Vision screening results in a cohort of Bhopal gas disaster survivors

Prem Nandhini Satgunam[1,*] and Leonid Chindelevitch[2]

[1]Bausch and Lomb School of Optometry,
Brien Holden Institute of Optometry and Vision Sciences,
L V Prasad Eye Institute, Hyderabad 500 034, India
[2]Simon Fraser University, School of Computing Science,
British Columbia, Canada

Eye-related symptoms were prominent at the time of and soon after the 1984 Union Carbide gas disaster in Bhopal, India. We conducted a vision screening on the survivors to examine their current ocular status. Fifty-nine patients enrolled. We analysed the results from 48 patients (mean age 51 ± 12 years) who had a documented history of gas exposure. The commonly reported symptoms were vision difficulties ($n = 30$), watering ($n = 21$) and headaches ($n = 16$). Thirty patients needed spectacles, 30 had cataracts and 17 had pinguecula. We found the prevalence of pinguecula to be significantly higher in this cohort. The need for vision care among this underserved population is highlighted.

Keywords: Dry eyes, gas disaster, headache, pinguecula, vision screening, watering.

THE world's largest industrial disaster occurred a little more than three decades ago in the city of Bhopal in central India. An estimated 26–40 tonnes of methyl isocyanate (MIC) gas leaked, killing at least 3000 people within 72 hours, and causing long-term morbidity and mortality among many of the estimated 569,000 people exposed to the gas[1–4]. The health effects resulting from this gas exposure have been documented in several studies and reports[1,5–9] at different time intervals, with a recent study[10] summarizing the wide spectrum of diseases ranging from psychiatric disorders and lung fibrosis to gynaecological problems and neonatal mortality. The now-defunct Union Carbide plant site was abandoned in the wake of the disaster and remains a source of continued environmental contamination. A meta-analysis of previous studies conducted to assess this environmental contamination was carried out in 2013, which concluded that the soil at the site remains heavily contaminated[11]. This toxic chemical waste has also contaminated the local aquifers, harming the health and impeding access to clean drinking water of people in the surrounding communities[12,13].

Ocular complaints such as burning and watering were predominant among the survivors soon after the disaster[14]. Several other studies subsequently investigated the ocular conditions in this cohort[15–18], with the last study published in 1990 (ref. 15), and long-term ocular changes were documented up to 1992 in an Indian Council for Medical Research (ICMR) report[6]. Corneal opacities, conjunctival congestion, trachoma and cataract (occurring at an earlier age in comparison to a control group) were the commonly documented ocular conditions. A review study concluded that the long-term effects on individuals with mild to moderate exposure to the gas would not result in blindness[1]. No further studies seem to have been reported since then.

In March 2012, 28 years after the disaster, we conducted a vision screening for the disaster survivors in Bhopal. This communication reports the results of the vision screening. Understanding the present ocular status may help identify any problems unique to this cohort, lay out directions for further research and, importantly, bring into focus the ongoing problems in this cohort. This, in turn, will inform the public health measures needed to provide appropriate care to the survivors of the Bhopal gas disaster.

We visited a local community clinic set up by a trust after the Bhopal gas disaster. This clinic treats disaster survivors free of charge and offers both Ayurvedic and Western medicine for a variety of health conditions. An eye examination unit with basic equipment had been set up in this clinic, but was suspended as the consulting ophthalmologist discontinued his/her part-time service three months prior to the vision screening. Permission to conduct the vision screening was obtained from the managing trust of the clinic. The vision screening protocol was debriefed with the trust and a physician in the clinic.

The patients who visited the clinic were informed of the availability of the vision screening by the clinic staff. If they expressed a desire to participate they were enrolled into the screening with informed verbal consent, in accordance with the guidelines of the Declaration of Helsinki. No invasive procedures or eye drops were used in this screening. All the patients who had a history of gas exposure according to their clinic medical records were included in the study analysis.

The patients were asked about their main complaints, general medical history, ocular history and family ocular history; their answers were recorded on the vision examination sheets that were later handed over to the clinic. Almost all the patients spoke Hindi; both authors were able to communicate with them to record their history.

Monocular visual acuity was measured on the eye reported to have poorer vision; else by default, the right eye was tested first. Distance visual acuity was measured using the Snellen chart drum optically from 6 m using a mirror, followed by the near visual acuity measured at the patient's habitual reading distance.

Autorefraction and/or retinoscopy (if autorefractor readings could not be obtained or were not reliable) were performed to estimate objective refraction. The average of three autorefraction readings was recorded. Subjective

*For correspondence. (e-mail: premnandhini@lvpei.org)

refraction was performed using fogging techniques when appropriate. When an improvement in visual acuity was noted, patients were asked about their preference for new spectacles, and those expressing a preference were given the spectacle prescription.

The anterior segment of the eye was evaluated and findings were recorded in the examination form. A torchlight examination was performed on one patient due to the unavailability of electricity at the time of the slit-lamp examination. Digital tonometry (finger tension) was subjectively estimated as 'normal' or 'hard'. Although several patients complained of dryness and watering, only tear film height was observed in the slit-lamp and no other dry-eye tests were performed due to unavailability of appropriate test materials.

Depending on the patient's complaints and conditions, an Amsler grid, confrontation perimetry, or relative afferent pupillary defect test was performed. In cases where unexplained vision loss, cataracts impairing vision or shallow anterior chamber angles were observed, patients were referred to an ophthalmologist.

The screening was performed on a convenience sample of $n = 59$ patients, who were predominantly female, visiting the clinic and complaining of at least one eye-related symptom during the vision screening. They were in the age group of 51 ± 12 years (from here on we report the mean $\pm$ the standard deviation). In the foregoing analysis we excluded seven patients who did not have a medical record, as well as four who were born in or after 1984, the year of the Bhopal gas disaster, for a final sample size of $n = 48$. Figure 1 shows the distribution of the presenting ocular symptoms reported without prompting in this cohort. Majority of the patients had more than one complaint.

We carried out a statistical analysis of the results of the screening using the *R* statistical computing language, version 3.0.0. We performed a comparison between the results of the present study and those of a large cohort study conducted elsewhere in India[19].

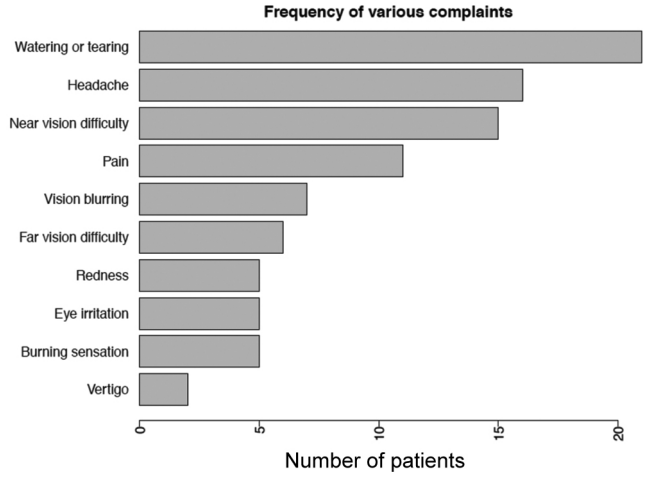

Figure 1. Distribution of complaints from patients participating in the vision screening.

Table 1 lists the various refractive conditions in the right eye and ocular conditions in either eye in the cohort, their frequencies and the corresponding 95% confidence intervals. Refractive errors were classified in accordance with the established literature[19,20], with myopia, hypermetropia and astigmatism requiring a magnitude exceeding 0.50 Diopter.

We used Fisher's exact test to compare the frequency of pterygium and pinguecula between our population and a South Indian population[21]. The prevalence of pterygium (6%) was not significantly different from the South Indian population, whether urban (144 out of 3850, or 4%; $p > 0.1$) or rural (596 out of 3924 or 15%; $p > 0.1$). However, the prevalence of pinguecula (35%) was significantly higher in Bhopal than in both the urban (238 out of 3850 or 6%; $p < 0.0001$) and rural areas (637 out of 3924, or 16%; $p < 0.01$) of South India. This finding suggests that the characteristics of our patient population predispose them to developing pinguecula. However, a study with a larger sample size, and perhaps a longitudinal design, with a control group from non-exposed areas of Bhopal is needed to confirm this hypothesis.

Figure 2 shows the presenting visual acuity and best corrected visual acuity according to WHO classification[22,23]. The age of the 30 people who had cataract, including those who showed early lens changes, was 56 ± 11 years, and the range was from 40 to 76. Cataracts were found in 9 out of the 18 patients aged 40–49 years (50%), 7 out of 9 patients aged 50–59 years (78%), and all 14 patients over the age of 60 years (100%).

Ocular complaints were prominent in the cohort of survivors of the Union Carbide disaster in Bhopal. Studies of ocular symptoms in this population have not

Table 1. Frequency of various refractive and ocular conditions in the examined cohort, with Yates' continuity-corrected 95% confidence intervals

Refractive and ocular conditions	Number of patients	Frequency	95% confidence interval
Astigmatism	11	0.23	(0.13, 0.38)
Hypermetropia	15	0.31	(0.19, 0.46)
Myopia	7	0.15	(0.07, 0.28)
Cataract	30	0.62	(0.47, 0.76)
Pinguecula	17	0.35	(0.23, 0.51)
Corneal opacity	7	0.15	(0.07, 0.28)
Pseudophakia	5	0.10	(0.04, 0.23)
Meibomitis	6	0.12	(0.05, 0.26)
Pterygium	3	0.06	(0.02, 0.18)
Presbyopia	25	0.52	(0.37, 0.66)
Amblyopia*	1	0.04	(0.001, 0.12)

*A tentative diagnosis of amblyopia was made for one patient (as fundus evaluation was not conducted). This patient had a difference of +7.00D in refractive error between the eyes and reported having reduced vision in his left eye since childhood.

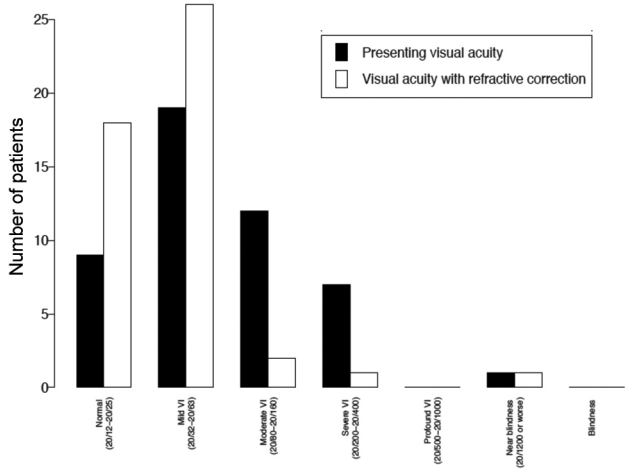

Figure 2. Patients' visual acuity status based on the World Health Organization classification[22,23], before and after refractive correction with lenses.

been conducted after 1989, five years after the disaster. The primary purpose of this vision screening was to investigate the present ocular symptoms and determine the ocular conditions in this cohort. Like elsewhere in India, uncorrected refractive error is prevalent in this cohort. Cataract is also not uncommon in this group. However, anterior segment complaints such as watering, irritation and redness are still present in this population, similar to those observed in the earlier studies[16]. It is striking that, in spite of 26 years having elapsed since the study of Andersson *et al.*[16], more than half of these patients still suffer from either watering or tearing of the eyes, or eye irritation. As we did not have a control population, we do not know if these patients are still roughly three times more likely to suffer from these symptoms than the unexposed controls, as noticed in the aforementioned earlier study[16]. Because majority of the patients in our sample were women over 40 years, it is possible that symptoms similar to those of dry eyes could be due to menopause. It is known that women experiencing menopause are more susceptible to dry eye[24,25]. It is also reported that postmenopausal women with dry eye have reduced corneal thickness relative to those without dry eye[26]. As corneal defects were predominant during the acute stages of gas exposure, it may be possible that a compromised corneal thickness is present in our patients, which perhaps is exacerbating the dry eye symptoms. Corneal pachymeter tests would be needed to validate this hypothesis. We also looked at the presenting symptoms of the seven men in this screening and found that four of them also had similar dry eye-like complaints. The need for careful evaluation with advanced imaging techniques, as suggested earlier for this cohort of people[16], will be beneficial for better assessment and treatment.

We also found pinguecula to be more prevalent in this cohort than in a population in South India. While the tropical climatic conditions are similar between these two study groups, more factors need to be studied to determine the cause of such a difference. The presence of pinguecula can also cause tear film instability that may potentially result in dry eye-like symptoms. Pinguecula was not noticed in earlier studies of the gas-exposed people in Bhopal. This is a degenerative disorder of the conjunctiva, and hence may not have occurred immediately following exposure to the gas. It is not clear if exposure to MIC makes the conjunctival tissue more susceptible to developing pinguecula. A long-term pathology study on rats (14 months following exposure to MIC gas) found eosinophil and lymphoid infiltrates in the conjunctiva[27]. It is not known if these immunological responses subsequently result in a chronic degeneration of the conjunctiva. Further studies will be needed to investigate this.

Twenty-three patients had vision impairment (best corrected visual acuity 6/9 or worse) resulting from cataract. Thirty patients preferred their refractive correction and were prescribed spectacles. These two conditions can be easily corrected to reduce preventable blindness. Thirty-eight per cent of the patients in this vision screening needed more comprehensive eye care (including referral for cataract surgery) and were counselled to seek the same. A risk of early onset of cataract has been previously reported in this cohort[6]. Sixteen out of 27 patients in the age group of 40–59 years were noted to have cataract in the screening, but with a smaller sample size and in the absence of a control arm, we are unable to ascertain the statistical significance of early onset of cataract. We also acknowledge the limitations in not performing the applanation tonometry or dilated fundus examination in our screening procedure. With this limitation, the status of ocular pathologies of the posterior segment of the eye that may be present in this cohort is not known.

The ocular conditions found among the survivors of the disaster in Bhopal are only one of many public health concerns affecting this population. Of particular importance is the heavy-metal contamination in soil and water in and around the area[28,29]. Heavy metals such as lead and mercury can have toxic effects on the eye[30]. The water contamination may therefore provide additional risk factors associated with the eye conditions, independently of gas exposure.

There are still unmet eye-care needs among the survivors of the union carbide gas disaster in Bhopal. Some of these needs are similar to those elsewhere in India (e.g. uncorrected refractive error and cataract), but there are also needs unique to this cohort (e.g. dry eye-like symptoms) that have persisted long after the disaster. A more regular eye-care unit needs to be set up in the clinic serving this cohort in order to reduce preventable blindness and provide symptomatic treatment. Careful studies are also required to investigate the etiology of the anterior segment symptoms in this cohort. Better government intervention and better public health policies need to be put

in place for the survivors of the disaster. In addition to the eye conditions, the current status of other health problems in this cohort should also be investigated to ascertain the long-term effects of gas exposure.

Competing interests: The authors have no financial competing interests. The authors travelled from Boston, USA to Bhopal for this screening. P.N.S. was returning to India after her postdoctoral training at the Schepens Eye Research Institute, Harvard Medical School, USA. L.C. had graduated with a Ph D in mathematics from MIT, USA. Both authors were part of the MIT student chapter of 'Students for Bhopal'. At the time of the screening, the authors were not affiliated with any of the institutions mentioned.

1. Dhara, V. R. and Dhara, R., The Union Carbide disaster in Bhopal: a review of health effects. *Arch. Environ. Health*, 2002, **57**, 391–404.
2. Hanna, B., Morehouse, W. and Sarangi, S., *The Bhopal Reader: Twenty Years of the World's Worst Industrial Disaster*, Apex Press, 2005.
3. Broughton, E., The Bhopal disaster and its aftermath: a review. *Environ. Health*, 2005, **4**, 6.
4. Balaram, P., Bhopal: the tragedy of collective amnesia. *Curr. Sci.*, 2010, **98**, 1547–1548.
5. Andersson, N., Kerr Muir, M., Mehra, V. and Salmon, A. G., Exposure and response to methyl isocyanate: results of a community based survey in Bhopal. *Br. J. Ind. Med.*, 1988, **45**, 469–475.
6. ICMR, Health effects of the toxic gas leak from the Union Carbide methyl isocyanate plant in Bhopal: Indian Council of Medical Research. Technical report based on population based long term epidemiological studies (1985–1994), New Delhi, 2004.
7. Bhargava, D. K., Verma, A., Batni, G., Misra, N. P., Tiwari, U. C., Vijayan, V. K. and Jain, S. K., Early observations on lung function studies in symptomatic 'gas' exposed population of Bhopal. *Indian J. Med. Res.*, 1987, **86** (Suppl), 1–10.
8. Sharma, S., Narayanan, P. S., Sriramachari, S., Vijayan, V. K., Kamat, S. R. and Chandra, H., Objective thoracic CT scan findings in a Bhopal gas disaster victim. *Respir. Med.*, 1991, **85**, 539–541.
9. Weill, H., Disaster at Bhopal: the accident, early findings and respiratory health outlook in those injured. *Bull. Eur Physiopathol. Respir.*, 1987, **23**, 587–590.
10. Vijayan, V. K., Methyl isocyanate (MIC) exposure and its consequences on human health at Bhopal. *Int. J. Environ. Stud.*, 2010, **67**, 637–653.
11. Centre for Science and Environment, Action plan: environmental remediation in and around UCIL, Bhopal: Centre for Science and Enviornment, 25–26 April 2013.
12. *Clouds of Injustice: Bhopal Disaster 20 Years on*, Amnesty International Publications, 2004.
13. Chander, J., Water contamination: a legacy of the union carbide disaster in Bhopal, India. *Int. J. Occup. Environ. Health*, 2001, **7**, 72–73.
14. Andersson, N., Muir, M. K. and Mehra, V., Bhopal eye. *Lancet*, 1984, **2**, 1481.
15. Andersson, N. *et al.*, Delayed eye and other consequences from exposure to methyl isocyanate: 93% follow up of exposed and unexposed cohorts in Bhopal. *Br. J. Ind. Med.*, 1990, **47**, 553–558.
16. Andersson, N., Kerr Muir, M., Ajwani, M. K., Mahashabde, S., Salmon, A. and Vaidyanathan, K., Persistent eye watering among Bhopal survivors. *Lancet*, 1986, **2**, 1152.
17. Andersson, N. *et al.*, Bhopal disaster: eye follow-up and analytical chemistry. *Lancet*, 1985, **1**, 761–762.
18. Salmon, A. G., Kerr Muir, M. and Andersson, N., Acute toxicity of methyl isocyanate: a preliminary study of the dose response for eye and other effects. *Br. J. Ind. Med.*, 1985, **42**, 795–798.
19. Dandona, R., Dandona, L., Naduvilath, T. J., Srinivas, M., McCarty, C. A. and Rao, G. N., Refractive errors in an urban population in Southern India: the Andhra Pradesh Eye Disease Study. *Invest. Ophthalmol. Vis. Sci.*, 1999, **40**, 2810–2818.
20. Rani, P. K., Raman, R., Rachapalli, S. R., Kulothungan, V., Kumaramanickavel, G. and Sharma, T., Prevalence of refractive errors and associated risk factors in subjects with type 2 diabetes mellitus SN-DREAMS, report 18. *Ophthalmology*, 2010, **117**, 1155–1162.
21. Asokan, R., Venkatasubbu, R. S., Velumuri, L., Lingam, V. and George, R., Prevalence and associated factors for pterygium and pinguecula in a South Indian population. *Ophthal. Physiol. Opt.*, 2012, **32**, 39–44.
22. World Health Organization. Visual impairment and blindness, Fact Sheet; http://www.who.int/mediacentre/factsheets/fs282/en/ (accessed on May 2016).
23. Colenbrander A. Visual standards, aspects and ranges of vision loss with emphasis on population surveys. In 29th International Council of Ophthalmology, Sydney, Australia, 2002.
24. Mathers, W. D., Stovall, D., Lane, J. A., Zimmerman, M. B. and Johnson, S., Menopause and tear function: the influence of prolactin and sex hormones on human tear production. *Cornea*, 1998, **17**, 353–358.
25. Versura, P. and Campos, E. C., Menopause and dry eye. A possible relationship. *Gynecol. Endocrinol.*, 2005, **20**, 289–298.
26. Sanchis-Gimeno, J. A., Lleo-Perez, A., Alonso, L., Rahhal, M. S. and Martinez-Soriano, F., Reduced corneal thickness values in postmenopausal women with dry eye. *Cornea*, 2005, **24**, 39–44.
27. Gassert, T., MacKenzie, C., Kerr Muir, M., Andersson, N. and Salmon, A. G., Long term pathology of lung, eye, and other organs following acute exposure of rats to methyl isocyanate. *Lancet*, 1986, **2**, 1403.
28. Hanna, B., Bhopal: Unending Disaster, Enduring Resistance, 2007; https://scholar.harvard.edu/files/bridgethanna/files/Unending_Disaster.pdf
29. Johnson, S., Sahu, R., Jadon, N. and Duca, C., Contamination of soil and water inside and outside the Union Carbide India Limited, Bhopal. In *Centre for Science and Environment*, 2009, pp. 1–31.
30. Erie, J. C., Butz, J. A., Good, J. A., Erie, E. A., Burritt, M. F. and Cameron, D., Heavy metal concentrations in human eyes. *Am. J. Ophthalmol.*, 2005, **139**, 888–893.

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