IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Engineering solutions of environmental problems in organic waste handling

To cite this article: A Y Briukhanov *et al* 2017 *IOP Conf. Ser.: Earth Environ. Sci.* **87** 042001

View the article online for updates and enhancements.

You may also like

- From the Paris Agreement to corporate climate commitments: evaluation of seven methods for setting 'science-based' emission targets
Anders Bjørn, Shannon Lloyd and Damon Matthews
- Precision livestock farming in the context of meat safety assurance system
I Nastasijevic, I Brankovic Lazic and Z Petrovic
- Global impacts of the meat trade on in-stream organic river pollution: the importance of spatially distributed hydrological conditions
Yingrong Wen, Gerrit Schoups and Nick van de Giesen

This content was downloaded from IP address 18.224.109.21 on 07/06/2024 at 03:09

Engineering solutions of environmental problems in organic waste handling

A Y Briukhanov[1], E V Vasilev[1], E V Shalavina[1] and O N Kucheruk[2]

[1] Institute for Engineering and Environmental Problems in Agricultural Production (IEEP), 3, Filtrovskoje Shosse p.o. Tiarlevo Saint Petersburg-Pavlovsk 196625, Russia
[2] Far Eastern Federal University, 8 Sukhanova St., Vladivostok 690090, Russia

E-mail: shalavinaev@mail.ru

Abstract. This study shows the urgent need to consider modernization of agricultural production in terms of sustainable development, which takes into account environmental implications of intensive technologies in livestock farming. Some science-based approaches are offered to address related environmental challenges. High-end technologies of organic livestock waste processing were substantiated by the feasibility study and nutrient balance calculation. The technologies were assessed on the basis of best available techniques criteria, including measures such as specific capital and operational costs associated with nutrient conservation and their delivery to the plants.

1. Introduction

Agriculture Development Program for the Russian Federation as a whole and the Northwestern Federal District in particular stipulates the substantial increase in animal and poultry stock. This will be achieved through the reconstruction of the existing livestock complexes and construction of the new ones with the use of highly intensive technologies and spot concentration of animals. Such development path adds to marketability and effectiveness of farming owing to the rational distribution of productive forces and the choice of highly efficient and power-saving technological solutions. The experience of intensive farming development demonstrates, however, that spot concentration of considerable animal stock creates big problems in securing ecological compliance, in the first place, due to the need to utilize big amounts of animal manure – up to 100,000 tons per farm annually [1].

The strategy of low environmental impact of the farm waste lies in its timely processing with the minimal loss of nutrients in the resulting organic fertilizer. However, certain lack of interaction between the livestock and plant production sectors leads to accumulation of waste in the form of raw manure, significantly increasing the ecological stress. So the rational utilization of manure becomes a pressing problem in the Northwestern Federal District of Russia.

2. Materials and methods

Taking into account the current situation with the animal waste handling in the agro-industrial complex of the Northwestern Federal District of the Russian Federation, the waste generation was analysed in different parts of the region through the animal and poultry manure output calculation with the use of official statistics on available animal stock, results of questioning and on-site inspection of the farms, some approaches and principles of engineering ecology, as well as regulatory documents

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

and standards.

The highest stock density, and correspondingly, the animal and poultry manure output in the Northwestern Federal District are registered in Leningrad Region. So this area was analysed district-wise in more detail with due regard to animal and poultry housing practices in place.

To conduct the study and generate the proposals, a special software was created for the environmental and economic assessment of manure handling technologies [2].

Based on investigation outcomes, the perspective technologies for animal and poultry manure processing and utilization were substantiated and recommended for application in Northwestern Federal District, [3, 4]. Selected elements of these technologies were tested in laboratory and field conditions in the Institute for Engineering and Environmental Problems in Agricultural Production (IEEP) and on the farms in Leningrad Region. The technologies were assessed by best available techniques (BAT) criteria.

3. Results and discussion

The study has shown that the total annual amount of animal and poultry manure produced in the Northwestern Federal District of the Russian Federation is around 14.5 million tons, with Leningrad Region accounting for around 5 million tons.

The major part of overall produced manure is semi-liquid (51%), with 85–92% relative moisture content (W), and liquid (24%), with $W > 92\%$. The solid manure accounts for 25%. The study has also revealed that the volume of semi-liquid and liquid manure on the farms is increasing, but its nutritive value drops.

The calculation of nutrient (NPK) balance in the manure produced and their removal with the estimated crop yield in Leningrad Region demonstrates that when implementing the Agriculture Development Program in the Russian Federation by the year 2020 all the nutrients from organic fertilizers will be consumed be the cultivated farm crops and may replace the major part of mineral fertilizers. The outcomes of integrated estimation of nutrient balance (N in particular) in Leningrad Region are shown in Figure 1. Only two districts of the region – Vyborgskij and Kirovskij – feature the unfavourable situation with the use of nutrients. The primary reason is the location of large-scale poultry factories and underdeveloped plant production sector.

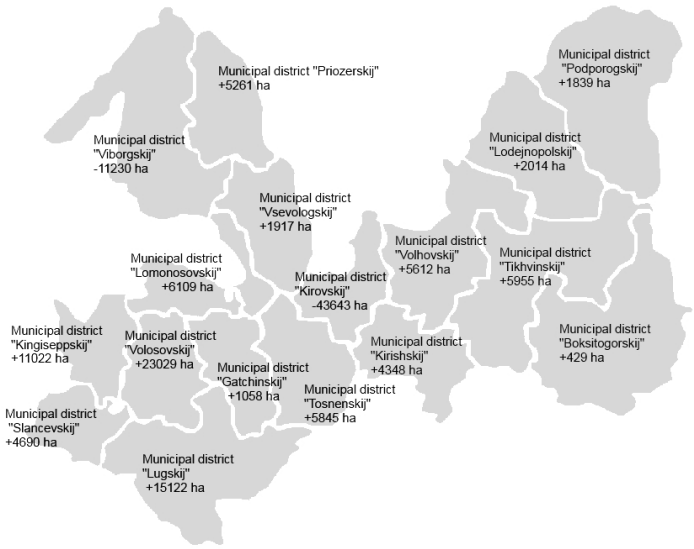


Figure 1. District-wise land reserve for organic fertilizers application in Leningrad Region.

The above map demonstrates the general situation in the districts of Leningrad Region but not at separate agricultural enterprises. To estimate the environmental conditions and draw reasonable conclusions, the calculation of nutrient budget/balance, nitrogen balance in the first place, at a particular farm level is of utmost importance.

The general approach to calculation of N *budget* at the farm level is shown in Figure 2 [5].

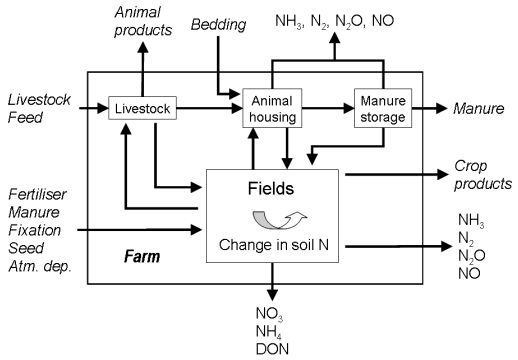
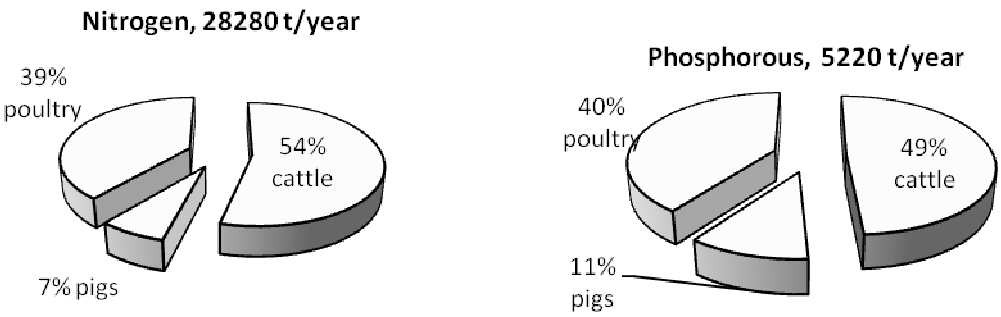


Figure 2: Calculation of a farm N budget.

When calculating a farm nitrogen *balance* (farm-gate balance), the main N inputs are from feed and fertilizers and the main outputs are crop and animal products. The nitrogen flows inside a farm are not considered [6].

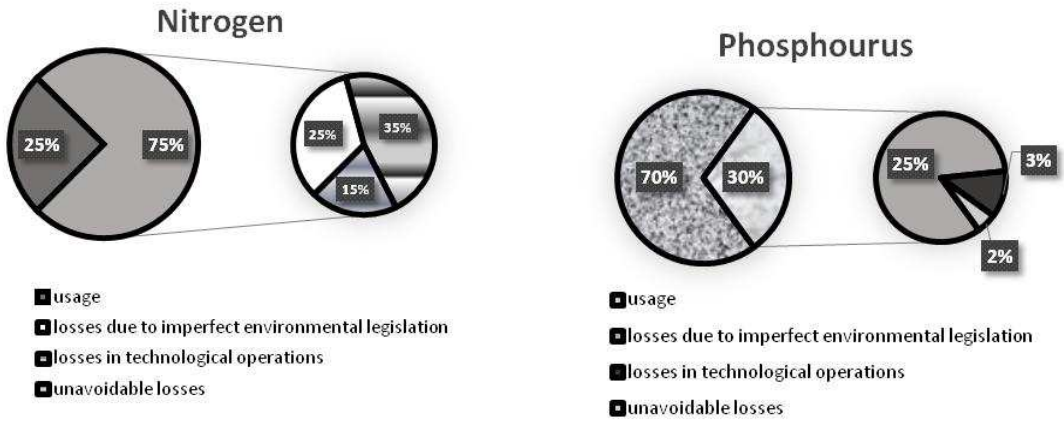
The above scheme shows that one of the important issues in calculation of N budget/balance is the nutrient input with organic fertilizers, which depends upon manure processing technologies and related nutrients loss.

In the framework of several international projects (BaltHazAR, BASE, ERAB and others) it was estimated that Leningrad Region produces annually around 28,280 tons of animal/poultry manure nitrogen and 5,220 tons of animal/ poultry manure phosphorous. At the same time, the N loss is up to 75% and the P loss is up to 29%, Figure 3 and Figure 4.



a b

Figure 3: N (a) and P (b) content in animal and poultry manure produced in Leningrad Region.



a b

Figure 4: The use and loss of N (a) and P (b) from animal and poultry manure in Leningrad Region.

Figure 4 shows that the nitrogen loss mainly occurs due to the inefficient technologies applied, while the phosphorous loss is related to imperfect environmental legislation and the lack of economic incentives for the application of high-quality organic fertilizers.

To calculate the nutrients loss on production cycle stages of livestock waste bioconversion into organic fertilizer, a mathematical model was created at IEEP.

The objective function of the mathematical model Y_{Ntotal} in general is the sum of losses in all technological operations:

$$Y_{Ntotal} = \sum_{i=1}^{K_{OP}} Y_{Ni}\,, \tag{1}$$

where

Y_{Ni} is the nitrogen loss during ith operation,

K_{OP} is the number of technological operations.

For the sequence of technological operations in the bioconversion cycle, the equation of nutrient loss takes the following form:

$$Y_{Ni} = \sum_{i=1}^{K_{OP}} \left\{ \begin{array}{l} [1-ktv1_1 \times ktv2_1 \times ktv3_1] \times [1-ktv1_2 \times ktv2_2 \times ktv3_2] \times .. \\ ..\times [1-ktv1_i \times ktv2_i \times ktv3_i] \times .. \\ ....\times [1-ktv1_{K_{OP}} \times ktv2_{K_{OP}} \times ktv3_{K_{OP}}] \end{array} \right\} \times 100 \to \min[\%] \tag{2}$$

where $ktv1$, $ktv2$, $ktv3$ are the coefficients of nutrient conservation, which express the dependence on technological operation, equipment and work mode.

In the advanced countries of the world, as a result of many years of increased attention to the issues of food and environmental safety, a highly efficient system of recommended for application Best Available Techniques (BATs) has been established on the basis of economically justified costs, sustainable use of natural resources, scientifically substantiated technological regulations of operations, including wastewater and emissions treatment, and waste management. Guidance books on BAT, referred to as BREF documents (Best Available Techniques REFerence Document), will be used as the basis for creating the similar Russian reference books on BAT.

For the integrated, based on BAT criteria, assessment of manure processing and use technologies the measures of specific capital costs K and operational costs E associated with nutrient conservation and their delivery to the plants are calculated as follows:

$$K = \left\{ \sum_{i=1}^{K_{OP}} Z_{si} + Z_{oi} + Z_{di} \right\} \cdot \left\{ M_{N1} - \sum_{i=1}^{K_{OP}} \left[\left(1 - \frac{M_{N_{i+1}}}{M_{N_i}} \right) \cdot M_{N_{i-1}} \right] \right\}^{-1} \tag{3}$$

$$E = \left\{ \sum_{i=1}^{K_{OP}} E_{gi} \right\} \cdot \left\{ M_{N1} - \sum_{i=1}^{K_{OP}} \left[\left(1 - \frac{M_{N_{i+1}}}{M_{N_i}} \right) \cdot M_{N_{i-1}} \right] \right\}^{-1}, \tag{4}$$

where

K are capital costs associated with nutrient conservation;

K_{OP} is the number of technological operations in the bioconversion cycle;

Z_{si} are the costs associated with buildings required for the ith technological operation;

Z_{oi} are the costs associated with the fixed equipment required for the ith technological operation;

Z_{di} are the costs associated with the mobile devices required for the ith technological operation;

M_{N1} is the initial mass of total *N* before the full bioconversion cycle (as of the start of the first technological operation);
$M_{N_{i+1}}$ is the final mass of total *N* after the full bioconversion cycle is completed)as of the end of the final technological operation);
E are the operational costs associated with nutrient conservation;
E_{gi} are the operational costs associated with *i*th technological operation.

Based on the above model and offered measures, an information system was created by IEEP for the choice and economical estimation of technological solutions for manure utilization. This system supports the decision-making process and is created on the basis of expert knowledge, which is formalized as a data model and algorithms for choosing the technology options. By a number of previously entered farm operation factors, such as type and number of livestock, availability and amount of land for organic fertilizer application, etc., the system suggests the techniques most suitable for the case under consideration and calculates the consolidated economic indices of each offered technique for the final decision-making. The framework of the system includes a catalogue of available and recommended animal and poultry manure utilization techniques, with both traditional and promising practices, such as biogas production and waste combustion, being listed.

Interested readers can refer this system at http://eco.sznii.ru. Summarizing the study outcomes, a number of technologies of manure processing and use may be recommended for application in the Northwestern Federal District, table 1.

Table 1. Recommended technologies of manure processing and use with the nutrient loss indicators

Processing technology	Nutrient loss	
	N_{total}, %	P_{total}, %
Bioferementation in the chamber-type installations	12.9	0.6
Bioferementation in the drum-type installations	6.1	0.7
Passive composting on field-edge sites	25	7
Multi-stage processing of liquid pig manure (biological cleaning)	19.6	4.6

It should be mentioned that the least nutrient loss is observed in the technology of solid animal and poultry manure processing in the designed drum-type bio-fermenter, with the latter having two useful model patents of the Russian Federation nos 145378 and 146604. To process the liquid pig manure in view of the fact that most pig farms cannot utilizer the organic fertilizers on their own lands, the technology of multi-stage processing with biological cleaning is recommended, which also has a useful model patent of the Russian Federation no.139469.

Bio-ferementation of the solid manure (solid fraction) in the drum-type bio-fermenter results from the life activity of aerobic microorganisms. Optimal values of moisture content of the initial material of 40–60% and the most suitable technical and technological parameters and operation modes of the installation make this activity more intensive. As a result of the biothermal treatment of bedding poultry manure, the high-nutrient compost is produced with 2.9% N, 1.8% P, and 1.1% K on dry basis content, featuring dark colour, friable structure and faint ammonia odour [3].

Multi-stage processing of liquid manure (liquid fraction) produces the solid organic fertilizer (40% from the initial manure weight) and purified liquid (60% from the initial manure weight) with N_{total} content of 1,000 mg/kg and P_{total} content of 13 mg/kg. Multi-stage processing removes the pathogens and lowers the organic substances concentration in the liquid fraction manifold that allows reducing significantly the area of land required for the fertilizer application and the transportation costs of fertilizers to the application fields [7].

4. Conclusion

The study demonstrated that to develop the sustainable intensive agricultural production and to lower its adverse impact on environment under conditions of the Northwestern Federal District, the livestock and plant production sectors are to be improved closely interrelated on the basis of the nutrient balance calculation, with the main part in this interrelation belonging to the processing of animal and poultry manure and the use of organic fertilizers. To address in part this global task:

1. a model was created to assess the nutrient loss during the manure processing into organic fertilizers, which takes into account the specific features of relevant basic technologies;
2. based on the BAT criteria, the measures were offered to assess the manure processing and use technologies, namely capital and operational costs associated with nutrient conservation and their delivery to plants;
3. based on the created model and offered measures, an information system was created for the choice and economical estimation of technological solutions for manure utilization;
4. the recommended technologies of animal and poultry manure processing with the minimal nutrient loss and economically feasible practical introduction were substantiated for application under conditions of the Northwestern Federal District; and
5. the most promising high-end technologies for processing animal and poultry manure were identified.

5. Acknowledgments

The part of the above research was funded from EU-HELCOM projects “Baltic Hazardous Waste and Agricultural Releases Reduction – BaltHazAR” (2009 – 2013) and “Implementation of the HELCOM Baltic Sea Action Plan – BASE project” (2013-2014) and the international project “Sustainable animal and poultry manure handling in farms of Leningrad Oblast, Russia”, realized by Nordic Environment Finance Corporation (NEFCO) as Implementing Agency and Leningrad Region Government, with Northern Dimension Environmental Partnership (NDEP), the Ministry of the Environment of Finland (FMoE), the Ministry of Agriculture and Forestry of Finland (FMoAF) as Financiers.

References

[1] Briukhanov A Yu, Maximov D A, Huhta H, Vasiliev E V, Minin V B and Subbotin I A 2012 *Recommendations on arrangement of full-scale ecological monitoring and control of animal and poultry manure processing and application systems. The order of development of Technological Regulations* (Saint Petersburg: SZNIIMESH) p 56

[2] Subbotin I A 2014 The choice of best available techniques for animal and poultry manure processing *Proc. of the Int. Sc. and Pract. Conf. with virtual participation “Problems of mechanisation of agrochemical service in agriculture”* (Ryazan: FGBNU VNIMS) p 199

[3] Uvarov R A 2015 Review of bioconversion techniques of cattle manure most suited for the conditions of the North-West Russia. *Innovations in Agriculture* **2 (12)** 273 – 277

[4] Orlova O V, Afansiev V N and Arkhipchenko I A 2009 Production technology of efficient biofertilisers from poultry manure with the use of microbial inoculums *Ecology and Industry in Russia* **11** 6

[5] Jarvis S , Hutchings N, Brentrup F, Olesen J E and van der Hoek K W 2011 Nitrogen flows in farming systems across Europe *The European Nitrogen Assessment: Sources, Effects and Policy Perspectives* (Great Britain: Cambridge University) p 228

[6] Moklyachuk L I, Lukin S M, Kozlova N P and Matrkoplishvili M M 2014 Environment pollution with reactive nitrogen from agricultural sources: problems and solutions. *Agroecological Journal* **1** 13 – 20

[7] Shalavina E V 2014 The choice of the best available technique of pig manure liquid fraction processing *Innovations in Agriculture* **3** 179 - 183