FINAL DRAFT
1994

Generic Scenario: Application of Waterborne Wood Preservatives Using Pressure Treatment

Background

Almost 600 million cubic feet of wood are treated with preservatives in the United States each year. Almost 75% of the wood (400 million cubic feet) is treated with waterborne preservatives, which are used to treat poles, piling, fence posts, lumber, timber, and plywood. Less than 25% of the wood is treated with oilborne preservatives such as pentachlorophenol (PCP) and creosote. The most common waterborne preservatives are chromated copper arsenate (CCA), ammoniacal copper arsenate (ACA), and ammoniacal copper-zinc-arsenate (ACZA), which are derived from ammonium arsenic pentoxide, sodium arsenate, or sodium pyroarsenate and other metal salts (e.g., chromium, copper, and zinc) [1]. Arsenic trioxide is converted to arsenic acid to produce these arsenical wood preservatives. All arsenic trioxide consumed in the United States is imported, and the wood-preserving industry uses 70% of this import [2]. The current U.S. demand for CCA is 150 million pounds (of active ingredient as oxide content). The U.S. production is about 165 million pounds. CCA is provided as a by manufacturers as a 50 or 60% concentrate.

The Occupational Safety and Health Administration (OSHA) has established standards limiting worker exposure to inorganic arsenic (see Table 1), and the U.S. Environmental Protection Agency (U.S. EPA) has listed inorganic arsenic as a hazardous air pollutant. The EPA also has listed process wastewater, process residuals, preservative dripping, and spent preservative as hazardous. EPA guidelines regulate the use of arsenical preservatives and stormwater runoff and provide standards for treatment plant design, operation, inspection, and closure [3].

Table 1. PELs, RELs, and TLVs for As, Cr(VI), Cu, and NH_3

	OSHA PELs[a] (mg/m^3)	NIOSH RELs[b] (mg/m^3)	ACGIH TLVs[c] (mg/m^3)
As	0.010	C[d] 0.002	Sc[f]
Cr(VI)	C 0.1	Ca[g] 0.001	0.05
Cu	0.1	0.1	0.2
NH_3[h]	27 (ST[i] 35 ppm)	18 (25 ppm)	18 (25 ppm)
		27 (ST 35 ppm)	27 (ST 35 ppm)

(a) The Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) are time-weighted average (TWA) concentrations that must not be exceeded during any 8-hr workshift of a 40-hr workweek.
(b) The National Institute for Occupational Safety and Health (NIOSH)-recommended exposure limits (RELs) are TWA concentrations for up to a 10-hr workday during a 40-hr workweek.
(c) The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) are 8-hr TWA concentrations.
(d) Ceiling concentration.
(e) The ceiling value is assessed as a 15-min TWA exposure.
(f) Suspect carcinogen.
(g) Occupational carcinogen.
(h) 1 ppm = 0.71 mg/m^3.
(i) Short-term exposure limit.

More than 400 plants in the United States treat wood with arsenical preservatives [3], of which about 100 to 150 are large treaters with an annual production of more than 40 million board feet of wood (1,000 board feet is equivalent to about 57 ft^3), about 150 to 180 are medium treaters with an annual production of 20 to 40 million board feet, and 120 to 150 are small treaters with an annual production of less than 20 board feet. Large treaters generally operate 5 days/week in 1 shift with 12 to 15 workers/shift. Medium treaters operate 5 days/week in 1 shift with 8 to 12 workers/shift. Small treaters operate 5 days/week in 1 shift with 4 to 8 workers/shift.

Wood-Treating Processes

Wood can be preserved using either pressure-treating processes applied in a treatment cylinder – the preferred commercial approach – or non-pressure-treating processes. CCA is the most common waterborne preservative used [3]. CCA is shipped by dedicated tankers to treatment plants as a 50 or 60% concentrate, transferred to concentrate tanks, and later diluted with water and transferred to work tanks in a concentration of 1 to 2% for use in treating wood [2]. The normal preservative retention in wood is 0.4 lb (active ingredient or oxide content)/ft^3. The retention for some ground contact and marine applications can be as high as 0.6 and 2.5 lb/ft^3, respectively.

Typically, stacks of lumber to be treated are forklifted from the wood storage area to the treatment area. There the wood is loaded onto a tram and pulled on rails into the treatment cylinder, and the cylinder door is closed. The cleaned and/or conditioned wood is vacuumed in the treatment cylinder to remove air from the wood cells to permit maximum retention of the treating solution. Preservative is then fed into the cylinder through piping from the work tank with hydrostatic or pneumatic pressure applied until the preservative permeates the wood. The wood is again vacuumed to remove excess preservative, which is returned to the work tank for reuse. After the intended preservative retention has been achieved, wood is pulled from the treatment cylinder, analyzed for chemical retention, and placed on drip pads until dripping has ceased. The treated wood is then transferred to drying sheds or placed in an open yard [3,4]. A typical flow diagram of wood-treating operations is presented in Figure 1.

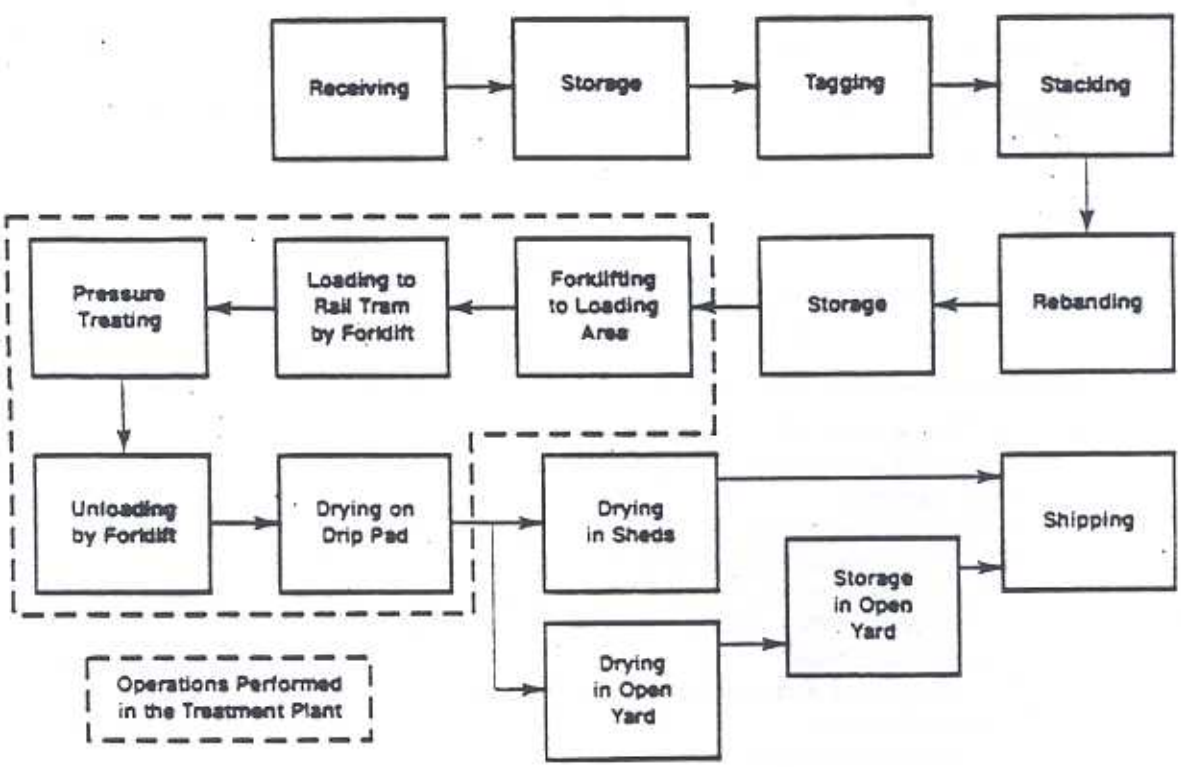

Figure 1. Flow diagram of wood-treating operations at a typical plant.

Wastes Generated from Wood-Treating Processes

Treatment processes that use water-soluble preservatives discharge little or no wastewater because liquid waste is reused to make fresh working solution. For example, solution dripping onto drip pads, washdown water and rainwater, and rinsewater for equipment and tool cleaning all flow to a collection sump and are transferred to the dilution water tank [3]. Tank farms are designed to contain spilled or leaking preservative, which also is returned to work tanks for reuse. Most of the hazardous waste generated by wood-treating plants consists of soil, sawdust, or wood chips. These wastes are dried, drummed, and taken to hazardous waste landfills for disposal. Worker exposure and environmental contamination can, however, occur as a result of accidental releases during delivery, storage, and mixing of preservative and during wood treatment and storage. Releases can be in the form of vapors, aerosols, dust, drips, spills, and stormwater runoff.

To prevent exposure during delivery, chemicals usually are unloaded from tankers on a drip pad or in a confined area. Industry-standard quick couplers are available to prevent release during transfer of the chemical to the concentrate tank. To minimize the potential for accidental release when diluting the concentrated chemical, preservative is transferred from concentrate tanks to work tanks and from work tanks to the treatment cylinder through an enclosed system of pipes. To mitigate the effects of leaks and spills, storage and mixing tanks usually are kept in an isolated, centralized location, on concrete floors, with linings and drainage systems to contain the chemical and return it to the work tanks.

Worker Exposures

Aerosols and vapors released from work tanks, concentrate tanks, and treatment cylinders are a greater threat to the environment and to worker health than are leaks and spills. Also, dust collected on drip pads can become airborne, presenting a hazard to workers. Chemicals can be transferred beyond the controlled area by movement of workers or equipment. Workers may be exposed to chemicals when cleaning up spills and leaks, washing down sump pits and drip pads, or packaging contaminated waste for disposal. Stormwater runoff and seepage can cause ground contamination in the open storage yard.

Enclosed treatment buildings and closed mixing systems reduce worker exposure and the possibility of contaminating the environment, as does covering the treated wood in the storage yard. Automating the treatment processes (using automatic lumber-handling systems, computer-controlled mixing systems, and remote monitoring) reduces the possibility of exposing workers to chemicals and of transferring chemicals outside controlled areas.

Waste Generation, Environmental Releases, and Exposure-Level Calculations

PMN chemicals may be used as replacements for, or additional components in, the wood preservative chemicals currently used in the process. In this generic scenario, the PMN chemical is used either as an additive to a current waterborne wood preservative or as a one-chemical new preservative.

Environmental Releases (total lb/year at a single wood treatment facility)

Solid Wastes: Solid wastes containing the PMN chemical arise from soil, sawdust, and wood chips contaminated with the wood preservative as a result of the treatment process. In a typical treatment facility, one to two 55-gal drums of solid wastes are generated every 90 days. These solid wastes are dried, drummed, and disposed of at hazardous or nonhazardous waste landfills, depending on the characteristics of the wastes. The PMN chemical may be one of the residual chemicals in these solid wastes. The extent to which the solid wastes are contaminated with the PMN chemical will depend on whether the chemical is volatile or inorganic, as well as the process by which the wastes became contaminated with the wood treatment chemical. The amount of PMN chemical released as solid waste can be estimated from measurements of PMN content in samples of solid waste from an actual operation. If such data are not available, data on the typical concentration of currently used chemical(s) in solid wastes may be used. The amount of PMN released can then be estimated from a ratio of mass fractions of the various chemicals in the wood preservative as:

$$C_i\ (lb/lb) * SW\ (lb/yr) * M_{PMN}/M_i = lb/yr$$

where C_i is the typical concentration of chemical i in solid waste from the facility, SW is the annual solid waste output from the facility, and M_{PMN} and M_i are the mass fractions in the wood preservative chemical of the PMN chemical and chemical i, respectively. This approach assumes that the PMN and reference chemicals are similar in volatility, reactivity, etc.

Air Emissions: Air emissions of a PMN chemical component in the wood preservative could arise from transfer of concentrate from shipment tankers to concentrate tanks; working and breathing losses from concentrate tanks, work tanks, and treatment cylinders; leaks from valves, connectors, and other plumbing used in the facility's flow lines; contaminated dusts and solid wastes stored at the facility; treated wood collected at the drip pad for drying; and chemical drips and spills in the treatment areas and on the drip pads. Most air emissions are expected to arise from venting and breathing losses from the various tanks and treatment cylinders.

The extent of air emissions of a PMN chemical depends greatly on its volatility. Inorganic chemicals currently used in waterborne wood preservatives have a low volatility. For a generic wood treatment facility and a PMN of unknown chemical characteristics (e.g., volatility), it is difficult to estimate the potential extent for air emissions. For a volatile PMN, air emissions can be calculated using emission factors developed by U.S. EPA/OAQPS (AP-42 and other related publications).

Alternatively, PMN air emissions may be estimated from a ratio of mass fractions of the PMN chemical to the chemicals currently used in wood preservatives. Information collected from one wood treatment facility [6] indicates that arsenic concentrations in vent emissions from treatment cylinders typically are less than 1 to 2 $\mu g/m^3$. Based on this information, a 7′ × 100′ cylinder that has a maximum wood capacity of 1706 ft^3 and can treat 6587 charges per year was calculated to vent 0.00208 to 0.00416 lb/yr arsenic emissions from cylinders. Using the same data, work tank venting losses of arsenic (18′ dia. × 22′ high) from blowback operations (refilling of the tank when the cylinder is emptied) are estimated at 0.00088 to 0.00176 lb/yr. These data could be used with appropriate ratio factors to estimate emissions of a PMN chemical from these sources.

The possibility of dusts containing the PMN chemicals becoming airborne also needs to be addressed. U.S. EPA and its contractors have developed empirical equations to estimate the extent of these emissions under a variety of conditions [7].

Water: Liquid containing the PMN chemical could arise from drips, leaks, and spills of the waterborne wood preservative during and after treatment. However, all wood treatment facilities are designed with a self-contained system for liquids to collect and reuse run-off and spills. In addition, dried-up wood preservative from the drip pad and other areas is rinsed off and returned to the work tank for reuse. Under these facility characteristics, PMN releases to water will be negligible.

Worker Exposure

Worker exposure to the PMN chemical in the wood preservative potentially could occur from both inhalation and dermal routes. The extent of worker exposure to the PMN chemical depends on the design of individual treatment plants and the extent of automation in each facility. Accurate quantification of the various routes for potential worker exposure is difficult for a generic treatment plant. However, assessment of worker exposure to arsenic currently used in wood treatment plants is a regulatory requirement. Data from current monitoring programs therefore may be used to analyze potential worker exposure to the PMN chemical.

Inhalation (mg/day): Inhalation of the PMN chemical is expected to be an important route of worker exposure to the PMN chemical. Inhalation of the air emissions is expected, and releases to the air from normal working operations are expected to be more significant than accidental spills or leaks. If the PMN chemical is volatile, the emission rates from concentrate tanks, work tanks, and treatment cylinders could be used to estimate worker exposure. However, the most accurate way of estimating worker exposure would be to use measurement data from personnel exposure monitoring.

Currently, OSHA rules state that arsenical wood treatment plants shall require all employees potentially exposed to airborne inorganic arsenic to wear respirators. Alternatively, the plant must implement a Permissible Exposure Limit (PEL) monitoring program. Many wood treatment plants have chosen to conduct monitoring programs to relieve their employees of the burden of wearing respirators. Measurement data from these monitoring programs could be used to estimate worker exposure to the PMN chemical, provided that the PMN chemical is inorganic in nature and reasonably similar in chemistry to arsenic.

Worker exposure to the PMN chemical in a wood treatment facility could then be estimated as follows. Assuming that the work involved is (on average) medium duty in terms of level of physical activity required, an inhalation rate of 1.25 m^3/hr can be assumed (CEB, 1991). Further, if $C_{TWA, As}$ is the measured time-weighted average (TWA) inorganic arsenic exposure concentration of a worker over a typical 8-hr shift, the inhalation exposure of a worker during an operating day to PMN chemical in the wood preservative may be estimated as:

$$C_{PEL, As}\ (\mu g/m^3) * 1.25\ m^3/hr * M_{PMN}/M_{As} * H\ (hr) = ??\ mg/day$$

where $C_{PEL, As} = 0.010\ \mu g/m^3$, and M_{PMN} and M_{As} are the mass fractions of the PMN chemical and inorganic arsenic in the wood preservative (the latter referring to when the measurements were made), and H is the number of hours per shift the exposed worker is present at the facility.

Dermal Exposure (mg/day): Dermal exposure can arise from during wood preservative transfer, spill and liquid management, and handling of treated lumber. Because current wood preservative chemicals are corrosive, workers are required to use gloves, rubber aprons, and rubber boots at all times. Assuming that the wood preservative solution containing the PMN chemical will continue to be corrosive, CEB (1991) guidelines can be used to characterize dermal exposure.

Direct contact with the PMN chemical is expected to be negligible because of the use of protective equipment. In qualitative terms, dermal exposure of workers at the wood treatment facility may be best characterized as incidental contact (CEB, 1991) from the contact of protective clothing with the PMN in the wood preservative solution.

Other Potential Concerns

Release of the PMN chemical to the environment also will occur as a result of the retention of wood preservative in the treated wood. The implications of this release may need to be addressed for the PMN chemical. Typically, 0.4 to 0.6 lb of wood preservative is retained per ft^3 of treated wood. The extent of PMN chemical retention can be estimated from the weight percent (on a dry solids basis) of PMN in the wood preservative.

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