Agronomy Research **15**(3), 658–663, 2017

Method of designing of manure utilization technology

A. Briukhanov, I. Subbotin, R. Uvarov and E. Vasilev*

Institute for Engineering and Environmental Problems in Agricultural Production – IEEP, Filtrovskoje shosse, 3, RU196625 St. Petersburg-Pavlovsk, Russia
*Correspondence: itmo1652@mail.ru

Abstract. Specific feature of modern livestock farms is concentration of a large number of animals and subsequent significant environmental load. The biggest negative impacts are on the atmosphere through ammonia emissions and on water bodies through nitrogen and phosphorus compounds leakage, with manure being the major source of these pollutants. The proper choice of an effective low-cost manure handling technology with high nutrients retention ensures the environmentally sound operation of these farms. With this aim in view a designing method of manure utilization technologies is proposed. Relevant available technologies were reviewed, a mathematical model was created and technology assessment criterion was defined. Manure utilization technology is understood as a set of activities, including manure processing, manure storage (if necessary) and soil application of organic fertilizers. To create a mathematical model 12 manure utilization technologies were examined. These technologies are based on various methods of manure processing, such as long-term maturing, composting, biofermentation, separation into fractions, drying and biogas production. The created mathematical model takes into account the economic and environmental performance of each technology. The proposed approach makes it possible to calculate and compare the level of nitrogen preservation in manure and required inputs for different technologies depending on the farm animal stock. To assess and select the most suited technology the eco-efficiency criterion is suggested, which takes into account the yield increase, the cost of generated energy (for biogas production), and reduced negative impact on the environment. The paper presents example of using the method to make a choice of technologies for a dairy farm. Experience in the use of the method shows that the average values of nitrogen preservation in the manure, which may be achieved without involving excessive costs, are 72% for cattle manure, 70% for pig manure and 78% for poultry manure.

Key words: environmental safety, technology assessment, utilization of manure technology, technology designing, best available technique.

INTRODUCTION

Specific feature of modern livestock farms is concentration of a large number of animals and subsequent significant environmental load. The biggest negative impacts are on the atmosphere through ammonia emissions and on water bodies through nitrogen and phosphorus compounds leakage, with manure being the major source of these pollutants (Integrated Pollution Prevention and Control, 2003). So it is very important to introduce the assessment of environmental safety of a technology already on the designing stage. This makes assessment of environmental safety at technology designing stage much more important. Currently, there are several methods of manure processing (Best Available Techniques, 2015) and the proposed method solves the problem of choosing recycling technologies for conditions of specific farm. The method was developed taking into account the modern technology assessment approach 'best available techniques' with the aim to reduce the negative impact of the technology without undue cost (Subbotin & Vasilev, 2016).

MATERIALS AND METHODS

Manure utilization technology is understood as a set of activities, including manure processing, manure storage (if necessary) and soil application of organic fertilizers. The proposed method consists of three stages:

1. Analysis of farm conditions. Choice of technologies appropriate to farm conditions and calculation of indicative values of the parameters for the available technology.
2. Choice of the most efficient (with minimal negative impact without undue cost) technology and forming technological solutions, which are understood as a set of machines, equipment and constructions (based on selected technology).
3. Calculation of indicators for the formed technology solutions and optimization of technological solution choice by Pareto optimization method.

At the first stage animal species, number of animals, water content in manure, size of field area and distance to this were considered. Depending on farm conditions suitable technologies were selected from the following 12 manure utilization practices:

1. Long-term storage and application of solid or liquid organic fertilizer.
2. Passive composting in clamps and application of solid organic fertilizers.
3. Active composting in clamps and application of solid organic fertilizers.
4. Biofermentation in chamber-type installation constructions and application of solid organic fertilizers.
5. Biofermentation in drum installation s and application of solid organic fertilizers.
6. Biological treatment of liquid pig manure in aeration tanks and application of liquid organic fertilizer.
7. Manure separation into fractions with further processing of the solid fraction by composting methods or biofermentation and long-term maturing of the liquid fraction and application of solid and liquid organic fertilizers.
8. Manure separation into fractions with further processing of the solid fraction by composting methods or biofermentation, advanced treatment of liquid fraction by biological methods and application of solid and liquid organic fertilizers.
9. Manure separation into fractions by using flocculants, further processing of the solid fraction by composting methods or biofermentation and advanced treatment of liquid fraction by biological methods and application of solid and liquid organic fertilizers.
10. Drying of manure, granulation and application of solid organic fertilizers.
11. Anaerobic treatment with generation of electricity and heat (biogas production) and application of solid and liquid organic fertilizer.
12. Vacuum drying of manure, granulation and application of solid organic fertilizers.

For selected technologies approximate values of economic and environmental indicators (E_{BAT}, C_C, and E_E) are calculated and used to determine the most efficient technology. E_{BAT} is an indicator of economic efficiency of introducing the best available technology (BAT):

$$E_{BAT} = \frac{Cop}{Lb - L} \tag{1}$$

where *Cop* – annual operating costs for the considered technology; *Lb* – nitrogen loss for reference technology; *L* – nitrogen loss for considered technology;
C_C is comprehensive cost indicator:

$$C_C = \frac{UC_c + UC_{op}}{NUE} \tag{2}$$

where UC_C – unit operating costs (per ton); UC_{OP} – unit capital costs (per ton); NUE (nitrogen use efficiency) index is environmental safety indicator, which shows the preservation of nitrogen and is calculated as the ratio of the amount of nitrogen in raw materials or products at the beginning of the production process to the amount of nitrogen at the time the process is completed (Maximov et al., 2014).

To estimate NUE index for technologies Spesivtsev-Drozdov calculation method was applied (Briukhanov et al., 2016).

E_E is ecological and economic impact of technology introduction:

$$E_E = P_h + P_{en} + Env_P \tag{3}$$

where P_h – profit from sale of additional crops or organic fertilizer; P_{en} – profit or benefit from generated energy (for biogas technology); Env_p – economic effect of reducing negative impacts on the environment.

Various technological solutions were suggested for the most efficient technology and indicators E_{BAT}, C_C, and E_E were calculated for each technological solution.

The third stage is to optimize the technological solution choice by Pareto optimization method by three indicators: E_{BAT}, C_C, and E_E. If optimization result is several variants (not one), then the final decision is taken by an expert.

RESULTS AND DISCUSSION

Experience of using the proposed method for assessing the potential of modernization of existing farms showed good results – provided specific farms solutions allow to reduce operating costs and/or reduce nitrogen loss.

Consider the application of the method to select manure utilization technology for cattle farm with loose tied housing system. Total animal stock is 2,600 head, manure water content is 92%, average transportation distance of organic fertilizers is 10 km. In first stage 4 technologies were selected for such farms:

1. Long-term maturing and application of liquid organic fertilizer.
2. Manure separation into fractions with further processing of the solid fraction by composting methods and long-term maturing of the liquid fraction and application of solid and liquid organic fertilizers.
3. Manure separation into fractions with further processing of the solid fraction by biofermentation and long-term maturing of the liquid fraction and application of solid and liquid organic fertilizers.

4. Anaerobic treatment with generation of electricity and heat (biogas production) and application of solid and liquid organic fertilizer.

Comparison of indicative values of technologies indicators is shown in Figs 1 & 2.

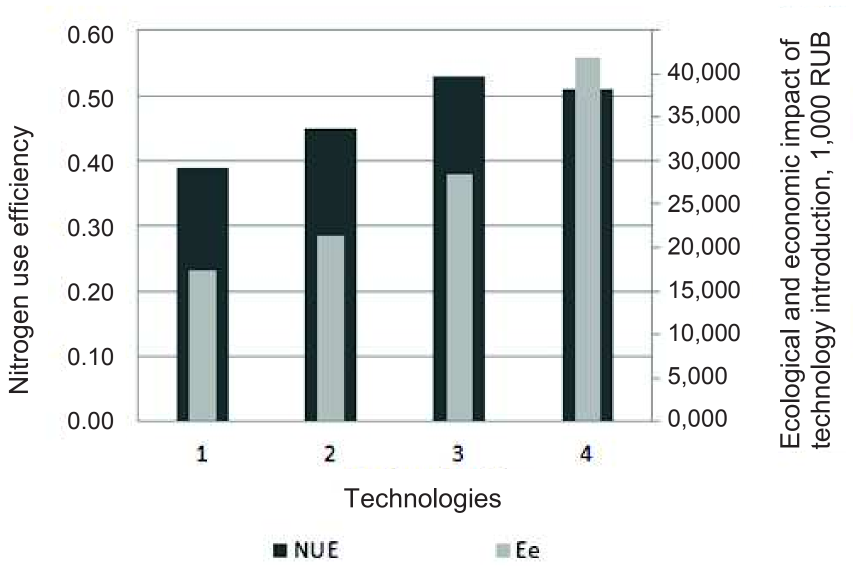

Figure 1. Comparison of NUE and E_E indicators for selected technologies.

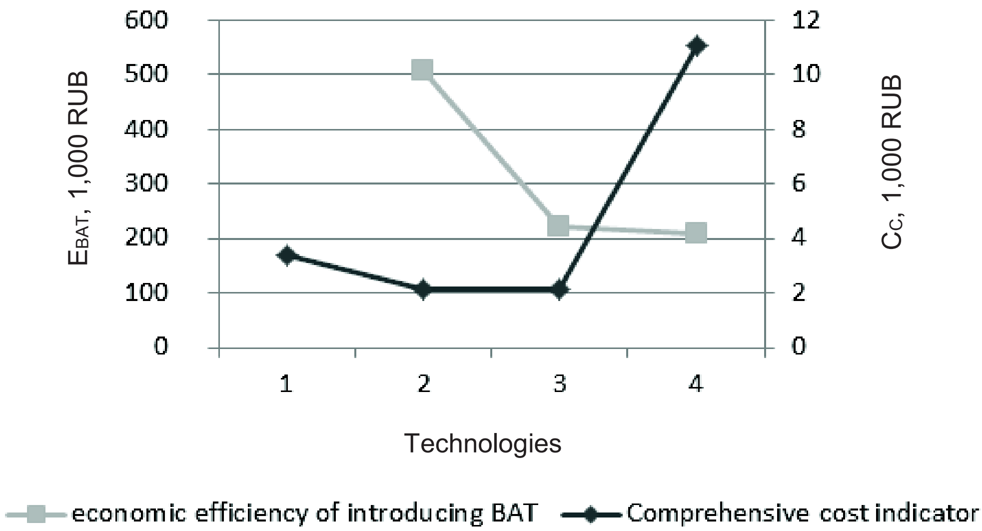

Figure 2. Comparison of E_{BAT} and C_C indicators for selected technologies.

The most rational in this case is Technology 3. For this technology, 12 technological solutions were formed taking into account the farm size with various equipments used in different combinations. The calculated data for the technological solutions are shown in Table 1.

Table 1. Calculated data for the technological solutions based on Technology 3

Indicator		C_C	E_E	E_{BAT}
Unit		1,000 RUB	1,000 RUB	1,000 RUB per ton
Optimization direction		min	max	min
Technological solutions	1	41,306	28,428.8	-*
(based onTechnology 3)	2	42,401	29,925.0	883.24
	3	43,071	34,912.5	275.20
	4	23,408	31,421.3	603.18
	5	23,774	33,416.3	409.21
	6	22,678	38,403.8	208.33
	7	42,888	27,431.3	-**
	8	42,888	28,927.5	1,666.08
	9	42,768	33,915.0	308.81
	10	19,756	29,925.0	854.45
	11	20,121	31,920.0	497.36
	12	19,025	37,406.3	221.70

* First technological solution is reference solution (for calculating E_{BAT} indicator); ** The seventh technological solution is less effective than the reference solution (in terms of nitrogen loss).

In this case, the Pareto optimal technological solutions are 6 and 12. They include the use of covered lagoons for storage and machines for spreading liquid fertilizer with hose or injection systems.

Application experience of the method for over 50 farms located in the North-West Russia shows that the average values of nitrogen preservation in the manure, which may be achieved without involving excessive costs, are 72% for cattle manure, 70% for pig manure and 78% for poultry manure.

CONCLUSIONS

1. Experience of using of the proposed method for existing farms showed good results – in most cases it is possible to reduce operating costs and / or nitrogen loss.
2. The method can be used for modernization of existing farms and selection the most rational manure utilization technology when establishing a new farm.
3. Application of the method has revealed that average values of nitrogen preservation in the manure, which may be achieved without involving excessive costs, are 72% for cattle manure, 70% for pig manure and 78% for poultry manure.

REFERENCES

Best Available Techniques (BAT) Reference Document for the Intensive Rearing of Poultry or Pigs FINAL Draft – 2015. [online] [11.04.2017]. Available at: http://eippcb.jrc.ec.europa.eu/reference/BREF/IRPP_Final_Draft_082015_bw.pdf

BriukhanovA, Y., Trifanov, A. V., Spesivtsev, A. V. & Subbotin, I. A. 2016, Logical-linguistic modeling in addressing agro-environmental challenges. In: *XIX IEEE International Conference on Soft Computing and Measurements (SCM)*, St. Petersburg, pp. 164–166. doi: 10.1109/SCM.2016.7519716

Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs 2003. [online] [11.04.2017]. Available at: http://eippcb.jrc.ec.europa.eu/reference/BREF/irpp_bref_0703.pdf

Subbotin, I. & Vasilev, E. 2016, Formalization of criteria for determining best available technologies: the case of Russia / ENGINEERING FOR RURAL DEVELOPMENT Proceedings. P. 845–850.

Maximov, D.A., Bryukhanov, A.Y., Subbotin, I.A. & Vasilyev, E.V. 2014, Selecting manure management technologies to reduce ammonia emissions from big livestock farms in the Northwestern Federal District of Russia. *Ammonia workshop 2012 Saint Petersburg. Abating ammonia emissions in the UNECE and EECCA region.* RIVM, Bilthoven, The Netherlands, pp. 163–168.