

#### IV. ENVIRONMENTAL DATA AND ENGINEERING CONTROLS

##### Sampling and Analytical Methods

Samples of air from the workplace should be monitored for hydroquinone during all manufacturing operations utilizing this chemical. Such operations include those which use hydroquinone to make photographic developer mixtures or antioxidant preparations, eg, for incorporation into rubber articles.

There are many general methods of sampling and analysis for organic vapor, dust, or mist. A few of these have been found suitable for quinone vapor or hydroquinone dust and mist. A direct readout method for analysis of airborne hydroquinone dust, aerosol, or vapor has not been developed.

One method of sampling hydroquinone aerosol, using midget impingers with distilled water as the collection medium and personal air sampling pumps, has been used for sampling employees' breathing zones and for stationary sites [98]. Little information is available on the different concentration ranges over which this method is applicable; however, the lower limit of detection for hydroquinone was 0.02 mg/cu m. In a test of this sampling method, a 409-liter air sample was drawn in 436 minutes for the employees' breathing zone sample and a 504-liter air sample was taken in 428 minutes for the developing room. The main disadvantage of such a sampling system is the difficulty of obtaining a personal sample. Since the collecting medium is liquid, some sample loss can occur from spillage.

Another method of sampling for quinone vapor and hydroquinone dust in air utilized an all-glass midget impinger containing 10-12 ml of isopropyl

alcohol as an absorbing agent [54]. A 5- or 10-minute air sample was drawn at a sampling rate of 2.82 liters/minute [99(p 9)] The efficiency of absorption of quinone vapor or hydroquinone dust in isopropyl alcohol in the midget impinger was about 85-95%, with an average value for 12 tests of 90.4% [54]. When tested, concentrations of quinone vapor in air collected by this sampling method ranged from 0.01 to 3.2 ppm (about 0.04-12.8 mg/cu m), and hydroquinone dust ranged from less than 1.0 to 35 mg/cu m. Unless care is taken, glass impingers can break and absorption solutions can spill during sampling and subsequent shipment to the laboratory. Such devices, however, may be used advantageously when analyses are to be completed near the sites of sample collection.

NIOSH's currently validated sampling method for airborne solid hydroquinone aerosol uses a mixed cellulose ester membrane filter (MCEF) with a personal sampling pump [100]. A sampling rate of 1.5 liters/minute for 60 minutes and a filter with a pore size of 0.8 $\mu$ m and a 37-mm diameter are recommended. The flowrate should be known with an accuracy of at least  $\pm$ 5%. A collection efficiency of at least 96% was determined for the collection medium, and the average recovery from the filters was 99.4%. For a sample size of 90 liters, concentrations of airborne hydroquinone aerosol collected by this sampling method ranged from 0.84 to 4.05 mg/cu m at 20 C and 762 mmHg. This sampling method uses a small, portable sampler and requires no liquids. Collected samples remain stable for 7 days when filters are stored in jars containing aqueous acetic acid solution; however, some sample workup is required during field operations to insure the stability of the sample.

Samples of airborne hydroquinone have been analyzed by potentiometric titration [101-103], oxidimetric titration [104,105], iodometric titration [106,107], colorimetric determination [54,108], ultraviolet absorption spectrophotometry [15,109,110], paper chromatography [111], and high pressure liquid chromatography [100].

Since potentiometric titration simplifies and speeds up routine analyses and minimizes the human error involved in judging color changes at the end of titration, it has been used to analyze photographic developer solutions [101,102] and rubber antioxidants [103] for hydroquinone. Two extractions with ethyl acetate are necessary to obtain the maximum amount (99.4%) of hydroquinone from the developer solution [102]. Precise temperature control is not essential. The analysis requires a minimum amount of equipment, but the determination of hydroquinone in the organic solvent after extraction is difficult and time consuming.

Kolthoff and Lee [104] analyzed pure hydroquinone solution, and Brunner et al [105] determined the hydroquinone content in color film developers, by oxidimetric titration. They used ceric sulfate in the presence of ortho-phenanthroline-ferrous sulfate complex (ferroin) as an indicator. This indicator made the titration simpler and faster than the potentiometric titration procedure described by Stott [101] because the color change was easily discernible. The determination of hydroquinone in color film developers was  $99.5 \pm 1.5\%$  accurate [105]. Oxidimetric titration of hydroquinone was 99.98% accurate [104].

Baumbach [106] reported a single methyl acetate extraction method involving potentiometric titration of Metol (methyl-para-aminophenol sulfate) followed by oxidation of both Metol and hydroquinone with iodine

(iodometric titration). Molecular hydroquinone and Metol were extracted from the photographic developer solution at pH 8.0-8.5 with methyl acetate. The extract was dissolved directly in water; then it was titrated, first with hydrochloric acid to determine Metol and then with iodine at pH 6.5-7.0, to determine the sum of Metol and hydroquinone. This procedure produced high extraction coefficients for both hydroquinone and Metol, but quantitative measurements were not presented. This method is time consuming and, in some cases, not sufficiently accurate [106]. Shaner and Sparks [107] modified Baumbach's [106] procedure by using a U-tube extractor and methyl ethyl ketone as a solvent. For hydroquinone analysis, the reproducibility (95.4-97.8%) and error (1.6-4.0%) of this method were quite adequate. However, it was difficult to determine the end point of titration when using these methods [106,107].

Oglesby et al [54] analyzed airborne quinone and hydroquinone samples by a colorimetric procedure based on comparing, at 520 nm, the yellow color developed by mixing the sample with phloroglucinol in potassium hydroxide with that of standards. Concentrations of airborne quinone vapor measured by this method ranged from 0.01 to 3.2 ppm (about 0.04-12.8 mg/cu m), and those of hydroquinone dust ranged from less than 1.0 to 35 mg/cu m. The sensitivity of this method is as low as 0.1  $\mu\text{g/ml}$  of solution, with good reproducibility between 0.1 and 2.0 mg/cu m, but it cannot distinguish quinone from hydroquinone.

Whettem [108] used sodium tungstate as the reagent for colorimetric determination of hydroquinone in 1 ml of styrene. Two milliliters of a sodium phosphotungstate solution and 4 ml of a sodium carbonate solution were added to the sample and standards, and the solutions were mixed well

after each reagent was added. After 15 minutes, the color of the sample was compared with that of the standards. This method is sensitive to 0.01 mg of hydroquinone in 1 ml of styrene, or to 10 mg/liter. It can be made to detect 1 mg/liter by extracting 10 ml of styrene instead of 1 ml with water [108].

Terakawa and Taguchi [109] detected hydroquinone in an aqueous solution containing a small amount of phenol. They used UV absorption at 295 nm, with sodium sulfite and ferric chloride as reagents. Small amounts (300 ppm) of hydroquinone, catechol, and quinone were measured within an hour with an error of 3-4%.

Guseinov [110] measured airborne hydroquinone vapor and aerosol in the air. The air was drawn at the rate of 2-4 liters/minute, first through a cartridge with a paper or "chlorinated polyvinyl chloride filter" and then through an absorber containing 4 ml of distilled water or ethanol. The filter carrying the hydroquinone particles was placed in a test tube containing 4 ml of distilled water or ethanol, and the solutions were analyzed spectrophotometrically at 294 nm for hydroquinone. An air sample of less than 10 liters was needed. The standard error of the method was about 4-5%, and its sensitivity was 0.8  $\mu\text{g/ml}$ , with good reproducibility between 2 and 20  $\mu\text{g/ml}$  of solution.

Using a Beckmann model DU ultraviolet spectrophotometer and methanol as a solvent, Woodard [15] analyzed hydroquinone by measuring absorption at 294 nm. Quantities of hydroquinone as low as 0.005 mg/ml of solution were determined easily by this method.

Borecky [111] reported a paper chromatographic method for separating and identifying 16 substances, including hydroquinone, that are used as

developing agents in various commercial photographic developing mixtures. The substances were separated by paper chromatography using various solvent systems. This method [111] had several disadvantages. The separation of the individual substances was indistinct. Occasionally, some decomposed during the chromatographic procedure. The working range over which this method is valid and its specificity and sensitivity for detecting hydroquinone at the environmental limit were not stated.

NIOSH recently validated an analytical method that can be used to measure hydroquinone aerosol [100]. A known volume of air is drawn through a mixed cellulose ester membrane filter to trap hydroquinone aerosol. The filter is transferred to a sample jar containing a 1% aqueous solution of acetic acid. An aliquot of the sample is injected into a high-pressure liquid chromatograph equipped with a variable wavelength UV detector set at 290 nm. The area of the resulting sample peak is determined and compared with peak areas obtained with standard solutions of hydroquinone. For a sample of 90 liters, the working range is 0.4-8.0 mg/cu m and the sensitivity of this method is estimated to be at least 1.5  $\mu\text{g}/\text{ml}$ . The coefficient of variation for the total analytical and sampling method, in the range of concentrations of hydroquinone of 0.84-4.05 mg/cu m, was 0.061. The sampling device is small and portable, and it uses no liquids. Interferences are minimal, and most can be eliminated by altering chromatographic conditions. It should be noted that this method of sampling does not collect hydroquinone vapor. Data on the vapor pressure of hydroquinone at various temperatures are given by Coolidge and Coolidge [8].

NIOSH recommends that hydroquinone be sampled by collection through a mixed cellulose ester membrane filter and analyzed by high pressure liquid chromatography. Sampling involves the collection of personal samples of hydroquinone aerosol on mixed cellulose ester membrane filters. Analysis involves extraction with 1% acetic acid and measurement with a high-pressure liquid chromatograph equipped with a variable wavelength UV detector set at 290 nm [100]. Details of the recommended methods are given in Appendix I. The recommended methods have not been validated for monitoring of an environment that may contain other substances that may interfere. Other sampling and analytical methods equivalent in accuracy, precision, and sensitivity to those given in detail in Appendix I may be used. The recommended sampling method will not collect vapors of hydroquinone or quinone, if any are present. It is valid only for airborne particulate material.

#### Environmental Levels

Oglesby et al [54] studied occupational exposure to airborne quinone vapor and hydroquinone dust. The air samples were collected from different work areas in the plant by using isopropyl alcohol as the absorbing agent in a midget impinger. Samples were analyzed colorimetrically, using phloroglucinol in potassium hydroxide as the reagent and measuring absorbance at 520 nm. The frequency of air-sample collections was not reported. The stationary air monitoring data were taken from mixing, filter press, oxidation, centrifugation, and hydroquinone packaging areas. Quinone vapor concentrations ranged from 0.01 to 3.2 ppm (about 0.04-12.8 mg/cu m).

The concentration of hydroquinone dust was 20-35 mg/cu m in the packaging area, but the method used to determine this range was not specified [54]. To minimize employee contact with quinone vapor and hydroquinone dust, more effective ventilation was installed and operations that produced high concentrations were isolated. After an exhaust cabinet was installed in the packaging area into which drums were placed to receive hydroquinone, the concentration of airborne hydroquinone decreased to 1-4 mg/cu m. Personal monitoring data were not presented.

Chrostek [98] documented occupational exposure to airborne hydroquinone mist and acetic acid when NIOSH conducted a health hazard survey in the film-developing room of a printing company. Hydroquinone mist was sampled with midget impingers using distilled water as the collection medium. Personal air sampling pumps were used in the employees' breathing zone and in the developing room, which contained a ceiling exhaust fan and an air conditioner. A 409-liter air sample was drawn in 436 minutes from the employees' breathing zone, and a 504-liter air sample was taken in 428 minutes from the developing room. Both samples were analyzed by UV spectrophotometry. The lowest concentration of hydroquinone in air detectable by this method is 0.02 mg/cu m. Both the personal and the area air samples were below this limit, and no complaints of eye irritations were reported.

A few companies have supplied NIOSH with the analytical results of air sampling performed at their plants. One chemical company [99(pp 74,87-88)] has reported stationary site monitoring data for its units that manufacture hydroquinone. Samples were collected during 20-minute periods



with Bendix C 115 sampling pumps, using redistilled isopropanol as the collecting medium. They were analyzed by the colorimetric method described by Oglesby et al [54]. The results of air monitoring on August 1 and September 5, 1974, are presented in Table XI-5. All the August 1 and September 5 samples were below the TLV (2 mg/cu m).

A second chemical company [99(pp 113-53)] has presented stationary site monitoring data for its units that produce hydroquinone. Seven hundred and forty samples were collected from stills (iron presses, dryers, barium cookers, panel boards, treating kettles, etc), oxidizers, centrifuges, and packaging areas between June 17, 1971, and February 21, 1977. The air samples were aspirated through a midget impinger containing 1% ethylene glycol, which absorbed hydroquinone and quinone. Samples were collected 3 times/week for 1-2 hours, and the data were extrapolated to 8 hours. Hydroquinone and quinone were analyzed colorimetrically by the method described by Oglesby et al [54]. Since this method cannot distinguish between quinone and hydroquinone, the results were reported in terms of hydroquinone. The hydroquinone concentrations in air from distilling, oxidizing, centrifuging, and packaging areas ranged from 0.00 to 2.50, 0.00 to 3.28, 0.085 to 2.25, and less than 0.01 to 4.04 mg/cu m, respectively.

A third chemical company [99(p 157)] has stated that air samples taken in 1968 near a filling-line operation indicated an average airborne hydroquinone concentration of 0.13 mg/cu m. Details of sampling and analytical methods were not given. Samples of air taken near the filling-line operation (nine different lines) in 1976 contained airborne hydroquinone concentrations of less than 0.08-1.55 mg/cu m over sampling

periods of 85-300 minutes. In 1976, MSA portable pumps were used to collect samples on 37-mm diameter Millipore Type AA open-face cassette filters with a 0.8- $\mu$ m pore size. The hydroquinone was extracted from the filter with an acetate buffer (pH about 4.9), and samples were then analyzed, with the aid of a computer system, by a UV detector set for 295 nm.

Environmental area and breathing zone samples collected at a fourth chemical company [99(pp 233-39)] in 1976 and 1977 with midget impingers were analyzed by the colorimetric method of Oglesby et al [54]. Environmental levels of hydroquinone were usually below the TLV (2 mg/cu m); those for breathing zone samples ranged from 0.01 to 2.33 mg/cu m and those for area samples from 0.1 to 1.8 mg/cu m.

### Biologic Monitoring

Many methods based on colorimetric, spectrophotometric, and titrimetric procedures have been used to detect urinary phenols. A few of them include quantitative determinations of hydroquinone [15,112,113]. The following analytical methods and information may be useful when considering biologic monitoring of hydroquinone.

Baernstein [112] developed a method of analyzing catechol, phenol, and hydroquinone in a single sample of urine. The urine was hydrolyzed by heating at 100 C for 2 hours with concentrated sulfuric acid (pH 1.0). The pH was then adjusted to 7.0 with sodium sulfite, and the phenols were extracted with ether for 4 hours in a continuous liquid-liquid extractor. The ether was evaporated, and the residue was taken up in water. Catechol

was precipitated from this solution, by adding lead acetate at pH 6.5 in the presence of a pyridine-acetate buffer, and was removed by filtration. The filtrate was acidified and its content of phenol was estimated by bromination and back titration of the excess bromine with 0.2 N sodium sulfite solution after addition of potassium iodide. An iodine-sensitive electrode was used as the indicator. The hydroquinone in the solution was analyzed by adding a bromate-bromide mixture, which liberates more iodine. The solution was brought back to neutrality with sodium bicarbonate. After the solution had stood for 1 hour, the excess iodine was determined by back titration with sodium sulfite. About 2 mg of hydroquinone/25 ml of urine can be determined by this method. The method is not specific for hydroquinone, since ketones react similarly.

Fassett [113] stated that conjugated or free hydroquinone can be estimated after hydrolysis of the urine with sulfuric acid by using the procedure described by Oglesby et al [54]. Amounts of less than 1  $\mu$ g of hydroquinone can be detected in this way.

Woodard [15] analyzed urine samples using a UV spectrophotometer set at 294 nm. Normal urine samples were extracted with ether for 4 hours in a continuous liquid-liquid extractor, as described by Baernstein [112]. The ether extracts were then evaporated under vacuum, taken up in methanol, and examined for their absorption in the UV range. The author found that hydroquinone had peak absorption at 294 nm and no absorption at 320 nm, so it was possible to calculate absorption due to hydroquinone. This calculation was done by measuring the absorption at 294 nm after extraction of normal urine with ether and subtracting this reading from those obtained with extracts of urine samples thought to contain hydroquinone.

### Engineering Controls

Both solids and solutions containing hydroquinone are encountered during most industrial production or applications of hydroquinone [1]. Although hydroquinone has a very low vapor pressure (0.000018 mmHg at 25 C) [8], it can be oxidized to the more volatile quinone in the presence of moisture [27]. The saturated concentration in air for hydroquinone vapor under standard conditions is estimated to be 0.108 mg/cu m. To reduce concentrations of airborne hydroquinone, adequate general dilution or local exhaust ventilation systems should be installed where hydroquinone is manufactured or handled in large quantities [27,114,115]. Portable local exhaust ventilation systems should be used to reduce the concentrations of airborne hydroquinone in situations such as cleanup of small leaks and spills, line and vessel entry, and emergency decontamination. Trained personnel should periodically, eg, monthly, measure airflow, static pressure, and leakage to determine the proper functioning of ventilation systems. Engineering controls should emphasize designs that prevent the escape of both hydroquinone vapor and dust into the environment.

Engineering controls in the workplace should be used to control airborne hydroquinone emissions so that exposures can be maintained at less than the ceiling value. Any line system or storage vessel necessary to transfer, store, or manufacture hydroquinone should be enclosed and ventilated. Additional engineering controls, preferably automated systems, should be used to provide a healthful work environment and minimize worker exposure to hydroquinone [99(pp 2-3)]. A closed system may be the best method of preventing eye and skin contact when hydroquinone is handled. Hydroquinone should be transferred in a closed-line system from the storage

vessel to the reactor [99(p 2)]. Closed systems that are properly designed, operated, and maintained should be used, where practical, to contain hydroquinone vapor and dust. The conventional method of manually filling storage tanks or reactor vessels with hydroquinone should be replaced with an automated, enclosed, or ventilated system [99(pp 2-3)]. Engineering controls should be designed to minimize eye and skin contact and inhalation hazards associated with hydroquinone usage.

If closed systems are not feasible, well-designed local exhaust ventilation systems should be provided. Guidance for proper design can be obtained in Industrial Ventilation--A Manual of Recommended Practice [116], or more recent revisions, and in Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Z9.2-1971 [117]. All ventilation air that contains hydroquinone vapor or dust or that has contacted any other form of hydroquinone should be controlled to meet EPA and local air standards, and exhaust air should not be recirculated into the workplace. A sufficient supplementary air supply should be provided to permit proper operation of local exhaust ventilation systems.

To effectively control hydroquinone exposure, good work practices and protective clothing should complement adequate engineering controls. Respiratory protective equipment should not be used as a substitute for proper engineering controls, but it should be worn when workers have to be exposed to hydroquinone dust or quinone vapor at concentrations exceeding the workplace exposure limits.

## V. WORK PRACTICES

Occupational exposures can occur in the manufacturing of solid forms of hydroquinone [17,50,51], in the mixing and packaging of photographic developers [53], and in the handling of hydroquinone derivatives that contain residual hydroquinone [55]. Prevention of occupational injuries resulting from exposure to hydroquinone appears to require protection against eye or skin contact with and inhalation of hydroquinone. Engineering controls coupled with good work practices and protective clothing are important means of limiting exposure to hydroquinone.

Manually cutting open bags of hydroquinone solid with a knife and dumping the hydroquinone into the reactor produced excessive dust exposure [99(pp 154,209)]. To minimize exposure, hydroquinone should be shipped in fiber drums in a way which complies with US Department of Transportation requirements and specifications for safe transportation at the lowest applicable cost to the point of delivery [118]. Furthermore, a mechanized and maximally enclosed or ventilated system should be used [115,99(pp 2-3)] so that removing lids and placing drums on an elevator are the only manual steps. Dust or vapor may be controlled by effective local exhaust ventilation and trapped by a filter. There is less chance of hydroquinone escaping in this system if the hopper is connected directly to the reactor. If the shipping drums are not reusable, they should be compressed and discarded.

Handling solutions of hydroquinone warrants special work practices to prevent eye and skin contact. Since there is a risk that solutions of

hydroquinone will splash into the eyes of a worker engaged in pouring fresh solutions into a storage tank, hydroquinone solution should be transferred in all cases, eg, from the truck to the storage tank and from the tank to the reactor, by closed-line systems [115]. Safety features on the tanks should also be checked regularly and defects should be corrected.

Respiratory protective equipment is not an acceptable substitute for proper engineering controls, although such equipment should be available for use in emergencies and during maintenance and repair procedures or irregular operations during which hydroquinone concentrations may exceed the environmental exposure limit. Standard procedures for opening lines or entering tanks and other confined spaces should be formulated and should include at least the following requirements [99(pp 231-32)]. Before opening a line, workers should set up a barricade to isolate the area and should check protective equipment usage and the condition and location of the nearest eyewash fountain and safety shower. All workers involved in the tank entry must be supplied with whole body protection, including coveralls and suitable respiratory protective equipment in accordance with Table I-1. Workers should wear this protective equipment when entering the tank or confined space unless prior measurements indicate that air concentrations are below the recommended TWA environmental limit and there is an acceptable oxygen concentration (about 20%). A second properly protected worker must be on standby outside the tank [99(pp 231-32)]. Effective communication must be maintained between all involved persons. A safety harness and lifeline should be used.

Work practices should emphasize the use of personal protective devices, good housekeeping, and personal hygiene. To minimize dermal

contact with solid hydroquinone or solutions thereof, all workers who are handling hydroquinone should wear clothing that will minimize access of dust to the skin, a face shield (8-inch minimum), goggles, and rubber gloves with cotton liners [99(pp 3-4,86)]. Clean work clothes should be provided at the beginning of each workshift, and washing facilities should be available for personnel at the end of the shift and at breaks during the shift [53]. Soiled work clothes should be left in bins or in separate lockers at the workplace for laundering after work. Work clothing and personal clothing should be kept apart [99(p 4)].

Extended skin contact with hydroquinone has been reported to cause dermatitis [57,58,63]. Therefore, clothing impervious to water should be worn when skin contact with concentrated solutions of hydroquinone is likely to occur. Note should be taken that a full suit of impervious clothing places a heavy load of heat on the workers by preventing evaporation of water from the surface of the body. Full suits may not be necessary or may be necessary only intermittently. Control of the temperature in the workplace becomes crucial if a full impervious suit is necessary for any appreciable length of time (30 minutes or more). These factors emphasize the need for showers, eyewash fountains, and proper engineering controls.

To ensure employee protection against exposure of the skin to hydroquinone, all protective clothing and gloves should be tested for their permeability to solutions of hydroquinone before being worn. If clothing becomes contaminated, it should be changed immediately and laundered.

To prevent skin contact, workers should wear impervious gloves with separate cotton liners and long-sleeved coveralls when handling equipment



or containers used in hydroquinone operations. The gloves should be either gauntlet type or long enough to overlap the sleeve. A supply of these gloves should be on hand in the workplace. After work, the outside of the gloves should be washed before removing them; if the insides of the gloves become contaminated, the hands should be washed immediately with water. Gloves should either be discarded or first washed thoroughly with a non-ionic detergent and water and then soaked in clean isopropyl alcohol (rubbing alcohol).

Since eye irritation and eye injuries have been reported in hydroquinone operations [17,50,52,53], chemical safety goggles [53,99(pp 86,229)] should be worn in unusually dusty areas and should be cleaned as often as is necessary to maintain good visibility. Face shields should also be worn during opening of lines carrying liquid hydroquinone and as a routine procedure in appreciably dusty areas. Eyewash fountains and emergency showers should be available in hydroquinone work areas. Hydroquinone poses neither explosive nor fire hazards when stored at room temperatures [99(p 170)], but it can produce dust explosions [119] and can oxidize to the more volatile quinone in the presence of moisture [27]. Therefore, when workers handle hydroquinone in bulk, the general precautions for handling explosive dusts and substances likely to irritate the eyes should be observed.

Good housekeeping should be instituted to minimize eye contact with or inhalation of hydroquinone, hazards which can occur when spilled or settled materials are dispersed in the work atmosphere by air movement and operational activities. Where hydroquinone is present in bulk, floors constructed of concrete should be sealed with a layer of impervious

material, such as epoxy resin, to prevent buildup of hydroquinone and to facilitate the removal of spills. Other floor covering formulations may also be effective. When spilled, hydroquinone should be either vacuumed or mopped up immediately, deposited in a covered drum [99(p 4)], and properly disposed of. The residual hydroquinone on the floor should be mopped with water and sodium sulfite, and the liquid residue should be properly disposed of. Any hydroquinone spilled on the surface of equipment should be removed and transferred to a covered drum and treated as described for floor spills. Contaminated surfaces of equipment should be washed with a detergent solution by a worker wearing long-sleeved coveralls and rubber gloves. The floor adjacent to contaminated equipment should be cleaned with detergent solution.

To prevent community exposures, solid hydroquinone wastes, including compressed contaminated bags, drums, drum liners, or containers, should be disposed of either by burial in an approved landfill away from drinking water sources or by burning in an approved industrial incinerator [99(p 4)]. Decontaminated solutions of hydroquinone or any aqueous hydroquinone waste solutions should be drained to a holding tank for subsequent treatment [99(p 4)].

Good sanitation and personal hygiene practices should minimize the risk of eye contact with hydroquinone or of ingesting it. Workers should wash their hands frequently, at least before using toilet facilities, drinking, eating, or smoking, and food and beverage consumption or smoking should not be allowed in any hydroquinone work or storage areas. Employees should shower after each workshift [99(p 4)] before leaving the workplace where hydroquinone is handled.

For emergency conditions, such as spills and leaks, full-body protection, including an air-supplied respirator, should be worn by all personnel entering the affected area [99(p 68)]. A program detailing escape and entry procedures and training of entry personnel should be formulated, written, and made available to all employees. An emergency situation, such as the occurrence of leaks or spills, should be corrected immediately by trained personnel. Persons not wearing protective equipment should be excluded from areas of spills or leaks until cleanup has been completed. If the eyes come into contact with hydroquinone, they should be immediately flushed with low-pressure flowing water for at least 15 minutes [3,99(pp 79,85)]. Any skin contacting hydroquinone should be washed immediately with soap and flowing water.

Prolonged or repeated eye and skin contact and inhalation of hydroquinone dust should be avoided. Annual eye examination by properly trained personnel with a slit lamp or any better technology is advisable for individuals with continuous exposure [51,114,119]. Employees found to have corneal injuries by this procedure or by other means should also be given slit lamp examinations by an ophthalmologist to assess the severity of the damage and to determine whether a change in work assignment is necessary. Persons with chronic conjunctival and corneal lesions should not be allowed to have daily contact with hydroquinone [27,114]. Persons with contact dermatitis, skin depigmentation, or eye lesions should be removed from further contact with hydroquinone [27,51,114] until the disorder is corrected.

Employees, physicians, and other medical attendants should be informed of the possibility of delayed eye injuries. All employees should

be trained and verbally informed about accident and first-aid procedures and the use of respirators. They should also be informed of the hazardous areas, with special attention being given to informing illiterate and non-English reading employees adequately of the hazards.

Records should be kept of maintenance schedules, written work practices, emergency procedures, storage locations, quantities of hydroquinone present in each location, employees' accidents, and employees' exposures. These records should be readily accessible to employees and management.