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DISPERSION OF TOXIC EXHAUSTS FROM LIQUID ROCKET PROPELLANT COMBUSTION

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ABSTRACT

Environmental impact assessment of liquid rocket motor exhaust obtained due to mainly liquid propellant combustion have been highlighted. Exhaust product analysis has been carried out theoretically by computer software NASA CEC -71 to identify toxic emissions of rocket combustion. In the present study a high volume Air Samplers (APM-430) was deployed at predetermined locations near launch pad for collection of toxic exhausts using liquid absorbents during actual missile launch. The collected samples were analyzed subsequently for quantitative estimation of suspended particulate matter (SPM), oxides of nitrogen (NOX) and oxides of sulphur (SOX) etc. with the help of a spectrophotometer. The dispersion pattern of the various toxic gases verses time and distance has also been monitored.

INTRODUCTION

Rocket is a device or engine that converts chemical energy into mechanical motion. Hot gases are produced in combustion chambers of jets and rockets by burning a fuel with oxygen or an oxidizer. The satellite launch vehicle programs use hydrazine, unsymmetrical dimethyl hydrazine (UDMH) and monomethyl hydrazine (MMH) as fuel along with red fuming nitric acid (RFNA), dinitrogen tetroxide and liquid oxygen as oxidizer. A typical liquid propellant consists of G-fuel (equal mixture of xylidene and triethylamine) and red fuming nitric acid is used by missiles. These hypergolic propellants are the most energetic propellants being used the liquid rocket motors all over the world. G-fuel which contains triethylamine with very high vapour pressure is a big fire hazard. Xylidene is toxic whereas triethylamine is a strong irritant. UDMH is known to be carcinogenic. Thus launching of rockets & missiles from a test range produce a lot of toxic gaseous exhausts and pollutants to the local atmosphere. To ascertain environmental safety of these toxic exhaust products there is a need to have study of nature of the combustion products and their quantitative estimation.

EXPERIMENTAL METHODS

Theoretical combustion products analysis was carried out for liquid propellant (G-fuel and RFNA) using a computer software NASA-CEC-71.3 Ideal gas

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equation was used in the theoretical calculations at an operating pressure of 0.1 MPa. Elemental compositions used for theoretical exhaust product analysis were C (21.92930 mol/kg), H (52.1416 mol/kg), N (13.4889 mol/kg) and O (30.9461 mol/kg) with a heat of formation value of ΔH_f : -2189.62 kJ/kg. A high volume Air sampler (APM-430) using glass fibre micro filter paper (GF/4) was employed for collection of suspended particular matter (SPM) as shown in Fig.1. The detailed experimental procedure has been described elsewhere.4 Quantitative estimation of SPM is normally expressed in $\mu g/m^3$. However, for collection of toxic combustion gases like oxides of sulphur, SOx and oxides of nitrogen, NOx etc. liquid absorbents were used. The collected samples were analyzed subsequently for quantitative estimation with the help of a UV-visible spectrophotometer. This experiment is repeatedly being carried out before, during and after actual rocket launch.

RESULT AND DISCUSSION

Air pollution may be described as the presence of air pollutants in the atmosphere to such an extent that they cause deterious effects. Primary air pollutants are emitted directly into the atmosphere and secondary air pollutants are formed in the atmosphere by reactions among two or more pollutants. The concentration of air pollutants depends not only on the quantities that are emitted directly from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions along with the various physical and chemical dissipation processes liable to remove pollutants through self purification processes (Garg, 1998). Vehicular transportation vitiated the environment by emanating obnoxious and toxic pollutants like oxides of nitrogen, (NOx), carbon monoxide (CO), hydrocarbon (HC) and particulate matter to the surrounding atmosphere, which results in serious health hazard to community. Similarly fly ash, oxides of sulphur, (SOx), oxides of nitrogen, (NOx) and CO_2 emerges to be four major pollutants of concern in thermal power plant emissions (Dash, 2004). In the wake of industrialization consequent rapid urbanization, economic development and ever increasing population over last few decades, ambient air pollution problems has increased by several folds (Kudisia, 2003).

The impact of air pollution on human beings has been the major force motivating efforts to control it.

Table 1. Theoretical exhaust product analysis for liquid propellants

Combustion products	Concentration (mol/kg)	Combustion products	Concentration (mol/kg)
CH_4	0.000006	HCO	0.000001
CO	19.763367	CO_2	2.165862
H	0.003118	H_2	19.218075
H2CO	0.000003	HCOOH	0.000001
H_2O	6.850863	HCN	0.000026
N_2	6. 74435	NH_2	0.000163
OH	0.000051		

* Cut-off value for the concentrations: 1.000E-0006

Table 2. Exhaust product analysis during experimental flights for liquid propellants

No. of experiments	Exhaust products	Safety standards	Ground level	During Mission 50 m	After 1 h	During Mission 100 m	After 1 h
Rocket -1	SPM	500	45-60	353.41	53.7	109	46
Rocket -2	(µg/m3)			445	60.5	99.7	55
Rocket -3				403	91	105	45
Rocket -1	SO_2	120	0.1-0.4	1.223	0.6	1.3	0.6
Rocket -2	(µg/m3)			2.5	0.5	1.34	0.3
Rocket -3				1.3	1.1	0.6	0.3
Rocket -1	NOx	120	2-10	135	17	56	9.87
Rocket -2	(µg/m3)			145	25	39	11.5
Rocket -3				183	39.21	51	10

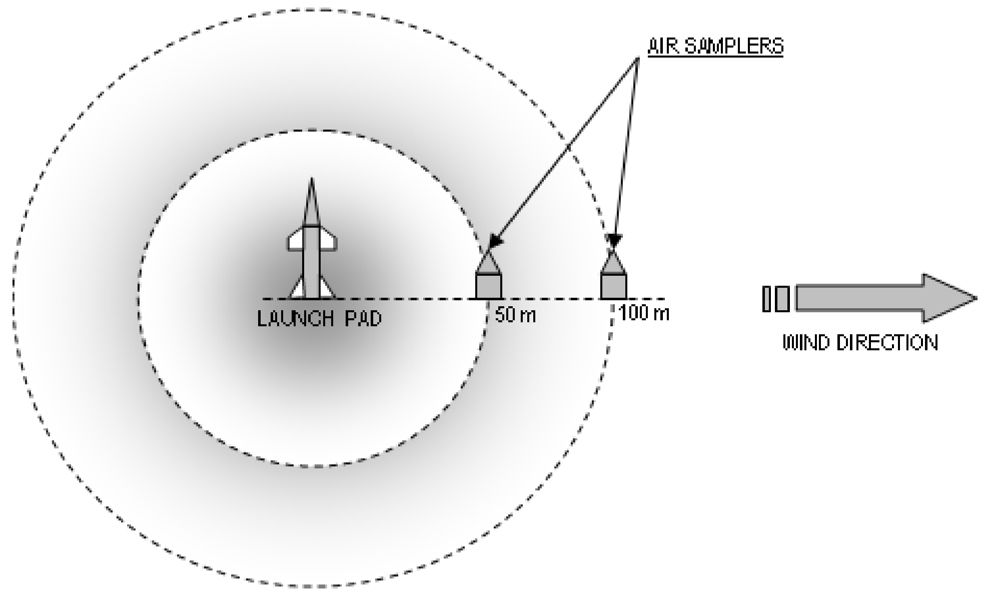

Fig. 1 Collection of gaseous exhaust with the help of Air Samplers

Most people do not have the luxury of choosing the air they breathe. Air pollution principally affects the respiratory, circulatory and olfactory systems in the human beings. Physiological or bio chemical changes have been observed in plants exposed to air pollutants including alterations in net photosynthesis and metabolic activities. The major air pollutants which are responsible for plant degradation are O_3, SO_2, NO_2, Florides, and Nitrates. Acid rain is the most popular term for a very complex environmental problem. In a simplest case, CO_2 dissolves in the rain drops forming Carbonic Acid. It represents the base line for acid rain, which can be aggravated by air pollutants like SO_2 and NOx. The effects of acid rain can be realized in loss of vegetation and aquatic eco system. Last but not the least, warming of the local atmosphere is expected to occur as a result of the increase of CO_2 and other green house gases. Considering the above facts one can concentrate on lower toxic emissions as it affects us, our local atmosphere including globally as well. Thus, the authors made an attempt to highlight environmental safety assessment of liquid rocket combustion.

Table 1 shows the theoretical exhaust product analysis of liquid propellants using G fuel and RFNA. The field evaluation results for different experimental rocket launches are listed in Table 2. It has been seen that before launching of rocket the level of toxic gases like SPM, oxides of sulphur, SOx and oxides of nitrogen, NOx etc in ambient air are negligible. During firing although the level of toxic gases are increasing to some extent but the concentrations are well within the safety limits for ambient air quality standards as prescribed by Central Pollution Control Board and Ministry of Environment and Forest, Gov't of India as shown in Table 2. To determine the dilution and dispersion pattern of various gases, samples are collected after 1 h of rocket firing. From the results it can be seen that the toxic gases and particulate matter are dispersed so quickly that after 1 h the level of toxicity falls down to a very low safety level i.e. close to calibration values. Similar reduction of toxic emissions are achieved by placing the air samplers at two different locations. The one which was positioned close to the launcher absorbs comparatively more toxicants than the other which placed far from the launcher. Thus rocket launch using liquid propellant is generating different toxic gases momentarily and dispersed very fast to ascertain environmental safety.

CONCLUSION

Combustion of propellant during rocket launch generates lot of toxic gaseous exhausts and pollutants to the local atmosphere. The concentrations of the toxic products are within the safety standards prescribed by CPCB Govt of India. Dilution and dispersion of toxic emissions are very fast thereby reducing any adverse effect to the environment.

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