**REPUBLIC OF AZERBAIJAN**

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# ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

# DEVELOPMENT OF ECOTECHNOLOGY OF SOLID HOUSEHOLD WASTE ON THE BASIS OF PHYSICAL-CHEMICAL STUDY OF NON-METAL MINERALS

Speciality: 3303.01– Chemical technology and engineering

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## GENERAL CHARACTERISTICS OF THE WORK

**Relevance of the topic and degree of development.** In recent years, the all-round development of the republic has led to the growth of the urban population and the expansion of cities. On the one hand, we accept development as a good thing, on the other hand it is necessary to take into account the environmental consequences it causes.

Thus, the rapid development of the industry, a large amount of production waste, and the increase in the population lead to the generation of solid household waste in the city. One of the main issues facing us now is the systematization of waste generated in the territory of the republic and the search for ways of their efficient disposal[1].

In the modern world, many scientists are engaged in solving this problem. Household and industrial wastes are simply burned or disposed of by burying in specially prepared pits[2].

In our scientific researches, this issue was approached from a completely different aspect, the household and industrial waste generated in the territory of the republic today was considered as a raw material base. The disposal of these wastes has been replaced by different processing methods.

One of such processing methods is the method of neutralization of solid household waste with the presence of minerals of non-ore origin, weak nitric and sulfuric acids. During this process, various microorganisms contained in solid household waste are neutralized by means of a weak acid solution, and at the same time, organic and nutrient substances are extracted from its contents and transferred to the solution. After the solution is neutralized and filtered, an organic-mineral complex fertilizer enriched with N, P, K, humus and various trace elements is obtained. The participation of weak nitric acid in the process affects the enrichment of the composition of the obtained

[1] Comprehensive action plan for 2006-2010 to improve the environmental situation in the Republic of Azerbaijan.

[2] Golubli, A.K. Solid household waste / A.K. Golubli, I.N. Klepatskaya, L.Ya. Shubov // Resources. Information. Supply. Competition: Analytical Journal, – 2006. No. 3, – c.48-51.

fertilizer with nitrogen, while the presence of weak sulfuric acid and gypsum affects the melioration properties of the prepared fertilizer. The organic-mineral-containing solid waste generated during the process can be used as an organic mineral fertilizer with weak fertilizer properties and as a chemical ameliorant during the improvement of salinized soils.

For this reason, the neutralization of solid household waste with the addition of minerals of non-ore origin and the presence of various acid solutions, as well as the development of new methods of obtaining organic-mineral fertilizers and meliorating substances from it, being **an urgent issue**, will have a positive effect on ensuring food security on a national scale, eliminating water shortages. Increasing the fertility of the soil, creating an abundance of crops, as well as improving the ecological situation in the republic and protecting the environment.

**The object and subject of the research:** It is solid household waste generated in large quantities in the territory of the Republic of Azerbaijan. Gypsum, mineral acids were used as additional raw materials which are modifiers in the development of production technology of organic mineral complex fertilizers and chemical ameliorants.

**The purpose and objectives of the study:** As a result of the addition of non-ore mineral substances, decomposition with the presence of acid solutions, and at the same time neutralization of solid household waste, which is a cheap raw material rich in nutritious minerals and organic substances, formed in the territory of the Republic, the obtaining of organic-mineral complex fertilizers and melioration substances is a new ecologically clean, as well as the development of new washing technologies for the purpose of ecological restoration of soils that have been subjected to salinization in various degrees through the development and application of economically efficient technologies.

**Research methods:** General principles derived from the essence of the solved issues and researched processes were used in the conducted research work. The works were prepared based on the study of existing techniques and technologies, their analysis and detection of their shortcomings. Evaluation, assignments, conducting experiments,

analyzing the obtained results, etc. issues are based on existing methodologies generally accepted and widely used. The "systematic approach" method was used during problem solving and generalization. The correctness, integrity and feasibility of the proposed theoretical considerations were checked on the basis of concrete experiments.

**The main clauses that have been defended:** In order to achieve the goal, the following issues were considered:

– In the process of production of mineral fertilizers and chemical ameliorants, justification of solid household waste, - non-traditional raw material, is suitable for production of organic-mineral complex fertilizers;

– Neutralization of solid household waste with the presence of weak solutions of mineral acids ($H_2SO_4$ and $HNO_3$) and decomposition to obtain organic mineral complex fertilizers and melioration substances, making them useful as raw materials;

– Selection of non-ore minerals used as modifiers and study of the conditions of inclusion in the process;

– Determination of effective technological parameters during the obtaining of organic mineral complex fertilizers and melioration substances based on solid household waste;

– Studying the effect of decomposition of solid household waste as the main raw material and the used modifier with the application of acid solutions and, as a result, the increase in the amount of calcium compounds of nutrient elements included in the composition of fertilizers;

– Study of the effect of the added modifier on the quality of the fertilizer;

– Studying the effect of prepared organic-mineral liquid fertilizers on the productivity of agricultural plants;

– Studying the optimal parameters of the dosage and the washing rate of the meliorating agent to develop washing technologies for the improvement of various degrees of salinized soils with the application of organic-mineral meliorating substances and applying them to production;

– Development of a technological scheme for the obtaining of

organic-mineral complex fertilizers and ameliorative substances based on solid household waste and modifiers;

– Development of a scheme of a universal technological unit for the preparation of organic mineral complex fertilizer based on the used technological scheme.

**Scientific novelty of the research:** As a result of the conducted research, for the first time in the republic, the technology of production of ameliorative substances was developed. The optimal dose of ameliorant defined under experimental conditions was determined for the application of the obtained ameliorative substances to agriculture, i.e. for the improvement of ecologically disturbed soils. Washing technologies with determined washing norms for specific regional soils have been developed and recommended for application in production.

For the first time, technologies for the preparation and production of ameliorative substances with humus and $CaSO_4$ and liquid fertilizer with ameliorative properties and weak fertilizer properties were developed.

Based on scientific research the following technologies were developed for the first time:

– Obtaining of organic-mineral liquid fertilizer and ameliorative substance based on solid household waste and 10% nitric acid;

– Obtaining of solid household waste, 10% nitric acid and organic-mineral liquid fertilizer and melioration agent based on late;

– Obtaining of organic-mineral liquid fertilizer and ameliorative substance based on solid household waste and 10% sulfuric acid;

**Theoretical and practical importance of research:** Based on the conducted scientific research, the scientific basis of the technology of obtaining organic mineral fertilizer from solid household waste has been developed. The possibility of using non-traditional raw materials as a modifier in this technology has been scientifically proven, it has been shown that the production of prepared fertilizers is of great importance for the republic.

If we take into account that the main part of the fertilizers used in the territory of the republic is imported, then the practical significance of the developed technologies becomes clear.

Thus, the production of organic mineral fertilizers with the proposed technologies prevents the introduction of fertilizers from outside, which are in great demand in agriculture today and have a positive effect on increasing the productivity of plants, which is practically a great impetus to the development of the agricultural industry, as well as ensuring the food safety of the population of the republic.

**Approval and application:** The results of the dissertation work were discussed in a report at the scientific conferences listed below:

Doctoral students, masters and young researchers' 10th Republican conference dedicated to the 93rd anniversary of the birth of the national leader Heydar Aliyev "Actual problems of chemistry" (Baku-2016); ; V-th International conference "Actual scientific & technical issues of chemical safety" (Kazan-2020); Scientific-practical conference of young scientists and researchers dedicated to the 100th anniversary of ASOIU (Baku-2020); Western Caspian University scientific-practical conference "Problems and development trends of modern chemistry" (Baku-2020); Ganja State University "Current problems of modern natural and economic sciences" International scientific conference (Ganja-2022); II international scientific conference "Reconstruction and recovery in post-conflict situations" (ASSU-2022); "Reconstruction and recovery in post-conflict situations" III international scientific conference (ASSU-2023); "Progressive Research In The Modern World" proceeding of VI international scientific and practical conference (USA, Boston-2023); V International Scientific and Practical Conference «Questions. hypotheses. answers: science XXI century" (Canada-2023).

The results obtained from scientific researches were applied in Salyan, Saatli and Agdash regions of the republic. Agricultural tests of the obtained organic mineral fertilizer were carried out under cotton and barley plants. With the application of fertilizers obtained at the farm located in the village of Khalaj, Salyan region, the productivity of the cotton plant was 30.6-31.7 centners per hectare, and in the test experimental areas, the productivity of the cotton plant varied between 31.8-32.3 centners. The tests conducted in the territory of Agdash region were conducted under the barley plant. The productivity of

barley changed in the range of 24.1-25.0 c/ha. In the washing experiment carried out in the territory of that region, the degree of salinization of the soil in the 0-50 cm layer was 0.99, respectively, during the washing carried out with 4000, 8000 and 12000 $m^3$/ha water norms by giving 10 tons of ameliorative material per hectare; was 0.99-0.42 and 0.21%, in a layer of 50-100 cm. It decreased to 2.06, 1.03 and 0.47%. Salinization has been completely eliminated.

25 scientific works covering the topic of the dissertation have been published, 12 of them are articles published in local and foreign journals. Including, 2 patents and 3 authorship certificates were obtained.

**Personal involvement of the author.** The author independently participated in the implementation of the dissertation work - planning the work, collecting literature materials, conducting basic experimental studies, mathematical calculations, including personally participating in the writing of the article, thesis and dissertation. The author's share in published scientific works is decisive.

**The name of the institution where the dissertation work was performed.** Dissertation work was carried out at the "Chemistry and Inorganic Substances Technology" department of Azerbaijan State Oil and Industry University.

**Scope and structure of work.** The dissertation consists of an introduction, 5 chapters, conclusion, appendix, 15 figures, 68 tables, literature list of 195 works, and the total volume is 180 printed sheets. Dissertation work consists of 185693 scans (introduction - 12514, chapter I - 49093, chapter II - 15314, chapter III - 24822, chapter IV - 12262, chapter V - 67246 and result – 4442), excluding figures, tables, list of literature.

**In the introductory** part, information is provided on the relevance of the problem to be solved, the purpose of the work to be performed, and information on the novelty of the received scientific and practical results is given.

**The first** chapter consists of literature review. In this chapter, the known methods of neutralization and disposal of solid household waste, as well as the scientific research carried out in the direction of obtaining mineral fertilizers from them, are given in detail.

**The second** chapter provides information about the raw materials used during the research, their chemical composition, their locations and their resources in the territory of the republic. The method of carrying out the experiments and both macro and micro fertilizers and other necessary analyzes are given in this chapter.

**Third** the chapter is dedicated to the technologies of preparation of organic mineral fertilizers and ameliorative substances. In this chapter, information is provided on increasing the effective quality of organic-mineral liquid fertilizers and meliorating substances obtained by neutralizing solid household waste with the participation of a modifier.

**The fourth** chapter provides information on agricultural tests of prepared liquid and solid fertilizers. Information about the effect of prepared fertilizers on the productivity of plants and the amount of yield increase is provided.

**The fifth** chapter contains information about the effect of ameliorative fertilizers and chemical ameliorants on the ecological restoration of salinized soils. In order to study the practical effect of ameliorants in different doses, the results of washing experiments conducted on saline soils taken from Agdash region were given and statistical reports of the obtained data were made.

At the end, the results and the list of used literature are given.

## MAIN CONTENTS OF THE WORK

**The current state of the research conducted in the direction of disposal of solid household waste and the conducted scientific research works.**

In this chapter of the work, information on methods of obtaining mineral fertilizers based on minerals, organic fertilizers, their type, agronomic characteristics and application in agriculture is given.

In addition, solid household waste and its disposal methods are shown in this section. It was reported that solid household waste is mainly disposed of in three ways: retail disposal; it was collected in open areas and disposed of by earthing and filling the pit. Information on chemical, biochemical, bio thermal processing methods of solid household waste and the influence of various factors on processing methods is given.

Methods of conducting composting processes in field conditions in a simple way and in industrial conditions are shown.

**Used raw materials, their characteristics.**

This chapter is dedicated to the raw materials and wastes used during the research. The chemical and morphological composition of solid household waste used instead of raw materials in the technological process, the amount of waste generated per person in the republic, and the GOST of mineral acids are indicated. Information is given on the gypsum, which is a mineral of non-ore origin, its chemical and mineralogical composition, its deposits and reserves in different regions of the republic.

The methodology of the conducted research is also given in this chapter. Here, the technological scheme of preparation of organic-mineral fertilizers in both laboratory and industrial conditions, methods of experimental and field tests and studies are given. Evaluation of obtained data, conducting experiments, analysis of results, etc. issues were conducted on the basis of generally accepted and widely used methods.

The "systematic approach" method was used during problem solving and generalization. The accuracy, integrity and feasibility of the theoretical judgments put forward were verified on the basis of concrete experiences.

**Development of technologies for the preparation of organic-mineral fertilizers and ameliorative substances.**

There are many methods of obtaining organic-mineral fertilizers based on solid household waste, the production technologies of which have been developed by both foreign and native specialists. In general, these technologies seem to consist of two parts. In the first part of the technological scheme, the neutralization of SHW is carried out, and in the second part, the process of obtaining fertilizer is carried out. During the preparation of organic-mineral fertilizers reported in this section, in the presented research study, deviating from this rule, the processes of neutralization, obtaining of fertilizer and its enrichment were conducted by applying weak sulfuric acid and nitric acid, which is an active oxidizer.

The weak acid solutions used in the process destroy bacteria and microorganisms in the SHW, break it down, and enrich the composition of the obtained liquid fertilizer with nutrients.

The studies conducted in the direction of development of technologies for obtaining organic-mineral fertilizers were carried out in two stages: In the first stage, the process of decomposition of SHW by means of 10% weak nitrate and weak sulfuric acid was studied. At this stage, the dynamics of SHW decomposition, i.e. its dependence on acid solution concentration, time, temperature and stirring intensity, were studied (Figure 1, Figure 2).

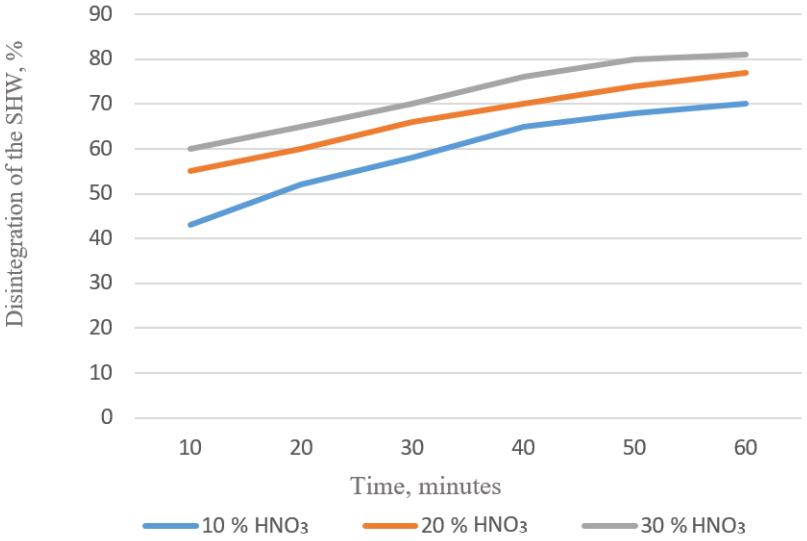


**Fig. 1. Nitric acid solution concentration versus time graph of SHW decomposition.**

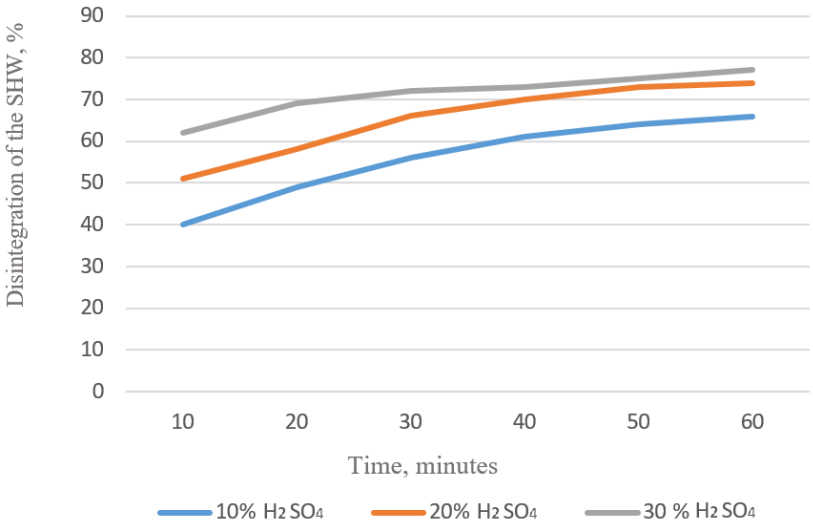


**Fig. 2. Sulfuric acid concentration vs. time graph of SHW decomposition.**

At this concentration, 70% of SHW can be decomposed in nitric acid solution and 66% in sulfuric acid solution within one hour. As a result of the study of the temperature dependence of the decomposition of SHW with a 10% solution of both acids, it was determined that at $20^0$C and 60 cycles/min. during rapid mixing, it allows to increase the amount of SHW decomposition in nitric acid solution to 68%, and in sulfuric acid solution to 64%. In both options, increasing the temperature to 60-$70^0$C is economically inefficient, due to the fact that the increase in the amount of dissolution is very small. For this reason, it is recommended to carry out the decomposition process of SHW at $20^0$C (figure 3, figure 4).

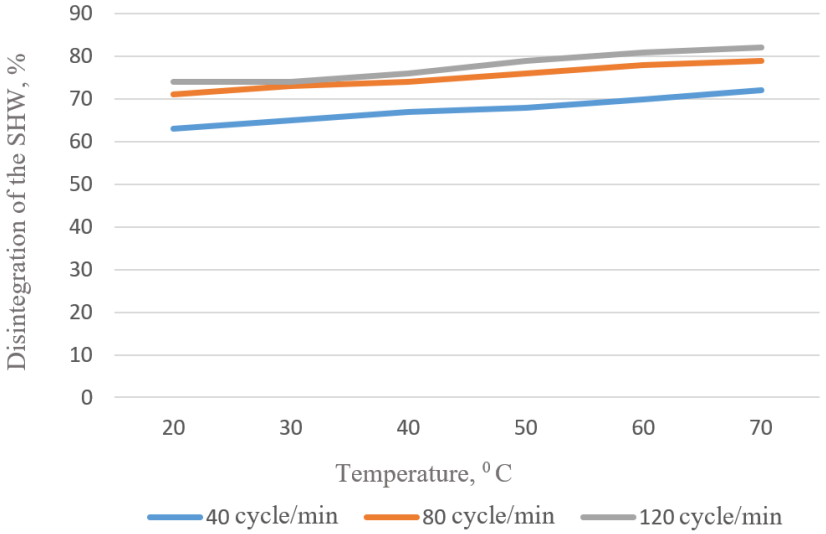


**Fig. 3. Graph of the decomposition of SHW as a function of the temperature of the $HNO_3$ solution and the stirring intensity.**

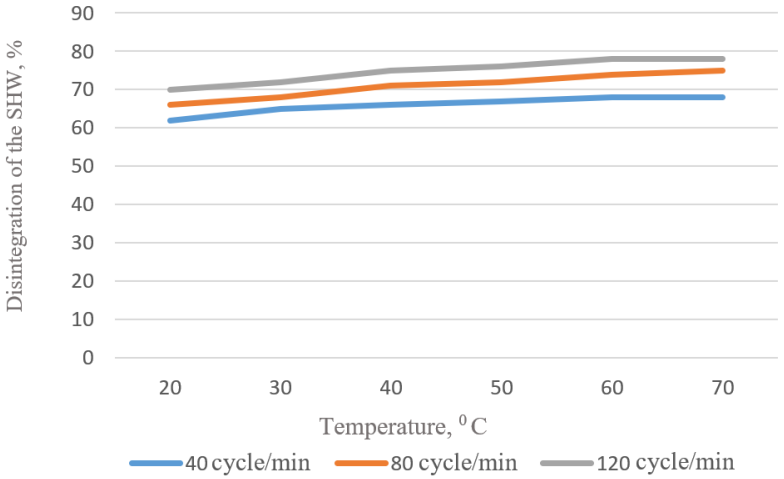


**Fig. 4. Graph of the dependence of SHW decomposition on the temperature of the $H_2SO_4$ solution and the stirring intensity.**

During the decomposition of SHW with 10% acid solutions, the stirring intensity was 60 cycles/min. it is reasonable to accept it.

At this rate of mixing, it is possible to dissolve SHW up to 70% in 10% nitric acid solution and 66% in 10% sulfuric acid solution. Increasing the stirring intensity to 120 cycles/min increases the amount of dissolution to 4% in nitric acid solution and only 6% in sulfuric acid solution.

Due to such a slight increase in solubility, the consumption of additional electrical energy is economically ineffective, the mixing intensity in the process is 60 cycles/min. it is reasonable to accept it (figure 5, figure 6).

The novelty of the method of obtaining organic-mineral fertilizer based on SHW and 10% nitric acid is that a weak nitric acid solution is used to increase the amount of nutrients in the finished product.

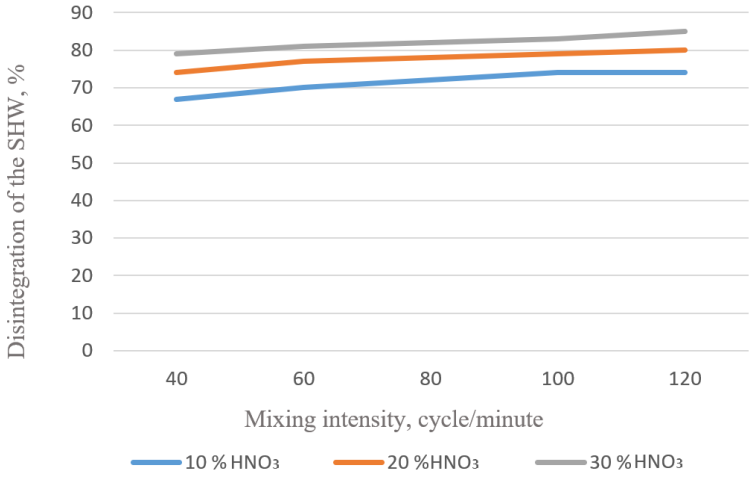


**Fig. 5. Graph of dependence of SHW decomposition on concentration of nitric acid solution and intensity of stirring.**

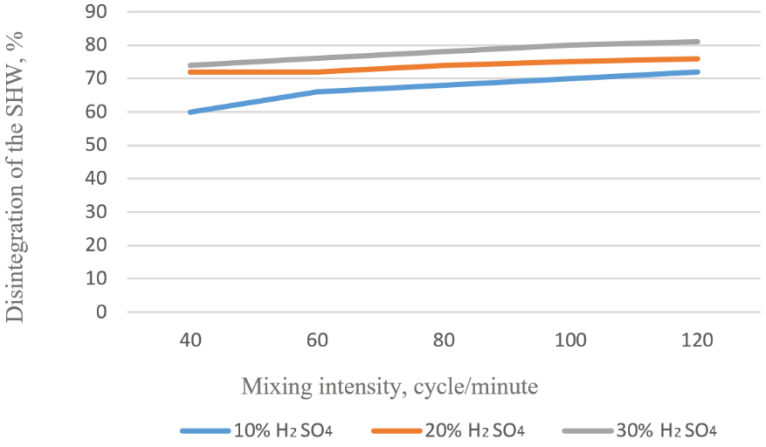


**Fig. 6. Graph of the dependence of SHW decomposition on the concentration of sulfuric acid and the intensity of mixing.**

Use of acidic solution causes an increase in $NO_3$ - ions in the liquid fertilizer, and when neutralizing the free acid remaining in the solution during the technological process, it causes the fertilizer

content to be enriched with $Ca(NO_3)_2$.

This increase leads to the improvement of the quality of the fertilizer, as well as the reduction of its transportation costs during its use. The preparation of organic-mineral liquid fertilizers and meliorating substances was carried out in two variants.

In the first option, the nutrients and microelements contained in SHW were extracted and separated using 10% nitric acid, and in the second option, the technological process was added to give melioration properties to both the liquid fertilizer and the residue with solid organic content after filtering.

Preparation of organic-mineral complex fertilizer based on SHW and 10% nitric acid was carried out according to the following scheme:

The technology of obtaining organic-mineral fertilizer by industrial method was developed based on the results obtained in laboratory tests.

The technological scheme is carried out in the following order: solid household waste is sorted (1), crushed (2) and then fed to the reactor (3). It is also supplied with 10% nitric acid from the acid tank (4). The ratio of the liquid part to the solid part in the reactor should be kept within 3:1. The stirrer is started and the mass in the reactor is 60 cycles/min. mixed rapidly for 1 hour until it became a mixture (figure 7).

After the mixing is completed, the mixture formed in the reactor is neutralized with milk of gypsum until the pH is 6.5÷7.0 and fed to the auger (6). In this unit, the liquid part is separated from the solid part and transferred to the packaging unit. It is filled in polyethylene containers with a volume of 5-10 liters.

The dry residue from the screw clamp (6) is fed to the drying drum (8) and dried to a moisture content of 15-20%. The solid part, which consists mainly of organic matter and a small amount of calcium nitrate, can be used as a chemical ameliorant for the improvement of saline and salinized soils. [Invention a 2022 0148].

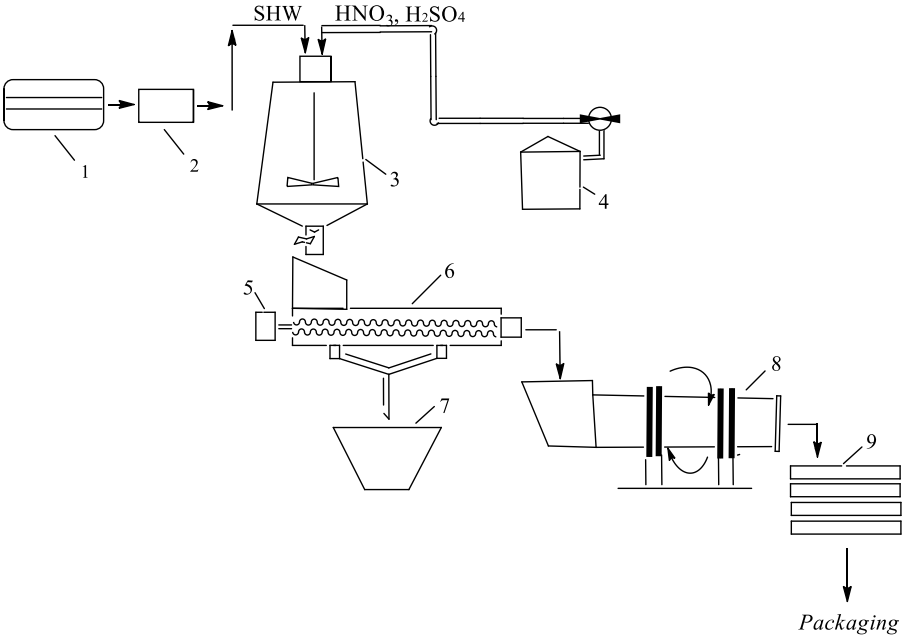


**Fig. 7. Obtaining of organic-mineral complex fertilizer under production conditions:** 1. Sorting shop; 2. Chopper; 3. Reactor; 4. Acid tank; 5. Electric motor; 6. Auger; 7. Liquid fertilizer tank. 8. Drying drum; 9. Sieve;

The composition of the prepared liquid fertilizer is as follows (mg/l): $NO_3^-$ – 81260; N – 18365; $PO_4^{3-}$ – 14; K – 411; Ca – 40200; organic substances – 1.34%; the rest is water.

The composition of the ameliorative material in the solid state, organic matter (mg/kg): $NO_3^-$ – 199140; N – 45006; $PO_4^{3-}$ – 512; K – 960; Ca – 12700; organic substances – 18.23%; the rest consists of water.

The obtaining of organic-mineral complex liquid fertilizer and ameliorative substances with the presence of 10% nitric acid of SHW with gypsum addition [С.с.№13259] is carried out in the following order:

Sorted (1) and shredded (2) solid household waste is placed in the reactor (3) and 10% nitric acid is added to it. The ratio of SHW to acid solution supplied to the reactor should be 1:3. 20 minutes after

starting the mixer, 1 mass part of gypsum is added to the reactor. Stirring 60 cycles/min. continues for 1 hour. The mixture-shaped mass neutralized with milk of gypsum is fed to the auger (6) for dehydration. Here, the solid part is separated from the liquid part (figure 7).

As a result of neutralization, the filtered liquid has a pH of 6.5-7.0, which allows it to be used as a liquid fertilizer in agriculture. The obtained liquid fertilizer is filled in 5- and 10-liter polyethylene containers for use.

The solid material coming out of the auger is fed to the drying drum (8). The solid residue, which consists mainly of organic matter, gypsum and a small amount of calcium nitrate, is dried to a moisture content of 15-20%. This substance obtained during the process can be used to improve salinized soils as an organic-mineral melioration agent.

The obtaining liquid fertilizer has the following composition (mg/l): $NO_3^-$ – 124120; N – 28051; $PO_4^{3-}$ – 11; K – 506; Ca – 49300; organic substances – 2.01%; the rest is water.

The solid chemical ameliorative substance has the following composition (mg/kg): $NO_3^-$ – 126660; N – 28600; $PO_4^{3-}$ – 30.04; K – 888; Ca – 71440; organic substances – 25.27%; the rest is water.

**Obtaining of organic-mineral complex fertilizer based on solid household waste and sulfuric acid.**

With this proposed method, SHW is neutralized with a 10% sulfuric acid solution during the obtaining of organic mineral complex fertilizer.

The main purpose of decomposition of SHW with a weak sulfuric acid solution is both the neutralization of the waste and the melioration of the obtained fertilizer. It is appropriate to use such fertilizers mainly during the assimilation of soils subjected to various degrees of salinization. The peculiarity of the prepared melioration fertilizer is that it is possible to adjust its composition according to the degree of salinization of the soil. In other words, by increasing or decreasing the ameliorative properties of their composition, they can be used in the assimilation of weakly, moderately, and severely saline soils.

During the fertilizer preparation process, the following reaction takes place when the mixture obtained in the reactor is neutralized:

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2CO_3$$

As a result of this reaction, calcium sulfate is formed, which affects the improvement of land reclamation properties and is widely used in the republic, since the 60-s of the last century in the ecological restoration of poor soils by the "plastering" method. A certain part of the gypsum formed in the process is included in the liquid fertilizer, and the main part remains in the ameliorative substance, which has a solid organic-mineral content, remaining after the separation of the liquid fertilizer. The liquid fertilizer used when saline soils are cultivated under agricultural crops has a weak ameliorating effect on the soil and has a greater effect on the productivity of plants compared to conventional fertilizers. The solid residue, which is rich in $CaSO_4$ and received as a waste during the technological process, when applied to the soil, acts as an organic fertilizer and also affects the elimination of soil acidity. So, when it is applied to the soil, the $Ca^{2+}$ cation contained in the gypsum displaces the absorbed $Na^{+}$ cation from the absorbing complex of the soil. During this process, the reaction occurs as follows:

$$[UK]^{Na^+}_{Na^+} + CaSO_4 \rightarrow [UK]Ca^{2+} + Na_2SO_4$$

The production of organic-mineral complex fertilizer based on SHW and 10% sulfuric acid was carried out in the same technological sequence as the method of production of organic-mineral complex fertilizer based on SHW and nitric acid (Figure 7). In this method, instead of 10% nitric acid, 10% sulfuric acid was used.

The composition of the prepared liquid fertilizer is as follows (mg/l): $NO_3^-$ - 146.6; N – 33.1; $PO_4^{3-}$ – 14.2; K – 404; Ca – 1170; organic substances – 0.85%; the rest is water.

The composition of the ameliorative substance in the obtained solid state (mg/kg): $NO_3^-$ – 7084; N-1601; $PO_4^{3-}$ – 258; K – 999; Ca – 26200; organic substances – 29.6%; the rest is water.

## Study of the effect of prepared liquid fertilizers on the productivity of agricultural plants

Tests of prepared liquid fertilizers were carried out under cotton plants in Khalaj village of Salyan region, Azadkend village of Saatli region, and under barley plants in Gumlag village of Agdash region.

Before planting, the field was plowed and 150 kg of nitrogen fertilizer was applied per hectare. The amount of the tested fertilizer was taken in an equivalent amount to the control option.

The tests were carried out under the "Lodos" cotton plant in the village of Khalaj, Salyan region. The norm of sowing was 17 kg per hectare. The productivity of the cotton plant is given in table 1 below.

**Table 1.**

**The results of the experiment conducted in the village of Khalaj, Salyan region**

| Variants of practice | Productivity, c/ha | Increase in productivity | |
|---|---|---|---|
| | c/ha | c/ha | % |
| Cultivation without fertilization - control | 18.7 | – | – |
| By giving $N_{150}$ amount of fertilizer – comparison | 23.3 | – | – |
| SHW + 10% $HNO_3$ –R5 | 30.6 | 7.3 | 23.8 |
| SHW + 10% $HNO_3$ +gypsum – R6 | 31.7 | 8.4 | 26.5 |

As it can be seen from the table data, as a result of the application of newly prepared organic-mineral liquid fertilizers, compared to conventional fertilizers, a yield increase of 6-8 s/ha can be obtained, which is explained by the presence of organic substances in the liquid fertilizer.

The experiments, were carried out under the cotton plant of "BO 440 Agh gyzyl" variety in the area of Azadkend village, Saatli region. The norm of sowing was 20 kg per hectare.

In this experimental area, 150 kg of nitrogen fertilizer was applied to the soil before planting. In the tested organic-mineral liquid fertilizers, the norms were taken in an amount equivalent to the norm given in the control variant. The productivity of the cotton plant is given in table 2.

**Table 2.**

**The results of experiments carried out in the village of Azadkend, Saatli district**

| Variants of practice | Productivity, c/ha | Increase in productivity | |
|---|---|---|---|
| | c/ha | c/ha | % |
| Cultivation without fertilization - control | 19.0 | – | – |
| By giving $N_{150}$ amount of fertilizer – comparison | 25.2 | – | – |
| SHW + 10% $HNO_3$ –R5 | 31.8 | 6.6 | 20.8 |
| SHW + 10% $HNO_3$ +gypsum – R6 | 32.3 | 7.1 | 22.0 |

As can be seen from the data obtained from the experiment, an increase in the productivity of the cotton plant was observed in the options where organic-mineral liquid fertilizer. This increase varies between 5-7 c/ha.

The experiments were conducted under the "Karabagh 22" variety of barley plant in the territory of Gumlag village, Agdash region. The norm of sowing was 220 kg per hectare. Barley plant productivity is as follows (table 3).

**Table 3.**

**The results of the experiment conducted in Gumlag village, Agdash region**

| Experience options | The height of the plant,cm | Productivity, c/ha | | Productivity increase, c/ha | | | |
|---|---|---|---|---|---|---|---|
| | | Barley | Hay | Barley | | Hay | |
| | | | | c/ha | % | c/ha | % |
| Cultivation without fertilization - control | 35.8 | 15.0 | 23.6 | – | – | – | – |
| By giving $N_{150}$ amount of fertilizer – comparison | 38.2 | 19.6 | 25.0 | 4.6 | 23.5 | 1.4 | 5,6 |
| SHW + 10% $HNO_3$ –R5 | 40.3 | 24.1 | 27.1 | 4.5 | 18.7 | 2.1 | 7.75 |
| SHW + 10% $HNO_3$ +gypsum – R6 | 41.6 | 25.0 | 28.3 | 5.4 | 21.6 | 3.3 | 11.66 |

From the data of Table 3 we see, 4.5-5.4 c/ha or 18.7-21.6% yield increase was obtained during the application of organic-mineral fertilizer.

## Results of field tests of chemical ameliorants based on solid household waste, mineral acids and gypsum

Field experiments were carried out in the field belonging to "Lavanda" LLC in the territory of Gumlag village, Agdash region. The test experiments were conducted according to the methodology described in the 3rd section of chapter II of the dissertation. Field experiments were carried out on the options with effective results obtained from tests conducted in experimental conditions:

1. Washing with ordinary water - control;
2. Washing by giving 10 tons of SHW and 10% $HNO_3$ per hectare (R-5);
3. Washing by giving 10 tons of SHW per hectare, 10% $HNO_3$ and ameliorant on a gypsum basis (R-6);
4. Washing by giving ameliorant based on 10 tons of BMT and 10% $H_2SO_4$ per hectare (R-7);

Experiments were carried out with three washing rates - 4000; 8000 and 12000$m^3$/ha.

**Washing with ordinary water.** In the option of washing with ordinary water, after washing norms of 4000, 8000 and 12000 $m^3$/ha in the upper half-meter soil layer, the degree of salinization is 1.39, respectively; It was possible to lower it to 0.99 and 0.69%. At this time, according to washing norms, the amount of washed salts is 32.20 per dry residue; It was 51.40 and 66.34%. At this time, the washed amount of chlorine anion is 47.33; 87.33 and 78.67%, and the amount of residual ions decreased from 0.150%, respectively; to 0.079, 0.019 and 0.032% (table 4).

The amount of sulfate ion decreased by 31-65% depending on the washing norms, the residual amount of these ions was 0.924; It is 0.669 and 0.471 %. In the second half-meter soil layer, the degree of salinization decreased from 2.15% to 2.49%; 2.23 and 1.81%. At this time, depending on the washing rate, there is a slight increase in the amount of chlorine ions in of 4000 $m^3$/ha, and in the options with the washing rate of 8000 and 12000 $m^3$/ha, respectively, 12.21; 49.76%, there was an increase of 0.212 and 0.068% in the amount of sulfate ions in the option of washing rate of 4000 and 8000 $m^3$/ha, and a

decrease of 0.142% in the option of 12000 $m^3$/ha.

**Table 4.**

**Changes in the degree of salinity of soils during the washing experiment with different water rates in the territory of Gumlag village, Agdash region, %**

| Depth, cm | Washing rate, $m^3$/ha | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | Amount of salts | Dry residue |
|---|---|---|---|---|---|---|---|---|---|
| Washing with ordinary water | | | | | | | | | |
| 0-50 | Initial salinization | 0.012 | 0.150 | 1,347 | 0.274 | 0.196 | 0.058 | 2,037 | 2.05 |
| | 4000 | 0.015 | 0.079 | 0.924 | 0.170 | 0.122 | 0.070 | 1,380 | 1.39 |
| | 8000 | 0.015 | 0.019 | 0.669 | 0.091 | 0.119 | 0.029 | 0.942 | 0.99 |
| | 12000 | 0.017 | 0.032 | 0.471 | 0.054 | 0.088 | 0.023 | 0.685 | 0.69 |
| 50-100 | Initial salinization | 0.015 | 0.213 | 1,349 | 0.268 | 0.205 | 0.088 | 2,138 | 2.15 |
| | 4000 | 0.020 | 0.261 | 1,561 | 0.312 | 0.244 | 0.098 | 2,496 | 2.49 |
| | 8000 | 0.020 | 0.187 | 1,417 | 0.281 | 0.204 | 0.092 | 2,201 | 2.23 |
| | 12000 | 0.021 | 0.107 | 1,207 | 0.191 | 0.187 | 0.077 | 1,790 | 1.81 |

As it can be seen, the efficiency of washing melioration measure in the option of washing with ordinary water was at a very low level. The amount of residual salts is 5. 3 and more than 2 times than the permitted limit according to washing norms. At this time, the amount of harmful salts in the residual salts corresponding to washing norms is 0.802; 0.665 and 0.498%, which is 58.16, 68.07 and 72.59% of the total of salts.

**The results of the washing experiment with the application of an ameliorative substance prepared on the basis of solid household waste and 10% sulfuric acid.**

The option of washing by giving 10 t/ha R7 ameliorant to the soil can be considered the most efficient compared to other options. Table 5 shows that as a result of washing, the amount of salts in the 0-50 cm soil layer decreased from the initial 2.08% to 0.99, 0.42 and 0.21% according to washing norms. At this time, the amount of salts washed to the lower layers was 1.09, 1.66 and 1.87% according to the washing norms.

The amount of harmful salts in residual salts was 0.071, 0.040

and 0.021%.

Good results were obtained in the washing of chlorine and sulfate ions. As a result of washing, the amount of chlorine ions according to washing standards is 86.33, 95.03 and 100%, and remaining amount in the soil was within the limit of 0.022, 0.008 and 0%. A sharp decrease in the amount of sulfate ions was also observed. Thus, the amount of these ions decreased to 0.681, 1.083 and 1.218 % according to the relevant washing norms; residual amounts after washing was 0.670, 0.268 and 0.133%. Results obtained from washing were higher than other options in the 50-100 cm layer. The degree of salinity according to the dry residue taking account the initial washing norms was 2.06, 1.03 and 0.47% from 2.23%, the amount of chlorine ions from the original 0.190 to 0.173, 0.084 and 0.027%, and the amount of sulfate ions from 1.430% - to 1.268, 0.630 and 0.284 %.

**Table 5.**

**Changes in the degree of salinity of soils during the washing experiment with different water rates in the territory of Gumlag village, Agdash region, %**

| Depth, cm | Washing rate, $m^3$/ha | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | Amount of salts | Dry residue |
|---|---|---|---|---|---|---|---|---|---|
| Washing by giving R7 ameliorant | | | | | | | | | |
| 0 -50 | Initial salinization | 0.013 | 0.161 | 1,351 | 0.205 | 0.217 | 0.106 | 2,053 | 2.08 |
| | 4000 | 0.013 | 0.022 | 0.670 | 0.270 | 0.016 | – | 0.991 | 0.99 |
| | 8000 | 0.013 | 0.008 | 0.268 | 0.107 | 0.009 | – | 0.405 | 0.42 |
| | 12000 | 0.014 | – | 0.133 | 0.053 | 0.004 | – | 0.204 | 0.21 |
| 50-100 | Initial salinization | 0.016 | 0.190 | 1,430 | 0.247 | 0.231 | 0.088 | 2,202 | 2.23 |
| | 4000 | 0.015 | 0.173 | 1,268 | 0.360 | 0.136 | 0.049 | 2,001 | 2.06 |
| | 8000 | 0.016 | 0.084 | 0.630 | 0.234 | 0.049 | – | 1,013 | 1.03 |
| | 12000 | 0.017 | 0.027 | 0.284 | 0.094 | 0.027 | – | 0.449 | 0.47 |

At this time, the amount of salts washed from the soil layer is 7.62 per dry residue; 53.81 and 78.92%, 8.95 for chlorine; 55.79 and 85.79%, and 11.33 for sulfate ion; It is 55.94 and 80.14%.

**The change of the main constituent elements of the soil under the influence of washing.** The study of the effect of washing on the

main constituent elements of the soil and the change in their amount in different options allows to say the following:

**Table 6.**

**Effect of washing on the main constituents of soil, before/after washing**

| Depth, cm | Washing rate, $m^3$/ha | $CaSO_4 \cdot 2H_2O$ | $CaCO_3$ | pH | Absorbed bases | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | of absorbed bases total, mg/eq. | In % of total | | |
| | | | | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ |
| 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 |
| Washing by ordinary water | | | | | | | | |
| 0-50 | Initial salinization | 1,403 | 7,200 | 8,10 | 25.68 | 63.75 | 24.09 | 12,16 |
| | 4000 | 1,216 | 7,180 | 8.25 | 27.10 | 64,24 | 24,26 | 11.50 |
| | 8000 | 1,004 | 7,172 | 8.50 | 28.76 | 65,71 | 23,10 | 11,19 |
| | 12000 | 0.812 | 7,168 | 8.70 | 30.04 | 67,28 | 21.64 | 11.08 |
| 50-100 | Initial salinization | 1,016 | 7,164 | 8.00 | 31,14 | 69.58 | 20.04 | 10.38 |
| | 4000 | 0.830 | 7,169 | 8.20 | 33.04 | 70.25 | 19,13 | 10.62 |
| | 8000 | 0.643 | 7,171 | 8.20 | 34,66 | 71.25 | 18.51 | 10,24 |
| | 12000 | 0.594 | 7,176 | 8.30 | 35.73 | 72.01 | 17.92 | 10.07 |
| Washing by giving R7 ameliorant | | | | | | | | |
| 0-50 | Initial salinization | 1,825 | 7,12 | 8.20 | 28,13 | 65.09 | 20.90 | 14.01 |
| | 4000 | 2,200 | 7.08 | 7,10 | 30,37 | 72.57 | 21.73 | 5.70 |
| | 8000 | 1,542 | 7.00 | 7,10 | 32,47 | 78,43 | 18.47 | 3.10 |
| | 12000 | 1,271 | 6.91 | 7.20 | 34,28 | 80,91 | 16,10 | 2.99 |
| 50-100 | Initial salinization | 1,146 | 7.28 | 8.55 | 30,16 | 64.53 | 21.53 | 13.94 |
| | 4000 | 1,512 | 7.20 | 7.20 | 31.73 | 71,88 | 21.90 | 6.22 |
| | 8000 | 1,387 | 7.16 | 7.30 | 35.94 | 83,28 | 13.72 | 3.00 |
| | 12000 | 1,226 | 7,12 | 7.20 | 37,42 | 82,33 | 15,18 | 2.49 |

–The amount of gypsum in the soil in the option of washing with ordinary water is 1.403% in the upper layer decreased correspondingly to 1.216%, 1.004 and 0.812%, and there was a slight decrease (0.02-0.03%) in the amount of $CaCO_3$. An increase in soil alkalinity of 0.15-0.60 was observed. There was a small decrease in soil fertility. Thus, the amount of absorbed sodium in the absorbent complex of the soil is 11.50, 11.19 and 11.08% of the total amount of absorbed bases

according to washing norms.

–In the version with chemical treatment, the salinization was completely eliminated in the 0-50 cm layer of the soil profile, as a result of the effect of the given ameliorants, in the washing option with a water rate of 4000 $m^3$/ha, an increase in the amount of gypsum in both layers was observed by 0.375 and 0.366%, respectively. 0.283-0.554% decrease in the 0-50 cm layer and 0.008-0.241% increase in the 50-100 cm layer were recorded in the variants with 4000 and 8000 $m^3$/ha water rate. The amount of $CaCO_3$ decreased by about 0.08-0.40% in both layers compared to their initial values.

–Regardless of the washing rate, the pH of the soil solution decreased from 8.55 to 7.10 in all options where chemical treatment was carried out.

–According to the options, the amount of humus in the upper soil layer varied between 2.01-2.40%. As a result of the effect of washing during the experiment, a slight decrease in the amount of humus was observed for all varieties.

**Optimization of experimental results through mathematical modeling**. Based on the conducted experiments, a statistical mathematical model of the process was built. Based on the set up mathematical model, the optimal mode parameters of the process were determined. Adequacy of the mathematical model to the process was checked for each sample. Fisher's test was used to check. At this time, the experimental value of the Fisher criterion was compared with the table value, and the mathematical model established was considered adequate for the process since the condition of the experimental value being smaller than the table value was met.

**Technical economic justification.** According to the technical and economic report, the cost of obtained fertilizers is 0.20-0.22 man/kg. Such a low value of the product is explained by the use of waste as the main raw material during its production. Processing costs consist of the amount spent on mineral acid and transportation costs.

## CONCLUSION

As a result of the conducted research, the following conclusions were reached:

1. Solid household waste, which is formed in large quantities in the territory of the republic, and the composition of which is rich in macro and microelements, is a useful raw material for the obtaining of organic-mineral fertilizers and chemical ameliorants [5].

2. The presence of harmful microorganisms and bacteria in its composition is the main factor preventing the use of solid household waste. Its complete neutralization during the technological process at a temperature above $60^0$C or processing with acid solutions has also been confirmed during our research [2,3].

3. The development of the technology for the production of organic-mineral fertilizers and meliorating substances based on solid household waste, which is very dangerous from an ecological point of view, has a positive effect on the ecological health of the environment, in addition to the economic efficiency of the obtained substances [11].

4. The dependence of decomposition of solid household waste with weak acid solutions on the concentration of the solution, time, intensity of mixing and temperature was studied, and it was determined that during the technological process, the optimal concentration of the acid solution is 10%, the temperature is 20-$25^0$C, the intensity of mixing is 60 cycles/min. and the time spent on decomposition is 60 minutes [17].

5. As a result of the conducted research, the composition (mg/l) as a result of decomposition of SHW in the presence of 10% nitric acid: $NO_3^-$ – 81260; N – 18365; $PO_4^{3-}$ – 14; K – 411; Ca – 40200; organic substances – 1.34%; organic-mineral complex liquid fertilizer with the rest being water, (mg/kg): $NO_3^-$ – 199140; N – 45006; $PO_4^{3-}$ – 512; K – 960; Ca – 12700; organic matter - 18.23% of ameliorative matter was obtained [25].

6. It was possible to obtain better quality organic-mineral fertilizer by late addition to the process during decomposition of SHW in the presence of nitric acid. The liquid fertilizer obtained during the technological process carried out for the first time with this method

has the following composition (mg/l): $NO_3^-$ – 124120; N – 28051; $PO_4^{3-}$ – 11; K – 506; Ca – 49300; organic substances – 2.01%; the rest is water.

The composition of the solid part (mg/kg): $NO_3^-$ -126660; N-28600; $PO_4^{3-}$ – 30.04; K – 888; Ca – 71440; organic substances – 25.27%; the rest is water [24].

7. For the first time, an organic-mineral fertilizer with ameliorative properties was obtained during the decomposition of SHW in the presence of sulfuric acid. The liquid fertilizer obtained by this method had the following composition (mg/l): $NO_3^-$ - 146.6; N – 33.1; $PO_4^{3-}$ – 14.2; K – 404; Ca – 1170; organic substances – 0.85%; the rest is water.

Content of the received chemical melioration substance (mg/kg): $NO_3^-$ – 7084; N-1601; $PO_4^{3-}$ – 258; K – 999; Ca – 26200; organic substances – 29.6%; the rest is water [20,23].

8. For the first time in fertilizer production, an organic-mineral complex ameliorative substance was prepared by using gypsum as a modifier, and it was recommended to use it in weak, moderate and severe salinized soils by adjusting the amount of gypsum in the ameliorative substance [15].

9. The technologies developed for the purpose of obtaining organic-mineral liquid fertilizers and meliorating substances are recommended to be applied to production for the following purposes:

Liquid fertilizer and melioration agent prepared on the basis of BMT and 10% $HNO_3$ acid in pure and weakly saline soils

- SHW, liquid fertilizer and ameliorative substance prepared on the basis of 10% $HNO_3$ acid and gypsum addition in medium salinity soils

- Liquid fertilizer and melioration agent based on SHW and 10% $H_2SO_4$ acid is used in severely saline soils.

10. When using R5 and R6 liquid fertilizers in pure and weakly salinized soils during land acquisition, its dose is equal to the dose of ordinary mineral fertilizers (mainly the nitrogen dose), and in soils with a medium degree of salinity, it is recommended to apply these fertilizers to the field after irrigation with washing mode is being It is considered appropriate to apply R7 liquid fertilizer during the development of washed areas [22,23].

11. It is considered appropriate to use R5 and R6 chemical ameliorants in order to improve their ameliorative condition and increase their fertility during the assimilation of pure and weakly saline soils. In moderately salinized soils, it is recommended to carry out current washing after applying these ameliorants to the soil. In both weak and moderately salinized soils, the norm of ameliorant should be accepted in the amount of 1-2 tons/ha. In highly salinized soils, it is recommended to apply R7 ameliorant to the soil in the amount of 5-10 tons/ha and wash with a water rate of 4000-8000 $m^3$/ha [12,16].

12. Based on the conducted experiments, a statistical mathematical model of the process was built. Based on the set up mathematical model, the optimal mode parameters of the process were determined, and the adequacy of the set up mathematical model to the process was checked for each sample. The mathematical model set up was considered adequate for the process, since the obtained experimental values were smaller than the table value.

13. Since waste is mainly used in the production of fertilizers, their cost is very low. According to reports, the cost of obtained items varies between 0.20-0.22 manat/kg [16].

**Dissertation of work main results the following article and publication in theses done:**


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