OPTICAL ADDITION TO X-RAY FLUORESCENCE ANALYSIS OF MINERAL FERTILIZERS

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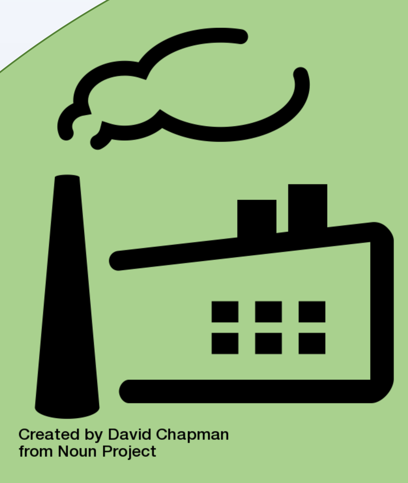
Study Design



Industrial Analytical Control

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Fast, Informative and Automated

↓

Multicomponent Analysis

↓

Optical Addition to X-ray Fluorescence

The Goal:

Develop optical surface recognition system for controlling physical parameters of mineral fertilizers produced on industrial scale.

Tasks:

- review of research objects and variation of its quality parameters;
- develop of optical analysis system (hardware and software);
- propose algorithms of features selection from image;
- evaluate the possibility of quality control for selected features.

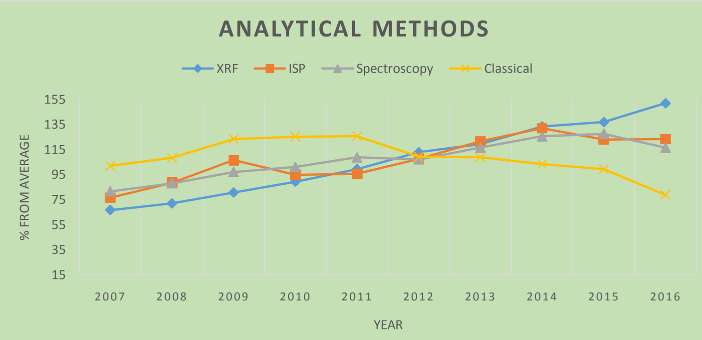
Conclusion:

1. Possibility of classifying the physical parameters of the quality of fertilizers and their samples preparation (the size of the compressed particles, the grade of fertilizer and confirmation if preliminary drying was done or not) with optical recognition system is shown.
2. The algorithm for extracting features from an RGB pixel matrix is described .
3. Suitability of the described system as an independent device for calculating the particle size of objects (precision is 94%) and assuming of the grade and humidity of the samples (precision more than 62%) was carried out*.
4. Signals associated with the characteristics of product quality were highlighted.

* However, in order to determine properly the last two parameters, an additional source of information is required, for example, the energy dispersive X-ray fluorescence analysis

Methods

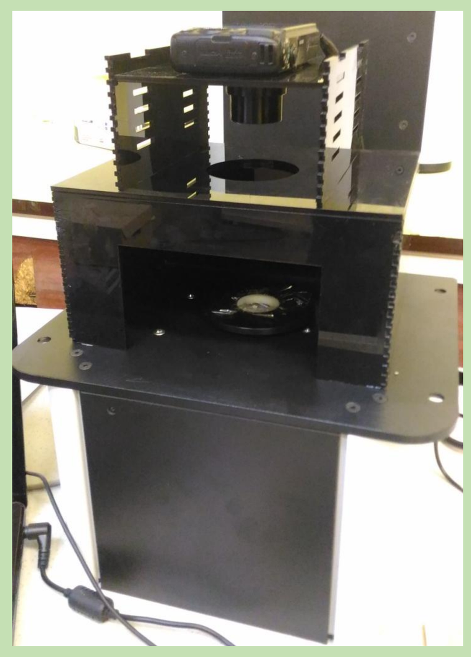
The method of ED XRF is the most informative and intensively developing control system.



(according to Scopus, "Environmental Science", "Earth and Planetary Sciences" and "Agricultural and Biological Sciences" subjects)

In addition, the system of optical surface registration was used

(ED XRF with photo registration of sample surface)

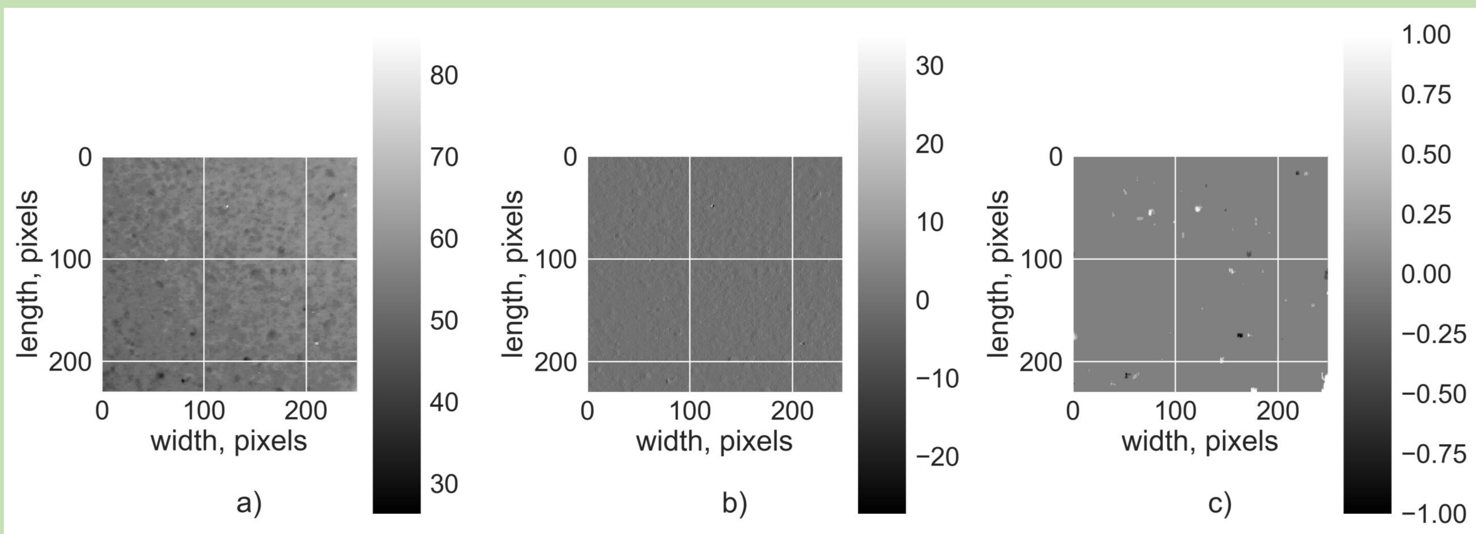


Optical system:

1	does not transmit external light;
2	equipped with a digital camera *(resolution not less than 640x480, focal length 2.8 - 12 mm and sensor type ½. 7`` CMOS)*
3	used LED lighting strip *(wavelength > 370 nm, light flow ≥ 50 lumens)*

Calculation

- Python 2.7 programming language was used for software.
- Image of each tablet was obtained at a fixed distance to the surface of the sample (± 3 mm).
- The area of the surface was selected with a resolution of at least 100 × 100 pixels in RGB format.
- "Surface map" was constructed: pixels converted to grayscale format; differentiated to eliminate the lighting trend and smoothed by a two-dimensional square median filter.



(Construction of a "surface map" for pressed powder ≤ 500 μm of NP(S+S)+Zn 12-40(6+3)+1 fertilizer. Surfaces: a) - original, b) - after differentiation, c) - after smoothing by a median filter. Color-map indicates the intensity of pixels in grayscale (brightness))

- Using the algorithm of "marching squares", areas of bright and dark pixels - "anomalies" were allocated.
- The average brightness of pixels, the average area (relative to image area) and the number of "anomalies" were considered as features.
- The "object-features" matrix was achieved.

Quality metrics for classification

(The matrix of classification errors where x – data, y – truly answer for data, a(x) – result of classification algorithm)

	y = 1	y = -1
a(x) = 1	the correct positive (CP)	the incorrect positive (IP)
a(x) = -1	the incorrect negative (IN)	correct negative (CN)

$$precision(a, X) = \frac{CP}{CP + IP}$$

$$recall(a, X) = \frac{CP}{CP + IN}$$

$$F = \frac{2 \times precision \times recall}{precision + recall}$$

Results

Using the "Random Forest" classification algorithm (standard parameters, the Python 2.7 programming language), the possibility of predicting the physical properties of fertilizers according to the selected characteristics was evaluated.

(Results of "Random Forest" classification)

	Precision		Recall		F-metric	
	Average, %	STD, %	Average, %	STD, %	Average, %	STD, %
Dry condition*	63.96	6.19	64.42	6.58	63.50	6.21
Particle Size	93.65	3.16	92.70	3.19	92.70	3.18
Grade	61.79	3.93	59.07	3.09	59.01	2.52

* binary properties: 0 – not dry, 1 – dry condition
** [presesed granules, powder 500 μm and powder 100 μm]

The obtained results show that the optical method is informative and can be used both as a stand-alone device (for particle size) and for supplementing other methods for monitoring quality parameters.

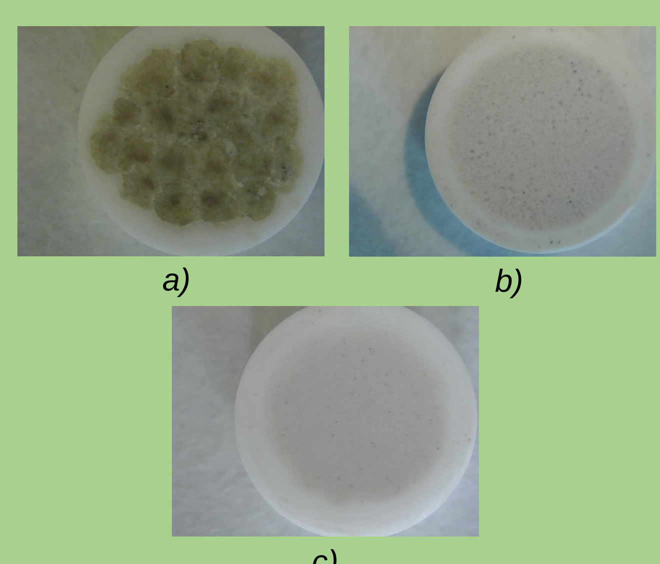
Objects of Research

Is phosphorus-containing mineral fertilizers at various stage of sample preparation.

Fertilizers: NPK(S) 4-30-15(16), NPK(S) 0-20-20(5), NP(S) 12-40(10), NPK 15-15-15, NPK 16-16-8, NP(S)+S+Zn 12-40(6)+3+1, NP 12-52

(Type of Probe Preparation)

No	Grinded to < 500 μm	Grinded to < 100 μm	Dried	Pressed	Duration, min
1	-	-	-	+	2
2	+	-	-	+	15
3	+	+	-	+	40
4	+	-	+	+	30
5	+	+	+	+	45



(Type of Samples:
a) pressed granules;
b) pressed powder < 500 μm;
c) pressed powder < 100 μm)

The work was carried out in the JSC "The Research Institute for Fertilizers and Insecto-Fungicides Named after Professor Y.Samoilov".

For more details about this study refer to:
- https://github.com/DimYun/DSpectra
- Mendeley Data, v1, 2018. https://doi.org/ 10.17632/4zywk4k8zk.2