Journal of Engineering Science and Technology Review
Special Issue on Telecommunications, Informatics, Energy and Management 2019

JOURNAL OF
Engineering Science and Technology Review

Conference Article

www.jestr.org

Research Study About the use of Patients with Cardiovascular Disease Medicines Waste for Electricity Production

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Received 24 September 2019; Accepted 12 February 2020

Abstract

In this paper a study is carried out on the possibility of utilizing the waste of patients with cardiovascular disease medicines for generating electricity. Specifically, the drugs being studied refer to a patient who suffered an acute myocardial infarction ten years ago, and since then he takes them without any change. All drugs under study are in tablet form. The waste tested for each drug includes the box, the package leaflet and the blister. Each sample is weighed separately on a four decimal precision scale and the annual mass of waste for each medicinal product is counted separately. Then, via the bomb calorimeter, the energy content of each waste is measured in cal/g. The problem that occurs when measuring the metallic blisters is solved by using minimum sample mass which causes accepted temperature change or in some cases by using substrates. Then the measurements are annualized, and compared with several electrical consumptions. Then proposals are made for their utilization, with the final aim of protecting the environment. All the conclusions and suggestions take into account the residue left in the capsule of bomb calorimeter after the burning of each of the aforementioned waste.

*Keywords:*Cardiovascular disease medicines; energy content; bomb calorimeter; residue; electrical power.

1. Introduction

Managing municipal solid waste has been acknowledged as a key principle for improving public health and for better environmental protection [1]. Human activities create waste, but it is the way in which these wastes are handled, stored, collected, and disposed of that can pose a risk to the environment and public health [2]. The chief characteristic that determines the quantity of energy recoverable from the combustion of a material is its thermal energy as measured by a bomb calorimeter [3].Bomb calorimeter is an instrument for measuring the energy content of materials in high accuracy [4].

2. Material and method

2.1 Instrumentation and material

The instrument used to measure the energy content of the samples in this research study is Parr 6400 bomb calorimeter (Fig 1) [4]. All the measurements were taken in Physics Laboratory of International Hellenic University Physics Department in Kavala, Greece. A small (approximately 1 g) sample mass is introduced into the bucket of bomb calorimeter (Fig 2) in the form of pelleted chip and is burnt [5]. At the end of the measurement process on the calorimeter display, the value of the temperature change (in ºC) of the water in the calorimeter and the value of the energy content of the sample (in cal/g) are shown.

In this study the measured samples are:

- The box of the medicine
- The instructions leaflet of the medicine
- The blister of the tablets of the medicine

A cardiovascular disease patient follows the medication shown in Tables 1 and 2 [6].

In Tables 2, 3 and 4 the annual amounts of boxes, instruction leaflets and blisters are estimated.

Fig. 1. Parr 6400 bomb calorimeter

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ISSN: 1791-2377

Fig. 2. The 1138 oxygen combustion bomb

Table 1. Medication description

#	Medication	Description
1	ATROST	Atorvastatin, 40 mg, 28 tbs, GAP
2	DILATREND	Carvedilol, 25 mg, 28 tbs, CHEPLA PHARM
3	EZETROL	Ezetimibe, 10 mg, 14 tbs, MSD
4	INSPRA	Eplerenone, 25 mg, 20 tbs, Pfizer
5	OZEPRAN	Pantoprazole, 40 mg, 30 tbs, SANDOZ (Novartis company)
6	SALOSPIR	Acetylsalicylic acid, 100 mg, 20 tbs, UNI-PHARM
7	Z-BEC	Lisinopril, 5 mg, 28 tbs, GAP

Table 2. Annual amount of boxes per medication

#	Medication	Daily dose (tbs/d)	Annual amount of tablets (tbs/y)	Annual amount of boxes (boxes/y)
1	ATROST	1	365	13,0357
2	DILATREND	2	730	26,0714
3	EZETROL	1	365	26,0714
4	INSPRA	1	365	18,2500
5	OZEPRAN	1	365	12,1667
6	SALOSPIR	1	365	18,2500
7	Z-BEC	2	730	26,0714

Table 3. Annual amount of instructions leaflets

#	Medication	Instructions leaflets per box (leaflets/box)	Annual amount of instructions leaflets (leaflets/y)
1	ATROST	1	13,0357
2	DILATREND	1	26,0714
3	EZETROL	1	26,0714
4	INSPRA	1	18,2500
5	OZEPRAN	1	12,1667
6	SALOSPIR	1	18,2500
7	Z-BEC	1	26,0714

Table 4. Annual amount of blisters

#	Medication	Blisters per box	Annual amount of blisters (blisters/y)
1	ATROST	4	52,1428
2	DILATREND	2	52,1428
3	EZETROL	1	26,0714
4	INSPRA	2	36,5000
5	OZEPRAN	2	24,3334
6	SALOSPIR	2	36,5000
7	Z-BEC	2	52,1428

2.2 Estimation of energy content of total amount of medicine waste

For the estimation of the total amount of the medicine waste all the samples are weighed and their annual mass per category is calculated (tables 5, 6 and 7) [7].

Table 5. Total annual mass of boxes

#	Medication	Mass of one box (g)	Total annual mass of boxes (g)
1	ATROST	5,8364	76,0816
2	DILATREND	6,8370	178,2502
3	EZETROL	4,8264	125,8310
4	INSPRA	5,3759	98,1102
5	OZEPRAN	7,6256	92,7784
6	SALOSPIR	3,7478	68,3974
7	Z-BEC	4,6914	122,3114

Table 6. Total annual mass of leaflets

#	Medication	Mass of one leaflet (g)	Total annual mass of leaflets (g)
1	ATROST	1,5346	20,0046
2	DILATREND	3,6992	96,4433
3	EZETROL	2,7400	71,4356
4	INSPRA	2,4887	45,4188
5	OZEPRAN	5,1681	62,8787
6	SALOSPIR	1,9750	36,0438
7	Z-BEC	1,5798	41,1876

Table 7. Total annual mass of blisters

#	Medication	Mass of one blister (g)	Total annual mass of blisters (g)
1	ATROST	1,6699	87,0733
2	DILATREND	2,1254	110,8243
3	EZETROL	1,9233	50,1431
4	INSPRA	1,8072	65,9628
5	OZEPRAN	2,3113	56,2418
6	SALOSPIR	0,9206	33,6019
7	Z-BEC	1,5743	82,0884

Following our research, we measure the energy content of each sample using the bomb calorimeter. In Table 8 the samples description and their IDs are shown.

Table 8. Samples description and ID

#	Medication	Sample description	Sample ID
1	ATROST	Box	ATROST-B-2
		Instructions Leaflet	ATROST-P-2
		Blister	ATROST-T-1
2	DILATREND	Box	DILATREND-B-1
		Instructions Leaflet	DILATREND-P-2
		Blister	DILATREND-T-1
3	EZETROL	Box	EZETROL-B-1
		Instructions Leaflet	EZETROL-P-1
		Blister	EZETROL-T-2
4	INSPRA	Box	INSPRA-B-1
		Instructions Leaflet	INSPRA-P-3
		Blister	INSPRA-T-1
5	OZEPRAN	Box	OZEPRAN-B-2
		Instructions Leaflet	OZEPRAN-SAND-P-6
		Blister	OZEPRAN-SAND-T-1
6	SALOSPIR	Box	SALOSPIR-B-1
		Instructions Leaflet	SALOSPIR-P-1
		Blister	SALOSPIR-T-2
7	Z-BEC	Box	Z-BEC-B-1
		Instructions Leaflet	Z-BEC-P-1
		Blister	Z-BEC-T-3

The problems we encounter at this stage of the experimental process are that the blisters of the tablets, as they contain metal parts, are burned with a sharp rise in temperature, resulting in the risk of instrument destruction.

For this reason, it was considered advisable to measure the blisters with a minimum sample mass or even using a substrate.

When a substrate is used during the measurement with bomb calorimeter there is in addition the process of calculating the actual energy content of the sample after the measurement [8].

In Table 9 the residues for all samples are shown.

Table 9. Residues for all medications samples (B: Box, P: Instructions Leaflet, T: Blister)

#	Medication	Sample	Residue
1	ATROST	B	Slightly yellowish water, almost no ash.
		P	Slightly beige water, almost no ash.
		T	Pure water, few gray balls, almost no ash.
2	DILATREND	B	Slightly beige water, little tiny gray balls, little ash.
		P	Pure water, rubble dust aggregates, zero ash.
		T	Pure water, small silver plate, almost no ash.
3	EZETROL	B	Pure water, tiny balls, zero ash.
		P	Pure water, almost zero ash.
		T	Slightly grayish water, almost no ash.
4	INSPRA	B	Slightly cloudy water, few tiny balls, least ash.
		P	Pure water, almost zero ash.
		T	Pure water, almost zero ash.
5	OZEPRAN	B	Pure water, small gray residue, not stitched to the capsule, no ash.
		P	Slightly beige water, zero ash.
		T	Slightly beige water, silver chips (few) untied in the capsule, a little ash.
6	SALOSPIR	B	Pure water, not sticking to the capsule, almost no ash.
		P	Pure water, dust clutter, almost no ash.
		T	Slightly cloudy beige water, a little ash.
7	Z-BEC	B	Pure water, not sticking to the capsule, almost no ash.
		P	Pure water, dust clutter, zero ash.
		T	Slightly brown water, a little ash.

In Table 10 the date and time of samples gross heat (energy content) measurements are shown.

In Table 13 the measured and the corrected values (when used substrate) of the energy content of samples are shown.

In Table 14 the total annual energy (in cal) for each sample is calculated by multiplying the energy content with the mass of it.

In order to find the actual value of the energy content of a material when a substrate is used, the energy released during the combustion of the sample, due to the use of substrate, is subtracted from the total amount of energy released, according to (1)

$$(GH)_s = \frac{(GH)_{tot}\, m_{tot} - (GH)_{substrate}\, m_{substrate}}{m_s} \qquad (1)$$

where $(GH)_s$ is the energy content of sample, $(GH)_{tot}$ is the total energy content of the mixture (sample and substrate), m_{tot} is the total mass of the mixture (sample and substrate), $(GH)_{substrate}$ is the energy content of substrate, $m_{substrate}$ is the mass of substrate and m_s is the mass of sample [8].

Table 10. Date and time of samples gross heat measurements

#	Medication	Sample	Date and time
1	ATROST	B	7/6/2018, 11:38:39
		P	20/6/2018, 13:40:33
		T	10/5/2018, 11:16:37
2	DILATREND	B	10/5/2018, 11:03:36
		P	20/6/2018, 13:18:56
		T	10/5/2018, 10:51:40
3	EZETROL	B	7/6/2018, 12:18:07
		P	20/6/2018, 12:38:21
		T	15/6/2018, 10:19:09
4	INSPRA	B	5/10/2018, 10:19:41
		P	20/6/2018, 12:53:19
		T	10/5/2018, 10:07:43
5	OZEPRAN	B	6/6/2018, 11:04:40
		P	21/6/2018, 12:42:20
		T	19/6/2018, 13:14:44
6	SALOSPIR	B	7/6/2018, 11:51:36
		P	20/6/2018, 13:05:57
		T	15/6/2018, 09:37:35
7	Z-BEC	B	7/6/2018, 12:05:26
		P	20/6/2018, 13:51:16
		T	15/6/2018, 10:03:42

In Table 11 the samples mass used for the measurements (pure sample or mixture with substrate) are shown.

After the end of the measuring process the temperature rise and the energy content of the sample (Tables 12 and 13) are displayed on the bomb calorimeter display and can be printed in the printer of bomb calorimeter.

Table 11. Mass of samples

#	Medication	Sample	Sample mass (g)
1	ATROST	B	0,3283
		P	0,2835
		T	0,5583
2	DILATREND	B	0,2432
		P	0,3150
		T	0,5505 (substrate Depon 0,5465 g)
3	EZETROL	B	0,2542
		P	0,2548
		T	0,2885 (substrate membrane 0,2325 g)
4	INSPRA	B	0,3105
		P	0,3184
		T	0,5511
5	OZEPRAN	B	0,5584
		P	0,3574
		T	0,2056 (substrate membrane 0,1462 g
6	SALOSPIR	B	0,3825
		P	0,2446
		T	0,1320 (substrate membrane 0,1070 g)
7	Z-BEC	B	0,3043
		P	0,2485
		T	0,1452 (substrate membrane 0,1265 g)

3. Results and discussion

By adding all the energy amounts for each sample, the total energy contained in the heart medication waste for one year can be found. It will be E_{tot}= 6557438 cal. Given that 1 cal = 0,000001163 kWh the total energy of all the cardiovascular medication waste will be 6557438 × 0,000001163 = 7,626300394 kWh. This energy is enough to operate an air conditioner for eight hours or to operate a refrigerator for half a month or for baking in the oven four cakes.

However the calculations were made for one heart disease patient. On a wider scale, the use of medicine waste may be of considerable value.

Table 12. Temperature rise

#	Medication	Sample	Temperature rise ΔT (°C)
1	ATROST	B	1,3135
		P	1,0369
		T	3,7225
2	DILATREND	B	1,0596
		P	1,0519
		T	3,6695
3	EZETROL	B	1,0921
		P	0,8734
		T	3,1576
4	INSPRA	B	1,3289
		P	1,0538
		T	3,6780
5	OZEPRAN	B	2,3213
		P	1,1083
		T	1,9386
6	SALOSPIR	B	1,3926
		P	0,8753
		T	1,4595
7	Z-BEC	B	1,2550
		P	0,9420
		T	1,6675

Table 13. Samples energy content

#	Medication	Sample	Gross heat of sample (GH)s (cal/g)
1	ATROST	B	3547,4908
		P	3199,7543
		T	6102,3126
2	DILATREND	B	3816,8041
		P	2924,0920
		T	Mixture: 6099,1962 Blister: 5989,375
3	EZETROL	B	3770,9735
		P	2963,0730
		T	Mixture: 9986,5931 Blister: 5779,1446
4	INSPRA	B	3796,8812
		P	2898,5105
		T	6106,9300
5	OZEPRAN	B	3765,5128
		P	2724,1932
		T	Mixture: 8494,3940 Blister: 2327,3973
6	SALOSPIR	B	3237,2884
		P	3093,7703
		T	Mixture: 9852,3928 Blister: 4940,632
7	Z-BEC	B	3648,4267
		P	3295,0205
		T	Mixture: 10290,3620 Blister: 5489,8717

Table 14. Samples total annual energy

#	Medication	Sample	Total energy (cal)
1	ATROST	Box	269899
		Instructions Leaflet	64010
		Blister	531348
2	DILATREND	Box	680346
		Instructions Leaflet	282009
		Blister	663768
3	EZETROL	Box	474505
		Instructions Leaflet	211669
		Blister	289784
4	INSPRA	Box	372513
		Instructions Leaflet	131647
		Blister	402830
5	OZEPRAN	Box	349358
		Instructions Leaflet	171294
		Blister	130897
6	SALOSPIR	Box	221422
		Instructions Leaflet	111511
		Blister	166015
7	Z-BEC	Box	446244
		Instructions Leaflet	135714
		Blister	450655

4. Conclusions

Bomb calorimeter is a high precision instrument which measures the energy content of materials. It is widely used in health sector, as well as in the sector of waste management, for environmental protection. Our research in the context of this work has shown that 8 kWh of cardiovascular disease patient drugs waste, may show little energy, but if we look at it in a wider sense, the amount of energy becomes remarkable.

To qualify a material suitable for the production of electricity from its combustion, it should leave a manageable residue. Residues from the combustion of the samples of this research are partly manageable. Therefore, for the exploitation of these wastes, special combustion devices and more maintenance is required.

However, experimenting with non-utilized, waste materials could derive new proposals for their use for electricity production in order to protect the environment.

Acknowledgements

This study was supported by the advanced research laboratory Hephaestus and by Physics Department of International University of Greece, in Kavala. The instrument used is the Parr 6400 bomb calorimeter located at Physics Laboratory.

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