Industrial dental erosion: a cross-sectional, comparative study

Keywords: industry, sulphuric acid, teeth, erosion

ABSTRACT

Occupational exposure to sulphuric acid mist (H_2SO_4) is a health hazard. The threshold limit value-time weighted average (TLV-TWA) of exposure to H_2SO_4 recommended by the American Conference of Governmental Industrial Hygienists (ACGIH, 1994-1996) is 1 mg/m³. This single-blind study conducted in an electro-winning facility in South Africa, compared dental erosion of anterior and premolar teeth of male workers exposed daily to H_2SO_4 in an exposed group (H_2SO_4 range: 0.3 mg/m³- 1 mg/m³) and an unexposed group (H_2SO_4 range: 0.1 mg/m³ - 0.3 mg/m³). The exposed group comprised all workers at the facility exposed to the aforesaid range of H_2SO_4 (N = 103). A total of 102 unexposed subjects similar in composition with respect to age and length of service were randomly selected from the rest of the 700 workers at the facility. A questionnaire was administered to seek information on possible worker habits associated with dental erosion and to determine perceptions of oral function. Clinical examinations assessed prevalence and severity of dental erosion. The mean age of subjects was 31.4 years and mean length of service 4.2 years. In the exposed group 48% complained of pain and sensitivity on their teeth compared with the 31% of unexposed persons (P = 0.020).

Dental erosion was present in exposed (96%) and unexposed (75%) subjects. Exposed subjects were more likely to develop erosion than unexposed subjects, the odds ratio being 5.531 within the confidence limits 2.167< OR < 14.117. There was a significant difference in the severity of tooth surface loss between exposed and unexposed groups (P = 0.001). Dental erosion was most severe in the anterior teeth and occurred mostly on the labial and incisal surfaces.

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Introduction

Dental erosion refers to the progressive loss of enamel and dentine resulting from chemical attack, usually by acids other than that produced by plaque bacteria (Rugg-Gunn, 1993). Industrial environmental factors, such as exposure to sulphuric acid mists, have been shown to be a primary aetiological factor in dental erosion (Malcolm & Paul, 1961; Petersen & Gorsman, 1991; Zero, 1996). Industrial airborne acids breathed in the working environment are commonly associated with erosion on the anterior teeth which are not protected by lips or cheeks (ten Bruggen Cate, 1968). Dental erosion can lead to pain, sensitivity, deterioration in appearance, temporomandibular dysfunction and stress corrosion of teeth (Nunn, 1996).

Occupational health legislation has undergone considerable change in industrialised countries since the study by Malcolm & Paul (1961) which recommended that workers be protected from the ravages of industrial dental erosion. The threshold limit values recommended by the American Conference of Governmental Industrial Hygienists (ACGIH, 1994-1996) are normally adopted as guidelines for good practice. The ACGIH threshold limit value-time weighted average (TLV-TWA) for occupational exposure to sulphuric acid mist is 1 mg/m³, while the short-term exposure limit (TLV-STEL) is 3 mg/m³. A TLV-TWA is the time weighted average air concentration for a normal 8-hour work day and a 40-hour work week to which the workers may be repeatedly exposed day after day, without adverse effect.

Occupational exposure to sulphuric acid should be controlled to reduce the level of airborne sulphuric acid and needs to be continually monitored. Preventive occupational measures are in place in most developed countries where workers are exposed to industrial airborne acids in the working environment. In developing countries environmental causes of dental erosion may still be of concern due to inadequate working conditions. Gamble *et al.* (1984) also suggest that sulphuric acid may cause dental changes

even when it is at concentrations below what is considered the recommended standard.

Attrition, abrasion and erosion often occur singly or simultaneously, making it difficult to determine the part played by each. The term 'tooth surface loss' has been suggested by Eccles (1982) to embrace all three processes. This study is about tooth surface loss, primarily on account of erosion, in workers exposed to sulphuric acid mists which are by-products of the electro-winning process. Electro-winning is the mechanism whereby a metal, in this case zinc, is extracted from an ore. This process occurs in a section of the facility called the 'cell house'. Measurement of sulphuric acid mist levels in the facility under study occurs three times a week. Samples are collected diagonally across the facility according to NIOSH (1974) criteria. The range of acid levels in the cell house as recorded varies from 0.3 mg/m^3 - 1 mg/m^3. Protective clothing and masks are available at the facility, but their use is not enforced. As a result, these items of clothing are not regularly worn by workers. Paper masks are worn on a more regular basis. The cell house is located within the facility under roof cover with no walls on the sides and relies on ambient air movement to dilute environmental exposure as opposed to engineering control measures. This has the effect that workers in the proximity of the cell house are also exposed to sulphuric acid (range: 0.1 mg/m^3 - 0.3 mg/m^3) as a result of air movement.

A single, cross-sectional, comparative study was conducted at the facility in an industrial town called Springs situated approximately 60 km from Johannesburg, South Africa, to evaluate and compare the prevalence and severity of dental erosion in the anterior and premolar teeth of male workers exposed daily to H_2SO_4 in exposed (range: 0.3 mg/m^3 - 1 mg/m^3) and non-exposed groups (range: 0.1 mg/m^3-0.3 mg/m^3).

Materials and methods

The daily exposed group comprised all workers employed in the cell house (N = 103). An equivalent number of subjects, working in an environment with an H_2SO_4 range of 0.1 mg/m^3-0.3 mg/m^3 and comparable for age and length of service, was randomly selected from the rest of the 700 workers at the facility.

A questionnaire was administered to workers to seek information on sociodemographic status, age, work history, possible habits associated with tooth surface loss and to determine perceptions of oral function. Gastric symptoms such as pain, vomiting and reflux were also noted. Dietary habits were carefully evaluated by means of questions relating to the consumption of special diets, acidic foods and juices, and medications.

Clinical examinations assessed presence or absence of tooth surface loss using a classification by Eccles & Jenkins (1974). The scale used for identifying and grading erosion was: grade 0 representing no tooth surface loss; grade 1 representing loss of surface features of the enamel giving a smooth glazed surface with no dentine involvement; grade 2 represented lesions with less than one-third of dentine involvement and grade 3 represented a lesion covering more than one-third of the tooth surface area. The buccal, lingual and incisal/occlusal surfaces of each anterior tooth and premolar teeth of both the maxilla and mandible were assessed. The unit of analysis was the person with one or more tooth surfaces affected. The Chi-square test and Fisher's exact 2-tailed test were used to establish differences between groups. Odds ratios were calculated and the level of significance set at 5%.

The survey was conducted at the health station of the facility during normal working hours although a number of shift workers were examined outside their work hours. Examinations were performed by one person (AJP). Attempts were made for the examiner to be blind (the examiner was not informed from which part of the factory the participants in the study came). This was not always possible as the examiner was able to discern from which section the participants were employed, from their dress and the smell of the acid on their clothes.

Results

Of the 205 men included in the study, 103 were in the exposed group and 102 in the unexposed group. The average age of the participants was 31.35 years (range: 20 - 60 years). The length of employment ranged from 1 month to 24 years with an average of 4.2 years. More than 78% of the sample were younger than 35 years of age. In order to have groups which were large enough for statistical analysis age bands of 5 years were chosen. The two groups were reasonably similar though not identical by age within the 5-year age groups (Table Ia). More than 61% of the sample had worked in the factory for 3 years or less. The length of service was grouped and paired in 3-year bands (Table Ib). There were no differences between exposed and non-exposed groups with respect to age and length of service.

In response to the questionnaire (Table II) 48% of the exposed group complained of pain and sensitivity compared with 21% of controls (P = 0.020). More persons in the exposed group than in the controls said that 'their teeth had changed since they had started working at the factory' (P = 0.022). When asked in what way their teeth had changed, persons in the cell house said that the colour had changed, their teeth 'looked dull',

Table Ia. Study sample by age and site of work in the factory

Age	Cell house	Other section	Total
25 and below	23	20	43
26 - 30	30	30	60
31 - 35	31	27	58
36 - 40	7	12	19
41 - 45	6	9	15
45 plus	5	4	9
Total	102	102	204

* No age was recorded for one person employed in the cell house.

Table Ib. Study sample by length of service

Length of service	Exposed	Non-exposed	Total
Under 3 years	71	56	127
3 - 6 years	23	35	58
> 6 years	9	11	20

had 'become rough', were 'sensitive', were 'shorter' and were 'painful when drinking water'. Persons in the unexposed group said that their teeth were decayed and 'blood came out' when brushing. Persons in both groups gave pain as reasons for the extraction of teeth. It could not be established whether the pain had been caused by erosion or decay. Five persons said that they had had teeth extracted 'because of acid'.

The prevalence and severity of tooth loss are illustrated in Table III. Tooth surface loss was present in the exposed group (97%) and non-exposed group (75%). Exposed subjects were more likely to experience tooth surface loss than the unexposed subjects. An odds ratio of 11.4 with confidence limits of $3.13 < OR < 49.23$ was obtained when comparing those subjects without erosion (grade 0) and those subjects with erosion (grades 1, 2 and 3) in the exposed and non-exposed groups (Figs 1, 2 and 3). Workers in the cell house were more likely to have tooth surface loss with grade 2 and 3 scores than workers in other parts of the factory who again were more likely to exhibit scores with grades 0 and 1 with an odds ratio of 5.531 with confidence limits of $2.167 < OR < 14.117$. There were significant differences in the severity of tooth surface loss between the groups ($P < 0.001$) in terms of the Chi-square test.

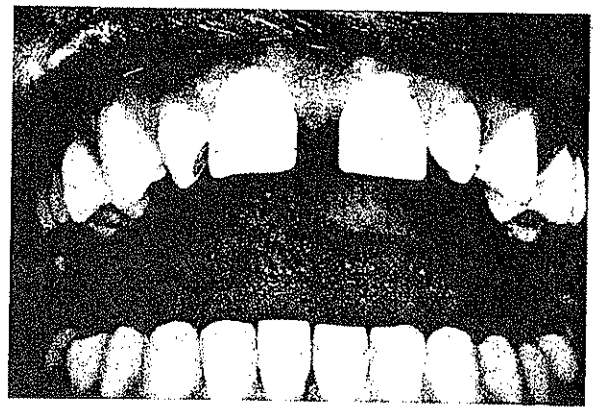

Fig. 1. Grade 1 tooth surface loss — there is loss of surface features on the upper and lower central incisors, including the smoothing out of developmental grooves, giving a smooth glazed appearance. No dentinal involvement is seen. Some incisal edges are chipped. Note the smooth glazed appearance of the incisal half of the lower incisors compared with the stained, pitted and grooved parts of the same teeth on the gingival half. Plaque and calculus are present around the gingiva of the incisor teeth.

Tooth surface loss was most severe in the anterior teeth and occurred mostly on the labial and incisal surfaces. There was a trend in the non-exposed group of increased loss of tooth surface with age (Table IVa). No statistically significant difference in the prevalence and severity of tooth surface loss was found when analysed against age and length of service for the exposed group

Table II. Responses to questionnaire

	Exposed group *N* (%)	Non-exposed group *N* (%)	*P* value
Smoking	50 (48.5%)	42 (41.2%)	0.327 (NS)
Stomach ailments	16 (15.5%)	19 (18.6%)	0.582 (NS)
Grinding	3 (2.9%)	3 (2.9%)	1.000 (NS)
Regurgitation	6 (5.8%)	5 (4.9%)	1.000 (NS)
Teeth changed	49 (47.6%)	32 (31.4%)	0.022 (S)
Pain and sensitivity	50 (48.5%)	21 (20.6%)	0.020 (S)

NS = non-significant; S = significant.

Table III. Prevalence and severity of tooth surface loss

	Number	Grade 0	Grade 1	Grade 2	Grade 3
Exposed group (cell house)	103	3	22	63	15
Non-exposed (other sections)	102	26	40	36	-
Total	205	29 (14.1%)	62 (30.2%)	99 (48.3%)	15 (7.3%)

Fig. 2. Grade 1 and 2 tooth surface loss. Grade 1 tooth surface loss is evident on the facial surfaces of maxillary incisor teeth. Note the lack of canine prominence on the buccal surfaces of the maxillary canines. Grade 2 tooth surface loss is illustrated on the lower central incisors with dentine involvement on less than one-third of the tooth surface. The rough and sharp edges may be caused by the combined effects of erosion and attrition.

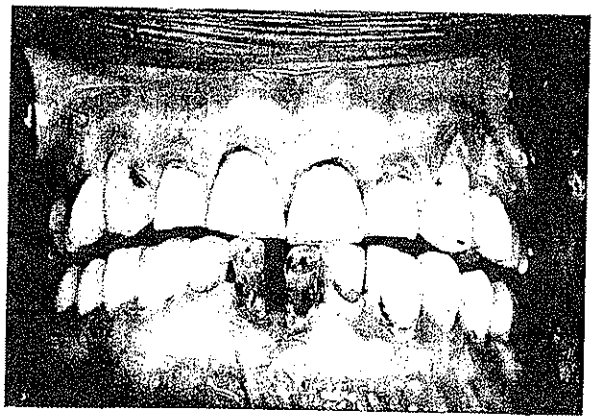

Fig. 3. Grade 1, 2 and 3 tooth surface loss. Grade 1 surface loss is shown on the maxillary lateral incisors illustrating loss of surface features on the enamel with no dentinal involvement. Grade 2 tooth surface loss is shown on the maxillary central incisors. The dentine is involved and less than one-third of the area of the tooth surface is affected. Grade 3 tooth surface loss is illustrated on the mandibular central incisors and lateral incisors with involvement of the dentine for more than one-third of the area on the smooth surfaces. The central incisors are more severely affected than the lateral incisors. The lower teeth have over-erupted.

Table IVa. Tooth surface loss with respect to age

Age group	Exposed *N* (Total)	Non-exposed *N* (Total)
25 and below	23(23)	13(20)
26 - 30	29(30)	20(30)
31 - 35	30(31)	21(27)
36 - 40	7(7)	11(12)
41 - 45	6(6)	9(9)
45 plus	4(5)	3(4)
Total	99(102)	77(102)

(Table IVb). The statistical significance ($P < 0.05$) of this trend was tested using logistic regression. In the non-exposed group the proportion of persons with tooth surface loss was significantly higher ($P < 0.05$), using the one-tailed Chi-square test, in the group with more than 3 years' service than among those with a length of service less than 3 years.

Table IVb. Tooth surface loss with respect to length of service

Length of service	Exposed *N* (Total)	Non-exposed *N* (Total)
Under 3 years	69(71)	36(56)
Above 3 years	31(32)	38(46)
Total	100(103)	74(102)

Strippers are those workers employed in the cell house to prise the refined metal from the electrodes, and work closest to the source of the aerosol. Within the cell house, a comparison between the strippers and other categories of workers shows that strippers are more likely to have grade 2 and 3 tooth surface loss (Table V). Analysis of tooth surface loss in respect of the number of teeth and the number of surfaces involved showed similar results to those obtained with individual subjects.

Table V **Tooth surface loss within the cell house (between strippers and other categories of workers)**

Occupation	Number	Grade 0	Grade 1	Grade 2	Grade 3
Strippers	53	0	5	36	12
Others	50	3	17	27	3
Total	103	3	22	63	15
		(2.9%)	(21.4%)	(61.2%)	(14.5%)
Odds ratio		0.127*	0.185	1.804	4.585
95% CI		0.006-2.519	0.062-0.349	0.804-4.000	1.209-17.384

* Small odds ratio could be due to empty cell in the strippers group.

Discussion

The characteristic finding of the study was tooth surface loss of the anterior and premolar teeth, accompanied by varying degrees of pain and loss of function for both the exposed and non-exposed groups. These results are similar to the findings of ten Bruggen Cate (1968) and Malcolm & Paul (1961). The occurrence of tooth surface loss was not limited to the area of the cell house although the severest forms of tooth surface loss occurred among persons working closest to the source of acid production. The results concur with the findings of Gamble *et al.* (1984) which suggested that sulphuric acid may cause dental changes at concentrations below the recommended standard. The higher prevalence levels and the more severe forms of tooth surface loss were observed where the concentration of acid mist was higher. No correlation was found in this study between age of the study participants, their length of service and the severity of tooth surface loss for the exposed group although a significant association was established for the non-exposed groups. The study by ten Bruggen Cate (1968) among industrial workers in Britain did not demonstrate a correlation between age and dental erosion while it did show a statistically significant correlation with length of service and dental erosion. The findings of the present study and that of ten Bruggen Cate may not be comparable due to the differences in study designs and working conditions of the participants. It may be worthwhile to investigate the impact of the variations in temperature and climate in relation to the effect of acid fumes on tooth surface loss.

The predominant sites of tooth surface loss in this study (buccal aspects of anterior teeth) are similar to those described in the BDJ Memorandum (1959) as the sites where dental erosion occurs due to exposure to industrial acids. It differs from the sites of dental erosion which occur as a result of the ingestion of dietary acids (Touyz, 1986) or the acids from regurgitation (Jones & Cleaton-Jones, 1989). In the latter cases dental erosion occurs typically on the palatal aspects of the anterior and posterior teeth. The clinical appearance of tooth surface loss was that of teeth with an etched appearance and loss of tooth contour with a matt and dull appearance. In more severe cases the dentine was exposed, and the teeth had rough and sharp edges. The participants in the study also observed that their teeth 'looked dull', 'had become rough', 'were shorter' and 'sensitive'.

Possible limitations of the study could be ascribed to (i) the use of questionnaires in English administered through an interpreter to persons who speak predominantly Zulu and North Sotho; (ii) absence of baseline data for comparison; (iii) reliability of past employment history taken from the workers; and (iv) the reliability of acid mist levels provided by the employers.

As a consequence of this project preventive measures have been initiated at the facility. The area where the most severely affected participants worked (the cell house) has been declared a 'respiratory zone' where the wearing of respiratory masks is obligatory. Legislation has also been tightened to compensate workers affected by erosion. There is also a greater awareness on the part of management and labour about occupational health and safety.

Recommendations

Processes generating sulphuric acid mists should be controlled to reduce the level of airborne sulphuric acid. Exhaust systems, enclosures, surface active agents and chips covering the acid could be effective. When the limits of exposure cannot be reduced further, a special programme of prevention to effect the required protection of every worker exposed, must be implemented. This should include impervious clothing, rubber shoes, goggles, face shields, masks, mouth guards and respiratory devices as appropriate to prevent acid contact with the skin, eyes or respiratory tract.

The management of tooth surface loss should include advising workers to restrict the consumption of dietary erosive products (foods with a high acid content) which could potentially exacerbate the problem. The use of an alkaline mouth rinse after exposure to acid is also recommended. While some advocate the desensitisation of teeth with fluoride-containing varnishes or by prescription of fluoride mouth rinses, others suggest that the fluoride mouth rinsing should be done on a daily basis where the frequency of the exposure to the acid is high. Workers exposed to the acid fumes should be advised to observe careful oral hygiene by brushing their teeth with a soft toothbrush and a non-abrasive fluoride toothpaste to encourage remineralisation, to avoid brushing immediately after exposure to the acid mists, and to avoid consumption of acidic foods and drinks immediately after exposure.

Conclusion

Tooth surface loss was observed at levels below the ACGIH recommended threshold limits. The findings suggest that tooth erosion takes place at low levels of exposure, or the exposure levels were higher than that recorded by management at the facility. This calls for a revision of the threshold limits under the conditions that the current workforce is operating, a refinement in the monitoring of sulphuric acid mist that is currently carried out at the facility, and an improvement in the working conditions of persons exposed to acid fumes.

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