shows the variable x as a function of time. It can be regarded as a negative ramp with upward flyback. The flyback has a structure which is shown by capturing it by manual intervention 7 times and plotting only those segments in Figure 2 *c*. Again, there are two distinct phases but their alternation is not as random as intermittency would seem to require. The flyback occupies a small portion of time in the total period, as does the bulb in Figure 1. That no two flybacks are exactly identical is seen more convincingly in Figure 2 *a* rather than in Figure 2 *c*.

The part-periodic, part-chaotic orbits illustrated here would represent systems in which over some time or phase-space region there is very good predictability provided by periodicity and elsewhere it is unpredictable due to chaos. The transitions from one of these behaviours to another are also predictable, i.e. there is a fairly regular alternation between predictable and unpredictable modes, indicating that these are not cases of intermittency as normally understood. The earlier discussion on terminological rigidity is entirely relevant in such cases.

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GC–MS evidence of dimethyl isocyanurate and 2,4-dione in the blood of Bhopal victims

It has been reported earlier by us that apart from methyl isocyanate many other reaction products, reformulated and reconjugated due to the high pressure and temperature developed in the tank, had escaped from the tank E-610 of Union Carbide India Limited, Bhopal, on 2/3 December 1984 (ref. 1–3). Some of these compounds were inhaled by the victims[4,5].

Materials corresponding to the peaks representing DMI and 2,4-dione of the compounds described earlier[1–3,6] with a common molecular weight of 157 amu were investigated. The 'reference compounds' were isolated and purified by column chromatography from the tank residue material obtained through the Central Bureau of Investigation (CBI), New Delhi.

The identity of these compounds was established on Varian model 3400 capillary gas chromatograph (GC) interfaced with ion trap detector (ITD) model 800 of Finnigan MAT Ltd., UK. This system was used to obtain GC retention time data as well as mass spectral data (GC–MS). Ultraviolet spectral analysis was carried out on Beckman simulated spectrophotometer.

One hundred and twenty-four randomly selected cryo-preserved blood samples of the gas victims, for the period 1984–1990, were studied. Fifty-two clinical samples of the blood collected during the same period were also exposed to this study. These were processed and analysed on GC–MS according to the earlier described method[4].

The isolated and purified DMI showed a melting point between 208 and 210°C. It exhibited 99.9% purity on GC-ITD and showed principal mass fragmentation peaks at m/z = 58, 157, 70, 43, 128, 100, 85 (Figure 1) and matched with fragments reported in the literature[6]. Its ultraviolet spectrum showed a maximum at 214 nm.

The isolated and purified 2,4-dione showed a melting point of 80–82°C; the literature values of the prepared compound were slightly variable. D'Silva *et al.*[6] observed 87–92°C and Etienne and Bonte[7] reported 95°C. The principal mass fragments on GC-ITD were at m/z = 42, 156, 56, 99, 113, 72 (Figure 2). The ultraviolet spectrum showed its maximum at 237 nm.

Some representative chromatograms with their respective mass spectra in the inset clearly show the presence of dimethyl isocyanurate and dione in the victims of the disaster (Figures 3 and 4).

Dimethyl isocyanurate (DMI) (1,3-dimethyl-1,3,5-triazine-2,4,5(1H,3H,5H)-trione) and 2,4-dione (dihydro-1,3,5-trimethyl-1,3,5-triazine-2,4(1H,3H)-dione) were found to be present in the blood of the victims. DMI was positive in the blood of 12 post-mortem and 2 clinical samples of December 1984, while it was absent in the samples for the years 1985–

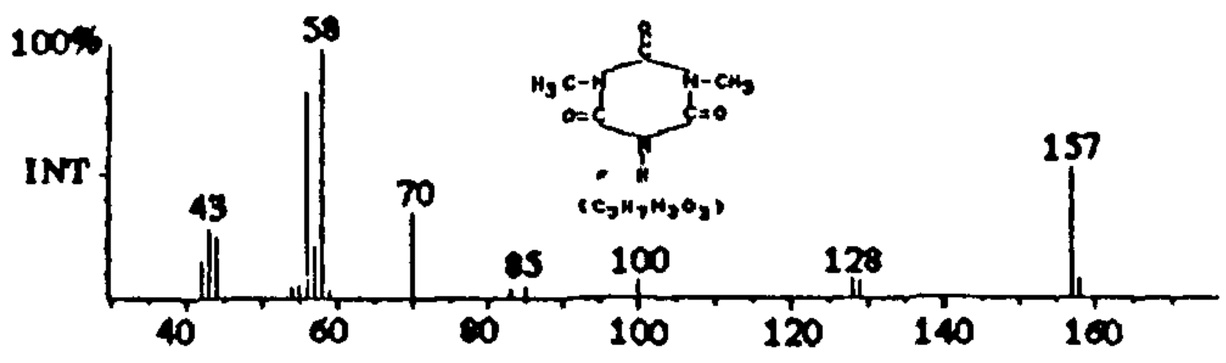

Figure 1. Mass fragmentation pattern of purified dimethyl isocyanurate

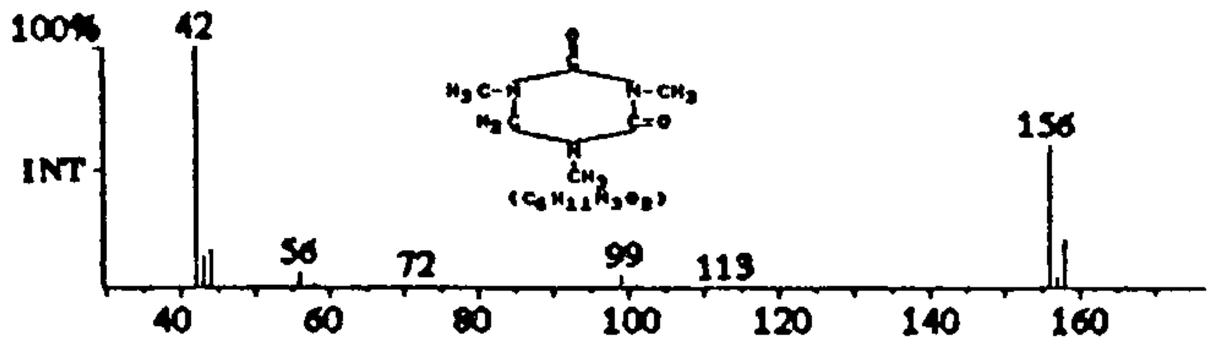

Figure 2. Mass fragmentation pattern of purified 2,4-dione

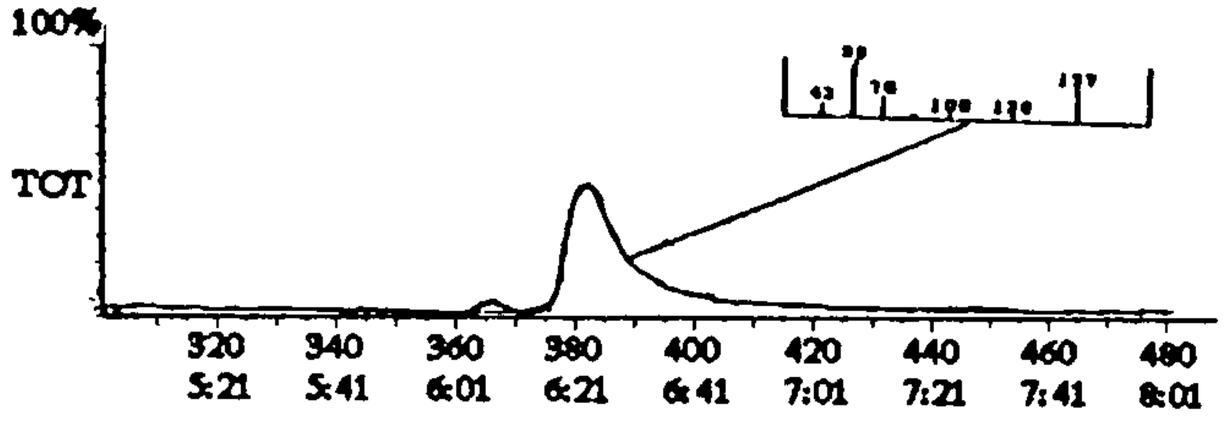

Figure 3. GC–MS chromatogram of an exposed blood sample showing the presence of dimethyl isocyanurate (inset – mass spectrum of DMI).

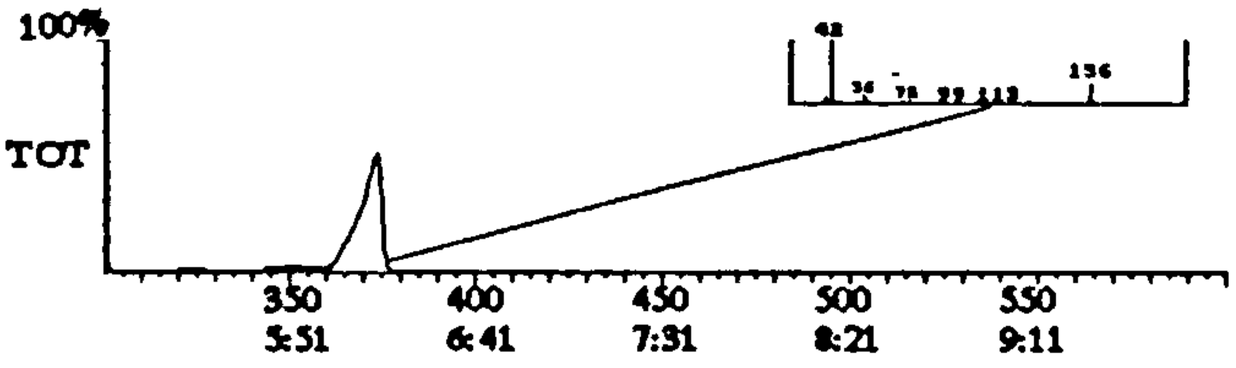

Figure 4. GC–MS chromatogram of an exposed blood sample showing the presence of 2,4-dione (inset – mass spectrum of 2,4-dione).

Table 1. Yearwise distribution of the GC-ITD analysis of clinical and post-mortem (PM) blood samples of aerosol-exposed victims for the presence of DMI and 2,4-dione

	Analysed		Blood samples positive			
			DMI		2,4-dione	
Year	Clinical	PM	Clinical	PM	Clinical	PM
1984 (Dec)	2	61	2	12	–	1
1985	30	28	–	–	–	–
1986–1990	20	35	–	–	–	–
Total	52	124	2	12	–	1

1990 (Table 1). One individual blood sample showed the presence of both DMI and 2,4-dione. (Other chemical ingredients present in the blood have been reported separately[4, 5, 8].)

Both of these compounds are of paramount importance because of their presence in the human body. In an earlier work, we have reported the presence of methyl isocyanate in the form of methyl carbamylation of valine[8], and the reaction products as such, viz. methyl isocyanate trimer[4] and a spiro compound having a molecular weight of 269 amu[5]. Toxicological effects of these compounds are not yet known. Experimental studies on animals are indicated in these circumstances and are proposed to be undertaken to find out their adverse effects on human health.

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