Spectral barcode label for fighting illegal waste dumps

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Introduction:

Illegal waste dumping is one of the biggest problem in environment 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 [1] 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 carrier for the spectral signal transducers (e.g. dyes and pigments). These pigment carrying magnetic particles are chemically and physically stable, can form unique spectral pattern to use as identifier tag.

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 analytical technique for code readout

The concept of spectral code:

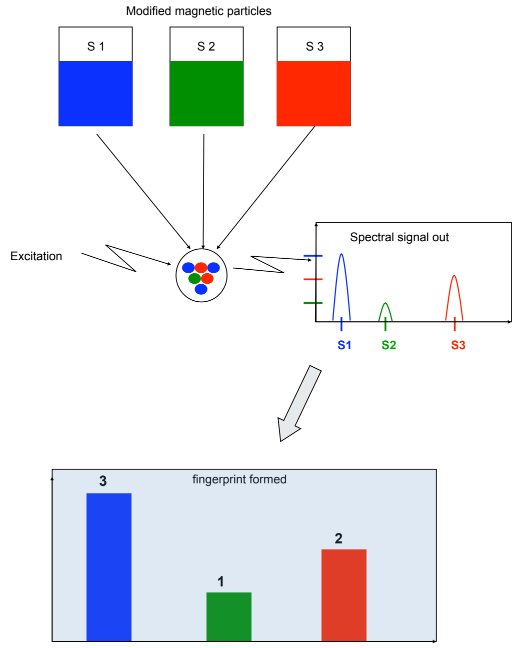

Fig.1 The principle of spectral barcode. Each starting substance gives a single spectral peak in a separate region of the spectrum. When these substances are mixed a combined spectrum can be obtained. The code is formed by a ratio of peak heights. The peak heights can be varied by changing the mixing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

Code tag retrieval - micromagnets:

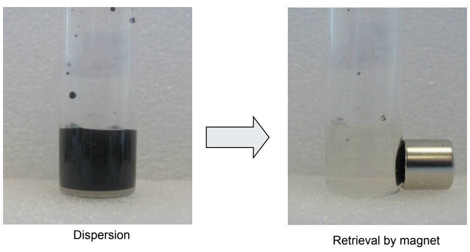

Fig. 2 Magnetic particles (Fe_3O_4) easily separated with a permanent magnet. Such magnetic core of the code-carrying particles would allow to retrieve the waste tag on site for decoding and analysis

Modification of micromagnets:

Pigment + binder (ethyl cellulose) + Fe_3O_4 + ethanol → mixing → drying → grinding

[%wt.]	Colour	S1	S2	S3
Ti	White	X	-	-
Cr	Green	-	X	-
Fe	Black	X	X	X
Zn	White	-	-	X
Ethyl cellulose		X	X	X

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

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.

Fig. 3 The XRF handheld analyzer (left), The elemental composition is avaliable imiedately after measurement on the build in display (right). The XRF gun's principle of operation (bottom).

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 patters differ from one another. The spectral patterns were stable between measurements. However leaching was observed in the powder that was dispersed and retrieved. It appeared that the titanium component of S1 was partially washed away. That explains the pattern behaviour. Ti peak decreased while other peaks increase because as there is less Ti in the retrieved powder sample more S2 and S3 take its place.

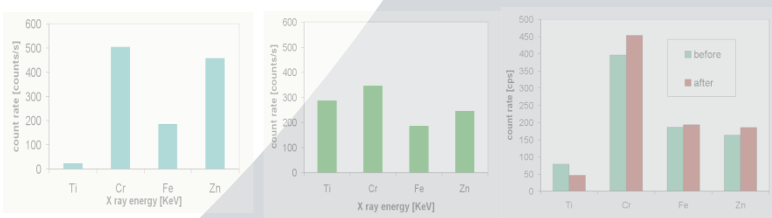

Fig. 4 Two codes formed by combining S1,S2 and S3 in 1:5:5 (left) and 3:2:1 (centre) weight ratios. Spectral fingerprint pattern after mixing the 1:5:5 tag with ethyl cellulose and retrieval by washing with water and magnetic separation (right)

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 fingerprint 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:

1. "The Nature and Extent of Unauthorised Waste Activity in Ireland", 2005, Environmental Protection Agency Ireland

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