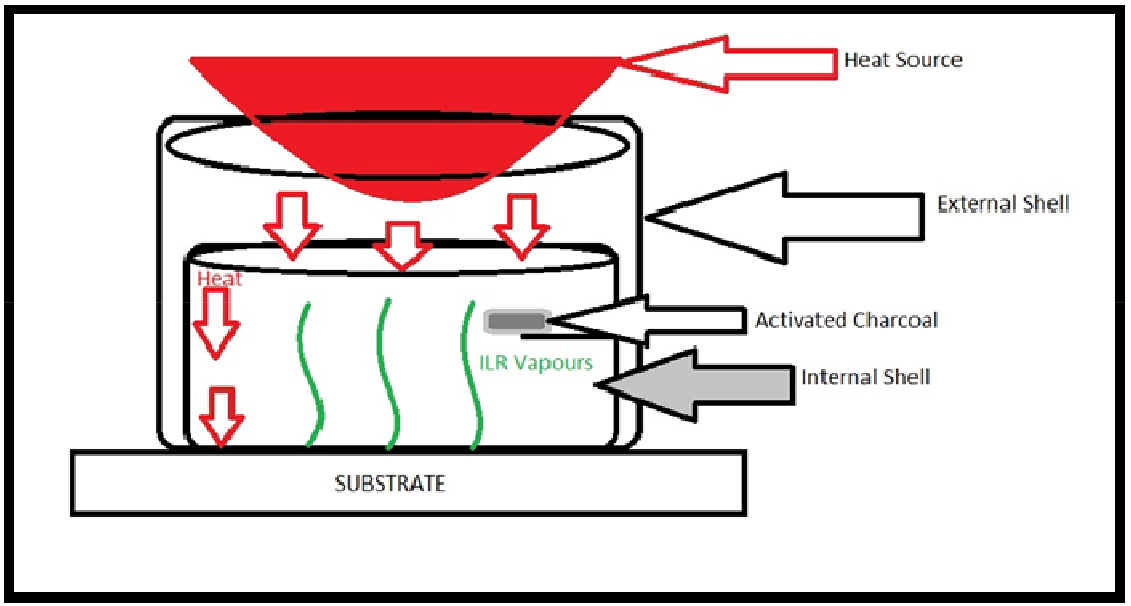
- This has led to the creation of the *Passive Headspace Residue Extraction Device (P.H.R.E.D.)*, designed to generate heat in a contained section of substrate via infrared radiation

P.H.R.E.D.

(Passive Headspace Residue Extraction Device)

- Image courtesy of Canberra Institute of Technology

How P.H.R.E.D. Works



- Image courtesy of CIT

Research 2011-2012

- The first PHRED was constructed and used to sample E10 Petroleum Distillate from a fixed concrete surface
- Collection was via activated charcoal with a subsequent dichloromethane (DCM) wash to extract the ILR compounds
- The DCM wash was then analysed via GC-MS
- The presence of petroleum ILR was indicated by the GC-MS detection of specific ASTM standard compounds used to identify petroleum [6]
- The relative abundance of several of these compounds was later used to compare the sensitivity of PHRED to other techniques

Target Compounds for Petrol

Toluene	1,2,3-Trimelthybenzene
Ethyl-benzene	Indene
m-Xylene	1,3-Diethylbenzene
p- Xylene	1-Methyl-3-Propylbenzene
o- Xylene	1,4-Diethylbenzene
Propyl-benzene	4-Ethyl-1,3-dimethylbenzene
1-Ethyl-3-Methylbenzene	4-Ethyl-1,2-dimethylbenzene
1-Ethyl-4-Methylbenzene	2-Ethyl-1,3-dimethylbenzene
1,3,5-Trimethylbenzene	1,2,4,5-Tetramethylbenzene
1-Ethyl-2-Methylbenzene	1,2,3,5-Tetramethylbenzene
1,2,4-Trimethylbenzene	Naphthalene
2-Methylnaphthalene	1-Methynaphthalene

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Toluene	1,2,3-Trimelthybenzene
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1-Ethyl-2-Methylbenzene	1,2,3,5-Tetramethylbenzene
1,2,4-Trimethylbenzene	Naphthalene
2-Methylnaphthalene	1-Methynaphthalene

Denotes compounds used for comparisons

2011-2012
PHRED on Concrete

Target Compound	Average Relative Abundance
Toluene	72,000 units
Xylene	39,000 units
Ethyl-benzene	39,000 units

2013

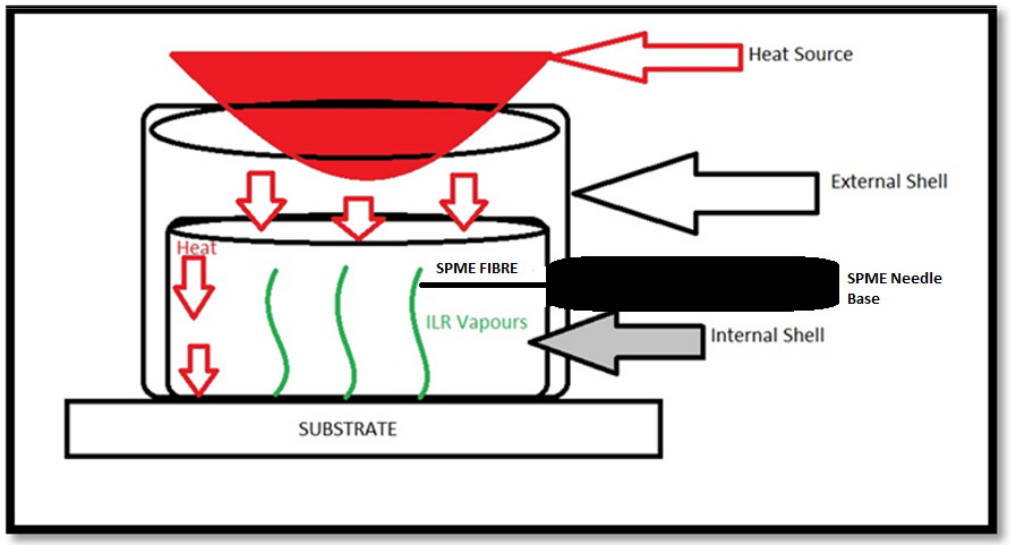
- The PHRED technique was used to extract kerosene samples from a concrete surface
- PHRED was used against an alternative technique:
  - The loaded concrete surface was washed with boiling water, which was then retrieved via sponging the surface
  - The water was later analysed using a Solid-Phase Microextraction needle
- Results indicated this washing technique was more sensitive than the activated-charcoal-based PHRED technique [7]

2013
PHRED vs Boiling Water Rinse

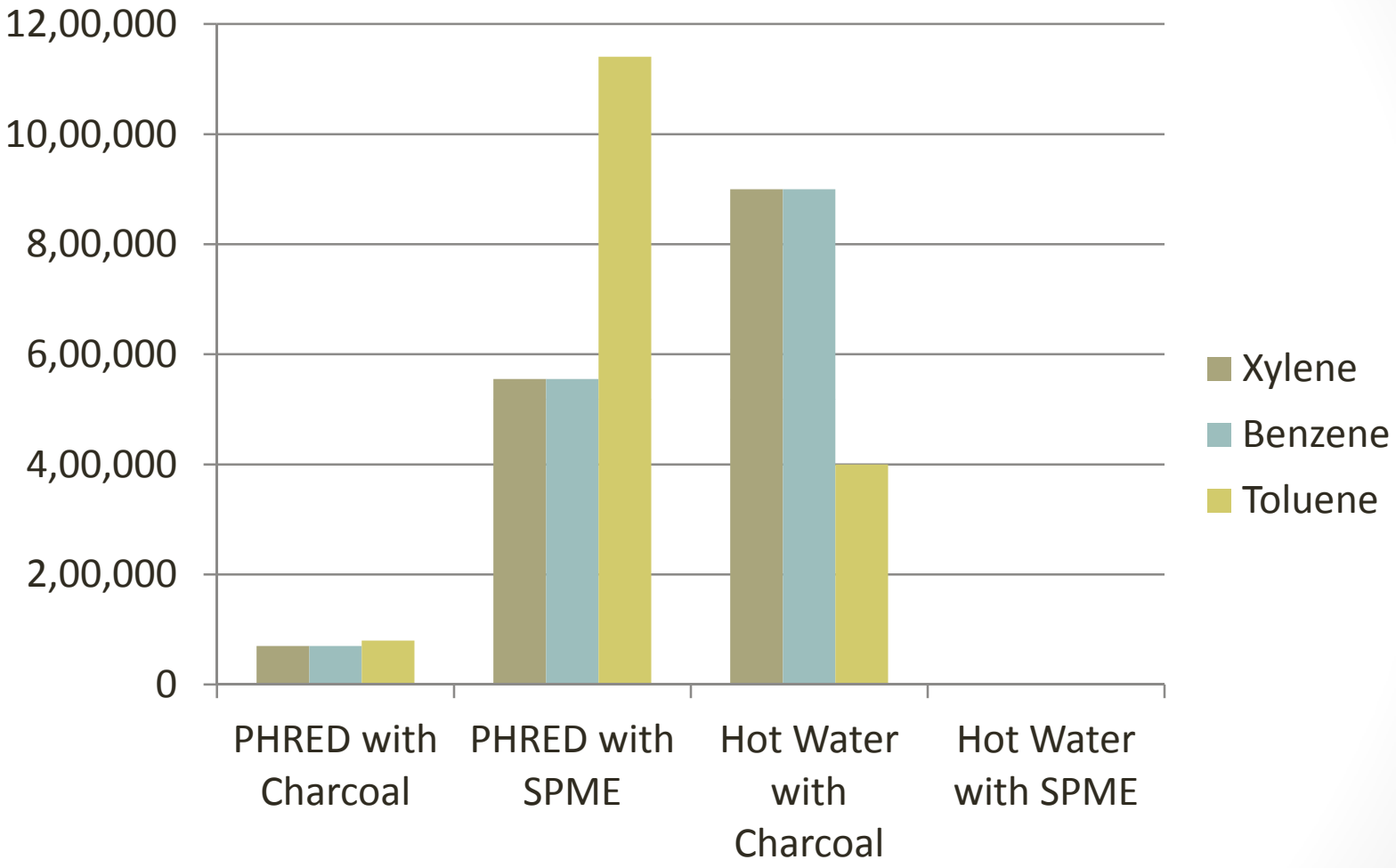
Target Compound	PHRED	Boiling Water
Naphthalene	9,000 units	9,000 units
Dodecane	10,500 units	100,000 units

2014

- The PHRED technique was modified
- SPME sampling from the headspace was used instead of activated charcoal

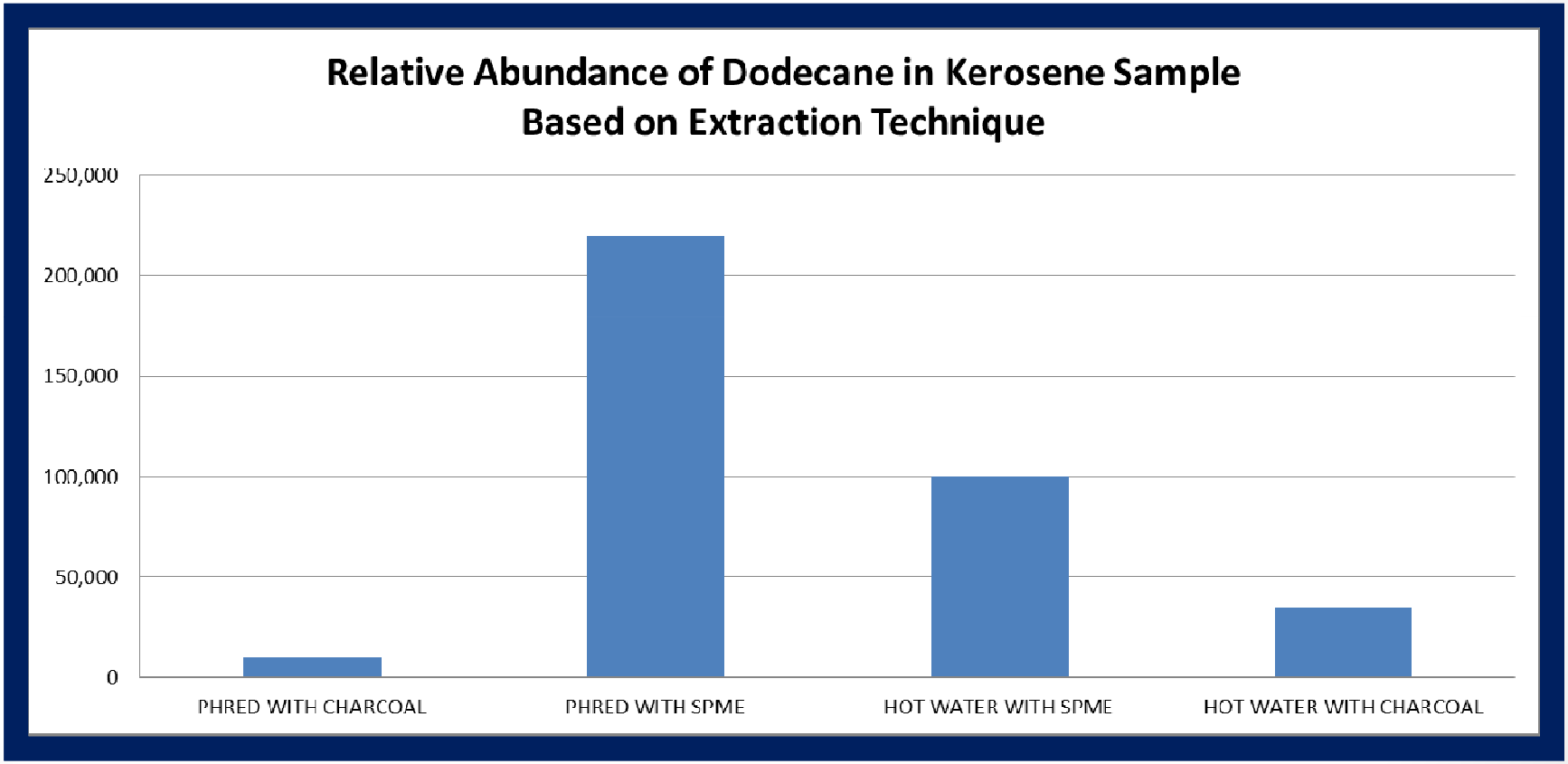


Analysis of Results- Petroleum



The results show a much higher degree of sensitivity for PHRED in conjunction with SPME than with charcoal

Analysis of Results- Kerosene



Conclusions

- Localised thermal desorption was effective in retrieving volatile hydrocarbons from both E10 petroleum distillate and kerosene-covered substrates
- Results indicate that the PHRED technique benefits greatly from the use of a SPME needle
- The use of a hot water rinse is a viable alternative
  - The sensitivity of both techniques differs depending on the particular type of accelerant and the use of charcoal versus SPME

Future Research

- Research is currently continuing to compare PHRED-SPME to other field-based extraction techniques, such as diatomaceous earth
- Combining the PHRED technique with a portable GC-MS would completely remove the necessity for a laboratory stage.
  - Research is needed to determine the efficacy of this technique
- The use of localised thermal desorption has not yet been applied to samples which have undergone heavy weathering or uncontrolled burning
  - Use of the PHRED in an authentic fire scene could provide data that would further develop the device

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