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Analysis of the Existing Technologies for Heat and Power Application of Waste

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Abstract: This study presents a various up-to-date methods of waste products recycling. These methods include the liquid-phase oxidation where it is small energy expenditures through the whole process; the heterogeneous catalysis where it is high percentage of the impurities oxidation; the waste products gasification that is effective in energy and technological fuel generation; the wastes pyrolysis where it can be also several environmentally-friendly ways of the process; the plasma method where the after fume cleaning is needed and the firing method that is one of the most effective in case of complete transformation into innocuous combustion products from organic and oxidizable inorganic impurities. All the results of conducted analysis with the positive and negative sides of the existing waste products technologies are presented below.

Key words: Waste products, recycling, neutralization, oxidation, pyrolysis, heat waste, incineration

INTRODUCTION

The problem of complete destruction or partial disposal of waste is relevant, especially from the point of view of the negative impact on the environment, particularly in urban environments. On the one hand, waste products are a rich source of secondary resources (including ferrous, non-ferrous and rare metals) and on the other hand, it is a "no-cost" energy source because household garbage is renewable carbonaceous energy raw material for the fuel power industry (Pan, 1996). To date, the primary disposing method of >95% of the waste generated in Russia is disposal in landfills.

Historically, one of the most common methods of solid waste disposal is storage of them in landfills. However, the appropriate areas for this have further reduced and the cost of its collection, delivery and disposal is continuously increasing. In addition, groundwater and surface water dilute suspended and dissolved substances from the waste and products of their biodegradation. Also, the gaseous products of waste decomposition issue to the atmosphere (Sanitarnaya, 1977).

There are various methods of waste treatment besides their disposal in landfills: pre-sorting; sanitary excavation backfilling; composting: aerobic and anaerobic composting; thermal methods of waste disposal (Vatset).

MATERIALS AND METHODS

Liquid-phase oxidation: The method of liquid-phase oxidation ("wet" combustion, Zimmerman's Method) is used for the disposal of liquid waste and sewage sludge. The method consists in the oxidation by atmospheric oxygen of the organic and elements of the organic impurities of wastewater at the temperatures of 150-350°C and pressure from 2-28 MPa.

At low concentrations of oxidizable impurities in the waste water (<3%) which corresponds to combustion heat less than 0.84 MJ kg^{-1}, the heat emission is not sufficient to cover the needs of the equipment in thermal and mechanical energy. In this case, the steam-boiler is eliminated from the scheme and the motor-generator along with the combined-cycle turbine is used as compressor electric drive.

In the range of combustion heats for waste water from 0.84-1.68 MJ kg^{-1} (concentration of oxidizable impurities is 3-6%) the process is provided with heat and partially mechanical energy. When the heat of combustion above the 1.68 MJ kg^{-1} (i.e., the concentration of impurities >6%) a significant part of the water is converted to steam; at the same time the energy of the steam-flue gas mixture completely covers the needs of the equipment in heat and mechanical energy and part of the energy may be used to generate the electric power and steam (Krasnov, 1984).

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Heterogeneous catalysis: The method of heterogeneous catalysis is used for neutralization of gaseous waste products (thermal catalytic oxidation, thermal catalytic reduction) and liquid waste (vapor-phase catalytic oxidation).

Thermal catalytic oxidation is used for the disposal of gaseous waste products with low concentrations of combustible gases, when the usage of other thermal methods requires high fuel consumption. The process of catalyst oxidation is carried out at temperatures below the autoignition temperature of combustible waste components. In case of using active catalysts the process of oxidation is going at temperature from 250-400°C. The temperature of the oxidation reaction depends mainly on the nature of oxidizable impurities and catalyst activity. The lowest temperatures for the beginning of oxidation reaction are characteristic for metals of the platinum group used as catalysts and the highest temperatures for oxides of some metals (aluminum, copper, chromium, manganese, cobalt, etc.) and some natural ores (bauxite, pyrolusite). The application of low-cost catalysts with high onset temperature of oxidation reaction (less active) leads to the increasing of plant sizes and of required fuel consumption to maintain higher temperature mode of oxidation (Torocheshnikov *et al.*, 1981).

Gasification of waste products: Gasification is designed for producing combustible gas, tar and slag by reprocessing solid, liquid and pasty waste products. Gasification is carried out by air, steam-air and steam-oxygen blowing in mechanized mine gas generators with rotating grate and solid slag removal; in gas-generators with fluidized bed; in shaft generators with the tuyere air-blast supply and liquid slag removal (hearth method).

Recycling of waste products by gasification has the following advantages compared to combustion method: the obtained combustible gases can be used as power-plant and technological fuel while in case of combustion it is possible to use only the heat of waste combustion (getting water vapor or hot water); the received resin can be used as liquid fuel or as chemical feedstock; the emissions of ash and sulfur compounds into the atmosphere are reduced (Carmev and Schaefer, 1983).

Pyrolysis of waste products: There are the following kinds of this method: oxidative pyrolysis with the subsequent combustion of pyrolysis gases and dry pyrolysis. Oxidative pyrolysis is a process of thermal decomposition of waste products at their partial combustion or direct contact with the products of fuel combustion. Oxidative pyrolysis is one of the stages of gasification process. The gaseous products of waste decomposition are mixed with the combustion products or with the part of waste products, therefore, at the output from the reactor they have a low heat of combustion but higher temperature. Then the mixture of gases is burned in typical furnace devices. During the process of oxidative pyrolysis there forms a solid carbonaceous residue (coke) while the solid residue after gasification process is a mineral product (ash and slag). Later on, the coke can be used as solid fuel or for other purposes.

Dry distillation (dry pyrolysis) is a method of thermal processing of waste products, ensuring the high neutralization effect and the application of them as fuel and chemical feedstock which contributes to creating non-waste and low-waste technologies and rational use of natural resources. The dry pyrolysis means the process of thermal decomposition of waste products, solid and liquid fuel without oxygen access. As a result of dry pyrolysis, there are formed pyrolysis gas with high heat of combustion, liquid products and solid carbon residue. The quantity and quality of the dry pyrolysis products depends on the wastes composition and temperature of the process. Depending on temperature, there are three types of dry pyrolysis:

- Low-temperature pyrolysis or semi-coking (450-550°C) where output of liquid products and solid residue (semi-coke) is the highest and the output of pyrolysis gas with a maximum heat of combustion is the lowest
- Medium-temperature pyrolysis or medium-temperature coking (up to 800°C) at which the gas output increases with the reduction of its heat of combustion and the output of liquid products and coke residue decreases
- High-temperature pyrolysis or coking (900-1050°C) where the output of liquid products and fixed residue is the lowest and the output of pyrolysis gases with minimum heat of combustion is the highest

Plasma Method: Plasma Method is used for the disposal of liquid and gas waste products in two ways: plasma chemical elimination of especially dangerous highly toxic waste products; and plasma chemical processing of wastes for the purpose of obtaining the marketable products.

The particularly toxic, carcinogenic and other hazardous wastes for which there are established strict standards of maximum concentration limit in the air, water and soil can be neutralized in the jet plasma. At the temperatures above 4000°C, the oxygen molecules and waste products are broken down into atoms, radicals, electrons and positive ions due to the energy of the electric arc in plasmatron. During the cooling in the plasma there go on reactions with the formation of simple compounds CO_2, H_2O , HCl, HF, RE, P_4O_{10}, etc.

Firing method: The method of fire neutralization of waste and processing of solid, liquid, pasty and gaseous wastes is the most versatile, reliable and efficient in comparison with other thermal methods. It concludes in combustion of combustible waste or fire treatment of non-combustible waste by the combustion products of high temperature (1000°C). Toxic components are exposed to oxidation, thermal decomposition and other chemical transformations with the formation of innocuous gases (CO_2, H_2O, N_2) and solid residue (metal oxides, salts).

The possibility of complete transformations of organic and oxidized inorganic impurities into innocuous products at high temperatures conditions the high hygienic efficiency of the fire neutralization method. The indicated possibility is accomplished in case of providing certain operating conditions which are the following temperature in the firing reactor, unit load of reactor's swept volume, dispersion of atomization, aerodynamic structure and turbulence degree of the gas flow in the reactor, etc.

Depending on the type of waste products and disposal mode the firing method is can be of three types: combustion, fire oxidation method and fire reduction method.

Combustion of waste products that are capable to burn without assistance (combustible waste products) is the most simple and reliable method of its neutralizing. To maintain the stable combustion process the waste combustion is realized at temperature not lower than 1200-1300°C.

In practice, incombustible wastes can be converted to combustible waste products. For instance, non-inflammable gaseous wastes with high concentrations of combustible components can be converted into combustible waste products and neutralized by incineration, if specific measures for increasing its adiabatic combustion temperature up to 1400°C would be taken. These specific measures include adding combustible gases with high temperature of combustion to the gaseous waste products: using technical oxygen or oxygen-enriched air for blowing; gas and oxidizer preheating.

Enriching the air with oxygen is possible only if it is produced at the same factory. The enrichment of the gaseous waste with combustible gas is only justified in cases when the heat of combustion is utilized, i.e., when enriched gaseous waste products are used as fuel in the fire installations.

The most efficient way to increase the adiabatic combustion temperature of the waste products is its pre-heating using the heat from the combustion chamber of flue gas. Sometimes preheating of combustion air is also rational. In this case, it is possible to neutralize gaseous wastes by Autothermal Method. Thus fuel is required only to start the installation.

In fire oxidation method of incombustible wastes disposal they are injected in high temperature combustion products flow. By mixing the gaseous waste products with the flue gases, it is heated and oxidation of combustible components at the expense of the oxygen of the flue gases or oxygen from the wastes occurs. The oxidation process usually proceeds as a homogeneous volumetric reaction, without flame front formation. This method used for disposal of incombustible gaseous wastes with a high concentration of combustible impurities and also in all the cases where the catalytic oxidation is impossible (the presence of large dust and water vapor amounts in waste, of components which are oxidized with difficulty, of catalytic poisons, etc.).

The fire reduction method differs from fire oxidation method by carrying-out neutralization (or only one stage of firing process) in reducing atmosphere (in the absence of free oxygen in the furnace atmosphere). This method is used for example, at the disposal of waste gas containing nitrogen oxides.

RESULTS AND DISCUSSION

Findings: The main advantage of liquid-phase oxidation over other thermal methods is less energy consumption for the process, since the waste water evaporates only partially and the vapors are not overheated to high temperatures (as for example, during firing method).

However, this method had some drawbacks: high cost and severe corrosion of the equipment; the formation of scale on the surface of heat exchangers which complicates the operation of unit installations; incomplete oxidation of certain chemicals; the impossibility of neutralizing wastewater with a high combustion heat; the need for post-treatment of highly saline waste water; high requirements to the equipment operation and to the qualification of maintenance staff.

The main advantages of catalytic oxidation are the high capacity of units; high completeness of the oxidation of impurities up to 99.8% (Proskuryakov and Shmidt, 1977) and low specific energy consumption. This method has all the above disadvantages and limitations that are typical for thermal catalytic neutralization of gaseous waste products.

A serious drawback of the method is the rapid deactivation of catalyst in the presence of condensed moisture containing dissolved mineral compounds in the gas-vapor mixture.

The gasification process is suitable for reprocessing a limited number of waste products and only for crushed, granular and gas-permeable ones. Pasty, large solid waste products and similar which melt at low temperatures are difficult to recycle by Gasification Method.

Research of combustion processes, oxidation and dry pyrolysis of different waste water residues allowed establishing that dry pyrolysis is the most cost-effective and has the least impact on the environment. The most effective method of solid organic waste disposal at the current technology development level is also pyrolysis. However, regarding the advisability of dry pyrolysis at combustion of solid waste and some of industrial wastes the experts have disagreement (Kasakura and Masakatsu, 1982). It is pyrolysis of special industrial waste products, the direct combustion of which is difficult and of waste water residues that is considered the most prospective. Waste heat from the reactor before being released to the atmosphere must be cleaned from acids and anhydrides with known methods.

One of the most effective ways of waste disposal is combustion in cement kilns and other construction materials production units. The high temperature in such cement kilns allows not only disposing of waste products in the accordance with the most stringent environmental requirements but also replacing part of the fuel that significantly improves the energy efficiency of technology (Trubaev, 2007; Zaytsev and Trubaev, 2010; Nuss *et al*., 2013).

CONCLUSION

Despite all the methods listed above, there is no universal method of the waste disposal that will satisfy the modern economy and resource conservation requirements. Unfortunately, Russia has not developed a centralized state system of accounting, collection and usage of recycled resources (Nesterov *et al*., 2013; Shirrime and Trubaev, 2014). During the transition to market economy there were not created conditions that would stimulate the recycling (Shirrime and Trubaev, 2014).

Only a complex of several complementary programs and activities not just one technology, even an up-to-date one can contribute to the effective solution of waste disposal problem.

REFERENCES

Carmev, P.J. and P.T. Schaefer, 1983. Toxic and Hazardous Waste. Proc. 15th MidAtlant. Ind. Waste Conf., Boston c. a., pp: 277-284.

Kasakura, T. and H. Masakatsu, 1982. Water Res., 12: 1569-1575.

Krasnov, B.P., 1984. Ochistka stochnykh vod metodom zhidkofaznogo okisleniya pod davleniyem i pri povyshennoy temperature: Obzorn. in-form. Ser. Okhrana okruzhayushchey sredy i ratsional'noye ispol'zovaniye prirodnykh resursov, 5 (54): 16.

Nuss, M.V., Trubaev P.A. and Klassen V.K., 2013. Upravleniye rabotoy tsementnoy vrashchayushcheysya pechi. Bulletin of BSTU Named after V.G. Shukhov, 1: 61-65.

Nesterov, A.M., P.A. Trubaev and M.Y. Mikhaylova, 2013. Intellektual'nyye energokompanii: seychas vremya dlya sleduyushchego shaga. Bulletin of BSTU Named after V.G. Shukhov, 5: 208-211.

Proskuryakov, V.A. and L.I. Shmidt, 1977. Ochistka stochnykh vod v khimicheskoy promyshlennosti. pp: 464.

Pan, L.P., 1996. Ekologicheskiye aspekty vtorichnykh resursov tsvetnykh metallov. Biogeokhimicheskiye i ekologicheskiye issledovaniya prirod-nykh i tekhnogennykh ekosistem Dal'nego Vostoka. Dal'nauka, pp: 140-146.

Sanitarnaya, 1977. Ochistka gorodov ot tverdykh bytovykh otkhodov, Stroyizdat, pp: 320.

Shirrime, K.J. and P.A. Trubaev, 2014. The analysis of the possibility of the energy management system integration in municipal institutions in Belgorod (Russia). Res. J. Appl. Sci., 9 (11): 862-868.

Shirrime, K.J. and P.A. Trubaev, 2014. Application of the energy management system in Russia. Res. J. Appl. Sci., 9 (12): 1176-1180.

Torocheshnikov, N.S., L.I. Rodionov, N.V. Kel'tsev and V.N. Klushin, 1981. Tekhnika zashchity okruzhayushchey sredy. Moscow, pp: 368.

Trubaev, P.A., 2007. Energotekhnologicheskiy analiz vysokotemperaturnykh protsessov I apparatov proiz-vodstva silikatnykh materialov. Bulletin of BSTU Named after V.G. Shukhov, 1: 11-13.

Zaytsev, Y.A. and P.A. Trubaev, 2010. Differentsiatsiya eksergeticheskikh poter' v linii proizvodstva keramzita. Bulletin of BSTU Named after V.G. Shukhov, 2: 146-150.