Spectral barcode label for fighting illegal waste dumps

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Introduction:
Illegal waste dumping is one of the biggest problems in environmental protection. Shipments of waste are left in wastelands, forests or dumped into the sea. These activities are difficult to suppress because technologies available to track the waste and hence the people responsible are very limited. This research focuses on developing an effective, low-cost way of labelling and detecting bulk waste material shipments. The technology is based on an easily retrievable material in the form of micro/nano magnets which are used as carriers for the spectral signal transducers (e.g. dyes and pigments). These pigment-carrying magnetic particles are chemically and physically stable, can form unique spectral patterns to use as identifier tags.

The project is divided into two parts:
(i) the modification of the magnet particles with various dyes and pigments to form spectral codes
(ii) the development of an analytical technique for code readout

The concept of spectral code:

Fig. 1 The principle of spectral barcode. Each starting substance gives a single spectral peak in a separate region of the spectrum. When these substances are mixed a combined spectrum can be obtained. The code is formed by the ratio of peak heights. The peak heights can be varied by changing the mixing ratios of the individual starting substances.

Code tag retrieval - micromagnets:

Fig. 2 Magnetic particles ($\text{Fe}_3\text{O}_4$) easily separated with a permanent magnet. Such magnetic core of the code-carrying particles would allow to retrieve the waste tag on site for decoding and analysis.

Modification of micromagnets:

Table 1: Compositions of the powders used to create spectral codes. Magnetic particles are functionalized with chosen block of elements.

<table>
<thead>
<tr>
<th>[wt%]</th>
<th>Colour</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti</td>
<td>White</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>Green</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Fe</td>
<td>Black</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ethyl cellulose</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 4 Two codes formed by combining S1, S2 and S3 in 1:5:5 (left) and 3:2:1 (centre) weight ratios. Spectral fingerprint pattern after mixing the 1:5:5 tag with ethyl cellulose and retrieval by washing with water and magnetic separation (right)

Results: Code formation

The codes were formed by combining samples S1, S2 and S3 powders in different weight ratios. The powders were then analyzed with the XRF gun to see if the spectral patterns differ from one another. The spectral patterns were stable between measurements. However, leaching was observed in the samples that were dispersed and retrieved. It appeared that the titanium component of S1 was partially washed away. That explains the pattern behaviour: Ti peak decreases while other peaks increase because as there is less Ti in the retrieved powder sample more S2 and S3 take its place.

Instrumentation:

The Niton handheld X-Ray Fluorescence analyzer can easily read the concentrations of metal elements in the sample and therefore the ‘hidden code’ in the retrieved tag on site. It is portable and can be fitted with a wireless connection device.

Conclusions:

Magnetic powders containing various inorganic pigments were successfully made. The paramagnetic character of the samples allowed easy retrieval from water. Because different pigments were used each mixture possessed unique X-ray fluorescence spectral fingerprints. The handheld XRF analyzer proved to be a fast and easy way of taking spectral measurements and extracting the coded spectral information. The stability of the spectral fingerprint is an issue but is planned to be solved with decreasing the size of the particles and using different functionalization methods.

References: