

Occupational Hazards for Workers in The Battery Factories and Phosphate Fertilizers: Brief Review and Case Presentation

Faiez Hattab

Visiting Professor of Pediatric Dentistry, Munich, Germany

*Corresponding Author: Faiez Hattab

E-mail : f_hattab@hotmail.com

Abstract

Background: Workers in the battery factory and phosphate fertilizer industry are exposed to harmful sulfuric acid and metal vapors in manufacturing units.

Aims: To describe dental, oral, and general health hazards to underappreciated workers in these industries and factors associated with the occurrence and severity.

Methods: Dental and oral conditions of workers in the production lines were determined by using indices for teeth erosion, oral hygiene, and gingival health. Interviews and questionnaires were used to assess the general health problems, habits, oral hygiene practices, years of service, protective and safety measures, etc.

Results: Results: Surveys show that 67%–86% of production line workers experience symptoms of tooth sensitivity, dry mouth and nose, dysgeusia, burning/itchy eyes, and abdominal discomfort. They also complain of loss of appetite, fatigue, irritability, and muscle or joint pain. Examinations revealed that nearly all workers had poor hygiene and periodontal problems, with 78% experiencing gum bleeding on probing (33%) and spontaneous bleeding (45%). More than two-thirds (79%) of workers had dental erosion on anterior teeth and occlusal abrasion of the posterior teeth. A dense teeth discoloration on the eroded anterior and tartar deposits was obvious.

Conclusions: Overexposure to hazardous vapors generated in the manufacturing processes associated with the unsafe workplace, lack of self-protection, poor personal health care, and inadequate medical services are factors strongly involved in the deterioration of workers' health.

Keywords: acidic plants, workers, battery, phosphate fertilizer, sulfuric acid, health

Abstrak

Latar Belakang: Pekerja di pabrik baterai dan industri pupuk fosfat terpapar asam sulfat berbahaya dan uap logam di unit-manufaktur.

Tujuan: Menjelaskan bahaya kesehatan gigi, mulut, dan umum bagi pekerja yang kurang dihargai dalam industri ini, serta faktor-faktor yang terkait dengan kejadian dan tingkat keparahan.

Metode: Kondisi gigi dan mulut pekerja di jalur produksi ditentukan dengan menggunakan indeks untuk erosi gigi, kebersihan mulut, dan kesehatan gusi. Wawancara dan kuesioner digunakan untuk menilai masalah kesehatan umum, kebiasaan, praktik kebersihan mulut, tahun pelayanan, langkah-langkah perlindungan dan keselamatan, dll.

Hasil: Survei menunjukkan bahwa 67%–86% pekerja jalur produksi mengalami gejala sensitivitas gigi, mulut dan hidung kering, disgeusia, mata terbakar/gatal, dan ketidaknyamanan perut. Mereka juga mengeluh kehilangan nafsu makan, kelelahan, iritabilitas, dan nyeri otot atau sendi. Pemeriksaan mengungkapkan bahwa hampir semua pekerja memiliki kebersihan yang buruk dan masalah periodontal, dengan 78% mengalami pendarahan gusi saat disentuh (33%) dan pendarahan spontan (45%). Lebih dari dua pertiga (79%) pekerja mengalami erosi gigi pada gigi anterior dan abrasi oclusal pada gigi posterior. Diskolorasi gigi yang padat pada gigi anterior yang tererosi dan penumpukan tartar sangat jelas.

Kesimpulan: Paparan berlebihan terhadap uap berbahaya yang dihasilkan dalam proses manufaktur terkait dengan tempat kerja yang tidak aman, kurangnya perlindungan diri, perawatan kesehatan pribadi yang buruk, dan layanan medis yang tidak memadai adalah faktor yang kuat terlibat dalam penurunan kesehatan pekerja.

Kata kunci: pabrik asam, pekerja, baterai, pupuk fosfat, asam sulfat, kesehatan

Background

The oral cavity is more susceptible to injurious hazards than other body organs, and maintaining oral health is critical to overall health and quality of life. Workers in a variety of industries are exposed to chemical, physical, and biological hazards that can have serious adverse effects on oral and systemic health. This article presents occupational hazards of workers in the automotive battery and phosphate fertilizers industries. Long-term occupational exposure to acidic mists, fumes, gases, and dusts (collectively referred to as vapors) results in various health hazards. Sulfuric acid (H_2SO_4) is the most commonly used acid in industry worldwide. About 60 to 70% of the acid is used in phosphate fertilizers industry.^{1,2} In the battery industry, H_2SO_4 is used during the charging process of lead plates; producing hydrogen ions and lead sulfate ($PbSO_4$), sulfur dioxide (SO_2) and trioxide (SO_3). Sulfur oxides react rapidly with moisture in the air to form sulfur-lead vapor; a highly corrosive and health toxic vapor.³ Inhaling the vapor at a level of 1-2 mg/m^3 can cause nose, throat, and at 5-6 mg/m^3 causes lung irritation with coughing. Higher exposure may result in pulmonary edema. Mists may produce tissue damage, particularly on mucous membranes of eyes, mouth and respiratory tract. Skin contact may produce burns. Lead is a cumulative toxicant that is absorbed into the body through inhalation and ingestion. Long-term lead exposure can damage body systems, including neurological, hematological, gastrointestinal, cardiovascular, renal, hepatic, and reproductive organ.^{4,5} Reports on battery factories indicated that acid fumes concentration varied from less than 1 to more than 5 mg/m^3 at different locations, with much higher fumes levels of 8.0 mg/m^3 and 16 mg/m^3 been found in some factories.^{3,6-8} OSHA have suggested 1 mg/m^3 as legal limit for sulfuric acid exposure.

Another common source of occupational hazards is the phosphate mining/fertilizer industry, where sulfuric acid is used to process (digest) phosphate rock to produce phosphoric acid which is a main ingredient in most chemical fertilizers. The reported global production of phosphate fertilizer amounted to 46 million metric tons. China dominates global phosphate production, followed by the United States and India. Morocco holds about 75% of the world's reserves of phosphate rock, and Jordan ranks the fifth. Hazards to workers can occur during mining and

manufacturing processes through vapor inhaling and ingesting, containing calcium phosphate, silica, sulfuric, phosphoric, hydrofluoric acids, sulfur dioxide, and metals.⁹ Traces include Arsenic (As), Chromium (Cr), Lead (Pb), Mercury (Hg), Nickel (Ni), Cadmium (Cd), Radium (Ra). Contact phosphorus can irritate skin, eyes, and mucous membranes. Breathing irritates the nose and throat. Overexposure may affect the liver and kidneys. OSHA have suggested 0.1 mg/m^3 as a limit for workplace phosphorus exposure. A study of worker mortality at phosphate fertilizer plants in Florida, USA, showed an increase in deaths from lung cancer and leukemia.¹⁰ This review describes prevalence and type of dental, oral, and systemic hazards among workers at an old battery factory and phosphate fertilizers industry in Jordan.

Epidemiology and Dental Health

Studies in Western countries of occupational hazards commonly directed toward the use of sulfuric acid in battery industry. A review of the literature showed that dental/oral/general health of workers in the battery industry varied widely. Wiegand and Attin (2007) reviewed 18 articles on battery and galvanizing workers. They reported that prevalence of dental erosion in acid-exposed workers amounting to 26-100%.¹¹ A study from battery factory in Germany showed that workers were exposed to sulfuric acids vapors in the workplace of 0.4-4.1 mg/cm^3 , with 31% of workers had dental erosion; mostly in the front teeth and 92% by attrition in posterior teeth.⁶ In Japan, Suyama et al (2010) reported that among 40 battery factory workers, 20% exhibited dental erosion in the anterior teeth. The prevalence of erosion rose from 42.9% for working period of 10-14 to 66.7% for a period over 20 years and increased proportionally to sulfuric acid air density.⁸ Very few studies on oral health status of battery factory workers came from developing countries.^{12,13} Recently (2014-2018) some studies on battery factories hazards from different cities in India have been published.¹⁴⁻¹⁹ China, Japan, and South Korea are the main battery producers.

A survey on 138 battery factory workers in Mandideep, Agrawal et al found that 74% of workers at the production line had dental erosion and 57% had tooth sensitivity.¹⁴ Raj et al examined 600 battery workers in Chinnai city and reported that the dental

erosion among acid-exposed workers was significantly greater than the control group ($P < 0.001$).¹⁵ In a study conducted on 1400 workers in 20 battery factories at Ghaziabad city, Kundu et al. showed a highly significant prevalence of dental erosion, gingival bleeding, and periodontal pockets among workers in the production line compared with the controls.¹⁶ Khurana et al examined 70 battery workers in Kanpur city and found that almost all of workers in the study group had dental erosion of which 48% had erosion score of 3 (Loss of enamel exposing dentin) and 83% had poor oral hygiene.¹⁷ Examination of 800 battery workers at the production line in the Baddi city showed that 48% had dental erosion.¹⁸ In all these studies the dental erosion and other oral pathologies were significantly higher in workers at the production line than the controls at the nonproduction line. Tuominen et al, (1991) conducted a survey in Tanzanian fertilizer factories on 68 acid workers exposed to high concentrations of sulfuric acid fumes. They found that 63.2% had dental erosion, while for controls was 37.7%.⁷ Few studies are available on the dental and oral changes of workers in phosphate fertilizer industries.^{12,13}

Data From the Field

This study describes oral and general health problems among workers at an old battery factory in the city of Amman, Jordan and at Al Hassa phosphate fertilizer plant 135 km south of Amman. In both, the production processes are conducted in the open-air units. In battery factory and during the sulfate-lead charging, a dense reaction cloud is discharged from the open container and rapidly diffuses into the surrounding air, with a sharp pungent odor. Structural questionnaires were completed by interviews and clinical examinations were performed at the sites. Written/verbal consent was obtained from the workers being inspected. Data were collected on oral and general health problems, diet, habits, oral hygiene, work conditions, dental and medical histories, years of service, protective and safety measures, and education levels. Information about gastric problems, foods, beverages, and medicines was obtained. The oral and dental status was assessed using dental mirror, probes, indices for tooth erosion, oral hygiene, and gingival health.

Diagnostic criteria and grades

Erosive lesions were recorded on the labial and palatal surfaces of the maxillary anterior teeth. The oral hygiene status (using OHI-S) was assessed on six tooth surfaces, that is the facial surfaces of the teeth 16, 11, 26, and 31 and the lingual surfaces of the teeth 36, 46 (FDI notation). Each tooth surface is divided horizontally into gingival, middle, and incisal thirds. The surface area covered by debris is recorded by running the side of an explorer along the tooth surface. The gingival condition scored on the mesial, distal, buccal and lingual aspects of the following selected teeth: 16, 11, 26, 36, 31, and 46.

- i. Dental erosion. (0) No, loss of enamel surface characteristics; (1) Loss of enamel surface characteristics; (2) Faceting or convexity in enamel; (3) Loss of enamel exposing dentin to less than one-third of the surface; (4) Loss of enamel exposing dentin for more than one-third of the surface or pulp visible through the dentin.¹⁹
- ii. Oral hygiene index. (0) No debris or stain / calculus; (1) Debris / calculus covering not more than one-third of the tooth surface; (2) Debris / calculus covering more than one-third of the tooth surface; (3) debris / calculus covering more than two-third of the tooth surface or a continuous band of subgingival calculus.
- iii. Gingival health. The gingival index was used to score gingival health as follow: (0) Normal gingiva; (1) Mild inflammation: slight change in color, slight edema. *No bleeding on probing*; (2) Moderate inflammation: redness, edema and glazing. *Bleeding on probing*; (3) Severe inflammation: marked redness and edema, ulceration. *Tendency to spontaneous bleeding*.

Questionnaire shows that more than two-thirds (67%-86%) of production line workers complain of tooth sensitivity, dry mouth, throat, and nose, taste disturbance (dysgeusia), impaired sense of smell (hyposmia), burning/itchy eyes and skin. More than half (56%-64%) of workers suffer from headaches, and bleeding gums. Between 24% and 47%, workers complain of gastrointestinal problems (heartburn, nausea, vomiting), loss of appetite, coughing, weakness, fatigue, nervousness, muscle and joint pain. More than

half of the workers were cigarette smokers for several years, and only 14% brush their teeth every day. The most frequent dietary habit was sugared tea intake. Few (12%) had visited dental clinic during the past year, mainly for tooth extraction. Most workers believe that their poor health is related to unsafe working conditions and lack of protective measures. The nonproduction line control group have significantly better oral and general than the group at the production line. They are more educated and care about health.

Clinical examination revealed that 79% of the workers in the production line had teeth erosion mainly on labial surfaces of the maxillary anterior teeth, and occlusal attrition of posterior teeth (**Figure 1**). Of the total erosion score, 25% of workers had grade 2; 37.5% had grade 3, and 16.7% had grade 4. Only 20.8% had zero erosion. Tooth erosion is the loss of tooth hard tissue through a chemical process in the absence of bacteria.¹⁹ Workers of long-term service in production unit exhibit extensive tenacious blue-green

teeth staining originates from acidic sulfur-lead mist deposited on the eroded and carious teeth surfaces. They are mostly located on the labial surface of the maxillary anterior teeth due to mouth breathing associated with nasal breathing problems (**Figure 2**). Nealy all workers had poor oral hygiene, with two-thirds (67%) scoring between 3.1 and 6.0, associated with severe deposits (**Figure 3**). None of the workers had healthy periodontal tissue. Examination showed that 20.8% of workers had a gingival score of 1, 33% had a score of 2 (bleeding on probing), and 45% had a score of 3 (spontaneous bleeding). Periodontal pockets are common among older workers. The severity of the conditions is directly related to the duration of acid exposure and long-term services (**Figure 4**). The control group has a significantly better oral hygiene compared to workers at the production line. The dental, oral and general health problems of workers in the phosphate fertilizer is similar to that of battery workers, but to a lesser degree due to the more open working spaces.



Figure 1. Erosion of the labial surface of maxillary anterior teeth with cervical debris accumulation and marginal gingivitis.



Figure 2. The maxillary teeth display stubborn blue-green stains on caries-eroded tooth surface and debris accumulation.



Figure 3. Calculus deposits on the mandibular anterior teeth associated with gum recession and attrition of the posterior teeth.



Figure 4. Deterioration of dental and gingival health in a worker after about 15 years service in the production line.

Discussion

The oral cavity is vulnerable to various external agents, which lead to pathological changes in hard and soft tissues. An “occupational hazard” is defined any workplace condition that causes a risk to employee health. The Occupational Safety and Health Administration (OSHA) has defined six main categories of occupational hazards, including safety, chemical, biological, physical, ergonomic, and workplace.²⁰ The present study describes the prevalence and type of dental, oral, and general health conditions associated to workers in a battery factory and phosphate fertilizer industry in Jordan. Workers are in the battery factory exposed to sulfuric-Pb vapor (in the form of mists, fumes, gases, and dust) or sulfuric-phosphoric vapor during manufacturing, as well as Inhalation and ingestion of reaction vapor can lead to tooth erosion and tooth sensitivity, as enamel dissolve and dentin becomes exposure. Dry mouth that workers exhibit may be related to mouth breathing and inadequate lip sealing, as a result of nasal breathing problems. A direct effect of the acid on the salivary glands and salivary ducts cannot be excluded. Reduced salivation compromises the defenses and protective effects of saliva that control periodontal disease and dental caries. Further, the acid vapor can damage the periodontal tissue and oral mucosa by disrupting the physiology, functionality of cellular tissue, salivary immune components, and impairing tissue renewal and healing processes.^{21,22}

Lead (Pb) is one of the most health-hazardous causes of acute and chronic poisoning at workplaces. It is estimated that one in three children worldwide are affected by lead poisoning.²³ According to the U.S.

Occupational Safety and Health Administration, the threshold limit for lead inhalation is 50 µg/m³, with blood lead levels below 40 µg/dL. Occupational exposure to lead is common in low- and middle-income countries, and there are few studies on blood lead levels (BLLs) in battery factory workers. A systematic review and meta-analysis of BLLs in battery factories' workers in these countries showed an average level of 37.9 µg/dL, with the highest level in Bangladesh (65.2 µg/dL), followed by Pakistan (60.4 µg/dL) and Egypt (52.4 µg/dL).²⁴ Haryanto²⁵ reports that there are more than 200 battery recycling smelters in Indonesia, 71 of which are located in Jakarta. The average BLLs for non-smelter workers was higher in 2015 (>39.3 µg/

dL) than in 2011 (27.9 µg/dL), and people living near smelters are at risk of Pb poisoning. Elevated blood pressure, hearing loss, and anemia occurred in 20% of smelter workers.²⁵ A study on 1- to 5-year-old children living near and distance from lead-acid battery recycling (Jakarta) revealed that 47% of children had BLLs ≥ 5 µg/dL and 9% had BLLs ≥10 µg/dL.²⁶

Conclusion

The present study and the review of literature showed that workers in battery factories and phosphate fertilizer plants are exposed to sulfuric acid vapor in the form of mists, fumes, gas and dust in the workplace, causing dental, oral and systemic pathologic changes and affecting the workers' quality of life. The severity of signs and symptoms in workers at the production line is related to the duration of acid exposure, long-term service, lack of health and safety knowledge, and negligence of health care. The present findings may alarm occupational health authorities in the developing countries to implement effective and mandatory a safety measures in the workplaces, provide personal protective equipments, and offer medical and dental care services, as well as educating workers on occupational hazards and health care. It is hoped that more research will be conducted on this important issue, especially in developing countries.

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