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Comparison of the Elemental Structure and Emission Characteristics of Selected PVC and Non PVC Ceiling Materials Available in Nigerian Markets

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Abstract

The recurring fire outbreak in buildings in Nigeria is quite alarming, just as the shift to the use of PVC as a choice for ceiling material due to its aesthetic appearance is on the increase. Hence this study determined the emission characteristics PVC and non-PVC samples. This was done with a view to establishing their suitability as ceiling materials in building designs for tropical countries and providing thermal and combustion data for building stakeholders that could help to checkmate man made fire disasters. This experiment involves the burning of a consistent mass, 50g of 6 samples of 3 PVC and 3 non-PVC in an open furnace where the combustion is carefully controlled. It investigates the flue gasses concentration emitted in the cause of fire outbreak and its effect on occupants. It responds to the question in mind that not only visible flame kills but also toxicity from flue gas can be detrimental to health of victims. The results showed that PVC samples are unwelcome in terms of their emission characteristics which were due to their elemental makeup of their composites such as PVC recorded highest Carbon composition of 77.9% and lowest oxygen composition of 18.0 %. VOCs are cancerous, cause dizziness, rapid heartbeat, vomiting and eventual death. Benzene, a known VOC, is used in making PVC which is a human carcinogen compound. Ceiling materials that will achieve low noxious emission and as well fire retardant should be investigated and employed for use. These materials can be improved upon to achieve environmental friendly building materials.

Keywords: emission characteristics, thermal, combustion, flue gas, fire disaster, fire fighter

INTRODUCTION

Ceiling is the location below the roof which is supported by roof trusses[1] and comes in different designs[2]. Ceiling is composed of elements which is the smallest indivisible substance that cannot be broken into a simpler one by a chemical reaction [3]. An understanding of the element that makes up the samples will help to report the presence of harmful and combustible elements which will either cause health hazard or fire outbreak. The widespread and unchecked fire outbreak of buildings in Nigeria is on the rise which is due to ignorance of the elements used in manufacturing these ceiling materials. Fire outbreak is preventable if and only if preventive measure is really adhered to by building stakeholders and standard organizations[4][5][6]. The specific objectives of this paper are to determine the elemental composition of PVC and non PVC ceiling materials, forecast their emission characteristics and report the integrity of the materials based on results of above objectives. The burning behavior of plastic was investigated and characterized by accounting for the ignition time and after flame time [7]. Plastics are categorized as ordinary combustibles in the class of wood, because they undergo thermal degradation[8][9][10]. The waste generated from newsprint and Kraft paper were used as materials for cement bonded ceiling boards as experimented by Owoyemi & Ogunrinde, 2013.Their result was aimed at managing waste materials from paper converting industries [11].His work recycled wood waste as a resourceful material to produce ceiling tile. Their work aimed at substituting clay component with high sawdust for ceiling tile[12]. Their work investigated the thermal conductivity, thermal absorptivity, thermal resistivity and specific heat capacity of PVC and asbestos establishing them as good insulating materials for ceiling purposes[13][14][15][16].In the work [17], it is reported that several air pollutants contribute to global warming while some inhibit it by impeding solar radiation. There is a national reduction objective for six air pollutants (SO_2, NOx,NMVOCs,NH_3, $PM_{2.5}$andCH4) to be met by 2020 and 2030.The control of thermofluid dynamic processes in combustion channel is proposed so as to reduce dioxin[18]

MATERIALS AND METHODS

Three commonly used PVC samples and also three plant originated ceilings were obtained from the Nigerian market. The samples are shown in plate below.

The emission characteristics of the samples were analyzed in a controlled locally designed combustion chamber which was cleared of ashes to obtain red hot flame free of particle. The combustion analyzers were placed near the flame and gasses concentrations were recorded such as VOC (Volatile Organic Compound), SO_2, CO, NO. The combustion analyzer displayed the gasses emitted and their concentration in part per million.

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Plate: Samples of PVC and natural Ceiling Materials

The elemental Structure of the PVC was carried out at the Centre for Energy Research and Development(CERD) using the Tandem Accelerator Rutherford Backscattering Method(RBS). "RBS is the most frequently used ion beam analysis method. It relies on the fact that the energy of an elastically backscattered particle depends on the mass of the target atom (kinematic factor) and on the depth at which the scattering took place (energy loss on the way to and from the point of interaction). This allows to profile the elemental composition of the sample close to the surface" [19]. Various elements were discovered that are responsible for their emission behavior during combustion.

RESULTS AND DISCUSSION

An insight into table 1 reveal the percentage composition of various samples of ceiling. Cardboard has the highest value of oxygen of 76.0%. This sample will combust very well while samples 7 and 10 with the same value of 18% will only support it at a minimal level. SamplesPVC 3 has composition of 63.6% which will support combustion next to cardboard.

PVC 7 and 10 have highest value of carbon of 77.9%. Their combination with oxygen will yield smoke which will make escape difficult. Cardboard has lowest carbon composition with value of 10%. Its combination with oxygen accounts for why it supports rapid combustion and the blue flame it yields when combusted.

Nitrogen is not detected in plant originated ceiling materials unlike in PVC samples.It has minimal implication to trapped occupant during combustion.

A prolonged inhalation of silicon fume causes a lung disease called silicosis. PVC 3 has the tendency to this implication as it has the highest trace with 3.5%. Other samples recorded similar composition of 0.2% though its effect is insignificant due to its low percentage composition.

PVC is a makeup of chlorine and its by product is usually dioxin which has damaging effect on the central nervous system in babies, liver damage and danger of cancer. Particle board is free of its implication unlike other samples which have trace of chlorine in them. It is present in PVC 3 with composition of 2.2%. The combustion of PVC 3 will release chlorine element to trapped individual and its prolonged inhalation will result into a damaging effect.

Sodium is 2% in PVC 3 and consistent in other samples with value 0.2%. Its combination with oxygen and hydrogen will cause extreme burns. PVC 3 has potential for the side effect and will be insignificant with other samples due to low percentage trace of the element.

Calcium is present in all the samples at different percentage as it is mostly significant in cardboard with value 5.1% and least significant in PVC 7and 10 with value of 0.1%. The experience of headache and irregular heartbeat during fire outbreak will be traceable to the presence of calcium.

Potassium is not present in the plant originated ceiling samples and its value is generally low, thus its effect will be negligible.

Aluminum is dominant in PVC3 though low at 0.5%and present in other samplesat 0.05%. Excess exposure to aluminum affects the central nervous system causing brain disease.

Titanium is not present in sample 10 and present in other samples with value 0.1%. it is a safe metal and it is not cacinogeneous. Over exposure to it will cause eye irritation during fire outbreak and rescue mission.

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Iron is only detected in sample 10 with value 0.1%. It is also a safe metal.

Sulphur causes irritation of the skin and is responsible for varied degree of burnt as it keeps dehydrating and peeling the skin during combustion. This is experienced in plant originated ceiling samples and highest in particle board with value 2.1%.

PVC 3 with value of 0.01% lead and PVC 10 with value of 0.02% will have a damaging effect to victim of fire outbreak such as rise in blood pressure and reduction in fertility level of men.

Magnesium is not detected in most samples except for plywood and cardboard with similar value 1.5%. It is highly flammable in its uncombined state resulting into an explosive hazard.

Emission Characteristics

Table 2 revealed that PVC3 ranked highest in VOC with 1999ppm, CO 1722.0ppm and NO 9ppm hence has highest total noxious gasses 3732.5ppm. A victim trapped will experience serious symptom, from 1500ppm of VOC upward when exposed to the hazard. For, CO there will be loss of consciousness starting from 100ppm. Symptoms of weakness to escape after 20 minutes of exposure and death after 1hour of exposure at 1600ppm.H_2S is not detected in PVC 3 hence no implication.SO_2in PVC 3 is 2.5ppm, the concentration is low hence no potential hazard is associated with this.

All PVC ranked high in VOC and are beyond the minimum exposure limit of 500ppm[20] which will lead to illness at 60minutes while plant originated ceiling materials ranked low and are acceptable in this regard. Particleboard is lowest in CO with 57ppm which is safe compared to the 100ppm unsafe level as predicted [20]. Particleboard will give visible flame due to less CO unlike PVC3 which will smoulder causing poor visibility and reduction of the oxygen level in the body needed to transport the blood.

SO_2 is highest in cardboard with value of 4.7ppm, it is however insignificant due to low concentration. It is not detected in plywood and particleboard.

Particleboard has highest NO value among plant originated ceiling materials with the value of 9ppm while cardboard and particleboard recorded 1ppm. There will be skin and eye irritation during fire outbreak[20][21].

Particleboard ranked first in terms of least noxious gasses followed by plywood, cardboard, PVC 7, PVC10 and highest in PVC3.

Table 1: Elemental Composition

SAMPLE TYPE	ELEMENTAL COMPOSITION (%)													
	O	C	N	Si	Cl	Na	Ca	K	Al	Ti	Pb	Fe	S	Mg
PVC3-RBS	63.6	15.9	10.6	3.5	2.2	2.0	1.0	0.5	0.5	0.1	0.01	ND	ND	ND
PVC7-RBS	18.0	77.9	3.0	0.2	0.23	0.2	0.2	0.1	0.05	0.1	ND	ND	ND	ND
PVC10-RBS	18.0	77.9	3.0	0.2	0.23	0.2	0.1	0.1	0.05	ND	0.02	0.1	ND	ND
Particle Board	39.9	56.7	ND	0.2	ND	0.2	1.7	ND	0.05	0.1	ND	ND	2.1	ND
Plywood	62.0	30.4	ND	0.2	2.1	0.2	1.4	ND	0.05	0.1	ND	ND	2.0	1.5
Cardboard	76.0	10.0	ND	0.2	0.6	0.2	5.1	ND	0.05	0.1	ND	ND	0.8	1.5

Table 2: Peak Concentration of Selected Samples at 0.05kg

z	Peak Concentration (ppm)					
	VOC	CO	SO_2	NO	H_2S	TOTAL NOXIOUS GASSES
3	1999	1722.0	2.5	9.0	ND	3732.5
7	740.6	732.0	1.1	3.8	ND	1477.5
10	842.8	726	0.0	0.2	20.9	1589.9
Plywood	17.0	482.0	0.0	1.0	ND	500.0
Particle board	31.2	57.0	0.4	4.0	ND	92.6
Cardboard	161.8	938.0	4.7	1.0	ND	1105.5

CONCLUSION AND RECOMMENDATION

PVC 3 usage should be discontinued due to its noxious gasses. A composite of particleboard and a negligible noxious material is recommended for ceiling.

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