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Physicochemical Analysis of Biomedical Waste Incinerated Bottom Ash Samples to Assess the Biomedical Waste Management Practices of Alwar City, India

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Abstract

Yellow category biomedical waste is a special waste, as it is pathogenic, infectious and hazardous and so it is treated by incineration so as to reduce its hazardness. But the incineration process has many disadvantages, cause it releases many harmful organic compounds, heavy metals and particulate matter which can be carcinogenic. Thus it is very essential that the process is conducted in a controlled manner. The type and concentration of pollutants released during incineration are highly influenced by the biomedical waste management practices followed by the hospital staff (during segregation of biomedical waste in colour coded bins) and at the common biomedical waste treatment facility (during incineration process). So by analysing the ash that is produced as a by-product of incineration two purposes can be achieved. First the toxicity status of the ash can be evaluated and second and most important the biomedical waste management can be assessed, which in itself is crucial as the toxicity level directly depends on this factor. This study was thus designed to analyse the bottom ash samples of incinerated medical waste for pH, total organic carbon (which determine the combustion efficiency of the incinerator at the common biomedical waste treatment facility) and elemental oxide composition (which determine the segregation of biomedical waste into different categories in the hospitals). The results showed that the combustion efficiency was insufficient and the elemental oxide composition highlighted incomplete segregation, suggesting improvements in biomedical waste management so that the toxicity of the waste generated can be reduced.

Keywords: Yellow biomedical waste, biomedical waste management, incineration, combustion efficiency, elemental oxide composition.

Introduction:

An expansion of 15% compound annual growth rate (CAGR) has been witnessed in the health care sector in recent years, but despite of these facts being published regularly, little concern has been shown towards biomedical waste management (BMW M), because only 28% of the hospitals segregate waste as per the rules and 40% of the Yellow category biomedical waste (BMW) is not treated (MoEFCC, 2016; WHO, 2019). The yellow category waste i.e. pathological and anatomical infectious BMW is mainly disposed of by incineration in the advancing countries of the world [1]. Though the disadvantages of incineration over its advantages have been loudly and very clearly vocalised yet because of its feasibility, its ability of reducing tons of BMW into smaller fractions and its capability to treat different types of BMW, many nations including India still adopt this method for final disposal of yellow category BMW [2]. Consequently increased environmental risks can be assured in these nations for increasing volumes of Yellow BMW [3]. Out of the four hazardous categories of BMW i.e. Yellow, Red, Blue and White, the largest fraction % (app. 50% or more) is of Yellow incinerable BMW. Realising this the Govt of India has installed 198 Incinerators at the CBWTF's across the country having a capacity to incinerate 782 tonnes/day of Yellow BMW, with an additional capacity to incinerate BMW through on site incineration being 72 tonnes/ day as per the Central Pollution Control Board (CPCB, 2020) Incineration is a heat based sterilisation technique [5] and in India most of the incinerators are installed at the Common Biomedical Waste Treatment Facility (CBWTF), and as per the CPCB guidelines these are advanced Rotary kiln type, dual chambered with air control devices installed. Despite these precautions it is a well documented fact that the incineration of Yellow BMW has a potential to emit several toxic contaminants such as heavy metals, oxides of metals and non metals and organic nano pollutants [6-8]. These pollutants can have carcinogenic or non carcinogenic effects on human health [9]. Also the ash that is released from incineration (bottom ash, fly ash) is disposed of as landfill. This ash based on its heavy metal contents can be toxic as these can leach into the ground waters [22]. The type and concentration of the pollutants released in the environment during incineration is greatly influenced by two factors: first the BMW M practices followed by the hospital staff for handling of BMW and second the combustion efficiency of the incinerator [8,10]. Thus both the temperatures of the primary and secondary chamber and the batch of Yellow BMW that is fed in the incinerator is very crucial in determining the air quality of the surroundings near a medical waste incinerator (MWI) [11]. It is critical to evaluate both these aspects and as such this study was planned to monitor the BMW M in the hospitals of Alwar city, India. Thus in this study we have tried to assess the combustion efficiency by analysing the bottom ash (BA) samples for pH and total organic carbon (TOC), followed by the elemental oxide composition. The results of both these analyses will definitely help us to evaluate the BMW M scenario of our city, which is very crucial as human health and environment are interrelated. We cannot simply just expand our health care facilities and forget the waste that is being produced from these health care activities. BMW has to be handled safely and this starts from its point of generation i.e. hospitals to its final disposal point i.e. CBWTF.

Method:

Three samples were collected each month from March to May 2022 from the CBWTF which is located in MIA, Alwar. The samples were randomly collected from the point where bottom ash (BA) is discharged from a medical waste incinerator. Residual ash samples were collected to be analysed for pH, TOC, elemental oxides. For this samples app 2 kg in wt were packed in an airtight plastic sterilised bag and were self delivered to JNU, Advanced Instrumentation Lab Delhi for analysis. While choosing the parameters to be analysed, first the importance of each in our study was ascertained. As such pH and TOC were chosen to calculate the combustion efficiency of the incinerator and the elemental oxides which are indicative of the sorting of BMW. pH was analysed by a digital pH meter and Total organic carbon (TOC) was analysed by a TOC Analyzer. The principle of working of a TOC is that it utilises a catalytic oxidation combustion technique at high temp's (upto 720^0 C) to convert organic Carbon into CO_2. The CO_2 formed is estimated by a non-dispersive infrared sensor (NDIR). TOC is thus a measure of the amount of carbon present in the BA samples. To assess the major metallic and non-metallic oxides of the ash samples, the instrument used was X-ray fluorescence (WD-XRF) spectrometer. We used X-ray fluorescence (XRF) technique for our analysis so that both quantitative and qualitative analysis of the samples could be achieved. XRF technique aids in the detection of chemical composition of the analytes present in the sample, along with their percent share occupancy by measuring the fluorescent (secondary) X-ray discharged from the sample upon excitation by primary X-ray source. It is a nondestructive technique and is extremely useful in determining the distribution of the elements in the given samples of ashes, rocks, soils etc. For analysing the three chosen variables the samples of bottom ash were first grinded so as to achieve a particle size of <60 m and then pressed to a pellet. The obtained sample analysis results were tabulated and mean values were calculated. These were also depicted graphically to highlight the monthly variations.

Results and Discussions:

Bottom ash chemical analysis results are shown in **Table 1:**

S No	pH	TOC %
BA1	9.3	4.7
BA2	11.7	2.8
BA3	9.9	5.3
mean	**10.3**	**4.3**

Fig 1 (i-ii): depicts variations in the pH and TOC values for different samples of BA.

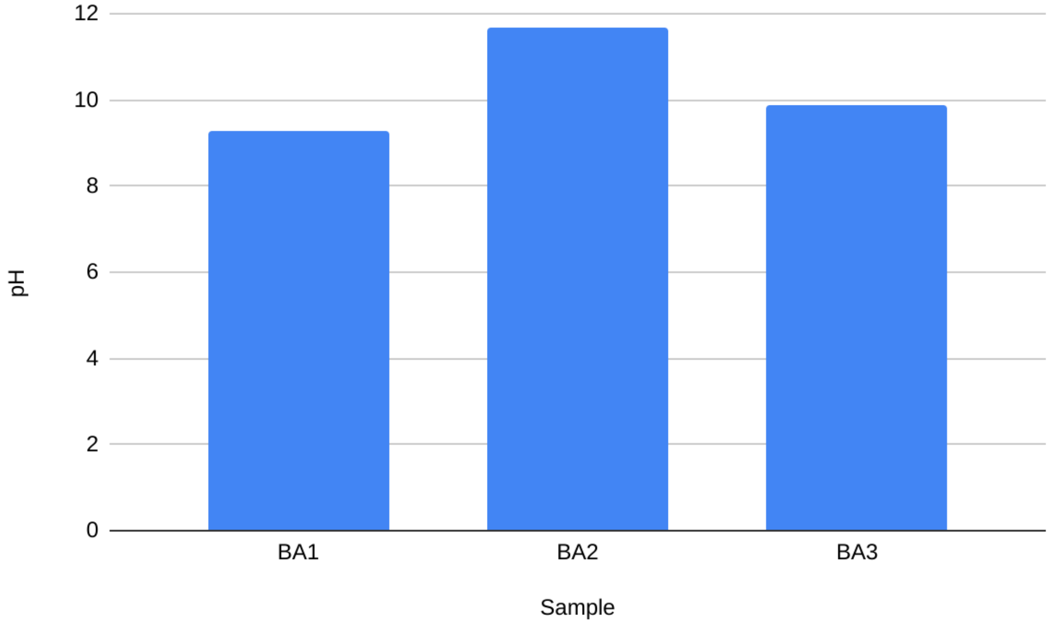

Fig 1 i

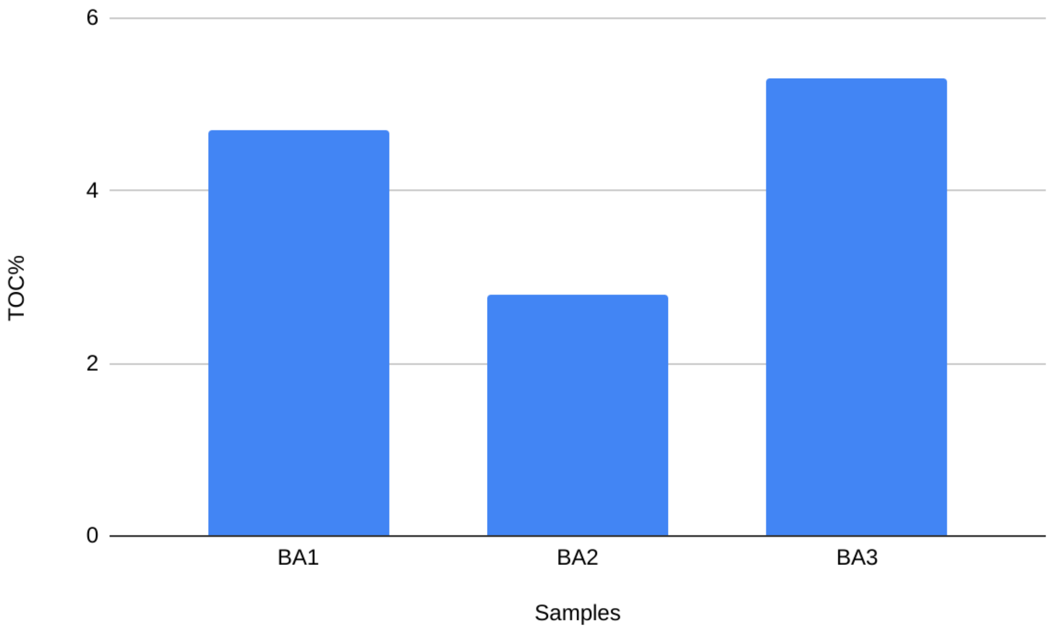

Fig 1 ii

Discussions:

The pH of all the three bottom ash samples was basic with a mean value of 10.3. Regarding Total Organic Content (TOC) the mean value obtained was 4.3%. pH and

TOC are inversely related and denote combustion efficiency (CE) of the medical waste incinerator at the CBWTF. Theoretically speaking a pH higher than 11 and TOC lower than 1 denote 99 % CE, which technically should be achieved by the CBWTF as per the BMW M rules 1998, but in our study this result was not obtained. Our results are in harmony with the findings of [14]. This signifies that nano pollutants (carcinogenic) formed due to incomplete combustion are being released into the atmosphere during pathological BMW incineration [4, 15, 17]. Such nano air pollutants have a delirious effect on human health and environment. The limitations of this study are that tests were conducted in the off-site laboratories so some sample deterioration might be possible.

Table 2 (i-ii): Depicts the elemental composition of BA samples

S No	Elemental Oxides	Percent
1	SiO2	16%
2	CaO	37%
3	Na2O	11%
4	Cl	12%
5	P2O5	4%
6	SO3	5%
7	Other metallic oxides	15%

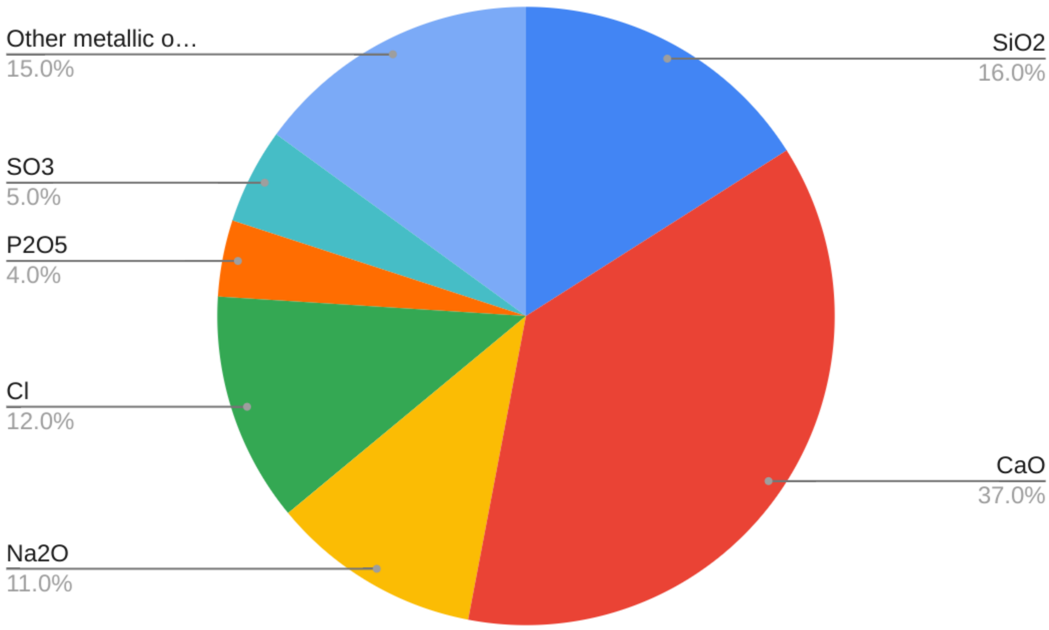

Fig 2 (i-ii):presents the % composition of elemental oxides

ii) Elemental oxides % concentrations.

Other Metallic Oxides	Concentration in %
K2O	2
Al2O3	4.5
MgO	3
TiO2	3
Fe2O3	2.5

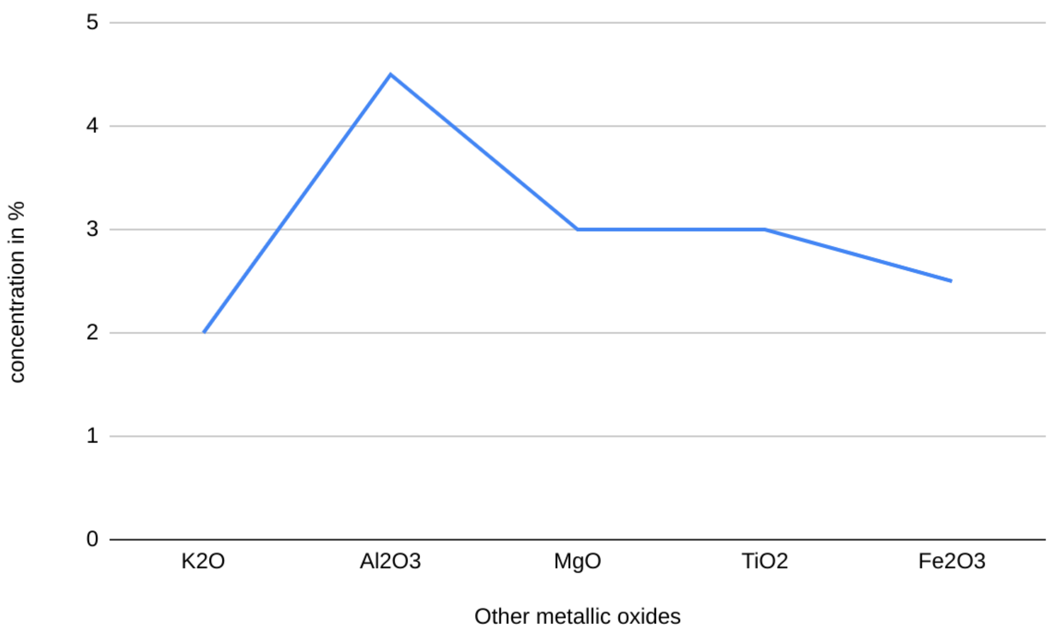

Fig 2 ii

Discussions:

The results of XRF analysis show that among the elemental oxides the major portion is occupied by the metallic oxides (79%). Among these metallic oxides the prime contributors (64%) are the three basic oxides of Ca, Si and Na with 37 % of CaO, 16 % of SiO_2 and 11 % of Na_2O, rest 15 % of metallic oxide share is shared by Al_2O_3 (4.5 %), MgO and TiO_2 each (3%), Fe_2O_3 (2.5%) and K_2O (2%). The remaining 21% are non-metallic oxides of Cl, S & P, with Cl having the largest %age of 12%, probably due to the intensive use of plastics and PVC in medical sector and also due to use of chlorinated drugs and disinfectants, SO_3 5% and P_2O_5 4%. The analysis for elemental oxide composition of BMW bottom ash has its own relevance as some valuable inferences regarding the BMW M status can be drawn from the observed results;

1) Si/Ca ratio: It acts as a diagnostic tool, indicating the mixing of paper and cardboard waste with yellow incinerable BMW. This ratio for BMW should be

less than 1 if paper waste is being segregated, in our results the ratio observed was.43. Our findings are in accord with the earlier results of similar analyses carried in India and elsewhere by [12, 13, 20, 21].

2) Phosphorus among non-metals in BMW should have the lowest % (app 1%) because it is mainly contributed by food and textiles which as per BMW M rules should be segregated as general Municipal waste and are not to be sent to CBWTF for incineration. In the earlier results of [14, 17, 20] the % of P in bottom ash samples of medical waste incinerator (MWI) was less than 1%. This is different from the results obtained in our analysis where P content is 4% which clearly indicates that the segregation is not complete and some mixing of non-hazardous waste with hazardous waste is occurring.
3) A high Cl % is a confirmation of BMW bottom ash samples, since municipal solid waste bottom ash samples have comparatively a lower Cl content of <3% [15, 16, 19]. Cl in MWI is contributed by the excessive use of polyvinyl chlorides in the medical care sector as such alternatives of this should be seeked for.

Conclusions:

Bottom ash is usually believed to be safer than the fly ash. In our study BA sample analysis showed incomplete combustion which may lead to the formation of persistent organic pollutants such as polychlorinated dibenzo-dioxins, polychlorinated dibenzo-furans, and polychlorinated biphenyls. Also the elemental composition showed some differences with the municipal solid waste incinerator ash. Thus before utilising the MWI ash for reclamation purposes its metal analysis for leachability should be done. As the disadvantages of incineration are comparatively more, many developed countries such as USA, Germany, Netherlands have banned the use of incineration and opted for alternative technologies such as microwave, plasma pyrolysis, autoclave which have minimum reported environmental and human health hazards for final disposal of Yellow BMW.

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