

Bauxite Mining and Alumina Refining

Process Description and Occupational Health Risks

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Objective: To describe bauxite mining and alumina refining processes and to outline the relevant physical, chemical, biological, ergonomic, and psychosocial health risks. **Methods:** Review article. **Results:** The most important risks relate to noise, ergonomics, trauma, and caustic soda splashes of the skin/eyes. Other risks of note relate to fatigue, heat, and solar ultraviolet and for some operations tropical diseases, venomous/dangerous animals, and remote locations. Exposures to bauxite dust, alumina dust, and caustic mist in contemporary best-practice bauxite mining and alumina refining operations have not been demonstrated to be associated with clinically significant decrements in lung function. Exposures to bauxite dust and alumina dust at such operations are also not associated with the incidence of cancer. **Conclusions:** A range of occupational health risks in bauxite mining and alumina refining require the maintenance of effective control measures.

Bauxite mining and alumina refining are the upstream operations of primary aluminum production. This review article describes the industrial processes of bauxite mining and alumina refining and outlines the physical, chemical, biological, ergonomic, and psychosocial health risks.

PROCESS DESCRIPTION: BAUXITE MINING

Bauxite is the principal ore of alumina (Al_2O_3), which is used to produce aluminum (Al). It is composed of hydrated aluminum oxides, hydrated aluminosilicates, iron oxides, hydrated iron oxides, titanium oxide, and silica. It contains mixtures of various minerals such as gibbsite, boehmite, hematite, goethite, Al-goethite, anatase, rutile, ilmenite, kaolin, and quartz.

Bauxite is a residual rock formed from the weathering of various igneous, sedimentary, and metamorphic rocks. These parent rocks have been exposed to long periods (millions of years) of weathering under tropical, subtropical, or very wet temperate conditions. Ninety percent of the known world bauxite resources are in tropical locations. Other deposits outside these latitudes have been exposed to long periods of intense weathering in their geologic past.

From Alcoa of Australia, Perth, Western Australia.

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The greatest concentrations of bauxite are in Central and South America, in West Africa, in particular Guinea, and then in India, Vietnam, and Australia. Some deposits also exist in the north of Russia and in the center of Saudi Arabia. Usually, bauxite occurs near the surface. Nevertheless, there are occurrences of buried bauxite deposits in which the bauxite has been covered by other materials postformation of the bauxite. The current estimated global bauxite resource is more than 70 billion tonnes. Of this the greatest concentration is in Guinea, where there are well-proven resources of approximately 25 billion tonnes.

Most bauxite occurs close to the surface, with only 1 or 2 m of overburden. Typical deposits range in thickness from 3 to 15 m. The majority of the bauxite can be mined and processed without beneficiation (further treatment of the ore to concentrate the minerals), but the ore in the north of Brazil and in Vietnam has a high clay content and has to be washed before processing.

There are some underground deposits; however, these are often linked to a surface occurrence, where the terrain that has helped form the bauxite has tilted, so the ore found at the surface then gradually gets deeper, and underground mining is needed to economically extract this material. This is typical of some of the deposits in Russia.

In China, there are many areas that have bauxite that is totally underground at depths from 200 to 300 m.

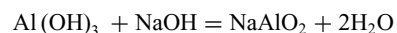
The typical processes involved in the mining of surface deposits are as follows:

- Clearing of vegetation and collection of valuable topsoil using scrapers and bulldozers.
- Removal of overburden.
- Blasting or ripping of some parts of the ore that cannot be dug easily. This involves drilling and placing explosives, or ripping with large bulldozers.
- Loading onto trucks and hauling to a crushing facility. Trucks ranging in size from 30 to 180 tonnes are used in different size mines.
- Landscaping and rehabilitating back to the existing land use in collaboration with the local people and government.
- Crushing and sorting.
- Washing and beneficiation (further treatment of the ore to concentrate the minerals) if necessary.
- Delivery to export or to local refineries.

Approximately 165 million tonnes of bauxite are mined each year. Bauxite is generally transported to refineries by conveyor, rail, or ship. Some alumina refineries are located close to their bauxite mines. Bauxite mines typically employ 500 to 1000 people.

PROCESS DESCRIPTION: ALUMINA REFINING

The bauxite ore contains aluminum trihydrate ($\text{Al}(\text{OH})_3$). Alumina refining produces alumina (Al_2O_3) from the bauxite ore, by exploiting the reversible reaction of the Bayer process¹⁻³:



The reaction is firstly driven in the sodium aluminate (NaAlO_2) direction by the addition of caustic soda (NaOH) to bauxite. Bauxite residues are then removed, leaving the process liquid,

termed “green liquor.” The reaction is then driven back in the opposite direction during precipitation, to produce crystals of aluminum trihydrate, which are then calcined to produce anhydrous aluminum oxide (alumina). The “spent liquor” leaving precipitation returns to the beginning of the refinery circuit.

The major steps in alumina refining are as follows¹⁻³:

- Wet grinding of the bauxite ore in rod mills, ball mills, or semi-autogenous grinding mills to produce fine slurry.
- Digestion of the slurry by caustic soda (NaOH) at strengths exceeding 170 g/L in vessels under pressure at temperatures ranging from 145 to 265°C depending on the type of bauxite being processed.
- Separation and washing of insoluble residues (termed “sand and mud”) from the process solution (termed “green liquor”). Residues are stored in residue drying areas.
- Crystallization (precipitation) of aluminum trihydrate from the sodium aluminate (NaAlO₂) of green liquor, leaving “spent liquor” containing primarily caustic soda to be returned to digestion.
- Calcination of the aluminum trihydrate crystals at approximately 1000°C, driving off water molecules and leaving the final product of anhydrous alumina.

Alumina refineries are generally located on or near the coastline to facilitate shipping of alumina to aluminum smelters. Refineries typically employ about 1000 people (Figs. 1 and 2).

PHYSICAL RISKS

Traumatic injury in bauxite mining is relatively uncommon compared with underground metalliferous mining or underground

coal mining. Nevertheless, potential causes of injury include vehicle rollovers, mobile equipment collisions, being struck by falling trees, falls from height, entrapment, explosion, and electrocution. An emergency medical response capacity is therefore required. This always involves an on-site capacity, but may also include the provision of a substantial medical facility or access to aeromedical evacuation depending on the local conditions.

Minor trauma is still reasonably common in refineries—particularly hand and finger injuries. Major trauma is uncommon, but there is the potential for falls from height, mobile equipment collisions, entrapment, and electrocution. Refineries usually have on-site medical centers with an emergency medical response capacity and provision to transfer patients to hospital.

Noise is generated in mining by scraping, drilling, blasting, excavating, hauling, crushing, and conveying. Exposure to noise is controlled primarily by enclosing personnel within vehicle cabins. This is not entirely successful however with noise-induced hearing loss still occurring at contemporary operations. Hearing conservation programs are essential and should include noise surveys, noise control initiatives, annual audiometry, and a range of hearing protection devices with fit testing and education.

Noise is commonly encountered throughout refineries and can be very loud during tasks such as the descaling of tanks using impact tools. Noise-induced hearing loss has been a significant problem in refineries. Education and assiduous use of quantitative fit testing of hearing protection has resulted in substantial reductions in noise-induced hearing loss at some refineries, with the Occupational Safety and Health Administration age-corrected 10-dB shift rate (averaged across 2, 3, and 4 kHz), falling from approximately 5% to 1% of employees per year at some refineries in Western Australia (Alcoa—unpublished data).

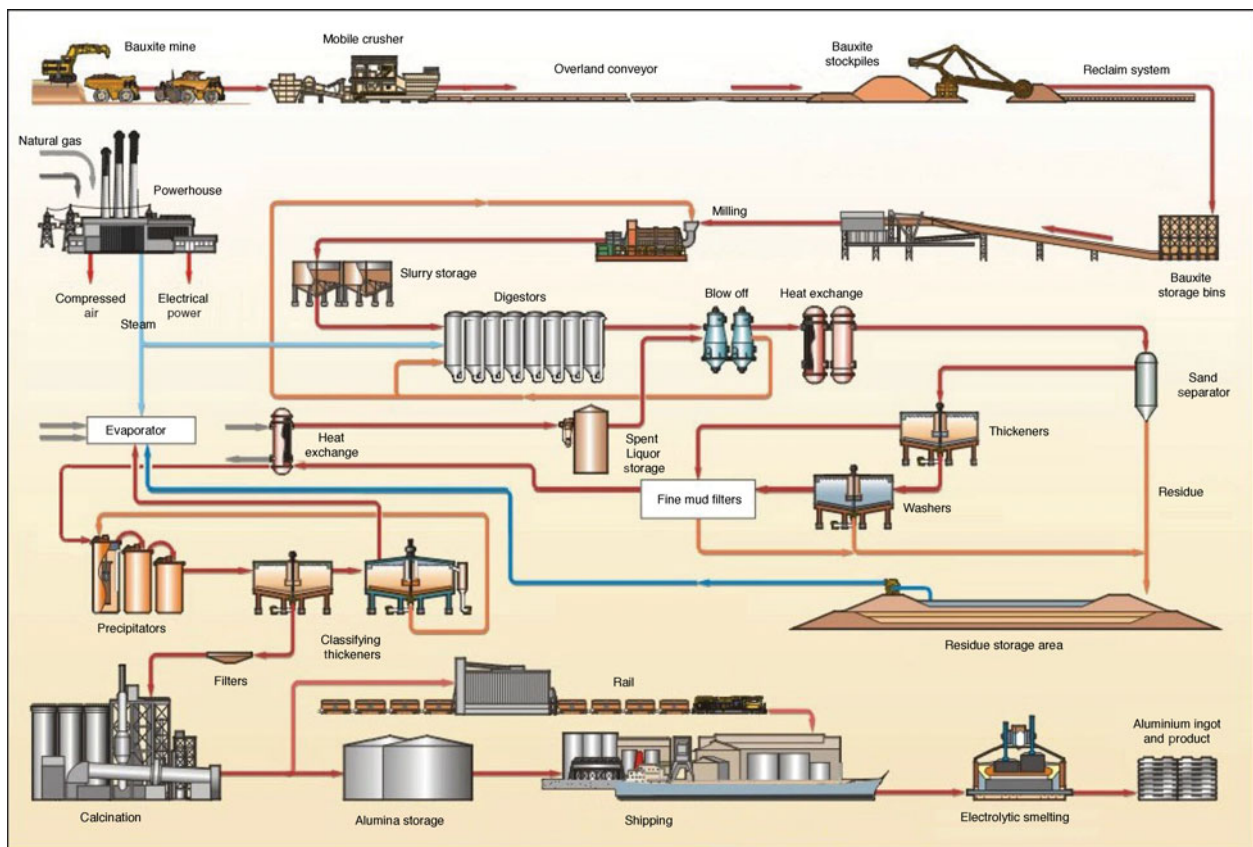


FIGURE 1. Process flow diagram for bauxite mining and alumina refining.



FIGURE 2. Aerial photograph of Pinjarra Refinery in Western Australia.

Heat and humidity are encountered in tropical locations. Although heat stroke has not been reported, heat exhaustion and malaria may occur. Control measures are necessary and have been discussed in detail elsewhere.^{4–6}

Whole-body vibration is commonly experienced while operating mobile equipment, such as scrapers, drilling rigs, excavators, and haulage trucks. This can cause or exacerbate spinal disorders. In some cases remote-controlled vehicles are used where the terrain is so rough that whole-body vibration could be excessive. Road and vehicle maintenance are important control measures.

Hand-arm vibration syndrome seems to be rare in bauxite mining and alumina refining. Vibrating hand tools are not an important part of the process at bauxite mines, but are common at alumina refineries. Nevertheless, most bauxite mines and alumina refineries are located in tropical climates, so cold-provoked vasospasm is less likely.

Bauxite is a low-level naturally occurring radioactive material. It contains small quantities of uranium (^{238}U), thorium (^{232}Th), and potassium (^{40}K).⁷ The low-level natural radioactivity present in the ore transfers almost entirely to the solid residue stream during refining—some to sand residue but most to mud residue. The bauxite ore, Bayer process materials before precipitation, mud residue, and sand residue are therefore of radiological interest, whereas the alumina product is not.⁸ Positional and personal monitoring data from bauxite mines and alumina refineries in Western Australia have been used to assess the above-background annual doses for the workforce across a range of jobs. Total incremental composite doses for individuals were all less than the public exposure limit of 1.0 mSv per year above background when gamma, radon progeny, and gross alpha exposures were considered.⁷ This is despite the activity of

some materials being slightly higher than the regulatory exclusion benchmark of 1 Bq/g. In summary, this is an issue that requires some consideration and monitoring at bauxite mines and alumina refineries, but is unlikely to be of concern.

Solar ultraviolet exposures in surface bauxite mining operations and alumina refineries are likely to contribute to the occurrence of squamous cell and basal cell carcinomas, although this is an inference drawn from studies of outdoor workers in other industries.^{9–11} Control measures include the use of enclosed mobile equipment cabins, the scheduling of outdoor on-foot work to avoid near midday exposures, long sleeve clothing, long trouser leg clothing, neck and ear flaps on helmets when outdoors on-foot, the provision of shade where practicable, and the use of sunscreen. Occupations involving substantial outdoor work seem not to be associated with an increased risk of melanoma.^{9,12–16}

Tropical cyclones (hurricanes) can impact bauxite mines and alumina refineries in tropical locations.

CHEMICAL RISKS

Bauxite is generally regarded as being relatively biologically inert. It is classified for occupational hygiene purposes as a nuisance dust or “particle not otherwise specified.” There has been a case report of mild pulmonary fibrosis—occurring in a man exposed to bauxite crushing and transport from 1936 to 1962.¹⁷ The incidental finding on autopsy led to confirmation of the presence of bauxite within the area of fibrosis. More recently, epidemiological studies of employees exposed to bauxite dust have been conducted.

A cross-sectional study of employees at a US bauxite mine, alumina refinery, and alumina-based chemical products plant studied

lung function in relation to cumulative total dust exposures.¹⁸ The subjects were employed at some time between 1975 and 1981. Because one third of the study cohort never smoked, the effects of dust exposure could be examined independent of the effects of smoking. Among never-smokers with cumulative total dust exposures of at least 100 mg/m³ · yr, sustained over at least 20 years, there was a mean reduction in forced expiratory volume in 1 second (FEV₁) of 0.29 to 0.39 L, in comparison to internal and external predicted values, respectively. The study did not report forced vital capacity (FVC) results, so it is not known whether the results reflect an obstructive or restrictive lung defect. Nevertheless, industrial bronchitis in response to high dust exposures is a possible explanation. Unfortunately, the exposure data did not distinguish between bauxite and other exposures such as alumina and caustic mist. It is therefore somewhat difficult to interpret the findings in relation to bauxite. Also, the exposures were clearly much higher than those typically sustained during contemporary bauxite mining. Chest radiography at the same facility found that 8% of employees had scanty, small irregular opacities—predominantly located in the middle and lower zones of the lungs.¹⁹ The prevalence was 4% among nonsmokers and 12% among smokers. The prevalence was statistically significantly increased among nonsmokers who had longer tenure and higher cumulative total dust exposures. The prevalence was 19% (4 of 21 cases) among nonsmokers with cumulative total dust exposures of at least 100 mg/m³ · yr, sustained over at least 20 years.

A cross-sectional study of employees at a large bauxite mining operation in Western Australia in 1995/1996 investigated respiratory symptoms and lung function in relation to bauxite dust exposures.²⁰ After adjustment for age and smoking, there were no significant relationships between any of the symptoms and quartiles of exposure to bauxite.²⁰ There were also no statistically significant decrements in lung function (FEV₁, FVC, and FEV₁/FVC) within any of the quartiles of exposure to bauxite. After adjustment for age, height, and smoking, there was a small but statistically significant decline in FEV₁ (7.3 mL/yr) associated with the duration of employment. No association was found between the duration of employment and FVC or FEV₁/FVC. The effect of aging on FEV₁ was estimated to be 27 mL/yr, whereas the effect of smoking was found to be 12.0 mL per pack-year among current smokers. The association between FEV₁ and the duration of employment was independent of bauxite exposure, which the researchers found difficult to explain.²⁰ Chest radiography was not thought justifiable.

In summary, it seems that bauxite exposures in contemporary best-practice mining operations have not been demonstrated to be associated with clinically significant decrements in lung function or pneumoconiosis.

A cross-sectional study of employees at three alumina refineries in Western Australia in 1995/1996 investigated respiratory symptoms and lung function in relation to bauxite dust, alumina dust, and caustic mist exposures.^{21,22} After adjusting for age, smoking, and atopy, most groups of production workers reported a greater prevalence of work-related wheeze and rhinitis than did office employees.²¹ Differences in FVC and FEV₁/FVC, but not FEV₁, were found between different process groups. These were thought unlikely to be clinically of note.²¹ Employees in the highest caustic mist exposure group reported increased prevalence of work-related wheeze and rhinitis, but did not have decrements in lung function.²² Alumina dust exposure was associated with minor increases in the prevalence of work-related wheeze and rhinitis, but no changes in lung function.²² Bauxite dust exposure in the refineries was not associated with either symptoms or lung function changes.²²

A cancer incidence and mortality study has been undertaken for a cohort of employees working in three bauxite mines and three alumina refineries in Western Australia.²³ This is the only cancer incidence and mortality study to date in bauxite mining and alumina refining. The most recent analysis of this ongoing study was

undertaken with data to the end of 2002, when 3717 (64%) of the cohort of 5828 men had been employed for at least 10 years, 1528 of whom (26% of the cohort) had been employed for at least 20 years. Mortality from all causes was significantly lower than in the Australian male population (standardized mortality ratio = 0.68; 95% confidence interval [CI] = 0.60 to 0.77). Mortality for all cancers combined was not significantly different from the comparison population. Mortality was significantly lower than the comparison population for circulatory diseases, respiratory diseases, injury/trauma, and “other or unknown causes.” The only significantly increased mortality risk was for pleural mesothelioma (see comments later). There were no statistically significant trends seen with the duration of employment for any of the causes of death. The incidence of all cancers combined was not significantly different from the comparison population (standardized incidence ratio [SIR] = 0.92; 95% CI = 0.82 to 1.03). There was an increased incidence of pleural mesothelioma (SIR = 3.49; 95% CI = 1.82 to 6.71) and melanoma (SIR = 1.30; 95% CI = 1.00 to 1.69). Nevertheless, an independent review by the Western Australian Mesothelioma Registry found that mesothelioma was associated with exposures outside the aluminum industry in all but one case—for example, five of the nine cases had exposure to crocidolite at Wittenoom, an asbestos mining location in Western Australia. For melanoma there was no increase in risk with the duration of employment. Subsequent analysis at one of the studied refineries found no statistically significant increase in the incidence of melanoma when state rather than national comparison data were used (unpublished data). There was an increased incidence of thyroid cancer in those who had ever worked in an office (*n* = 6; SIR = 5.35; 95% CI = 2.02 to 19.18), but no significant excess in those who had ever worked in production or ever worked in maintenance. The researchers commented that there was no known exposure related to office work in this industry, and the finding may be an artifact of the large number of analyses performed in the study. An internal analysis of the same cohort looked at cancer incidence, circulatory mortality, and respiratory mortality in relation to bauxite dust exposure and alumina dust exposure.²⁴ There was some evidence of an exposure–response relationship between cumulative inhalable bauxite exposure and nonmalignant respiratory disease mortality (trend *P* = 0.01) and between cumulative inhalable alumina exposure and cerebrovascular disease mortality (trend *P* = 0.04). These associations were based on very few cases, and for nonmalignant respiratory disease, the deaths represented a heterogeneous mixture of causes. Further follow-up is needed to clarify these preliminary findings. There was no evidence of an excess risk of any cancer type with bauxite or alumina exposure.

Serum aluminum levels have been measured in bauxite miners and a comparison group of employees at a wood processing factory, both in Surinam.²⁵ No statistically significant difference in serum aluminum levels was found.²⁵

Some bauxites contain trace quantities of beryllium. The concentrations in mining and subsequent refining are unlikely to present a significant risk of beryllium sensitivity or chronic beryllium disease. Nevertheless, it is known that beryllium concentrates in the aluminum smelter bath if the alumina has originated from bauxite containing beryllium. The prevalence of beryllium sensitivity in aluminum smelters has been reported to be 0.28% in one Norwegian smelter and 0.47% across nine smelters owned by four different companies.^{26,27}

Bauxite contains trace quantities of mercury, which can give rise to elemental mercury vapor, especially in the upstream part of the refining process—typically in the digestion area. Some refineries use condensers to remove mercury from vapor. Occasionally, collections of metallic mercury are encountered and removal is undertaken by trained staff using safe handling measures and appropriate personal protective equipment. At Alcoa's three Western Australian refineries, personal sampling for mercury among refinery

employees in a range of roles and operating areas has consistently found all results to be within the current 2013 American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Value (TLV®) of 0.025 mg/m³ (Alcoa, unpublished data). A biological monitoring campaign at Pinjarra Refinery in Western Australia in 2002 found that all urinary mercury concentrations of 673 employees and contractors from a range of roles and operating areas were within the current 2013 ACGIH® Biological Exposure Index (BEI®) of 20 µg/g creatinine. The 95th percentile was 3 µg/g creatinine (Alcoa, unpublished data). Routine biological monitoring for mercury is not therefore required at these alumina refineries.

Older alumina refineries may still have asbestos in situ, so care is required to have a rigorous asbestos management plan. Asbestos-containing materials were used in gaskets and lagging/insulation.

Chemical splashes still occur in refineries despite many engineering and administrative controls. Sometimes this is because of failure of equipment such as valves, or a loss of process control leading to spills from tanks. A great majority of chemical splashes involve strong alkalis—usually caustic soda (sodium hydroxide), which is present in refinery liquor throughout the circuit. Caustic splashes can cause serious chemical burns of the skin and eyes, and immediate decontamination is essential. The incidence of skin splashes among Australian refinery employees has been reported as 4.06 per 200,000 hours worked.²⁸ Traditionally, first aid measures have involved emergency showers and emergency eyewash stations in proximity to any areas of risk within the plants. More recently, the use of Diphoterine® solution for first aid treatment of alkali skin splashes at alumina refineries in Western Australia has been found to result in better outcomes than the use of emergency shower water.²⁸ Diphoterine® is a commercially available amphoteric, hypertonic, chelating solution used to decontaminate and irrigate chemical splashes. Among employees who applied Diphoterine® first, there were no signs of a chemical burn in 52.9% of cases and blisters or more severe signs in only 7.9% of cases. These results were significantly different from those for employees who applied water first, with no signs of a chemical burn in only 21.4% of cases and blisters or more severe signs in 23.8% of cases ($P < 0.001$). Employees are typically issued with a personal aerosol can of Diphoterine® to be worn on their belt in the operational areas of refineries. Some refineries have also deployed Diphoterine® for emergency eye wash/irrigation.

Diesel particulate is generated by diesel-powered mobile equipment, but exposures in bauxite mining occur at low levels compared with underground mining. Diesel exhaust is an International Agency for Research on Cancer group 1 human carcinogen—sufficient exposure can increase the risk of lung cancer.²⁹ Control measures include the use of low-sulfur diesel fuel, engine maintenance, and air-conditioned cabins. Diesel-powered bob cats with impact equipment are used inside large tanks at alumina refineries to descale them. Additional controls in this situation include forced dilution ventilation and respiratory protection.

Irritant dermal exposures and dermatitis can occur in a range of jobs at alumina refineries and to a lesser extent at bauxite mines. Relevant agents include industrial solvents, alkalis, and acids.

Considerable welding is undertaken at alumina refineries and to a lesser extent at bauxite mine workshops. The control of exposure to welding fumes is therefore important with local exhaust ventilation and respiratory protection.

Confined space entry is also an important issue at alumina refineries where there are very many process vessels of differing types. Entry permits ensure that all elements of a safe system of work are in place before anyone enters a confined space. Atmospheric monitoring is required to detect oxygen-deficient, toxic, or flammable atmospheres. Ventilation of confined spaces before and during entry is common; however, additional respiratory protective equipment may also be necessary. Isolation of any hazardous systems

within, or connected to the confined space, is important during entry—using “tag and lockout.”

Noncondensable gases are produced in the digestion section of the refining process from the breakdown of organic matter in bauxite. They consist of a suite of volatile organic compounds and ammonia. They are called noncondensable gases because they do not condense to a liquid during cooling of the hot digestion stream. They are subsequently released from refinery vents and stacks—with time-weighted average concentrations in the workplace typically well below occupational exposure limits. Some of the noncondensable gases are malodorous and irritating. Brief encounters of transient fugitive emissions occur occasionally and can give rise to complaints of malodor and short-term respiratory irritation.

BIOLOGICAL RISKS

The risks of tropical diseases such as malaria and dengue fever are significant at some bauxite mining and alumina refining locations. Precautions to prevent mosquito bites are important, and malaria prophylaxis is sometimes prescribed. Vaccinations for yellow fever are also required for travel to some locations. Access to travel medicine advice before, during, and after travel is important.

In some countries, community-acquired infectious diseases can present a risk to the health of employees. Human immunodeficiency virus and tuberculosis are two examples. Mining companies at relevant locations are therefore engaged in education, screening, and treatment activities.

Tropical locations often involve the potential for encounters with venomous or dangerous animals, such as snakes, spiders, jellyfish, and crocodiles. This can be particularly relevant where employees undertake recreational activities such as bushwalking, hunting, fishing, swimming, or diving after hours.

The microbiological aspects of water quality management are important at alumina refineries, where potable water may not be from a municipal supply and recycled water may be used in the plant for process applications because of water scarcity. Also, cooling towers are common at alumina refineries, so regular microbiological analysis of the water is necessary to detect *Legionella* contamination or high concentrations of other heterotrophic microorganisms.³⁰

ERGONOMIC RISKS

Bauxite mining has become highly mechanized, with relatively few tasks requiring significant manual handling. Broken ground is often encountered when on-foot tasks are undertaken and can cause ankle and knee injuries.

Ergonomic hazards at alumina refineries include repetitive stair climbing, compressed air rattle guns for tightening or loosening bolts, sledgehammers to open or close valves, awkward postures in confined spaces, forceful and repetitive manual tasks, and heavy lifting. Recently, there has been substantial progress in systematically identifying and assessing ergonomic risks using standardized risk assessment tools. As a result there has been a shift toward nonimpact tools, mechanized valve operation, and rattle guns with lower vibration intensity. Nevertheless, musculoskeletal conditions generally remain the largest proportion of work-related injuries at refineries.

Most mines and refineries operate 24 hours per day, 7 days per week, so shift work is very common. In Australia and some other developed nations, there has been a trend toward 10- or 12-hour shifts in recent years. Fatigue and the risk of accidents in relation to extended shifts have been studied in the aluminum industry.³¹ This has resulted in the application of overtime limits within some organizations. Sleep deficits, which can occur for various work-related and personal reasons, have been shown to cause impairments of cognitive and motor performance among drivers from other industries.³² Fatigue risk management programs are increasingly being deployed in the aluminum industry. Key points addressed in such programs are adequate staffing levels and appropriate shift rosters to allow

adequate sleep, education and training to enable risk assessment, and the detection of behavioral indicators of fatigue, workplace modification to enhance alertness, and fatigue monitoring.^{33,34} Referral of employees by a medical service for polysomnography generally occurs where a history or risk factors suggest the possibility of obstructive sleep apnea.

The remote control of mobile equipment in bauxite mining has been introduced in a few unusual situations to reduce the risk of exposure to excessive whole-body vibration. This has required attention to cognitive ergonomic issues, many of which are similar to those found in metallurgical plant control rooms.

PSYCHOSOCIAL RISKS

Policies and procedures for managing drug and alcohol abuse are now in place at many mining and refining operations. These include the measurement of urinary or salivary drug metabolites and breath alcohol on pre-employment, during random sampling and after accidents, or impaired behavior (for cause testing).

Remote locations are common in bauxite mining and to a lesser extent also occur in alumina refining. Some mines operate by “fly-in-fly-out” with mine employees separated from their families and communities during work periods. Others are closer to urban centers but involve substantial driving to and from the site.

Expatriate placements are also common in bauxite mining and alumina refining. The psychosocial hazards of expatriate assignments have been reviewed.³⁵

Severe traumatic injuries and fatalities are rare in bauxite mining and alumina refining, but if they do occur, there is the potential for posttraumatic stress disorders to develop in witnesses, colleagues, and managers.

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