Parameters of optimized system of technological process of waste water disinfection of livestock enterprises in integrated physico-chemical effects

N V Byshov1, I A Uspensky1, I A Yukhin1, N V Limarenko2, I V Fadeev3 and S D Fomin4

1Ryazan State Agro-technological University named after P A Kostychev, 1, Kostychev Avenue, Ryazan, 39000, Russia
2Don State Technical University, 1, Gagarin sq., Rostov-on-Don, 340000, Russia
3Chuvash State Pedagogical University, 38, street Karl Marks, Cheboksary, 428000, Russia
4Volgograd State Agrarian University, 26, University Avenue, Volgograd, 400002, Russia

E-mail: fsd_58@mail.ru, limarenkodstu@yandex.ru

Abstract. The development of livestock production is one of the main factors in ensuring food security of most states. Unfortunately, the safe use of livestock wastes is impossible without their decontamination. In this paper the parameters of the method of disinfection of the liquid fraction of livestock wastes with the complex physicochemical effect of a rotating electromagnetic field with ferromagnetic rods moving inside it and active chlorine are optimized. The result of optimization is a reduction in the electric energy consumption of the process while meeting the requirements for epidemiological safety. The parameters of the optimized system have the following definitions: the filling of the working zone of the inductor with ferromagnetic rods $\rho = 5.18\%$; magnetic induction $B = 40$ mT; ratio of the length of the ferromagnetic rods to their diameter $l/d = 25$; active chlorine concentration $\omega = 15.60$ mg/l; duration of action $t = 2.81$ s; while the specific electricity consumption is $N_u = 3.09$ W·c/ml, and the epidemiological safety indicators do not exceed the permissible limits of normative documents.

1. Introduction
Ensuring food security of the country is one of the main factors of socio-economic stability. The livestock sector in the Southern Federal District of the Russian Federation, pig production in particular, makes a significant contribution to the development and maintenance of this cluster. About 65-70% of cattle in this region are concentrated in small farms with a population of up to 1,500 animal units. An important problem in this approach to livestock breeding is the issue of environmentally safe waste management and the development of maximum resource-saving.

According to the set of normative documents State standard 26074-84, State standard 51769-2001 and Methodical Instructions 2.1.5.800-99 the wastes of livestock farms have solid and liquid fractions, the utilization of which must be carried out separately after dividing them. One of the main operations of wastes recycling is the disinfection. In the framework of this study the issue of optimizing the method of disinfection of the liquid fraction was considered. Unfortunately, the methods of disinfection of
livestock wastes that are applied today do not allow taking into account the specifics of this material and that significantly reduces the efficiency of the development of technological approaches to their utilization. Considering the high content of biogenic matter, the most rational variant of utilization is the use of wastes for irrigation of agricultural fields. Advantages of this approach are: rational nature management, increase in soil humus content and, as a consequence, fertility growth. Thus, the task of optimizing the method of disinfection of livestock wastes enterprises is a relevant objective.

According to the analysis of information sources and the results of preliminary studies [1-9], the most promising method for decontaminating livestock wastes from enterprises is the complex physicochemical effect of a rotating electromagnetic field with ferromagnetic rods moving inside it and active chlorine.

The advantages of this impact are:
- prolonged bactericidal effect;
- no correlation of disinfection effect and turbidity, stiffness and pH level of the medium;
- minimization of negative by-products.

The most promising device for implementing the selected impact is the inductor, consisting of the body 1, the working zone tube 2, the inductor 3, the ferromagnetic rods 4. The schematic diagram of the inductor is shown in Figure 1.

![Figure 1. Schematic diagram of the inductor for disinfection in livestock wastes.](image)

2. Materials and methods
Factor analysis and experiment planning. On the basis of factor analysis and the results of preliminary studies performed in [10, 11], the five most significant factors that could influence the technological process of disinfection of wastes in the inductor were selected. The denominations and levels of variation of the selected factors are presented in Table 1.

| Selected factor                                      | Code symbol | Factor levels |
|------------------------------------------------------|-------------|---------------|
| The filling of the working zone of the inductor with ferromagnetic rods \( \rho \), % | \( X_1 \) | 0.74 2.96 5.18 |
| Ratio of the length of the ferromagnetic rods to their diameter \( l/d \) | \( X_2 \) | 5 15 25 |
| Magnetic induction \( B \), mT                         | \( X_3 \) | 40 60 80 |
| Active chlorine concentration \( \omega \), mg/l        | \( X_4 \) | 6 12 18 |
| Duration of action \( t \), s                          | \( X_5 \) | 2 4 6 |
After determining the most significant factors that can influence the technological process of disinfection of wastes in the inductor experimental studies were carried out. To improve the efficiency the mathematical theory of experiment planning was used.

Based on the conducted experimental studies mathematical models were obtained, which allow describing correlation of the selected factors with parameters characterizing the quality of the process of disinfection in the inductor.

The epidemiological state of the wastes, according to STATE standard 51769-2001 and Methodical Instructions 2.1.5.800-99, was characterized by the number of colony forming units of total coliform bacteria (TCB), representing the most typical bioindicator.

\[ y_{ref} = 71.72 - 9.13x_1 + 1.32x_2 - 20.15x_3 - 31.74x_4 - 14.02x_5 + 5.81x_2^2 + 4.31x_1^2 + 7.98x_4^2 + 3.14x_3^2 - 18.92x_5x_4. \]  

(1)

The energy component of the technological process of disinfection of wastes from livestock enterprises was characterized by electric energy consumption and described by equation [11]:

\[ y = 5.59 - 2.14x_1 - 0.44x_2 + 2.24x_3 + 1.14x_4 + 1.52x_1^2 - 1.48x_4^2. \]  

(2)

Materials for the formulation of the optimization problem. The costs of electric energy consumption were chosen as a criterion of optimality of the disinfection process.

The maximum permissible value of TCB, equal to 100 units according to Methodical Instructions 2.1.5.800-99, became a limitation on the quality of disinfection. The frequency of oscillations of the electric current in the network equal to \( f = 50 \text{ Hz} \) also became a limitation. The objective criterion of optimality corresponds to the objective function (2) in the form of a polynomial of the second degree that is the dependence of the optimality criterion on the parameters of the technological process of disinfection. Figure 2 shows the block diagram of the optimization task.

Methods of solving the optimization problem. Exhaustive method and steepest ascent method (or descent, depending on the task of reaching the maximum or minimum) was chosen as the most promising techniques.

The essence of the method of steep ascent is successively stepping along the surface of the response in the direction of the gradient by linear approximation to the investigated response surface.

The advantage of this method is a relatively high efficiency, in terms of time spent on calculations. The disadvantages include the possibility of accepting a local optimum for the global.
The essence of the exhaustive method is the sequential calculation of all possible variants of a combination of the required parameters of the system in the given intervals of their variation.

The advantage of this method is the simplicity of the algorithm, the high reliability of obtaining a global optimum, can serve as a standard for determining the effectiveness of other methods in solving similar problems. The disadvantage is low efficiency, in terms of time spent on calculations.

Technological material and its bacteriological properties for experimental verification of the reliability of optimization results.

The liquid fraction of waste taken from the production premises of the farm was used as the technological material. Assessment of the bacteriological properties of the initial material was carried out under laboratory conditions by sowing it on a nutrient medium.

3. Results and Discussion

The results of optimizing the system parameters performed in the Matlab Simulink software environment are presented in Table 2.

| No. | Parameters of the optimized system                      | Optimization technique | steepest ascent method | exhaustive method |
|-----|--------------------------------------------------------|------------------------|------------------------|-------------------|
| 1   | Criterion of optimality: Electric energy consumption N, W·s/ml |             | 3.10111                | 3.09751          |
| 2   | The maximum permissible value of TCB 100 units         |             | 98.13057               | 98.13417         |
| 3   | The filling of the working zone of the inductor with ferromagnetic rods ρ, % |             | 5.18097                | 5.18457          |
| 4   | Ratio of the length of the ferromagnetic rods to their diameter l/d |             | 25.08413               | 25.08753         |
| 5   | Magnetic induction B, mT                                |             | 40.04792               | 40.05152         |
| 6   | Active chlorine concentration ω, mg/l                  |             | 15.64570               | 15.64960         |
| 7   | Duration of action t, s                                |             | 2.81349                | 2.81709          |

Based on the above, the following conclusions were made:

- divergence of the results, with the methods of calculation considered, does not exceed 0.36%, which is insignificant;
- the time taken to calculate by the steepest ascent method was 3 seconds, and by the exhaustive method – 15 seconds, which is equally acceptable. In this case, the exhaustive method is the most cost-intensive in terms of the duration of the calculations. Therefore, when choosing the method for solving the majority of technical optimization problems of this class, it is necessary to be guided by the reliability of the result and the simplicity of the method and not by the time spent performing calculations.

4. Conclusion

In the course of the study the following parameters of the optimized system of the process of disinfection of livestock wastes in the inductor were obtained: ρ= 5.18 %; l/d=25; B=40 mT; ω=15.60 mg/l; t =2.81 s; criterion of optimality (electric energy consumption of disinfection process) equals N =3.09 W·s/mg; the maximum permissible value of TCB equals 100 units; calculated value of TCB number is 98 units.
References

[1] Bondarenko A M, Lipkovitch E I and Lipkovitch I E 2017 J. of Industrial Pollution Control. 1(33) 1163–1170

[2] Byshov N V, Habarova D V, Vinogradov B I and Kochurov B I 2018 South of Russia: ecology, development 2 (13) 132–143

[3] Dotson A D, Rodriguez C E, Linden K G 2012 J. American Water Works Association 104 (5) 318–324

[4] Briukhanov A, Subbotin I, Uvarov R and Vasilev E 2017 Agronomy Research 15(3) 658–663

[5] Guan C, Yang J and Shan J 2014. Nongye Gongcheng Xuebao. Transactions of the Chinese Society of Agricultural Engineering 30(23) 253–259

[6] Shchegolkov A V, Trufanov B S, Hmyrov V D, Kudenko V B, Guryanova Y V and Guryanov D V 2017 Nano Hybrids and Composites 13 130. Uvarov R, Briukhanov A, Subbotin I and Shalavina E. 2017 Agronomy Research 15(3) 915–920

[7] Bryukhanov A, Gaas A 2016 Ecology and industry of Russia 2 (20) 60–63

[8] Daifullah A A, Girgis B S and Gad H M 2003 Materials Letters 57(11) 1723–1731

[9] Limarenko N V 2017. News of Higher Educational Institutions. Food technology. 3 108–112

[10] Meskhi B Ch, Limarenko N V, Zharov V P and Shapoval B G 2017. Vestnik of Don state technical university 4(91) 129–135