Technology Review Of Rapid Methods To Detect Counterfeits & Illegal Materials

(Findings From Industry Analytical Expert Team.)

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- Guy Lucain (Dow)
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Agenda

• Why Review Technology Now
• Process Used By Team
• Conclusion Of Team
• What Is FTIR/ATR Spectroscopy
• Demonstration Of FTIR/ATR Capability
• Next Steps
Why Review Technology Now

- Counterfeit-and illegal pesticides are entering EU in increasing amounts and are causing threats to farmers, environment and safe food production.
- The ability to rapidly detect illegal materials where they are found would help competent authorities to act and create a strong deterrent to criminal activity.
- Technology has improved in recent years.
- Industry would like to support authorities to find and implement solutions to detect and stop criminal activity with highly regulated pesticides.
Two contrasting worlds:

**Authorised pesticides**

- *Tested:*
  - >100 specific safety tests
  - Risks understood, controlled
  - Benefits documented
- *Authorized:*
  - European Commission, Member States, Agencies
  - Reviewed every 4-year average review
- *Suppliers:*
  - Vested in delivering safe, high quality products
  - Cooperates with authorities
  - Provides stewardship support

**Counterfeit and illegal pesticides**

- *Counterfeit* and illegal**:
  - *Untested:*
    - No safety tests
    - Unknown Risk
    - Possible harm (no benefit)
  - *Authorized:*
    - Unregulated
    - Not reviewed
  - *Suppliers:*
    - Criminals
    - Unknown to authorities
    - No Stewardship
    - Support other illegal activities

*Counterfeit – Trick consumer to believe it is authentic
**Illegal – Unregister product, or hidden actives*
Industry Expert Team Process

Vision/Objective: Identify the current, low cost, effective technology(s) for rapid detection of illegal, counterfeit and authentic pesticides through objective evaluation of current technology.

- Effective Technology:
  - Assess all compounds in a formulation
  - Identify pesticide(s) in a formulation
  - Identify pesticide in pure samples

- Low cost:
  - Less than $50,000
  - Commonly found in labs (no cost)

- Rapid:
  - Result < 1 hour
  - Mobile (move to sample)
  - Common
Steps for objective assessment.

1. Created a “Technology requirements/attributes” list before suggesting technology

Example of requirements/attributes list items:
- Able to identify hidden actives
- Portable
- Requires little training
- Safety to the operator
- Etc...

2. Add weighting factors to each attribute

3. Identify technologies that might meet requirements

4. Assess and document strengths, weaknesses of each technology

5. Each person rated each technology against the attributes list

6. Discuss and clarify ratings results to ensure accuracy

7. Select primary technology(s)
Attributes & Assessment

Attributes

- On spot analysis
- Portable
- Fast
- Only little training required
- Non-invasive (analysis without opening of sample container)
- No/little sample preparation
- Low costs
- Forgery Proof
- No safety concerns
- No safety problems for user
- yes/no answer without complicated interpretation of measurement results
- usable for any kind of formulation
- now/little maintenance of instrumentation
- Identify hidden materials
- Id and confirm mixtures
- unnecessary to configure/calibrate each instrument
- Single/small sample set needed for calibration
- Calibration electronically shareable with all other instruments
- Share data remotely with Experts
- Accepted by courts
- Accepted by scientist as definitive
- Company does not lose proprietary information
- Multiple vendors without issues
- All organic material
- All inorganic material
- Analysis of Packaging
- First shot analyzer.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>FTIR/ATR (Diamond)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Weighting Factor</td>
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<tr>
<td>On spot analysis</td>
<td>10</td>
</tr>
<tr>
<td>Portable</td>
<td>10</td>
</tr>
<tr>
<td>Fast</td>
<td>10</td>
</tr>
<tr>
<td>Only little training required</td>
<td>5</td>
</tr>
<tr>
<td>Non-invasive</td>
<td>10</td>
</tr>
<tr>
<td>No/little sample preparation</td>
<td>8</td>
</tr>
<tr>
<td>Low costs</td>
<td>8</td>
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<tr>
<td>Forgery Proof</td>
<td>10</td>
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<tr>
<td>No safety concerns</td>
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<td>No safety problems for user</td>
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<tr>
<td>yes/no answer</td>
<td>10</td>
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<tr>
<td>usable for any kind of formulation</td>
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<tr>
<td>now/little maintenance</td>
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<tr>
<td>Etc….</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>114</td>
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</table>
Technologies

- Near Infrared (NIR)
- Mid-Infrared (FTIR)
- Raman
- DART MS
- Ion Mobility
- GC (micro)
- LC/UV or DAD

- GC-MS
- LC-MS
- Micro LC
- Cell phone camera
- Image Analysis (Far UV)
- Image Analysis (vis/NIR)
- X-ray Fluorescence (XRF)
FTIR/ATR (diamond)
(Example of Strength/Weakness Assessment)

**Strengths**
- All organics, many inorganics
- Common technology
- ATR (diamond)
  - allows all liquids and solids
  - Little to no training
- Spectra for library (all instruments produce same spectra)
- Semi-portable instruments exist (desktop, and handhelds with limited abilities)
- Can ID compounds in mixtures
- Can ID pure compounds

**Weaknesses**
- No separation of compounds
- Not so selective/definitive
- Not able to see low level compounds (much below 1%)
- Id of unknown materials can be masked by other materials.
- Cost is about $20K
- Open containers
Results

<table>
<thead>
<tr>
<th>Technology</th>
<th>Rank</th>
<th>Total of all ratings</th>
<th>Guy*</th>
<th>Xiangke</th>
<th>Frank</th>
<th>Freidhelm</th>
<th>John</th>
<th>Christian</th>
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<tr>
<td>FTIR FTIR/ATR (Diamond)</td>
<td>1</td>
<td>7824</td>
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<td>1526</td>
<td>1537</td>
<td>1488</td>
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<td>Raman</td>
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<td>NIR</td>
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<td>DART MS</td>
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<td>1442</td>
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<td>1133</td>
<td>982</td>
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<td>LC/MS</td>
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<td>1442</td>
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<td>1128</td>
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<td>1363</td>
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<td>Micro GC on a chip</td>
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<td>994</td>
<td>1485</td>
<td>1311</td>
<td>1144</td>
<td>1103</td>
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<tr>
<td>Micro LC</td>
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<td>4781</td>
<td>946</td>
<td>1469</td>
<td>1064</td>
<td>1136</td>
<td>1112</td>
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<td>LC/UV or DAD</td>
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<td>4390</td>
<td>844</td>
<td>1490</td>
<td>1017</td>
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<td>1429</td>
<td>1131</td>
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<td>Image Analysis (near IR)</td>
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<td>3881</td>
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<td>1365</td>
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<td>1194</td>
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<tr>
<td>Image Analysis (far UV)</td>
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<td>3845</td>
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<td>1365</td>
<td>0</td>
<td>1224</td>
<td>1256</td>
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</tbody>
</table>

Conclusions:

- FTIR/ATR(Diamond) and Raman were too close to call form this data
- FTIR/ATR and Raman were significantly different from others
- Team decided to vote on which to move forward.

*Guys’ data was not used because he rated Raman “0”. He did this because he did not know enough about it to rate it.
Vote on FTIR versus Raman

Which technology do you choose?

FTIR/ATR spectroscopy

Raman Spectroscopy

# of times chosen

Which technology do you choose?
Conclusion

An Industry Analytical Expert team used an objective process to determine the best technology for effectively, rapidly and simultaneously authenticating legitimate pesticides, and for detecting illegal, and counterfeit pesticides when and where they are discovered. From this process, the Expert team determined FTIR/ATR to be the best technology for this purpose.

***Because this technology is not specific to Crop Protection products, implementation at boarders and ports can be used to detect fakes and illegal activity in other industries.
What Is Mid-Infrared Spectroscopy?

- Mid-Infrared Spectroscopy (Mid-IR, FTIR) measures the fundamental vibrations of covalently bound atoms in molecules.

- Just as one can determine which musical instruments is being played by the sound it makes, each molecule can be identified by the subtle differences in its vibrational spectrum.

- It has been well established and scientifically proven that the Mid-IR spectra of a compound is unique to the compound, and represents a fundamental, unique property of each compound.

- This means that if the Mid-IR spectrum of a substance matches exactly with that of a know compound it is conclusive evidence* that the substance is the compound.

*Good scientific practice is to always confirm a result with at least one other method.
What Does A Mid-IR Spectra Look Like?

Band Height is related to abundance and interaction of functional group.

Location of band is related to the functional group.

Why Does it Work?
- Relationship between band location and intensity produces an infinite number of possibilities.
- All organic molecules have unique IR spectra.
- Many inorganic molecules have unique IR spectra.
- Mixtures have unique “fingerprint” spectra.
- Almost no interferences.
The ATR accessory

Attenuated Total Reflection is observed when the sample absorbs internally reflected electromagnetic radiation through interaction with the evanescent wave.

This technology allows the analysts to reproduce spectra with a very high degree of precision.

This technology/apparatus is available from all vendors.
Proven Semi-Portable FTIR Spectrometers
Example of Precision
10 batches of a formulation:

- Spectra overlay with high degree of overlap (region below 2000 are most important)
- All peaks are represented
- Peak shapes are all similar
- Minor difference represents
  - Minor variation in measurement system
  - Minor, batch to batch variability
Example of Sensitivity & Precision

Shows that even with high variation, the spectra still look the same!

<table>
<thead>
<tr>
<th>Lot #</th>
<th>Active A (%)</th>
<th>Active B (%)</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct. 2012</td>
<td>25.1%</td>
<td>25.2%</td>
<td>Light Blue</td>
</tr>
<tr>
<td>Oct 2012</td>
<td>24.9%</td>
<td>24.4%</td>
<td>Light Red</td>
</tr>
<tr>
<td>Nov 2012</td>
<td>26.4%</td>
<td>26.6%</td>
<td>Dark Blue</td>
</tr>
<tr>
<td>Mar 2012</td>
<td>25.1%</td>
<td>25.2%</td>
<td>Green</td>
</tr>
<tr>
<td>Feb 2012</td>
<td>25.2%</td>
<td>24.5%</td>
<td>Dark Red</td>
</tr>
</tbody>
</table>

- All peaks are present
- All peaks at same location are
  - Generally the same height
  - Generally the same width
- Minor differences in height due to differences in concentrations of formulants
Example of original versus Generic

Suspect Rimsulfuron sample from Ukraine
Shows how easy it typically is to see a sample is not the same as another.

**HQI = Hit Quality Index**
Measures how well one spectrum matches another. In this case, how well the generic spectrum matches the original manufacturer spectrum.
Example of precision & global comparison

Generic Rimsulfuron from several countries

HQI = Hit Quality Index
Index measures how well one spectrum matches another
Example Authentic versus illegal parallel
Shows that even minor peaks can show that formulations are different. Peak at about 3,600 wave numbers not in fake, so fake is missing an authentic formulation ingredient.

Authentic (blue) and illegal Parallel Import (red)

Circles show areas that are different
Example Match Of Fakes
Fake actually matches previously found illegal product. Shows ability to detect networks of criminals across country borders; illustrates international serious organized crime

Overlay of illegal material found in the marketplace at a different time and in different countries

Notice overlay is nearly perfect compared to previous slide overlay.
Questions?