MEASUREMENT OF ELECTRICAL CONDUCTIVITY OF FERTILIZER NPK 20-8-8

Josef Krupicka, Petr Sarec, Petr Novak
Czech University of Life Sciences Prague
krup@tf.czu.cz

Abstract. The paper deals with the measurement of electrical conductivity of significant size groups of the mineral fertilizer NPK 20-8-8 divided in the air stream. Samples of these groups were dissolved in distilled water and the values of electrical conductivity recorded. Measurements will be used to monitor the electrical conductivity of other mineral fertilizers and to create a standard for qualitative assessment of fertilizer solutions. On the basis of the electrical conductivity, the concentration of dissolved mineral fertilizers can be determined. The results indicate that the values for the significant portions sorted by air flow are analogous in opposite to the portions sorted by sieves. In the latter case, bigger particles reached higher values of electrical conductivity, suggesting thus higher content of soluble nutrients. Measurements are taken as the guidance for the methodology verification that will be used to measure other samples of similar fertilizers. These results will be used for precise application of fertilizers and can be used as a reference for qualitative assessment of fertilizer solutions.

Keywords: electrical conductivity, air flow, fertilizer solution, concentration, NPK 20-8-8.

Introduction

The concentration of fertilizers can be determined on the basis of the electrical conductivity (increasing the electrical conductivity). The value of the electrical conductivity can be used for precise application of fertilizers in liquid form. Monitoring the conductivity and knowing its value for target fertilizer concentrations enables to start the field application of fertilizers at an optimum moment. This would significantly increase the precision compared to the commonly used "mass percentage method" where the concentration accuracy attains only ±10 % according to fertilizer manufacturers. According to the electrical conductivity, the quality of the measured fluid can be assessed accurately along with other data such as the level of pollution, the concentration of the various components of the solution, etc. [1; 2]. In that way, electrical conductivity is reciprocal of electrical resistance, it is indicated with the letter G and its basic unit is the Siemens (S).

The effectiveness of mineral fertilizers in crop cultivation depends on the particle stability and speed of their transformation to solution state to be acceptable by plants. This process depends on the particle dimensions, so that the dimension of particles is one of the main parameters that influence the fertilizer effectiveness.

Application of solid commercial fertilizers plays an important role in precision farming technologies. The application quality is dependent on the chemical composition and physical properties of fertilizers. Important from the physical properties point of view is the grading of aggregate evaluation that is still performed by the standard ČSN 01 50 30. The dimension of particulars only is characterized by this way.

In this paper we continue the previous research program, in which the granulometric study mineral fertilizers were studied. On contrary to similar studies of other authors, seat and airflow sorting were combined.

Experiments with particles can be designed differently. An elutriator was designed and constructed in which airflow is supplied by a centrifugal fan [3]. Methods for measuring the coefficient of friction, the coefficient of restitution, the aerodynamic resistance coefficient, and the breaking force (particle strength) of fertilizers were taken into account [4]. The breaking force feature was skipped. The problem of particle destruction was overcome by fertilizer selection. The control of fertilizer discharge was studied for different designs of distributors and an experimental accurate fertilizer distributor with a rotary vessel type feeder was developed by Kudoh [5] what shows that dissolution of fertilizer also causes some problems. Consequent logistical problems are the same difficult for both pumping liquids, and transportation of particles by the air.

The size of the particles makes the fertilizer shelf life and stability of particulars behavior in the airflow more stable in storage and better acceptable by the plant. Therefore, experiments studying motion of particles through the air were accompanied by grading of particles.

This paper contains results obtained for the compound fertilizer NPK 20-8-8 using the method developed previously. Each particle of the fertilizer should contain all the nutrients in the ratios declared. The mentioned fertilizer was sorted by air and subsequently by sieves in order to gain particles of different critical speed and of different sizes. Electrical conductivity of the samples of significant portions was subsequently measured and evaluated.

Materials and methods

Electrical conductivity was measured by a device using Conductivity inoLab model WTW Cond 720. Measurement was carried out for the mineral fertilizer NPK 20-8-8 (alternative trade name Agro Lawn Fertilizer; manufacturer AGRO CS a.s. – the Czech Republic). The composition of NPK 20-8-8 is the following: granular fertilizer with 20 % ammonium nitrogen (11 % of NH4-N; 9 % of N-NO3), 8 % of water-soluble phosphorus (P2O5), 2 % of soluble potassium (MgO) and 2 % of magnesium (MgO). The fertilizer is an all-purpose fertilizer suitable for fertilization of heavily stressed lawns and winter crops, and spring crops. Distribution of the air stream was carried out in the laboratory of the Department of Agricultural Machinery using the laboratory air sorting machine K-293 (see Fig. 1).

Fig. 1. **Laboratory Air sorter K-293**: 1 – adjustable damper hoppers; 2 – vertical (aspiration) channel; 3, 4 – tanks; 5 – control panel with buttons; 6 – small and large graduated cylinder; 7 – cylinder adjusting screws; 8 – fan

The measurement procedure was as follows. First, the laboratory seed sorting machine Petkus K-293 determined ranges of the required amount of air, i.e. the minimum amount of air in which the particles are carried, and in the opposite, a maximum amount of air in which the sample is completely sorted. With the help of graduated cylinders, the interval of gradually increasing speed of the air flow is selected so that the number of classes was 7 to 10. It is necessary to ensure the right leveling for the scales to measure accurately. The scales are calibrated and set to zero. The fertilizer is mixed for sake of the measurement accuracy and a sample of fertilizer weighing 500 g removed. An appropriate, predetermined air speed is set for the laboratory device using graduated cylinders and adjusting screws. A sample of fertilizer is poured into the tank (1) with pre-set for the damper. With the help of a vibrator, the fertilizer gets into the air flow in a vertical channel (see Fig. 2). Here comes the separation. Granules with higher critical speed than the one set fall through the channel into the container (3). Granules with lower critical speeds are vertically carried in an air stream and in the extended part of the channel are falling into the tray (4). The amount of the fertilizer separated using air flow into the tray (4) is then placed in a pre-labeled bowl for later use. The emptied tank (4) is placed back into the machine and the speed of the air flow is checked. Then the fertilizer from the tank (3) is filled back to the tank (1) and the graduated cylinder is set to the next value of the air stream speed. In this way, the experiment continues until the entire sample of the fertilizer gradually falls into the tank (4).

The whole process is repeated with eight different samples of fertilizers to maintain the accuracy and reliability of statistical data measurements. Measurement in an air stream was carried out at a temperature of 22 ºC and humidity of 22 %. Out of all the classes separated using the air flow, three portions with the most significant share were taken. From each of the portions, three samples weighing five grams were taken and further divided by the laboratory sieves Haver EML 200 according to the particle sizes. Again, the particle sizes with the most significant share were picked, i.e. two sizes for each significant class previously separated by the air flow.

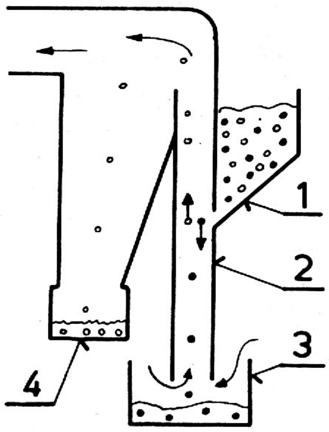

Fig. 2. **Vertical channel (detailed view):** 1 – tray; 2 – vertical (aspiration) channel; 3 – stack; 4 – tray (particles of lower critical speed are carried into this tank)

Electrical conductivity was measured on the machine Conductivity meter WTW inoLab model Cond 720. The instrument for the measurement of electrolytic conductivity, especifically electrical conductivity of liquids, consists of a measuring probe or conductivity sensor, transducer and evaluation unit. According to the manufacturer, accuracy of the device is 0.5 % of the value when measuring conductivity. Most of the apparatus is adapted for measuring the resistivity and weight concentrations of some components of the solution, which can be derived from the electrical conductivity. It is very sensitive and allows you to measure the content of various substances from small to very high concentrations and is often used to control a wide range of industrial processes [1]. The samples corresponding to three different air flows and two different particle sizes were measured in three repetitions. The measurements were carried out over ten hours in one-hour intervals. Before each conductivity measurement took place, the sample was mixed to ensure its homogeneity.

Results and discussion

From the material divided by the air stream and the sieves, three samples weighing 5 grams were taken of each of significant portions that were gained by the air stream of 105, 115, 125 $m^3 \cdot hr^{-1}$ and by the sieves of the size 2.00 and 3.15 (Table 1).

Subsequently, the samples were collected and mixed and then dissolved in distilled water of the volume of 50 ml and of the room temperature of around 17 ºC.

Table 1

Relative representation of groups of NPK 20-8-8 after sorting by air stream and sieves (significant proportions highlighted by italics)

Air stream, $m^3 \cdot h^{-1}$	Sieves, mm				Total
	1.00	2.00	3.15	4.00	
105	1.73 %	*14.52 %*	*7.89 %*	0.01 %	**24.15 %**
115	5.08 %	*21.07 %*	*6.83 %*	4.75 %	**37.73 %**
125	1.72 %	*33.31 %*	*2.64 %*	0.46 %	**38.12 %**

Table 2 shows the average measured values of electrical conductivity. Conductivity measurements were performed in one-hour steps and started half an hour after solution had begun.

Table 2

Average measured values of electrical conductivity of NPK 20-8-8 fertilizer for individual air flow classes and sieve sizes

Time, h	Electrical conductivity, dS·m^{-1}						
	Sieve, mm						Average
	2.00			3.15			
	Air stream, m^3·hr^{-1}						
	105	115	125	105	115	125	
0.5	41.90	35.97	37.00	37.60	47.33	52.23	42.01
1.5	59.10	63.33	56.40	64.30	75.43	76.23	65.80
2.5	63.17	67.63	65.03	75.40	86.17	87.87	74.21
3.5	67.27	70.77	72.67	87.67	87.03	94.23	79.94
4.5	70.93	74.43	74.23	93.07	95.77	97.00	84.24
5.5	72.73	77.10	75.90	94.33	96.80	98.37	85.87
6.5	73.63	77.37	76.57	95.60	97.30	98.63	86.52
7.5	74.50	78.13	77.10	96.93	98.47	99.90	87.51
8.5	74.93	78.57	77.47	97.80	98.20	100.80	87.96
9.5	76.13	80.43	79.30	98.37	100.33	102.20	89.46

Fig. 3 demonstrates the logarithmical increase of electrical conductivity of the air flow classes 105, 115, and 125 m^3·h^{-1}. The differences among the classes were minor only. After five hours, the electrical conductivity values got stabilized and showed slight increase only.

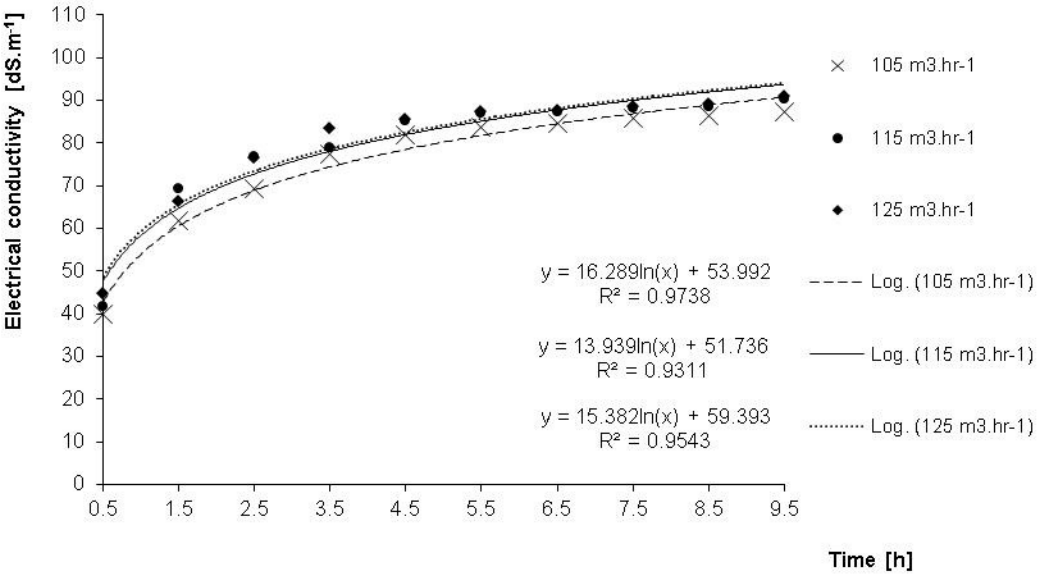

Fig. 3. **Graph of time dependence of average electrical conductivity for the air stream of 105, 115 and 125 m^3·h^{-1}**

When taking into account only the separation sieve sizes (see Fig. 4), i.e. the sizes of fertilizer particles of significant portions, the differences in electrical conductivity between the two groups were considerably higher. Higher conductivity values reached by bigger particles suggest higher content of nutrients compared to fertilizer carrier in the particles.

Undissolved residues were detected by using filter paper – the solution was filtered and the solids were weighed and dried in a dryer at a constant temperature of 105 ºC to constant weight. These weights are not given here, because we cannot determine the amount of undissolved fertilizer and of undissolved fertilizer carrier.

This measurement was performed as indicative and following additional measurements based on it were done where the sample was dissolved until it stopped to change its electrical conductivity, i.e. ended its dissolution. The undissolved remains of fertilizer were weighed. You could determine again only using nutrient analysis whether the undiluted sample contains nutrients, or it is carrier roughage. Quality of fertilization also significantly impacts the quality the final crops [6]. The measurement data are usable particularly in terms of precise application of mineral fertilizers. Krupička [7] analysised NPK fertilizer aerodynamic particle testing that can be used directly in evaluation of the aerodynamic spreading of the fertilizer in the field conditions.

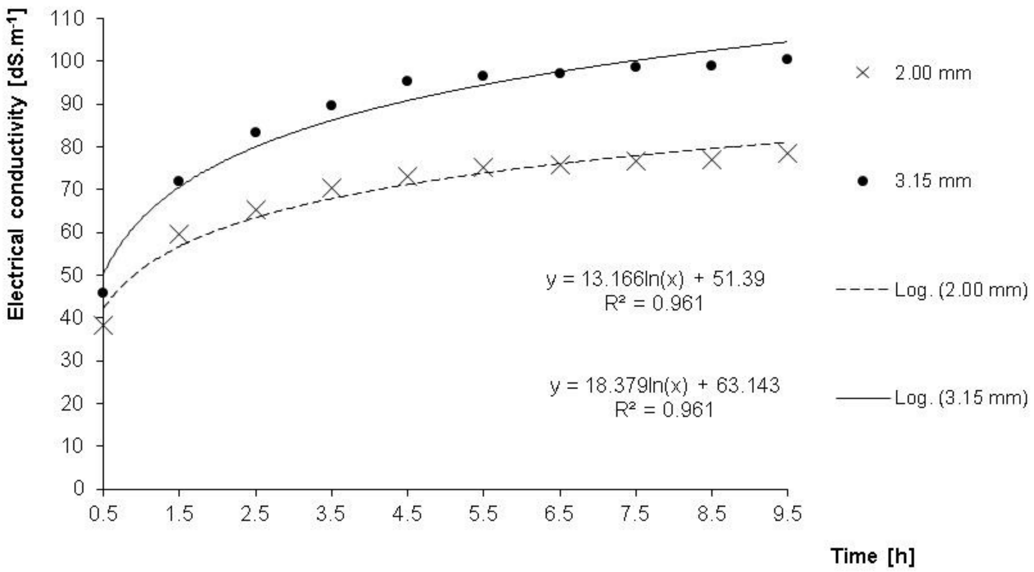

Fig. 4. **Graph of time dependence on electrical conductivity for the two significant sieve sizes**

Conclusions

On the basis of the electrical conductivity, the concentration of dissolved mineral fertilizers can be determined. The results indicate that the values for the significant portions sorted by the air flow are analogous in opposite to the portions sorted by sieves. In the latter case, bigger particles reached higher values of electrical conductivity, suggesting thus higher content of soluble nutrients. These values are crucial for production of concentrated solutions of mineral fertilizers that can be applied by sprayers. The measurements suggest that the NPK 20-8-8 fertilizer is well soluble, and thus five hours are a sufficient time period for dissolving it. Electrical conductivity values are noticeably high, which means that the ions can be absorbed easily by plant roots. The NPK 20-8-8 is therefore suitable for application into soil.

Measurements are taken as the guidance for the methodology verification that will be used to measure other samples of similar fertilizers. These results will be used for precise application of fertilizers and can be used as a reference for qualitative assessment of fertilizer solutions. The research is about to continue with simultaneous measurement of concentrations in order to determine the relationship between the concentration and electrical conductivity. Unfortunately, current measurement devices available to the authors do not allow such approach.

Acknowledgements

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