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THERMAL ENERGY FOR STERILIZATION OF HAZARDOUS WASTE

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Abstract. *This research paper presents the results of determining the amount of thermal energy generated during the treatment of hazardous medical infectious waste and sharp objects by steam sterilization. By destroying microorganisms, infectious waste becomes municipal waste. The methods used in the work are: Bowie-Dick test, Biostrip, Tachograph, survey, and calculation. The results investigate the possibility of obtaining combined systems for energy and district heating and cooling from medical waste by plasma gasification for the needs of integrated waste management in the City of Niš.*

Key words: *Combined energy, Infectious waste, Steam sterilization, Thermal energy, Bowie-Dick method*

1. INTRODUCTION

Of the total amount of produced medical waste, 20% is dangerous, while 80% is common municipal waste [1]. Two-thirds of hazardous medical waste include infectious waste that can cause infectious diseases on contact [1], and which is removed by steam sterilization treatment. Other hazardous medical waste, including pathological, chemical and pharmaceutical waste, pressure vessels, and waste containing heavy metals, is exported for incineration treatment to EU countries. The goal of the research is to determine the amount of thermal energy produced during the destruction of medical waste by steam sterilization. Healthcare institutions/sites for treatment of infectious medical waste in Serbia and the City of Niš are divided into 2 categories. The first is the Central Treatment Site (CTS), which represents the central unit for collection and treatment of the infectious waste generated within the healthcare institution and waste from the assigned healthcare institution. The other is the local treatment site (LTS), which represents a central place for collection and treatment of the infectious waste generated within the healthcare facility [2-5]. An experiment to determine the thermal energy produced during the destruction of the medical waste by steam sterilization

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was carried out in an automatic autoclave “Göttingen” at the Niš City Hospital at a temperature of 121°C, for the duration of the sterilization cycle of 15 minutes.

1.1 Model P30489

Model P30489 is a software model used to measure parameters of the energy efficient process of infectious waste steam sterilization, which takes place through the following phases: heating phase - time required to reach the sterilization temperature (up to 120ºC), sterilization phase - constant temperature for infectious waste required sterilization time, and cooling phase - the necessary time to lower the temperature in the autoclave [6,7]. Energy flow of the infectious waste sterilization cycle is presented in Graph 1.

1.2 Calculation of thermal energy that occurs after the sterilization of infectious waste treatment

The calculation of thermal energy that remains after the sterilization treatment of infectious waste is done using the formula [8]:

$$Q = \frac{m}{3600} c(T_2 - T_1) \text{ [kWh]} \quad (1)$$

where: m – mass of waste/cycle [kg]; c – 4,18 kJ/kg·K - water specific heat capacity [J/kgK]; T_1 - chamber temperature [K]; T_2 - heater temperature [K].

2. RESULTS

Before the sterilization of infectious waste, the Bowie-Dick method is used to inspect the empty autoclave.

The Bowie-Dick test is a method for monitoring the amount of air in the steam sterilizers daily. The test package is placed on the bottom of the autoclave before the first filling for the day, at a temperature of 134°C for 5 minutes. The presence of air reduces the sterilization temperature by two degrees, and the indicator turns yellow. Without the amount of air present, the indicator turns black and the sterilization process continues.

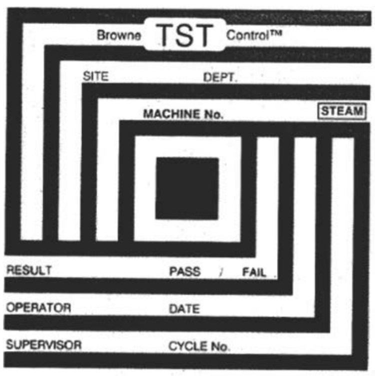
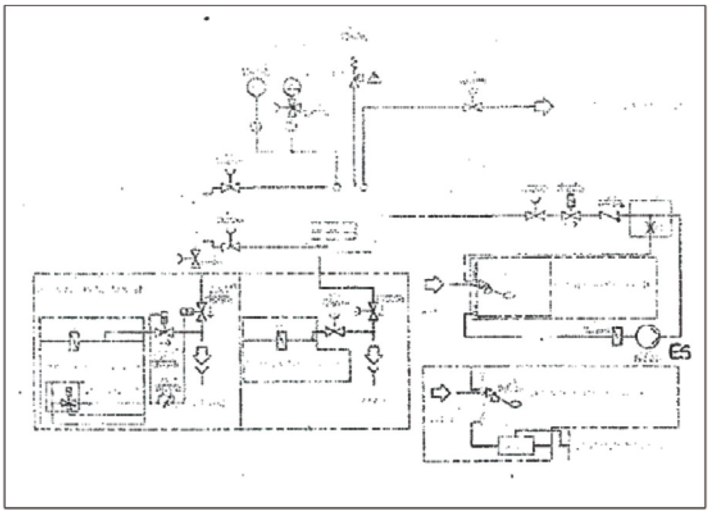
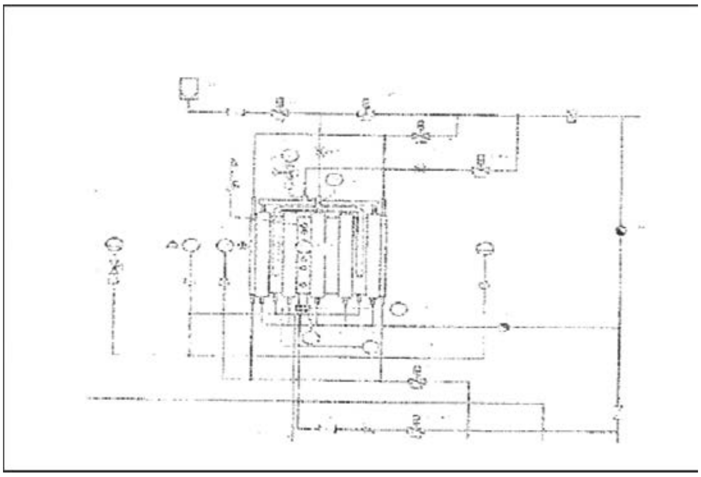


Fig. 1 Results of the Bowie-Dick Test

The automatic sterilizer consists of two containers, a sterilizer chamber in which the sterilization material is placed (24 kg of waste per one sterilization cycle), and a steam generator, shown in Fig. 2.



a) sterilizer chamber



b) steam generator

Fig. 2 Sterilization of the infectious waste in the central waste treatment facility, “CTM”, in the City Hospital in Niš

The parameters for determining the sterilization cycle of infectious waste are shown in Table 1.

Table 1 The parameters for determining the sterilization cycle of infectious waste

No	Process	Methodology	Parameters to measure	Unit	Allowed values	Measured values
1.	Analysis of the amount of infectious waste	Survey	Maximum capacity and total amount of infectious waste	kg		
2.	Checking the sterilization	Bowie-Dick Test	Pre-pulses in vacuum		3	3
			Pre-pulses in superpressure		5	5
			Sterilization temperature	°C	121-134	121
			Sterilization duration	min	0-15h	3.5
			Drying time	min	0-(99)h	3
3.	Destruction of microorganisms		Pre-pulses in vacuum		3	3
			Pre-pulses in superpressure		5	5
			Temperature of destruction of microorganisms	°C	121-135	121
			Time of destruction of microorganisms	min	30-99h	30
			Post-treatment	min	0-99h	5
4.	Automatic Leak Rate Test	LOT	Temperature	°C	134	134
			Time	min	7-10	7
			Pressure	bar	0,013	0,013
5.	Cooling phase		Temperature	°C	0	
			Time	min	7-10	
			Pressure	bar	0,998	

The obtained results show the temperature change - a decrease in the temperature at the chamber outlet, compared to the temperatures at the inlet and at the outlet of the steam generator $t_1 > t_2$ [7,9]. The energy flow of the infectious waste sterilization cycle is shown in Fig. 3.

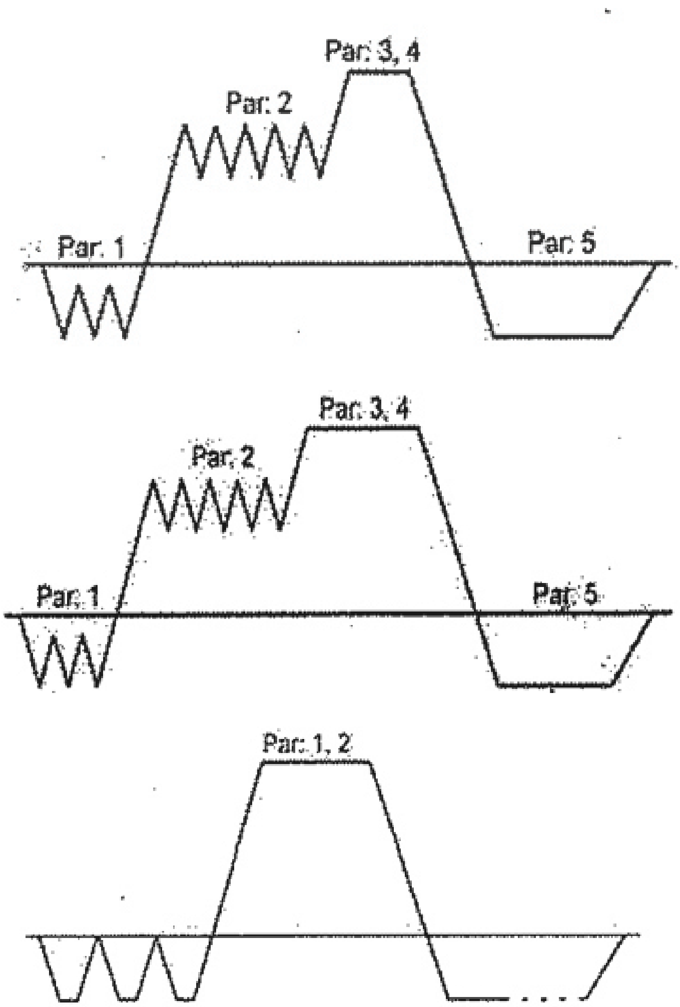
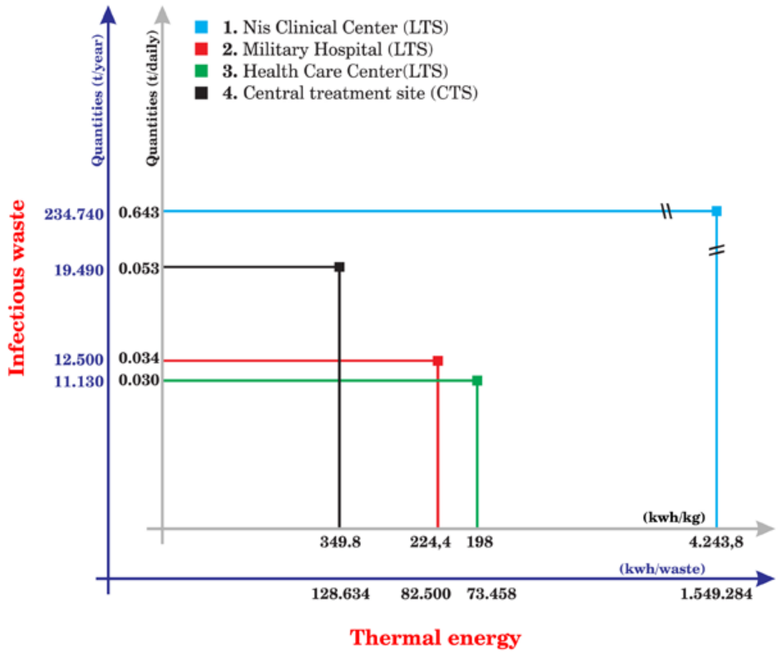


Fig. 3 Energy flow of the infectious waste sterilization cycle

The thermal energy obtained by steam condensation in the steam generator (steam/water system) can be used in district heating systems [7,10,11].

The amount of thermal energy released in the steam generators at waste treatment sites is given in Graph 1.



Graph 1 Thermal energy released in the steam generators at waste treatment sites

The experiment to determine the amount of heat energy used for the sterilization treatment of infectious waste was carried out in the Clinical Center, at the Institute of Health Protection. It is the central place of waste treatment (CTS), as the Clinical Center is the largest generator of infectious waste. The methods used in the work are: survey, Bowie-Dick test, Tachograph, and calculation. The results of the infectious waste sterilization cycle are read on the automatic tachograph test. Measured temperatures of the working fluid (at the entrance of the steam generator - t_{1u}, t_{2u}, and at the exit of the autoclave chamber - t_{1i}, t_{2i}), are used to calculate the total amount of heat energy for the infectious waste sterilization cycle [12]. The remaining thermal energy can be used for the district heating and cooling system.

Due to the incomplete sterilization, caused by other medical waste treatment limitations stemming from high pressure and temperature (flammable substances, oxidants, etc.), a chemical accident can occur. Possible incidents are: leakage of cytotoxic and toxic drugs that generate the emission of heavy metals, contamination of the working environment and operators, process heat losses, pollution of natural resources, lack of post-treatment, crushing (which could reduce the landfill capacity by 154m^3/year), high costs of exporting other hazardous medical waste for incineration treatment, etc. The advantages of the incentives of the Republic of Serbia to privileged electricity producers (0.082 rsd/kWh) point to a new choice of sustainable treatment of hazardous medical waste.

Based on the above, we can conclude the following: the treatment of infectious waste by steam sterilization is a safe and environmentally acceptable way of handling infectious waste for the City of Niš in the Republic of Serbia. The results of the experiment show a sufficient amount of waste as well as the required amount of thermal energy generated by the sterilization treatment of infectious waste in the Göttingen autoclave at the central treatment site (CTS) in the City hospital for the production of combined energy from plasma gasification via two steam generators. One generator would produce steam directly by electrical discharge from the plasma generator. The other produces electricity from purified components of the combustible gas (syngas) with the addition of LPG. The economic aspect is in itself a sufficient reason for consideration, but the main arguments are still on the side of environmental protection and sustainable development [13-15].

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