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ECOLOGICAL AND ECONOMICALLY OPTIMAL MANAGEMENT OF WASTE FROM HEALTHCARE FACILITIES

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ABSTRACT
Modern healthcare facilities generate more and more waste, and their management is a significant constitutes a significant cost of their functioning. The undertakings aimed at lowering the costs of expenses in waste management may have a positive influence on budgetary accounts in the institutions rendering health care services.
On the example of a hospital in Lublin the costs of waste management and the possibilities to lower these costs by intensifying segregation procedures were presented. Moreover, the article presents the influence of specific waste neutralisation on the costs of waste management.

Keywords: medical waste, infectious waste, municipal waste, disinfection of waste, disposal of waste, the cost of waste management.

INTRODUTION

The wastes produced in healthcare facilities differ in terms of quantity, morphological composition and properties between the types of rendered medical services, modernity of medical appliances and equipment, technological solutions and standards of medical care. Proper classification and selective collection of waste can increase the level of recycling and lower the costs of waste neutralisation. These costs translate directly to the costs of medical care in a given facility. Special attention should be paid to infectious waste, including the waste that had direct contact with infectiously ill patients and the waste with microorganisms in such numbers that generate risks of infection transfer. According to the legal norms (Waste bill of 14 December 2012) infectious medical waste must be thermally disinfected in hazardous waste incinerating plants. Due to significant costs of waste disinfection in this way, in order to lower the costs of waste management, the rules of segregation and classification in the facilities should be organised in such a way that reduces the amounts of waste sent to thermal processing.

On the example of a hospital in Lublin the costs of waste management and the possibilities to lower these costs by intensifying segregation procedures were presented. Moreover, the article presents the influence of specific waste neutralisation on the costs of waste management.

THE CHARACTERISTICS OF MEDICAL WASTE

The waste produced in medical facilities can be systematised into four major groups. These are the wastes of the composition and technological properties that are similar to typical municipal waste, medical waste, special waste and secondary waste.

Significant amount (from 75% to 90%) [7] in the total amount of waste from healthcare facilities is municipal-type waste. They do not constitute infectious or chemical hazards. They primarily include paper waste, cardboard, plastics, glass, metal, wood, leaves, and branches of trees, textiles, magnetic and optical computer drives and food waste from non-infectious wards. In order

to manage this type of waste, technological solutions known in the management of municipal waste management are used.

According to the bill on waste, medical waste is the one that is generated with relation to medical diagnosing, treatment and prevention. The group of medical waste includes the waste with infectious properties, pathological and anatomical waste, special waste and other. Infectious waste is the one which, due to the presence of infections microorganisms, can cause epidemiological risks. The risk of infection is conditioned by the type, number and durability of microorganisms and their penetration into organisms. Legal regulations define which types of medical waste should be considered infectious. According to U.S. Environmental Protection Agency infectious waste makes from 10% to 15% of the total waste produced in medical facilities [1]. They include blood, excretion or secretion infected dressing materials, disposable medical equipment, sharp operation instruments, infected disposable tools, blood and its products, blood containers, waste contaminated with blood and body fluids, waste from operation theatres, isolation wards, pathological laboratories and dissection rooms, if they had contacts with infections agents. Infected waste must be collected in the place of their production in a manner that allows their separation from the surrounding. Then they need to be directed to neutralisation.

The group of pathological and anatomic waste covers recognisable human body parts, bodies of stillborn infants or infants that died within 24 hours after birth.

Special wastes set apart in the group of medical waste are hazardous wastes. They encompass chemicals, wastes generated from radionuclide in diagnostics and therapy, cytostatics and cytoxics, outdated pharmaceuticals and wastes of dentistry amalgam.

Other wastes listed in the group of medical wastes are not considered hazardous. They include chemicals and medicines, other than hazardous, surgical instruments which did not contact with infectious agents.

The functioning of medical facilities is related to the generation of such wastes as used batteries, wastes including mercury (such as measuring devices, used light bulbs, elements of electric and electronic appliances), silver-bearing waste, photographic films, pressured containers, gases in containers, used tires, oiled wastes, and used lube oils. These wastes called special (other than in the group of medical wastes) are characterised by their various hazards for people and the environment, which depends on their physical and chemical properties. They must be selectively collected

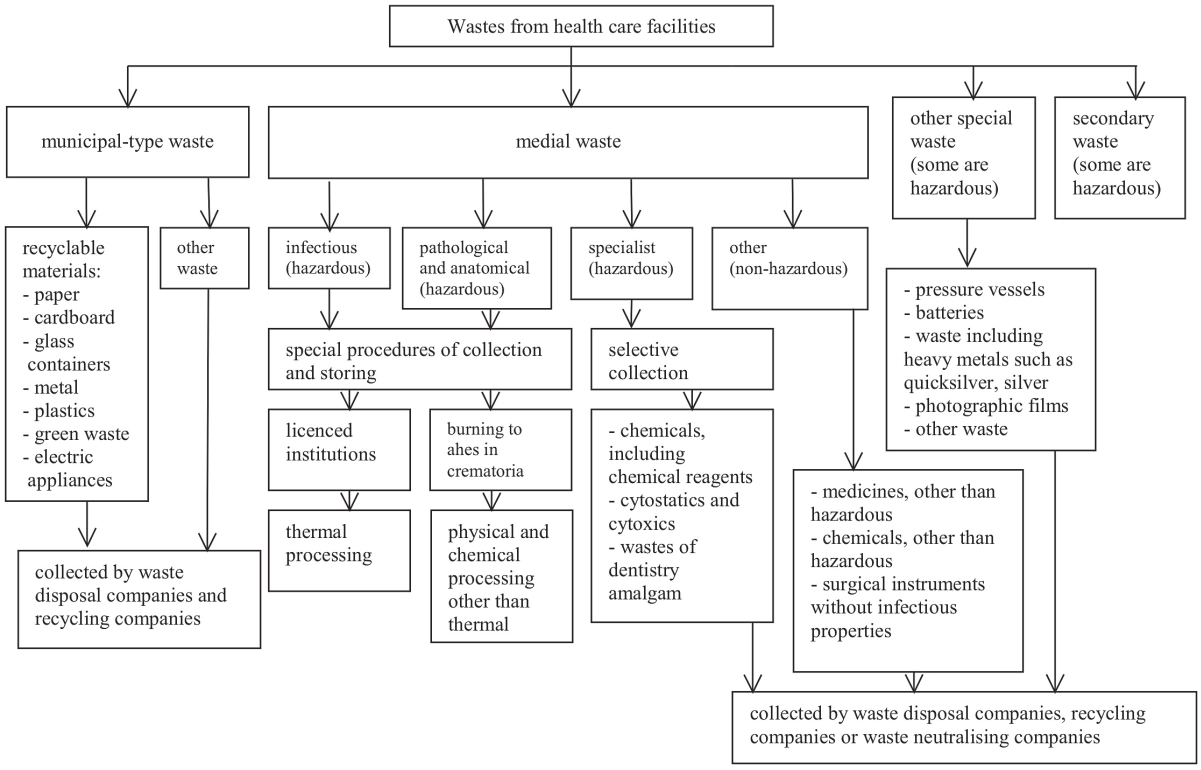

Fig. 1. The division of wastes produced in health care facilities

until defined amount is gathered (they are present in limited amounts most frequently) and handed over to companies specialised in a given type of recycling.

Secondary wastes include the remnants from autoclaving, thermal disinfection, thermal and chemical disinfection, microwave disinfection, and form other physical and chemical methods (alternative to thermal processing) of neutralising infectious wastes. Moreover, secondary wastes also include the wastes from thermal processing of wastes in the incinerations functioning at hospitals. These types of wastes cover: ash, cinder with metals and other components, dusts and sludge from devices cleaning technical gases. Some of them are included to hazardous wastes.

The division of waste types generated in medical facilities is presented in Figure 1.

WASTE MANAGEMENT ON THE EXAMPLE OF A HOSPITAL IN LUBLIN

In the catalogue of wastes in subgroup 1801 there are wastes from treatment,, diagnosing and medical prevention. Wastes with infectious properties (their codes are: 180102*, 180103*, 180180*, 180182*) are called specific wastes. Hazardous wastes have the following codes: 180106*, 180208*, 180110* and other wastes which do not manifest hazardous properties are identified with the following codes: 180101, 180104, 180107, 180109, 180181.

In the Independent Public Clinical Hospital no 4 in Lublin medical wastes are selectively collected and neutralised in a thermal process. The services of waste collection, transportation and thermal neutralisation are rendered by „EKO-TOP" Sp. z o.o. in Rzeszów, Poland, which manages an incineration of medical and industrial wastes in Rzeszów. The costs of managing medical wastes, according to the contract signed for a 12-month period (since April 2012) is going to amount to 553 046.40 PLN [4]. The list of types and amounts of medical wastes that are planned to be neutralised during the period is presented in Table 1.

In Lublin hospital in the period when methods of medical waste neutralisation alternative to incineration were allowed, part of hospital waste was thermally and chemically disinfected with an Italian apparatus *Newster 10* [1]. In the device, hazardous properties of the wastes were liquidated under the influence of high temperature and sodium hypochlorite in atmospheric pressure conditions. Heating the wastes is accompanied by the phenomena of mixing and blending the wastes by a rotating cutting blade. After water evaporation (at c.a. 95–100 °C), the temperature in disinfection chamber raises up to 155 °C. Then water with sodium hypochlorite is automatically added to the disinfection chamber. Water moistens the wastes and is evaporated. Water steam is the disinfecting agent The dosage of water and sodium hypochlorite is controlled in such a way to obtain and maintain the temperature of c.a. 155 °C for 2 minutes in the chamber. In the next stage of the process, a stream of dozed water cools the neutralised wastes down to c.a. 85–90 °C.

Disinfected wastes were classified into group 19 as a waste coded as 190210, i.e. combustible wastes other than those included in 190208 or 190209. The collector of this waste was „EKO-TOP" Sp. z o.o. in Rzeszów, Poland, which thermally processed waste in industrial and medical waste incineration. The cost of infectious waste

Table 1. The list of types and amounts o medical wastes generated in Lublin hospital sent to thermal neutralisation in Rzeszów incineration [4]

Waste code	Type of waste	Amounts, Mg
18 01 02*	Parts of body and organs, blond containers and preservatives used in blond storing.	5.5
18 01 03*	Other wastes which include microorganisms and their toxins and other forms capable of transforming genetic material and which are recognised as the ones that cause or can possibly cause diseases in humans or animals.	330.0
18 01 06*	Chemicals including chemical reagents, chemically hazardous substances	0.5
18 01 08*	Cytostatics and cytoxics medicines	3.0
18 01 09	Medicines other than those listed in 18 01 08*	1.0
18 01 01	Surgical instruments and their remnants, (except. 18 01 03*)	1.5
18 01 82*	Food wastes from patients in isolated wards	4.5
Total waste amount in 12-month period		346.0

management with the use of *Newster 10* was lower in comparison to the management without the thermal and chemical method. Lowering the management costs is related to lower frequency of disinfected waste collection and transportation (at least twice a month) to the incineration. The costs of waste neutralisation with the use of disinfection processes might be additionally lowered, if disinfected medical wasted processed in *Newster 10* could be sent to municipal incineration in hospital vicinity. Lack of municipal incineration in the closes neighbourhood disabled such a solution.

The costs of medical waste management (subgroup 1801, according to waste catalogue) involving two parallel methods of neutralisation, i.e. disinfection part of the wastes in hospital and thermal processing of the rest of specific medical waste outside the hospital were presented in Table 2.

According to the waste bill (of 14 December 2012) thermal transformation of medical waste is acceptable only in case of waste with infectious character. Permission to use alternative methods of medical waste management might lower hospitals' expenditures. Another consequence of such a legal regulation would be leaving the decision about the method of waste management for hospitals. On the other hand, allowing alternative methods which eliminate infectious properties of medical waste does not solve the whole problem with this waste. Other legal regulations prohibit the storage of wastes obtained in alternative methods. Allowing the use of alternative methods will be economically justified, provided there are municipal incinerations which can accept the waste neutralised in these methods.

MANAGING MUNICIPAL-TYPE OF WASTE ON THE EXAMPLE OF THE LUBLIN HOSPITAL

Municipal-type wastes are collected by an external subcontractor. The service of waste collection is realised on the basis of a contract concluded for a 12-month period. The cost of this service depends on the number of permanent and on demand containers for waste. According to the contract (from 19.12.2013 for 12 months) the company rendering the service is obliged to provide 22 1100-litre containers, including 21 containers for non-segregated wastes and 1 container for waste plastics and one KP-7 container for for mixed (non-segregated) municipal waste.

Table 2. The costs of medical waste management on the example of Lublin hospital

Item	Waste code, according to *Catalogue of wastes*	Cost
Medical waste neutralised in thermal processing outside the hospital Total amount for 12-month period [5] (from the day of contract conclusion), Mg		196
Including: Parts of body and organs, blond containers and preservatives used in blood storing., Mg	18 01 02*	5.5
Other wastes which include microorganisms and their toxins and other forms capable of transforming genetic material and which are recognised as the ones that cause or can possibly cause diseases in humans or animals, Mg	18 01 03*	180
Chemicals including chemical reagents, chemically hazardous substances, Mg	18 01 06*	0.5
Cytostatics and cytoxics medicines, Mg	18 01 08*	3.0
Medicines other than those listed in 18 01 08*	18 01 09	1.0
Surgical instruments and their remnants, (except. 18 01 03*), Mg	18 01 01	1.5
Food wastes from patients in isolated wards	18 01 82*	4.5
The cost of waste collection, transportation and thermal neutralisation are rendered by „EKO-TOP" Sp. z o.o. in Rzeszów, in the period of 12 months [5] (from the day of contract conclusion: 31.01.2011), PLN	x	236983.6
Wastes generated in neutralisation process in *Newster 10* Total for 24-month period [6] (from the day of contract conclusion: 16.11.2010), Mg	190210	240
Cost of collection, transportation and neutralisation of the above post-sterilisation wastes by Firma Usługowo-Handlowa „ EKO-TOP" Sp. z o.o. in Rzeszów in the period of 24 months [6] (from the day of contract conclusion: 16.11.2010), PLN	x	141214.0

Depending on the needs, the company will also provide other containers, appropriate for the type of wastes, including KP-7 BIO, KP-15, KP-10 ECO, KP-4. The type and amount of municipal-type wastes considered in the calculation of costs for their transportation and neutralisation in the period of contract realisation were presented in Table 3 and Figure 2. The intended expenditures on municipal-type wastes for a 12-month period, according to the offer, amount to 228 182.29 PLN [3].

POSSIBILITIES OF LIMITING THE COSTS OF WASTE MANAGEMENT IN A MEDICAL FACILITY

Total cost of waste management in a medical facility is the sum of management costs of municipal-type waste (included in group 18 in Waste catalogue), special wastes (other than those included in group 18 in Waste catalogue) and secondary waste:

$$K_c = K_{ok} + K_m + K_{sp} + K_w$$

where: K_c – total costs of waste management in the medical facility, K_{ok} – cost of municipal-type waste management, K_m – cost of medical waste management, K_{sp} – cost of special waste management (without medical waste), K_w – costs of secondary waste management

The size of the first cost ingredient depends to large extent on the amount of recyclable waste in the mass of wastes. The wastes with the features of recyclable materials can be sold or send to recycling for free. Regardless of the variant, increasing the level of product recycling brings the decrease of neutralisation costs (e.g. storage) of municipal-type waste. This will decrease the mass of this type of waste, intended for neutralisation [2]:

$$K_{dk} = m \cdot k_j - p_o$$

Table 3. Types of municipal-type wastes collected in the containers and the number of containers considered in the calculation of costs for the service [3]

Waste code	Type of waste	Container size	Number of containers
200301	Mixed, non-segregated types of waste	1100 l KP-7	4250 50
200199	Other unlisted fractions collected selectively	1100 l KP-10 ECO	220 50
200201	Selectively collected biodegradable waste (leaves and branches)	KP-7	42
200111 200307	Textiles Large-size wastes (from textile scraping)	KP-15	5
170101 170107	Concrete aggregate and debris from demolition Mixed waste from concrete and brick debris	KP-4	9

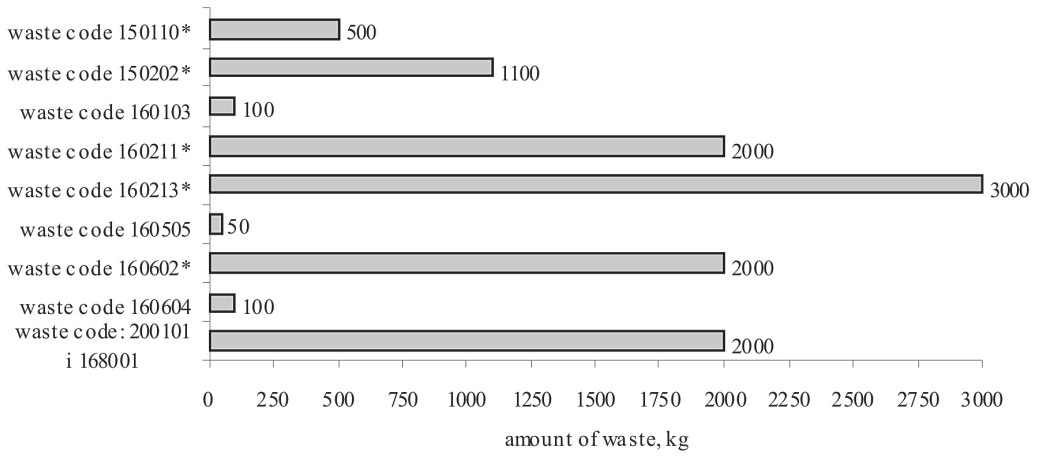

Fig. 2. The types and amounts of municipal-type wastes in the mass units in the calculation for the collections of wastes in the period of 12 months [3]

where: m – mass of municipal-type waste that need neutralisation, k_j – cost of municipal-type waste neutralisation per unit, p_o – income from the sale of potential recyclable materials

Selective collection of wastes should be directed to recyclable materials whose voluminal and mass share are the most significant in the municiap-type waste. In the stream of municipal-type waste generated in hospitals, the highest share is represented by fractions: paper and cardboard, plastics and textiles. On their basis it is possible to conduct a variant economic analysis for the waste management in a medical facility. Among the analysed variants the costs of municipal-type wastes for 100% selective collection of paper and cardboard waste and separately 100% selective collection of paper, cardboard and plastics can be considered. Both of these variants analyse the situation with sale and without sale of recyclable materials.

According to the waste bill, medical infectious waste can be neutralised with methods alternative to thermal processing in the incinerations of hazardous waste. In the light of the above, lowering the costs of infectious waste neutralisation is possible provided the wastes are correctly classified to this group. Then, not only will the wastes which had contacts with infectious agents be classified as medical infectious wastes. Lower mass of infectious wastes and potentially infectious wastes mean lower costs of their neutralisation.

CONCLUSION

In modern medical facilities more and more wastes are generated and their management is a significant component of their functioning. The undertakings aimed at lowering the costs of waste management can have a positive influence on economic conditions of medical facilities.

In the light of the binding regulation, the only appropriate method of medical waste management is their thermal processing in specialised installations, it is necessary to limit misclassification of waste to the appropriate group. The technology of hazardous waste combustion is expensive in terms of both investment and exploitation. Lowering the amount of waste directed to expensive incineration will generate financial savings.

The implementation of effective segregation system of municipal-type waste can contribute to appropriate classification of waste, and consequently, lowering the costs of neutralising waste, especially from group 18 and 20 from the Catalogue of waste. The costs of municipal-type waste collection are calculated for the voluminal unit of waste (1 m^3). In the analysed Lublin hospital, they are collected in 1100 litre containers. The price for waste collection depends on the number of containers, regardless of the their being full or half-empty. Therefore, significant voluminal share in municipal-type waste is the mixture packaging, which should be eliminated "at the source". Consequently, the amount of municipal-type waste intended for neutralisation by their processing or storing will decrease.

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