Visual disturbances after experimental human exposure to triethylamine

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ABSTRACT Two volunteers were exposed to various airborne concentrations of triethylamine. Levels of 18 mg/m³ for eight hours caused subjective visual disturbances (haze and halos) and objective corneal oedema. The effects faded within hours after the end of exposure. The visual disturbances are unpleasant and may cause accidents at work and in traffic after the end of work.

Aliphatic and alicyclic amines are widely used as catalysts for polymerisation reactions—in urethane and epoxy resin systems, for example—solvents, and corrosion inhibitors. They are also used as intermediates in the production of various chemicals and pharmaceuticals.

Industrial exposure to some of these amines may have several effects on health including dermatitis,¹ throat and eye irritation,² and asthma.^{3,4} Furthermore, massive experimental exposure in animals may cause eye damage⁵ and visual disturbances ("blue haze") have occasionally been noted after industrial exposure to certain volatile aliphatic and alicyclic amines, both in plants producing polyurethane foam and in plants manufacturing amines.⁶⁻¹⁰ Nevertheless, only scanty data on the exposure levels of amines associated with visual disturbances have been reported.^{7,9,10}

Triethylamine is a common catalyst in polyurethane foam. It has been mentioned as causing visual disturbances,^{10,11} but detailed information is lacking. We report here on the ocular effects after experimental human exposure to different concentrations of that amine.

Methods

EXPOSURE CHAMBER

The exposure chamber consisted of two polyvinylchloride film (1 mm) cylinders, an inner (height 2.2 m, diameter 1.4 m) and an outer (height 2.4 m, diameter 1.8 m). The cylinders were suspended from a 2.0 × 2.0 m wood lamellate plate which could be lifted; during the experiments it was kept 2.7 m above

the floor. The chamber contained two chairs and one desk. Desk work was performed in the chamber during the experiments. Experiments lasting four hours were made without breaks but during experiments lasting eight hours there was an exposure free period of five minutes after each two hours.

Air (50 m³/h; 23°C; turn over rate 12/h; 43% relative humidity) was blown into the chamber through the top of the inner cylinder. Turbulence was caused by the injector arrangement and by two fans. The air was evacuated through the slit between the cylinders by an evacuation system with a capacity somewhat higher than the inlet system. Triethylamine was injected with an automatic infusion device (regulated stepwise between 0.1 mm/min and 20 mm/min) in a separate air stream (12 l/min) that was added to the main air stream on the top of the inner cylinder.

The level of the amine in the chamber was monitored continuously by an infrared (IR) gas analyser (MIRAN-1A; wavelength 9.3 µm; pathlength 20-25 m). In addition, the air level of amine in the chamber was determined during 15 minute sampling periods every two hours. Samples were obtained by the use of pumps (MSA, 1 l/min) and an impinging vessel containing 10 ml 0.1 M HCl.

Analysis of the amine was made using the method of Audunsson and Mathiasson¹² with minor modifications. To 1 ml of the absorption solution was added 250 µl 1 M NaOH in a 0.25% (v/v) NH₃ solution. Analysis was made by gas chromatography (GLC; Varian 3700; injector temperature 170°C; stainless steel column, Carbowax 4000 special and 2% KOH on Chrom W AW, column temperature 130°C; TSD, detector temperature 190°C) of a 1 µl aliquot).

The detection limit for the GLC analyses was 0.01 mg/m³, and for the IR determinations 0.1 mg/m³. The amine level in the exposure chamber was stable,

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the coefficients of variation in the IR recordings (at readings each 15 minutes at average levels of 48 and 18 mg/m³) were 4% and 7%, respectively.

OPHTHALMOLOGICAL EXAMINATIONS

Two healthy men (age 44 and 46) were studied and subjective descriptions of the visual disturbances (including the latent time between onset of exposure and start of effects) and a grading of the effect were obtained during and after each experiment.

A detailed ophthalmological examination was made before each experiment and 15–30 minutes after each exposure. The examination included visual acuity, slit lamp examination and the anterior segment of the eye, and pachymetry (Haag-Streit) of the cornea.

Results

Ophthalmological examination before exposure showed no abnormalities except slight myopia in subject 1 correctable to 1.0 (table).

Exposure for four hours at an average level of 48 mg/m³ caused pronounced visual disturbances that started one hour after the onset of exposure (table). Both subjects experienced a heavy hazing of the visual fields and the outlines of objects 100 m or more away could not be made out. Lights were surrounded by pronounced bluish halos. Both subjects complained of slight discomfort in their eyes but no definite irritation.

An ocular examination of both subjects showed a slight decrease in visual acuity (table). There was a pronounced epithelial corneal oedema and slight con-

junctival injection of both eyes, strictly confined to the palpebral fissures. Pachymetry readings showed an increase in corneal thickness (table).

The phenomena faded away gradually and had totally disappeared after four and four and a half hours, respectively, in the two subjects.

The next morning visual acuity was 1.0 in each eye of both subjects. There was no sign of corneal oedema and the eyes were pale. Pachymetry readings in each eye of both subjects had returned to the base line (0.54 mm).

Similar effects were noted after an exposure for four hours to 34 mg/m³, but the visual phenomena then started after about two hours and were less severe. Both subjects this time noted that it was possible to "avoid the fog" by bending the head forward, thus "looking over the haze." The fog and blurring of outlines was, however, obvious and there were also distinct halo phenomena. No discomfort of the eyes was noted.

Ocular examination showed no objective reduction in visual acuity. A moderate epithelial corneal oedema was present in both subjects, slightly more pronounced in subject 1, but virtually no conjunctival injection. Pachymetry readings were somewhat increased in subject 1 but only marginally so in subject 2 (table).

A level of 18 mg/m³ caused visual disturbances after four to six hours of exposure. The phenomena occurred gradually and were at most, slight. In one of the subjects the effects might not have been noted had he not been particularly observant.

Ocular examination after four hours exposure

Ocular effects of exposure to different levels of triethylamine (TEA)

TEA level (mg/m ³)	Time of exposure (h)	Subject No	Ocular effects			Visual acuity		Corneal thickness		Duration of "blue haze" (h)
			Latent time* (h)	Subjective intensity†	Corneal oedema‡	RE	LE	RE (mm)	LE (mm)	
0	—	1	—	—	—	1.0	1.0	0.54	0.54	—
		2	—	—	—	1.0	1.0	0.54	0.54	—
48	4	1	1.0	+++	+++	0.5	0.8	0.64	0.61	4.0
		2	1.0	+++	+++	0.7	1.0	0.60	0.59	4.5
34	4	1	1.9	++	++	1.0	1.0	0.58	0.59	2.5
		2	1.7	+(+)	+(+)	1.0	1.0	0.56	0.56	1.7
18	8	1	4-6	+	+	1.0	1.0	0.57	0.57	1.0
		2	4-6	(+)	(+)	1.0	1.0	0.55	0.56	1.0
18	4	1	—	—	—	1.0	1.0	0.54	0.54	—
		2	—	—	—	1.0	1.0	0.54	0.54	—
10	8	1	—	—	—	1.0	1.0	0.54	0.54	—
		2	—	—	—	1.0	1.0	0.54	0.54	—

*Time between onset of exposure and start of visual disturbances.

†Haze and halo phenomena. For grading, see text.

‡Slit lamp examination. For grading, see text.

RE = Right eye.

LE = Left eye.

showed no pathological findings in either subject. After eight hours exposure a slight epithelial corneal oedema was present in both subjects, somewhat more pronounced in subject 1. There was no reduction in visual acuity in either but pachymetry readings were marginally increased in both subjects.

An exposure of 10 mg/m³ had no effects, not even after an exposure time of eight hours.

Discussion

These experiments show that exposure to triethylamine at about 20 mg/m³ for eight hours may cause corneal oedema. Studies of workers exposed in a polyurethane foam industry indicate that even numerous bouts of oedema do not cause permanent damage to the cornea.¹⁰ The acute attacks are unpleasant, however, and the visual disturbances may be severe enough to cause accidents at work or in traffic at the end of work.

From the fact that oedema occurred only in the directly exposed part of the cornea (and not under the eyelid), it may be deduced that the effect is not systemic but local. This view is supported also by the presence of epithelial, and the absence of stromal, oedema in the exposed subjects. Corneal epithelial oedema may be produced by epithelial or endothelial cell dysfunction, or both. Stromal oedema results from dysfunctioning endothelial cells and epithelial oedema is seen only after hydration has increased the stromal thickness to approximately 30% above normal.¹³ Pachymetry readings in this study showed at the most, and on one occasion only (subject 1 exposed to 48 mg/m³ of triethylamine) an 18% increase of corneal thickness in one eye. There is good evidence to conclude, therefore, that triethylamine has a direct toxic effect on the epithelial cells, thereby causing the accumulation of water in the superficial part of the cornea.

The experimental findings in the two individuals studied were consistent at different exposure levels. Caution must be exercised before extrapolating these results to workers exposed in industry, however, as an interindividual variation in susceptibility may exist. The present findings are in accordance with those

found in workers in the polyurethane industry¹⁰ and we thus consider them generally applicable.

The level at which effects on the eye were noted (about 20 mg/m³) is far below the TLV in Sweden¹⁴ and the United States.¹⁵ We think, therefore, that new exposure limits should be established.

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