Recycling of waste from housing and communal services into secondary material resources based on the study of the qualitative composition of sewage sludge from Blagoveshchensk treatment facilities

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Abstract. The article considers the possibility of introducing low-waste technology as a method of production. It allows to have the most rational and integrated use of raw materials and energy in the cycle of raw resources, production, consumer and secondary resources, so that any impact on the environment does not disrupt its normal functioning. Intensification of agriculture and insufficient introduction of organic matter into the soil lead to a decrease in humus, which is the main fertilizer. Hence, there is an urgent need to maximize the production of all types of organic fertilizers, including non-traditional ones. Therefore, the priority aim in this field is to identify the possibility of using sewage sludge as a fertilizer to produce a good environmentally safe crop.

1. Introduction

Technology that allows getting a minimum of solid, liquid and gaseous waste is called a low-waste one and at the present stage of development of scientific and technological progress it is the most realistic one. The set of measures to reduce the amount of harmful waste to a minimum and decrease their impact on the environment includes development of various types of waste-free technological systems and water circulation cycles based on wastewater treatment; development of systems for processing industrial waste into secondary material resources; creation and release of new types of products taking into account the requirements of their re-use; creation of fundamentally new production processes that allow to eliminate or reduce the technological stages at which the waste is generated. Development of waste-free and low-waste technological processes is the most rational way to protect the environment from pollution, which significantly reduces the anthropogenic influence.

A rational system of water disposal and wastewater treatment is a necessary element of life support for every modern city. Sewage sludge (SS) is the main waste generated during the operation of treatment facilities. SS contains a wide range of various organic and inorganic substances of biogenic and abiogenic origin, including toxic elements (heavy metals, arsenic, fluorine, etc.), pathogenic microorganisms, petroleum products, etc. The bulk of SS isn’t used for practical application and is stored in landfills, causing large-scale environmental pollution. The most rational approach to dealing with SS is to prevent (or minimize) their formation. This approach requires a radical restructuring of
2. Results and discussion

Any waste can be considered as secondary material resources (SMR), since they can be used for economic purposes, either partially (i.e. as an additive), or completely replacing traditional types of raw materials and fuel and energy resources, and the main feature of such resources is their constant reproducibility in the process of material production, services and final consumption.

In the Russian Federation, secondary material resources are used in almost all industries. At the same time, the scale and degree of processing of various types of SMR vary significantly depending on the resource value of waste, on the environmental situation caused by their properties as pollutants, and most importantly on the specific economic conditions that determine the profitability of using waste in a particular type of production.

Thus, such traditional types of secondary raw materials as scrap and metal waste, high-quality waste of polymers, textiles, waste paper are easy to collect and process. On the contrary, complex multicomponent waste, as well as contaminated waste, is practically not recycled.

As a secondary raw material, waste is most fully used in metallurgy, the pulp and paper industry, and in the production of construction materials. Some types of products are made entirely or almost entirely from secondary raw materials, such as some types of paper and cardboard, household products made of polyethylene (boxes, buckets, watering hoses, film, etc.).

With the growth of the population, the scale of industrial activity increases, so the problem of optimizing the interaction of man and nature is important and its solution is of great significance in improving the environment.

Intensification of agriculture and insufficient introduction of organic matter into the soil lead to excessive mineralization of humus, the main fertilizer. For example, over the past 2-3 decades, the humus content in the Nonchernozem belt has decreased by 0.5-0.7 t/ha, and in the Central Chernozem belt by 1.0-1.5 t/ha.

It has been found out that the soil under grain crops annually loses 0.5-1.5 t/ha of humus, and under tilled crops losses are 1.5-3 times higher.

In 1985 in the Russian Federation 457 million tons of organic fertilizers including salt were applied; in 1990 it was 575 million tons, but by 1995 this figure had increased up to 697 million tons.

According to calculations of scientific claims, even this growth of fertilizers applying is unable to provide self-supporting balance of humus in the soil. Hence, there is an urgent need to maximize the production of all types of organic fertilizers, including non-traditional ones.

Every year in our country, livestock breeding alone accumulates about 1.0 cubic km of waste water. It contains 4.5 million tons of nitrogen, 100 thousand tons of phosphorus, and 700 thousand tons of potassium. Using only animal waste water to improve the cultivation of crops, it is possible to get an additional crop over 7 million tons of grain.

In this research it is suggested to use municipal waste, namely, the sewage sludge (SS) formed after the mechanical dewatering shop.

The undeniable advantage of SS is the high content of organic matter which is up to 75% (Schultz W., 1951, Jahnson S., 1963, Turovsky I. S., 1977) [1]. A high assessment of organic matter is also given in the works of M. M. Kononova (1969) [2], Annabi et al. (2011) [3]; Diacono and Montemurro (2010) [4], Gigliotti et al. (2000) [5], Lal R (2015) [6], Mirko Cucina (2016) [7] in which it is noted that organic matter largely determines the process of soil formation, as well as biological, chemical and physical properties of the soil medium.

With long-term cultivation, the soil begins to lack organic substances, since cultivation accelerates its destruction, and the "return" from plowing crop residues is insufficient to compensate for losses. Organic matter forms aggregates from soil particles between which large pores remain and air penetrates to the roots while excess water evaporates. When there is a lack of organic substances, soil aggregates lose their strength and disintegrate. The soil becomes more dense, air access stops and, as a
result, root growth occurs abnormally. Sandy and dusty soils are most affected by such structural changes. Adding organic fertilizers to such soils improves their quality, resulting in a higher crop than when applying the optimal amount of conventional fertilizers, but without adding organic matter (De Haan S., 1980).

Sludge solids are more effective than equivalent amounts of farmyard manure (Epstein E., Taylor J., 1976; Gypta S., Dowdy V., 1977; Kladivko E., Helson D., 1979).

In Blagoveshchensk, several tons of sewage sludge (SS) are produced annually at treatment facilities (table 2), which is then taken for storage to specially prepared sites. Currently, these sites are almost all filled with SS, so there is a problem of further disposal. According to the results of SS studies after the mechanical dewatering shop in the waste water control laboratory of the testing center for water quality research of Amur municipal systems LLC, Blagoveshchensk, the qualitative composition of the sludge in Blagoveshchensk is the following: ash content 47.6 %, organic matter 52.4%, total phosphorus 13.35% (table 1, 2).

### Table 1. The results of the tests of sewage sludge after mechanical dewatering shop (MDS) for January-June 2019.

| Name of indicators | Units | January 14.01 | February 12.02 | March 11.03 | April 12.04 | May 08.05 | June 07.06 |
|--------------------|-------|---------------|---------------|-------------|-------------|-------------|-------------|
| Humidity           | %     | <82           | 76.10         | 75.77       | 75.82       | 75.30       | 70.42       | 76.13       |
| Hygroscopic humidity| %   | 7.0           | 7.0           | 7.0         | 6.0         | 6.0         | 6.0         | 6.0          |
| Ash content        | %     | >20           | 66.2          | 63.5        | 37.6        | 40.4        | 51.2        | 61.7         |
| Organic matter     | %     | >20           | 10.11         | 13.18       | 16.85       | 12.34       | 12.76       | 8.03         |
| Total phosphorus   | %     | >1.5          | 0.38          | 0.54        | 0.21        | 0.24        | 0.32        | 0.078        |
| Total nitrogen     | %     | >0.6          | 5.5-8.5       | 10.8        | 11.1        | 10.9        | 11.8        | 10.6         | 12.0         |
| Violent reaction (pH)| un. pH | 11.08 | 12.38 | 19.72 | 11.87 | 15.11 | 12.21 |
| Nickel             | mg-kg dry sub. | <400 | 11.08 | 12.38 | 19.72 | 11.87 | 15.11 | 12.21 |
| Copper             | mg-kg dry sub. | <1500 | 73.43 | 167.73 | 187.47 | 138.84 | 141.39 | 99.86 |
| Zinc               | mg-kg dry sub. | <4000 | 302.34 | 341.93 | 381.41 | 272.03 | 300.13 | 285.81 |
| Ferrum             | mg-kg dry sub. | <1000 | 11049.8 | 11409.7 | 10434.8 | 6712.4 | 6602.9 | 10197.4 |
| Plumbum            | mg-kg dry sub. | <1200 | 2.74 | 3.49 | 10.65 | 12.29 | 13.49 | 9.46 |
| Chromium           | mg-kg dry sub. | <1200 | 3.67 | 10.08 | 12.05 | 18.72 | 14.30 | 17.82 |
| Cadmium            | mg-kg dry sub. | <30 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| Viable helminth eggs: | cake after MDS | 0 | 14.01 | 12.02 | 21.03 | 12.04 | 08.05 | 06.06 |
| from silt fields (as they are disposed) | 0 | not ident. | not ident. | not ident. | not ident. | not ident. | not ident. | not ident. |

The composition of the sludge also includes heavy metals such as: Cd – Cu – Zn – Cr – Pb – Ni – 121.2 mg-kg/dry substances, Pb – 13.4 mg-kg/dry substances, Zn – 462.8 mg-kg/dry substances, Cd – 1.21 mg-kg/dry substances, Cr – 31.9 mg-kg/dry substances, Ni – 36.11 mg-kg/dry substances (table 1).

The maximal allowable (MA) of heavy metals in SS as a fertilizer for agricultural crops is Cd<30 mg-kg/dry substances, Cu<1500 mg-kg/dry substances, Pb<1000 mg-kg/dry substances, Zn<4000 mg-kg/dry substances, Cr<1200 mg-kg/dry substances, Ni<400 mg-kg/dry substances [8].
Table 2. The results of the tests of sewage sludge after mechanical dewatering shop (MDS) for July-December 2019.

| Name of indicators      | Units  | July 08.07 | August 19.08 | September 11.09 | October 11.10 | November 14.11 | December 06.12 | Average for the year |
|-------------------------|--------|------------|--------------|-----------------|---------------|----------------|-----------------|---------------------|
| 1. Humidity             | %      | 64.46      | 66.01        | 59.91           | 65.60         | 67.83          | 70.80           | 70.35               |
| 2. Hygroscopic humidity | %      | 8          | 6            | 7               | 7             | 7              | 6               | 6.7                 |
| 3. Ash content          | %      | 42.1       | 54.7         | 60.3            | 50.6          | 53.8           | 48.7            | 47.6                |
| 4. Organic matter       | %      | >20        | 57.9         | 45.3            | 39.7          | 4.94           | 4.94            | 51.3                |
| 5. Total phosphorus     | %      | >1.5       | 19.01        | 7.89            | 7.19          | 17.69          | 12.39           | 22.80               |
| 6. Total nitrogen       | %      | >0.6       | 0.30         | 0.207           | 0.076         | 0.48           | 0.11            | 0.18                |
| 7. Violent reaction     | un. pH | 5.5-8.5    | 8.7          | 9.5             | 11.3          | 9.1            | 8.9             | 9.0                 |
| 8. Nickel               | mg-kg   | <400       | 20.04        | 9.61            | 7.19          | 17.69          | 12.39           | 13.35               |
| 9. Copper               | mg-kg   | <1500      | 133.24       | 95.40           | 109.03        | 106.46         | 126.00          | 128.74              |
| 10. Zink                | mg-kg   | <400       | 195.69       | 202.45          | 214.11        | 211.13         | 205.20          | 201.28              |
| 11. Ferrum              | mg-kg   | 17462.9    | 11871.6      | 14681.6         | 9423.5        | 11124.0        | 18503.6         | 11623               |
| 12. Plumbum             | mg-kg   | <1000      | 8.68         | <0.005          | 1.33          | 2.95           | 4.79            | 10.59               |
| 13. Chromium            | mg-kg   | <1200      | 9.22         | 17.49           | 27.89         | 15.47          | 22.32           | 9.71                |
| 14. Cadmium             | mg-kg   | <30        | <0.0005      | <0.0005         | <0.0005       | <0.0005        | <0.0005         | 14.90               |
| Viable helminth eggs    |        |            |              |                 |               |                |                 |                    |
|                         |        | 0          | 29.08        | 18.09           | 23.10         | 14.11          | 17.12           |                    |
|                         |        |            |              | 29.08           | 18.09         | 23.10          | 14.11           |                    |
|                         |        |            |              | 0              | not ident.    | not ident.     | not ident.      |                    |
|                         |        |            |              | 29.08           | 18.09         | 23.10          | 14.11           |                    |
|                         |        |            |              | 0              | not ident.    | not ident.     | not ident.      |                    |
|                         |        |            |              | 29.08           | 18.09         | 23.10          | 14.11           |                    |
|                         |        |            |              | 0              | not ident.    | not ident.     | not ident.      |                    |
|                         |        |            |              | 29.08           | 18.09         | 23.10          | 14.11           |                    |
|                         |        |            |              | 0              | not ident.    | not ident.     | not ident.      |                    |

By reducing the intensity of accumulation, metals are placed in the next row: Cu, Cd, Pb, Ni, Zn. It was found out that the action of humic substances on Cu, Pb, Cr leads to the formation of chelated compounds and a decrease in the toxicity of these heavy metals.

Based on the above, it can be concluded that the sludge of Blagoveshchensk wastewater treatment plants is very diverse in its chemical composition. Heavy metals that are part of the sewage sludge of Blagoveshchensk do not exceed the maximal allowable (table 3).

As for organic matter, ash and phosphorus, their percentage content in the sludge is quite large, which increases the value of the sludge as a fertilizer and will have a favorable effect on the crop. The sludge obtained at the Blagoveshchensk treatment facilities has a high fertilizer value and can be used as a fertilizer for agricultural crops [9].

3. Conclusion.

The lack of effective methods of disposal of this type of waste in the world practice and the resulting aggravation of the environmental situation (pollution of the atmosphere and hydrosphere, rejection of land areas for landfills for SS storage) indicate the relevance of finding new approaches and technologies to involve SS in economics.

Currently, we have to deal with the problem of multi-tonnage waste generated annually at domestic and industrial wastewater treatment plants. According to research results, sewage sludge from the biological treatment plant of sewage treatment facilities in Blagoveshchensk has agrochemical
properties that characterize their high fertilizer value. These wastes as fertilizers acquire great national economic significance in the conditions of shortage of organomineral fertilizers.

Table 3. The amount of sludge after the mechanical dewatering shop for 2019.

| Month of the year | Sludge formation | Sludge disposed |
|------------------|------------------|-----------------|
|                  | Cake after MDS   | On silt fields  | On grit dewatering bays | Total            |
|                  | humid m³         | excessive silt  | raw sludge               | humid m³         |
|                  | % dry sub., t    | in dry m³       | m³                        | in dry sub., t   |
|                  | H=85%            | H=85%           | H=75%                     | H=75%           |
|                  | t                | in dry m³       | m³                        | in dry m³       |
| January          | 81.0             | 450             | 141                       | 277             | 41.6 | 508 | 76.2 | 38.4 | 9.6 | 1274 | 269 | 1449 | 85.0 | 217 |
| February         | 79.9             | 485             | 153                       | 263             | 39.5 | 317 | 47.6 | 38.4 | 9.6 | 1109 | 250 | 2338 | 85.0 | 351 |
| March            | 78.6             | 372             | 128                       | 247             | 37.1 | 329 | 49.3 | 34.8 | 8.7 | 983  | 223 | 1708 | 85.0 | 256 |
| April            | 72.6             | 690             | 238                       | 205             | 30.8 | 376 | 56.4 | 38.4 | 9.6 | 1309 | 335 | 2254 | 85.0 | 338 |
| May              | 75.5             | 832             | 254                       | 206             | 30.9 | 86  | 12.9 | 37.2 | 9.3 | 1161 | 307 | 777  | 75.5 | 190 |
| June             | 78.0             | 538             | 171                       | 109             | 16.4 | 146 | 21.8 | 38.4 | 9.6 | 831  | 219 | 1104 | 78.0 | 243 |
| July             | 75.6             | 553             | 199                       | 226             | 33.9 | 623 | 93.4 | 37.2 | 9.3 | 1439 | 336 | 420  | 75.6 | 102 |
| August           | 72.5             | 750             | 257                       | 303             | 45.4 | 454 | 68.1 | 38.4 | 9.6 | 1545 | 380 | 383  | 72.5 | 105 |
| September        | 74.5             | 566             | 197                       | 460             | 69.0 | 223 | 34.9 | 38.4 | 9.6 | 1287 | 311 | 642  | 74.5 | 164 |
| October          | 75.5             | 716             | 227                       | 447             | 67.1 | 160 | 23.9 | 37.2 | 9.3 | 1360 | 327 | 378  | 75.5 | 93  |
| November         | 78.2             | 718             | 212                       | 225             | 33.7 | 243 | 36.5 | 38.4 | 9.6 | 1224 | 292 | 474  | 78.2 | 103 |
| December         | 77.8             | 774             | 228                       | 287             | 43.0 | 253 | 38.0 | 38.4 | 9.6 | 1352 | 319 | 1071 | 85.0 | 161 |
| Total            | 76.6             | 7444            | 2405                      | 3255            | 488  | 3718 | 559.0 | 453.6 | 113 | 14871 | 3566 | 12998 | 79.6 | 2324 |

References

[1] Turovsky I S 1975 *Treatment of sewage sludge* (Moscow: Stroizdat Publishing)
[2] Bogatyrev S M 1999 *Environmental assessment of the effectiveness of using sewage sludge as a fertilizer in the conditions of the Kursk region* (Kursk)
[3] Annabi M, Le Bissonnais Y, Le Villio-Poitenraud M and Houot S 2011 Improvement of soil aggregate stability by repeated applications of organic amendments to a cultivated silty loam soil *Agric. Ecosyst. Environ.* **144** (1) 382–89
[4] Diacono M and Montemurro F 2010 Long-term effects of organic amendments on soil fertility *A review* Agron. Sustain. Dev. **30** (2) 401–22
[5] Gigliotti G, Giusquiani P and Businelli M 2000 A long-term chemical and infrared spectroscopy study on a soil amended with municipal sewage sludge *Agronomie* **21** (2) 169
[6] Lal R 2015 Restoring soil quality to mitigate soil degradation *Sustainability* **7** 5875–95
[7] Cucina M, Ricci A, Zadra C, Pezzolla D, Tacconi C, Sordi S and Gigliotti G 2019 Benefits and risks of long-term recycling of pharmaceutical sewage sludge on agricultural soil. *Science of The Total Environment* (**69510**) 133762
[8] Molchanova T G 2011 Qualitative composition of the sewage sludge of Blagoveshchensk treatment facilities *Materials of the regional scien. conf. "Interaction of scientific and educational institutions, business and government"* (Blagoveshchensk) pp 57–59
[9] Molchanova T G 2013 Quantitative and qualitative characteristics of municipal wastewater sludge for the purpose of using it as a fertilizer for agricultural crops *Materials of the regional scien. and practical conf. devoted to the problems of land reclamation and construction of the Amur region* (Blagoveshchensk) pp 69–74