The study of the ashes obtained by burning the dry sludge of urban sewage treatment systems

Alexey Cheremisin¹*, Roman Davydov², Valeriy Meshalkin³, Alexander Zhuchenko⁴, Ivan Savchenko⁵ and Nikita Popovskiy⁶

¹All Russian Research Institute of Phytopathology, Moscow Region, Russia
²Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia
³Mendeleev University of Chemical Technology of Russia, Russia
⁴All-Russian selection and technological Institute of horticulture and nurseries, Moscow, Russia
⁵All-Russian Scientific Research Institute of Medicinal and Aromatic Plants, Moscow, Russia
⁶The Bonch-Bruevich Saint Petersburg State University of Telecommunications, St. Petersburg, Russia

Abstract. Currently, the problem of processing various wastes for their further use, such as, for example, sewage sludge, is of considerable interest. The processing itself takes place by burning the sludge to obtain ash, the use of which may further require its additional cleaning from heavy metals. The proposed approach to assessing the composition of ash using a Fourier-transformed infrared spectrometer, express control devices based on NMR and an X-ray spectrometer allows us to qualitatively assess the composition of ash and make informed decisions about its further use, storage and processing.

1 Introduction

Now the problem of disposal of various waste is quite acute. It is due to an increase in the population, as well as an increase in needs, especially of the well-to-do part of the population [1]. The growth of cities and cottage settlements has led to an aggravation of the problem associated with the availability of places for storing waste [2] and an increase in the cost of their storage. Therefore, research aimed at finding effective solutions for waste processing is becoming extremely urgent [3-6]. For the successful implementation of waste processing, it is necessary to assess the degree of their pollution effectively [7-14]. The most effective in this case is sampling and their study with various devices [10-16].

As the population grows and industrial production expands, the pressure on the urban sewer system increases. In addition to wastewater treatment in the sewer system, a big problem there is the treatment and disposal of the sludge formed in it. These objects may contain heavy metals [17], which determine the high hazard class of them. The sludge is processed in high-temperature incineration furnaces. The result is a dry ash precipitate.

In most cases, ash is a fine yellow-brown powder with a homogeneous structure. The colour of the ash could vary depending on the chemical elements that were in the sludge being burned. The particle size in the ash varies from about 1 micron to several tens of microns. The main elements included in it are SiO2, Fe and Ca phosphates, metal silicates.

* Corresponding author: laksacher@yandex.ru
Further ways of utilizing ash can be its use in agriculture [18-20], construction [21-23], land reclamation [24] and in some other areas, for example, creating ceramic materials [25]. In this case, it is necessary to take into account the degree of ash contamination with heavy metals, the assessment of the composition of which is of great interest for researchers [26-28].

2 Methods

The study of the composition of ash occurs in several stages. After sampling, a study of the granulometric composition is carried out using the Fourier-transformed infrared spectrometer “Tensor 27” (company Bruker) and express control devices, the principle of which is based on the method of nuclear magnetic resonance [15, 16, 29-31]. For express optical control (determination of the number of particles by size), portable devices with hybrid photodetectors can be used [32–34]. Using these devices, the concentration of various fractions is determined. Also, it is possible to determine the presence of heavy metals and other substances in the ash that does not change when exposed to temperature during combustion. Figure 1 shows sludge from the sewerage system and a typical fragment of ash obtained during its incineration.

![Fig. 1. Appearance of the samples: (a) sewage sludge from the sewerage system; (b) ash from incineration.](image)

The control of the presence of heavy metals in ash is carried out using an X-ray spectrometer. The hazard class is determined by the presence of heavy metals in the ash. It allows us to decide on its further use or disposal. When using ash in agriculture (applying it to the soil), it is necessary to measure the pH to calculate the amount of ash that needs to be added to the soil so as not to damage the future crop.

The use of the measurement results on these devices makes it possible to implement an integrated approach to determine the state of ash and the possibilities of its use for solving various problems.

3 Results and Discussion

For the collected ash samples, the composition and particle size analysis are carried out according to the above method. The averaged results are shown in Figure 2.
Fig. 2. Analysis results: (a): discrete size distribution of ash particles. (b): cumulative size distribution.

Analysis of the results obtained shows that the particle sizes correspond to the standard particle sizes of various elements, which are present, for example, in dust or agricultural fields. This confirms the possibility of using ash for agriculture or landscaping. [35-44].

Figure 3 shows the results of determining the composition of one of the ash samples according to the results of spectral analysis.

Fig. 3. Distribution of chemical elements in ash samples.
The obtained results show the standard content of a number of elements in the ash, such as iron, silicon, calcium. These elements are easily absorbed by the soil. Elevated phosphorus content is observed in the ash sample. And a high concentration of magnesium. This must be taken into account when adding ash to the soil. In agricultural fields, this ash can be added to the soil only in autumn. The concentration of other metals is within normal limits. Ash has a low hazard class.

4 Conclusions

The developed methodology for studying the composition of ash makes it possible to qualitatively evaluate the samples under study and make informed decisions about the possibility of their applicability in an urban environment, on agricultural fields, or on taking measures to clean up ash.

The results obtained show the effectiveness of an integrated approach to the problem of disposal of the dry residue of wastewater, control of the chemical composition of ash and recommendations for its further use. It allows to reduce the load on landfills and to supplement the fertile soil layers, both in urban areas and in agricultural fields, with chemical elements for the development of living plants.

Studies have shown that for the more efficient disposal of the dry residue of wastewater (turning it into ash), the combustion process is more expedient to carry out at a high temperature (1073-1173 K).

References

1. S. Kaza, L. Yao, P. Bhada-Tata, and F. Woerdan 2018 What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 (London: The World Bank)
2. H. Duan, J. Li, and G. Liu, Nature 546, 599 (2017)
3. R. Heidari, R. Yazdanparast and A. Jabbarzadeh, Sustainable Cities and Society 47, 101457 (2019)
4. N. Hoang, T. Ishigaki, R. Kubota et al, J Mater Cycles Waste Manag 22, 315–325 (2020)
5. A. Minelgaitė, and G. Liobikienė, Science of The Total Environment 667, 86–93 (2019)
6. M. M. Mian, X. Zeng, A. a. N. Nasry et al., J Mater Cycles Waste Manag 19, 1127–1135 (2017)
7. R. Li, Z. Zhai, Y. Li et al., Journal of Hazardous Materials 347, 227–232 (2018)
8. E. Gryznova, N. Grebenikova, D. Ivanov, and V. Bykov, IOP Conference Series: Earth and Environmental Science 390(1), 012044 (2019)
9. A. Yu. Karseev, and V. A. Vologdin, Journal of Physics: Conference Series 643(1), 012108 (2015)
10. V. Fadeenko, I. Fadeenko, V. Dudkin, and D. Nikolaev, IOP Conference Series: Earth and Environmental Science 390(1), 012022 (2019)
11. V. I. Dudkin, Russian Physics Journal 59(7), 1008 – 1015 (2016)
12. M. Andrianova, E. Bondarenko, S. P. Reimikainen, and A. Cheremisin, IOP Conference Series: Earth and Environmental Science 390(1), 012006 (2019)
13. N. S. Myazin, V. V. Yushkova, and T. I. Davydova, Journal of Physics: Conference Series 917(4), 042017 (2017)
14. E. Gryznova, Y. Batov, and N. Myazin, E3S Web of Conferences 140, 09001 (2019)
15. N. S. Myazin, Journal Physics: Conference Series 1124(1), 031004 (2018)
16. V. V. Davydov, V. I. Dudkin, N. S. Myazin, and V. Yu. Rud’, Instruments and Experimental Techniques 61(1), 140–147 (2018)
17. H. Herzel, O. Krüger, L. Hermann, and C. Adam, Science of The Total Environment
18. N. S. Raymond, M. D. Stöver, A. E. Richardson et al., J. Plant Nutr. Soil Sci. 182, 175–186 (2019)
19. O. Krüger, and C. Adam, Waste Management 45, 400–406 (2015)
20. Z. Chen, and C.S. Poon, Construction and Building Materials 154, 791–803 (2017)
21. Y. Zhou, J. S. Li, J. X. Lu et al., Journal of Cleaner Production 244, 118856 (2020)
22. S. I. Doh, A. M. Aizat, S. C. Chin, and G. Q. Jing, IOP Conference Series: Earth and Environmental Science 244, 012027 (2019)
23. Q. Wang, J. S. Li and C. S. Poon, Chemosphere 226, 587–596 (2019)
24. A. A. Negm, T. Y. Elrasasi, H. A. Khoder et al., Int J Appl Ceram Technol. 17, 907–916 (2020)
25. H. Kirchmann, G. Börjesson, T. Kätterer, and Y. Cohen, Ambio 46, 143–154 (2017)
26. S. R. Naqvi, R. Tariq, Z. Hameed et al., Renewable Energy 131, 854–860 (2019)
27. L. M. Ottosen, I. M. G. Bertelsen, P. E. Jensen, and G. M. Kircelund, Construction and Building Materials 249, 118684 (2017)
28. N. Grebenikova, A. Moroz, M. Bylina, M. Kuzmin, IOP Conference Series: Materials Science and Engineering 497, 012109 (2019)
29. N. S. Myazin, V. V. Yushkova, and V. I. Dudkin, Journal of Physics: Conference Series 1400(6), 066008 (2019)
30. E. V. Rukin, N. S. Myazin, and V. I. Dudkin, Journal of Physics: Conference Series 1368(4), 042011 (2019)
31. N. S. Myazin, V. V. Yushkova, and N. I. Taranda, Journal of Physics: Conference Series 1410(1), 012130 (2019)
32. K. J. Smirnov, Journal of Physics: Conference Series 1368(2), 022073 (2019)
33. K. J. Smirnov, S. F. Glagolev, and G.V. Tushavin, Journal Physics: Conference Series 1124(1), 022014 (2018)
34. K. J. Smirnov, S. F. Glagolev, N. S. Rodygina, N. V. Ivanova, Journal of Physics: Conference Series 1038(1), 012102 (2018)
35. V. Yushkova, G. Kostin, V. Dudkin, and L. Valiullin, IOP Conference Series: Earth and Environmental Science 390(1), 012016 (2019)
36. M. Petrichenko, N. Vatin, D. Nemova, N. Kharkov, and A. Staritsyna, Applied Mechanics and Materials 627, 297–303 (2014)
37. S. Van, A. Cheremisin, and V. Yushkova, E3S Web of Conferences 140, 09008 (2019)
38. S. Van, A. Cheremisin, A., Chusov, and F. Switala, IOP Conference Series: Earth and Environmental Science 390(1), 012111 (2019)
39. M. Petrichenko, N. Vatin, D. Nemova, N. Kharkov, and A. Staritsyna, Applied Mechanics and Materials 627, 297–303 (2014)
40. M. Kozar, L. Sabliy, M. Korenchuk, S. Makeev, A. Korshunov, and V. Kosolapov, IOP Conference Series: Earth and Environmental Science 390(1), 012002 (2019)
41. S. Chirikov, A. Shkirin, I. Savchenko, N. Bunkin, and M. Diuldin, IOP Conference Series: Earth and Environmental Science 390(1), 012030 (2019)
42. K. Artem'ev, L. Kolik, I. Podkovyrov, V. Meshalkin, and M. Diuldin, IOP Conference Series: Earth and Environmental Science 390(1), 012039 (2019)
43. T. Akimov, O. Beloshapkina, M. Diuldin, and J. Molnár, IOP Conference Series: Earth and Environmental Science 390(1), 012015 (2019)
44. E. Stepanov, S. Kotelnikov, G. Ratushnyk, E. Nikulina, and M. Diuldin, IOP Conference Series: Earth and Environmental Science 390(1), 012033 (2019)