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ECONOMIC AND ENVIRONMENTAL EFFECTIVENES OF INFECTIOUS MEDICAL WASTE DISPOSAL SYSTEM: A CASE STUDY OF THE TERTIARY HEALTH-CARE INSTITUTION

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Abstract: *Medical waste represents a growing problem worldwide. This category of waste is very significant and special since the negative effects that it can have on both human health and the environment. The proper disposal of such waste, and especially infectious medical waste that poses the greatest risk, is crucial in a responsible functioning of health-care institutions. This paper presents a research study of gaining economic and environmental efficiency of using appropriate infectious medical waste disposal system by exploring the benefits of introducing an autoclave and shredder system in a public tertiary health-care institution - Clinical Hospital Center Zemun, Belgrade, Serbia. The presented model showed that it would have both financial gains in providing new savings as well as benefits for the human health and environment in lowering the risk of infections and pollution.*

Keywords: *Economic effectiveness, Environmental effectiveness, Infectious medical waste, Infectious medical waste management.*

1. INTRODUCTION

> *"However, each type of hazardous medical waste presents hazards that jeopardize the enjoyment of human rights."* Calin Georgescu, UN Special Rapporteur on human rights and toxic waste

Medical waste represents a very important waste category, having in mind that during the past two decades the problems associated with it have become of a significant global issue when considering possible negative effects of medical waste and its inadequate treatment and final disposal practices together with a new trend of favoring single use medical devices which additionally affect the increase of this type of waste.

Negative impact of medical waste is reflected in: harm on patients and medical workers as well as the participants in waste management within and outside the health care facility (workers and the scavenger population that is working on the streets or at the final disposal facilities); increasing of the public health; impacts on ecosystems and environment (Institute for Environmental Medicine and Hospital Hygiene, 2000; Manyele, 2004; Emmanuel and Stringer, 2007; Ferreira and Teixeira, 2010; International Committee of the Red Cross, 2011, Karliner and Guenther, 2011; Al-Habash and Al-Zu'bi, 2012; Koo and Jeong, 2015; Xin, 2015; Makajic-Nikolic et al., 2016). For these reasons, medical waste that is created as a "negative byproduct" of medical service is gaining more and more attention and importance, and has become a subject of duties of medical institutions contained in the legislation worldwide and the possibilities of implementing best practice in this area (Mihailović, 2017).

When it comes to the health risk caused by medical waste, it should be noted that some types of medical waste have a greater health risk than others, because 15-25% of the total amount of medical waste is considered infectious (Shinee, Gombojav, Nishimura, Hamajima, & Ito, 2008; WHO, 2015). Infectious medical waste contains infectious waste, toxic and/or radioactive substances or a mixture of the previously-mentioned waste (WHO, 2015). When it comes to the Republic of Serbia, about 10-25% of medical waste is hazardous waste or infectious waste - dangerous to human health and the environment. It is estimated that all health institutions in the Republic of Serbia generate about 48,000 tones of medical waste per year, out of which about 9,600 tones of this waste is considered infectious (WMS, 2009).

Given the previous, the authors in this paper gave their research relating to possible improvements of economic and environmental efficiency of infectious medical waste disposal through the introduction of on-site use of the system of an autoclave shredder (AS), with the goal to show that implementing this eco-friendly disposal system would not only solve the problem of infectious waste by turning it into noninfectious compressed waste ready for recycling or safe disposal as communal waste, but provide financial savings as well. In this paper we described such a model of efficiency infectious medical waste disposal in the case of a public tertiary health-care institution - Clinical Hospital Center Zemun, Belgrade, Serbia.

2. INFECTIOUS MEDICAL WASTE

Infectious medical waste is all infectious and harmful wastes produced by health-care institutions. This waste is categorized as hazardous waste because it is consisted of: various infectious and chemical components; germs and viruses; sharp and cutting objects such as surgical blades and syringes. The alarming figures published by WHO indicate that, each year about 23 million people get infected with Hepatitis B and C and HIV which are transmitted to them by sharp and cutting objects found in medical wastes (WHO, 2004; LaGrega, Buckingham, & Evans, 2010). Infectious medical waste is most dangerous for these endangered groups: physicians, nurses and unprofessional workers, patients, visitors and their companions (Da Silva, Hoppe, Ravanello, & Mello, 2005; Guerrero, Maas, & Hogland, 2013). The greatest risk of infectious medical waste is the risk of needle stings, needle injury, which is suspected to contain pathogens (bacteria, viruses, parasites, or fungi). Besides, needle punctures or cuts with a sharp object, are in 68% of cases the cause of injury (HPA, 2008). Exposures, which are the most frequent, involve contact with sharp objects, infectious agents and toxic substances; personal injuries when handling the waste; injury when handling; slip, trip, fall; contacts during the procedure (Akpieyi, Tudor, & Dutra, 2015).

According to Waste Management Strategy for the Republic of Serbia (WMS, 2009), the infectious medical waste generation rate is 0.7 kg/bed-day. However, in the literature can be found different, mostly lower values: 0.53 kg/bed-day (Mbarki, Kabbachi, Ezaidi, & Benssaou, 2013), 0.341 kg/bed-day (Pandey, Ahuja, Madan, & Asthana, 2016), 0.1-0.7 kg/bed-day (Qadir, Murad & Faraz, 2016).

3. METHODOLOGY

In developing countries, the more common treatment of infectious medical waste are: autoclaves and retorts, microwave disinfection systems, chemical disinfection, combustion, and disposal on land (Diaz, Savage, & Eggerth, 2005). In this paper, we analyzed the economic and environmental effectiveness of introducing the integrated autoclave with shredder in a public tertiary health-care institution - Clinical Hospital Center Zemun. The reason for the authors choice of AS disposal system lays in the fact that this system could be well established as on-site disposal system in Serbia, as well as fact that on-site treatment of infectious medical waste offers a large quantity of advantages: minimum handling hazard; reduction of transportation and storage expenses; decrease of air pollution and emission of greenhouse gases; low operating cost (Mari and Chapon, 2017).

Medical waste that can be treated by this disposal system is: sharps, cultures, items contaminated with blood, residues from surgery, gauze, linen, gowns, non-chemical laboratory wastes (Diaz, Savage, & Eggerth, 2005). It should be added that using this system is a more environmentally friendly way of disposing waste that enables replacing incineration as a disposal method.

3.1. Economic Effectiveness

Precise assessment of the cost-effectiveness of autoclave procurement in a tertiary health care facility would require the use of the exact data about the costs of the infectious medical waste treatment services. However, these costs are usually not recorded on this level of detail, but they relate to the overall cost of medical waste management. Therefore, costs related only to services concerning infectious medical waste must be assessed indirectly. In this paper, we propose assessment by the number of hospitalization days for which records are kept in each health care institution. In order to assess costs of the infectious medical waste treatment services, the following parameters are used:

N – the set of clinics;

n_i – annual number of hospitalization days in i-th clinic, $i \in N$;

p – estimated (average) production of infectious medical waste (IMW) (kg/bed-day);

ct – unit costs of IMW treatment (RSD/kg);

tc – annual IMW transportation costs.

Total annual cost of transportation and treatment of infectious medical waste, *C* can be estimated using the following formula:

$$C = ct \cdot p \cdot \sum_{i \in N} n_i + tc \tag{1}$$

When deciding on the procurement of AS system, these costs should be compared with the price of the autoclave and shredder. In this decision, the purposes for which the AS system will be used should be taken into account: on-site, cluster treatment or central treatment. Certainly, the prices of these different usage of the AS system are rising respectively. However, the second and third, in addition to cost savings, would bring the health-care facility a certain income.

In addition, it is necessary to first consider what quantities of infectious medical waste are generated and what the infectious medical waste disposal systems are used in the region (Ugrinov and Stojanov, 2013). The decision-making process for the infectious medical waste disposal system is illustrated in Figure 1.

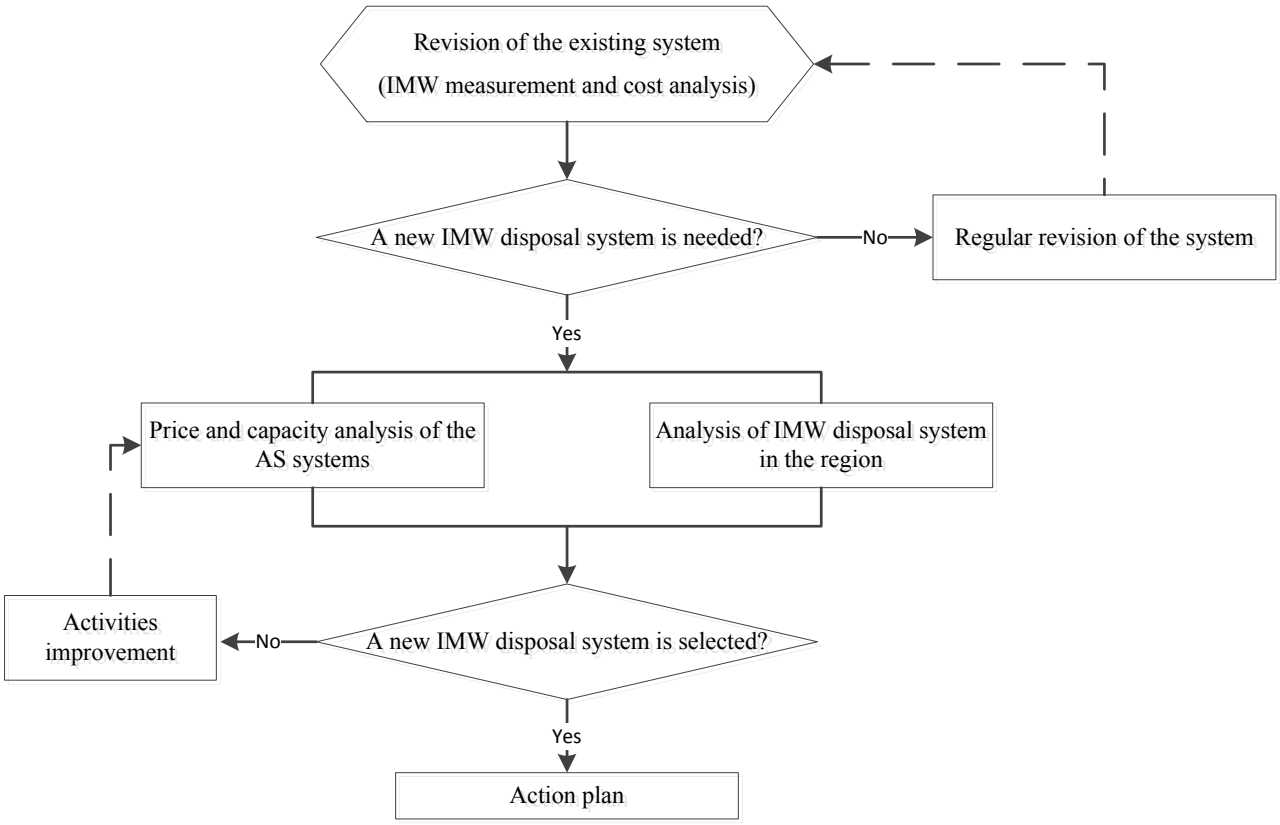

Figure 1: The decision-making process for the infectious medical waste disposal system (adapted from Ugrinov and Stojanov, 2013)

3.2. Environmental Effectiveness

The greatest environmental threats related to current way of infectious medical waste disposal are caused by possible accidents during transporting. The risk of transporting hazardous material, such as infectious medical waste, is characterized by two attributes: the probability of a release accident, and a measure of the consequence of a release accident (Erkut and Ingolfsson, 2005). Some of the possible risks in infectious medical waste transportation are given in Table 1.

The use of AS system does not affect the probability of an accident but it has a significant impact on the consequence if an accident occurs. Moreover, infectious medical waste treated by autoclave and shredder no longer constitutes hazardous waste and, consequently, there is no negative environmental impact if an

accident occurs during its transportation. Therefore, use of the AS system decreases the overal risk of produced and discarded infectious medical waste by hospitals and other health-care sites.

Table 1: Possible risks in IMW transportation (adapted from Cudečka-Puriņa, Atstāja, & Cudečkis, 2013)

Type of risk	Influence on	Effects/risk description	Predictability rate
Incineration	Air (Co_2, NO_x, CH_4, O_3); GHG; Inhabitant health	Occurs due inflammation of waste inside the waste collection truck. In this case the truck has to be totally emptied and only then the fire has to be extinguished.	Low
Spilling	Air (Co_2, NO_x, CH_4, O_3); Water	High waste liquidity causes spilling of waste while transportation. It has an impact on air pollution (smell) and on water, in case the waste is absorbed and reaches the groundwater.	Low
Un-optimized routes	Air (Co_2, NOx, CH_4, O_3); GHG Noise; Operational expenditures	Existence of various management companies within one region leads to ineffective usage of vehicles and increases volume of emissions.	High

In addition, transportation of the infectious medical waste requires special attention in vehicle routing planning due to the hazardous materials being transported (Alagöz and Kocasoy, 2008). As a result, the vehicles often do not use optimal routes thus increasing fuel consumption and emission of greenhouse gases. By using the AS system this problem is completely eliminated.

4. NUMERICAL RESULTS

For the purpose of our research, we chose a public tertiary health-care institution - Clinical Hospital Center Zemun, Belgrade, Serbia as institution which practices health-care activity in the secondary and tertiary levels that is, highly specialized consulting and in-patient health care. Under this name, the hospital has been working since 31st of December 1983, while it was founded in 1784, and is the oldest hospital in Serbia.

When it comes to infectious medical waste, Clinical Hospital Center Zemun has a contract on the treatment of infectious medical waste with the Vozdovac Health Center, Clinical Hospital Center Zvezdara. Infectious medical waste is transported on a daily basis and the cost of the treatment paid for 1 kg of infectious medical waste is 120 RSD gross.

In this stage of the research, revision of the existing infectious medical waste disposal system and costs analysis were performed (first phase on Figure 1). This pilot analysis was carried only for the infectious medical waste generated in the clinics during patients' hospitalization. Based on data collected in the period 01.10.2015.-30.09.2016, values of parameter n_i are calculated (Table 2).

Total number of hospitalization days is 148,917 that, multiplied by 0.7 kg/bed-day, gives 104,241.9kg of infectious medical waste generated during one year. Since unit costs of infectious medical waste treatment are 120 RSD/kg, total annual costs of infectious medical waste treatment are 12,509,028 RSD.

Transportation costs are estimated based on distance between Clinical Hospital Center Zemun and Vozdovac Health Center (12.2km) and characteristics of vehicle (Peugeot Partner Court NV1 1.6 HDI). Estimated annual transportation costs are 319,521 RSD and finally, total costs expressed by the equation (1) are 12,828,549 RSD.

This amount represents 0.52% of the total expenditure of the Clinical Hospital Center Zemun. This low percentage share of the costs for the disposal of infectious medical waste in total expenditures, confirms the current legal regulations in the field of the waste management in Serbia, by which even if the principle of "polluter pays" applies, the cost of waste that has to be paid is by no mean economic, but social (WMS, 2009). The first reason is of a social nature: through these price the living standard of the population was maintained. Another reason for low prices should be sought in the nature of ownership of public enterprises such as tertiary health-care institutions in Serbia.

Table 2: Annual number of hospitalization days per clinics (Source: Clinical Hospital Center Zemun, 2016)

Clinic	Annual number of hospitalization days
Nephrology	5,528
Endocrinology	5,598
Pulmonology	8,148
Hematology	4,797
Gastroenterology	8,248
Cardiology	13,644
Geriatric	11,561
Pediatric	9,170
Neurology	7,846
Surgery	18,690
Traumatology	5,630
Neurosurgery	7,203
Urology	6,839
Otorhinolaryngology and Maxillofacial surgery	5,890
Gynecology	3,803
Obstetric	8,163
Hyperbaric medicine	3,368
Medical oncology	9,052
Neonatology	5,739

5. CONCLUSION

It is evident that the infectious medical waste is a type of high-risk waste and, unfortunately, a necessary byproduct of activities of health-care institutions. This type of medical waste is, unfortunately, a growing category in total medical waste produced. The risks that it carries with itself are most manifested when handling it, and can lead to various hazardous and incurable disease such Hepatitis B and C and HIV.

On the other hand, the current practices in Serbia of safe medical waste disposal usually implies transport to other institutions that will continue with its disposal. In the paper, the authors suggested that the introduction of integrated autoclave with shredder as on-site disposal system will solve the problem of infectious medical at the source - leading to economic efficiency, reduced risks to human health and increased positive environmental impacts.

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