

Synthetic Rubber

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Household Technologies

[Field Guide to Appropriate Technology](#), 2003

SYNTHETIC RUBBER

The different types of [synthetic rubber](#) include [neoprene](#), Buna rubbers, and butyl rubbers, and they are usually developed with specific properties for specialist applications. Styrene-butadiene rubber and [butadiene](#) rubber (both Buna rubbers) are commonly used for tire manufacture. Butyl rubber, since it is gas-impermeable, is usually used for inner tubes. Table 1 shows the typical applications of various types of rubber.

TABLE 1. Types of rubber in the manufacture of vehicle tires

Type of Rubber	Application
Natural rubber	Tires for commercial vehicles such as trucks, buses, and trailers
Styrene-butadiene (SBR) and butadiene rubber	Tires for small trucks, private cars, motorbikes, and bicycles
Butyl rubber (BR)	Inner tubes

Tires are made up of both natural and [synthetic rubbers](#), together with carbon, nylon or polyester cord, [sulphur](#), [resins](#), and oil. During the tire-making process, these are vulcanized into one compound product that is not easily broken down.

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Fire Retardancy of Elastomers and Elastomer Nanocomposites

S.K. Srivastava, T. Kuila, in [Polymer Green Flame Retardants](#), 2014

6.6 Acrylonitrile–butadiene rubber

Nitrile Rubber is a [synthetic rubber](#) produced by the [polymerization](#) of [acrylonitrile](#) with [butadiene](#). This rubber is also known as NBR, acrylonitrile–butadiene rubber, acrylonitrile rubber and nitrile-butadiene rubber. The properties of acrylonitrile–butadiene rubber (NBR), e.g. high [tensile strength](#), high [compression](#) set, and poorer cold flexibility depends on the acrylonitrile content. It has an excellent resistance toward oils and fuels, and it is widely used in oil seals, packaging, diaphragms, blankets, etc. [84]. NBR has a wide variety of applications; therefore, an improvement of its flame resistance has become of major importance.

A great deal of research has been carried out on the improvement of the [flame retardant](#) characteristics of NBR by the addition of flame retardant materials preferably by using environmental friendly flame retardant/fillers or both [150–154]. Silica constitutes important [fillers](#) used in industrial applications. Hence, the flame retardant aspects of NBR with [silica](#) as the [filler](#) have also been investigated. Rybinski et al. [151] used two different grades of silica (Zeosil 175C and Ultrasil VN-3) to decrease the [flammability](#) of NBR (18% AN content). The fillers were loaded at 20, 30, 40, and 50 phr levels in unmodified and [cryogenic](#) modified states. It was observed that neat NBR exhibits an OI of 0.270. With increasing amounts of silica (grade Ultrasil VN-3) in an unmodified state, the value of OI increased as well; at 50 phr loading, the OI value was found to be 0.298. A further increment in the OI value was obtained with the cryogenic modification of the filler, OI value 0.305. In the case of a filler of a different grade, Zeosil 175C silica, at 50 phr loading, the OI was 0.285 and on modification of this filler, the OI raised to 0.310. The time of burning in air also increased for the NBR vulcanizates containing silica (ultrasil VN-3) at 20 and 30 phr, whereas the vulcanizates with 40 and 50 phr of silica showed a self-extinguishing behavior in air. An improvement in the OI values of sulfur and [peroxide](#) NBR vulcanizates modified with [tetraethoxysilane](#) compared to the corresponding NBR vulcanizates has been also reported. The presence of silica was proposed to restrict the passage of flammable [decomposition](#) products to inner layers and thereby reduce further combustion. Also, the char formation reduces the probability of further burning. In another study, NBR (18% AN content) was modified with hybrid poly(methyl siloxane) [152]. OI measurements showed that

the OI value of NBR was 0.285, and it varied between 0.310 and 0.365, when NBR was modified by poly(siloxanes). This improvement in flame retardancy is due to the formation of silica on combustion, which improves the [thermal stability](#) and restricts the flow of energy and volatile products to inner layers thereby protecting the polymer.

Organomodified silicates have been also found to be highly effective in retarding the combustion of polymeric materials due to their layered structures. Very recently, the effect of modified MMT on the flame retardant characteristics of NBR with a 22% AN content was investigated [153]. The vulcanizates were prepared in the presence of sulfur and peroxide. Fillers like clay improve the flame retardant properties of polymers by the restriction of chain movements, thus increasing the degradation temperatures. The modified MMT used were nanobentonites, commercially known as Nanobent and Nanofil. The OI values for NBR were shown to be 0.205 and 0.215 when produced through peroxide and sulfur [vulcanization](#), respectively. In the case of the peroxide vulcanizate, OI values with various grades of nanobents were observed to be >0.34 ; however, with nanofill grades, the values of OI were lower (in the range of 0.269–0.303). The OI values with sulfur vulcanizates have also been reported. These results indicated that both the grades of fillers are successful in improving the OI values. They reduce the flammability through the [labyrinth](#) effect: the volatile products are trapped in the layers of MMT, and thus, further combustion of inner layers of polymer is restricted.

NBR–clay composites, prepared by the cocoagulation process, exhibit also improved FR properties; with respect to unfilled NBR (24–26% AN content), which shows an OI value of 18.4 [154], the OI values of the composites with 10, 20, and 30 phr of silica loadings have been found to be 19.2, 19.5, and 20.7, respectively, indicating that the OI is improved with silica loading. Also, with clay as the flame retardant filler at 10, 20 and 30 phr loading, the OI values obtained are 10, 20.2, and 21.2, respectively. Therefore, it can be concluded that at similar phr loadings of silica and clay, the OI values were of the same range. In both cases, the char formation during burning restricted the flow of mass and heat to inner layers.

Moon and coworkers [150] prepared NBR foams compounded with different amounts of halogen-free flame retardants, namely RP, APP, and EG (10, 20, and 30 parts added too 100 parts of NBR) and a constant amount (195 parts) of other flame retardants, primarily [alumina](#) trihydrate (ATH) and studied their flame resistance properties. It was noted that the HRC, AHRR, and the THR ranged from 10 to 74 J g⁻¹ K⁻¹, 8–60 kW m⁻², and 2.6–7.3 MJ m⁻² for the nonhalogenated NBR foams with a closed-cell structure; these values were significantly decreased upon increasing the amounts of the flame retardants. This reduction is attributed to the hard char formation and production of water arising from the interaction with aluminium trihydrate. It was also reported that the LOI values of NBR foams compounded with

various halogen-free flame retardants were always higher compared to that of NBR. Cone calorimetric experiments have also been performed in order to investigate the flame retardancy of modified MMT-filled NBR (22% AN content) composites [151]. The findings show that the TTI, PHRR (HRR_{max}), THR, the average effective [heat of combustion](#), and the average MLR are improved compared to that for NBR vulcanizates.

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Environmental Health Solutions

Edwin M. Kilbourne, Henry Falk, in [Environmental Solutions](#), 2005

The Chemical Environment

The need for [munitions](#), [synthetic rubber](#), and many other products required to fight World War II spurred remarkable growth in the in the U.S. chemical industry. That growth continued during the post-war era, based on the enormous success of the rapidly developing technology underlying polymer and synthetic chemistry in the manufacture of consumer products. Currently, new substances are identified (literally) by the minute. The centralized CAS registry of chemical compounds is updated daily, and as of this writing (March 4, 2005), there are 25,434,241 individual organic and [inorganic substances](#) listed. (Of course, if all of the known macromolecular sequences are counted, there are many more.) (ACS 2005a)

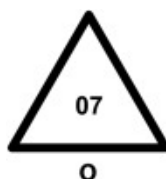
Outside of the synthetic [chemical laboratory](#), human beings are likely to encounter only a relatively small proportion of CAS-registered compounds. Nevertheless, because the total number is so large, the absolute number of compounds to which humans are likely to be exposed is still considerable. Under the [Toxic Substances Control Act](#) (TSCA), the U.S. [Environmental Protection Agency](#) (EPA) tracks and maintains an “inventory” of potentially toxic substances that are imported, used in commerce or are present in substantial quantities in U.S. commercial establishments. The current inventory includes some 80,000 substances (ACS 2005b).

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Physiochemical properties and degradation

Christopher Blair Crawford, Brian Quinn, in [Microplastic Pollutants](#), 2017

Polychloroprene (neoprene)



Although polychloroprene is regarded as a [synthetic rubber](#) and thus an [elastomer](#) as opposed to a plastic resin, the inclusion of the material here is important and shall be listed in the preceding sections. Owing to its low-density buoyant nature and widespread aquatic applications (wet suits/dry suits/flip flops), polychloroprene has the potential to contaminate [aquatic environments](#). Furthermore, polychloroprene is often used as a material for weather balloons, which can subsequently descend into bodies of water and break apart over time.³²³ When polychloroprene is cured, the [tensile strength](#) of the material is increased. However, both cured (vulcanized) and uncured polychloroprene exhibit a high degree of [crystallinity](#) due to the large extent of stereoregularity on the polymer backbone. Possessing a unique balance of properties, polychloroprene has good mechanical strength and ageing resistance as well a slow [flammability](#) as a result of the [chlorine](#) atoms attached to the polymer backbone (Fig. 4.25).

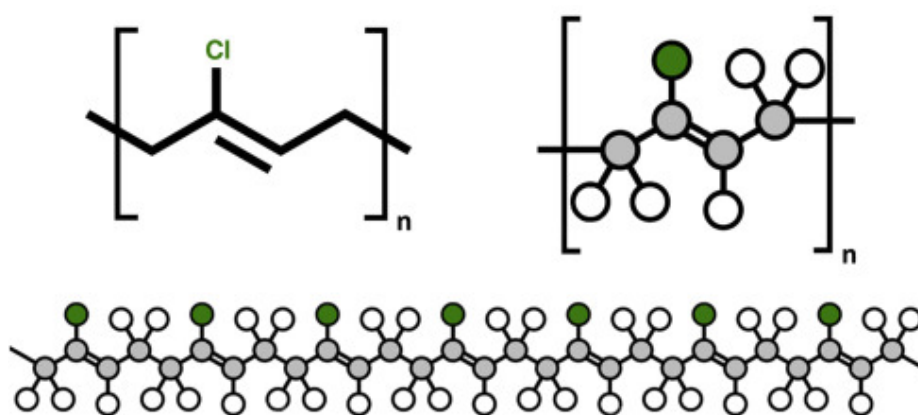


Figure 4.25. Polychloroprene (Neoprene).

Chemical formula	$(C_4H_5Cl)_n$
Abbreviation	CR
Classification	Elastomer
Molecular orientation in solid phase	Semi-crystalline
Monomer	Chloroprene
General properties	Used as a natural rubber substitute with good mechanical strength. Exhibits high temperature resistance. Paradoxically, thermal degradation results in hardening as opposed to melting. At temperatures below 0°C, the material starts to stiffen. Good weathering resistance and excellent water resistance. High elasticity and low flammability

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Polymer Characterization

Godfrey S. Beddard, Norman S. Allen, in [Comprehensive Polymer Science and Supplements](#), 1989

22.3.1 Type A Polymers

Type A polymers include polyalkenes, [synthetic rubbers](#), aliphatic [polyamides](#), [polyurethanes](#), poly(vinyl halides), [aliphatic polyesters](#), [polystyrenes](#), polyacrylics and [polyacetals](#). Typically the [chromophores](#) present in these polymers are carbonyl and π,π -unsaturated [carbonyl groups](#), *e.g.* these chromophores have been found to be responsible for the fluorescence and [phosphorescence](#) emissions from polyalkenes,^{43–46} aliphatic polyamides,^{47–51} synthetic rubbers,^{52,53} polyacetals^{54,55} and poly(vinyl chloride).^{56–58} [Low molecular weight](#) aliphatic molecules of this type have very low fluorescence and phosphorescence yields due to [spin–orbit-coupling](#) induced transitions between singlet and [triplet states](#). Twisting about unsaturated bonds may also reduce yields. Cyclic $\pi\pi$ -unsaturated carbonyls have also been reported to luminesce.⁵¹ Consequently the origin of the [luminescence](#) from this type of polymer has been the subject of some controversy. In the case of polyalkenes, such as low density [polyethylene](#) and [polypropylene](#), it has been suggested that the presence of polynuclear [aromatics](#), such as [naphthalene](#), is responsible for the [fluorescence emission](#).^{59–62} Some of the fluorescent species could be extracted from the polymer by *n*-hexane, and the fluorescence was subsequently regenerated in air over a period of time.^{59–64} However the fluorescence [emission spectra](#) of *n*-hexane extracts of four polyalkenes [polypropylene, low and high density polyethylene and poly(4-methylpent-1-ene)] have been found to differ from that of naphthalene recorded under the same conditions.⁴⁶ An example of this is shown in Figure 5, where it is evident that the [excitation](#) spectrum of naphthalene does not resemble that of the *n*-hexane-extracted species from polypropylene.⁴⁶ Furthermore, the results in Figure 6 demonstrate that the fluorescence [regeneration](#) process, which follows the extraction of films of polypropylene with *n*-hexane, is an oxidative one, since the regeneration of fluorescence is much faster in pure oxygen than in air.

Figure 5. Fluorescence spectra: (—) absorption spectrum of naphthalene in *n*-hexane; (— · — · —) emission spectrum (EM) of an *n*-hexane extract of polypropylene (1 g powder/40 cm³ *n*-hexane); (----) excitation spectrum (EX) of naphthalene in *n*-hexane (reproduced from ref. 46 with permission from Elsevier Applied Science Publishers Ltd.)

Figure 6. Rate of regeneration of fluorescence emission from *n*-hexane-extracted polypropylene film in: (—) air, (---) N₂ and (— · — · —) O₂. Excitation at 280 nm; emission at 340 nm (reproduced from ref. 46 with permission from Elsevier Applied Science Publishers Ltd.)

Aliphatic polyamides, such as [nylon 6,6](#), have more complex spectra. Nylon 6,6 contains at least two major fluorescent species (emitting at 326 and 420 nm), as shown by the spectra in Figure 7.⁵¹ The fluorescence emission at 326 nm is similar to that of the extractable species in polyalkenes, but there is another chromophore which emits at 390 nm and 420 nm which has been associated with ketoimide groups (CH₂COCONHCOCH₂) introduced into the [polymer chain](#) during manufacture and thermal processing.⁶⁵ The phosphorescence emission from nylon 6,6 is also complex, which is due to the variety of carbonyl groups present.⁵¹ A recent study⁵¹ combining GC–mass spectrometry and luminescence, has shown that all the fluorescent and phosphorescent species in nylon 6,6 can originate from the aldol [condensation reaction](#) of [cyclopentanone](#), the latter being a [thermal degradation product](#) of the polymer.

Figure 7. Fluorescence spectra of nylon 6,6 film (100 μm thick). (—) emission spectrum (EM) after excitation at 290 nm and excitation spectrum (EX) produced from species emitting at 326 nm; (----) emission spectrum (EM) after excitation at 340 nm and excitation spectrum (EX) produced from species emitting at 390–420-nm (reproduced from ref. 51)

Unsaturated carbonyl groups are also produced by the thermal oxidation of polybutadiene⁶⁶ and PVC.⁵⁷ Some early workers attributed the fluorescence of PVC to the presence of polyconjugation,⁵⁶ but more recent studies suggest that carbonyl groups are essential for emission to occur.^{57,58}

Other commercially important type A polymers are the polyurethanes. In a study of a polyurethane with constitutive unit $\text{ROCONHC}_6\text{H}_4\text{CH}_2\text{C}_6\text{H}_4\text{NHCOO}$, where R is an aliphatic polyester or a [glycol](#) residue, the phosphorescence emission has been associated⁶⁷ with the presence of a benzophenone-type chromophore. Other workers,⁶⁸ however, believe that the emission is due to a triplet [excimer](#).

The luminescence [spectroscopy](#) of wool has received attention, because of the [photodegradation](#) that takes place in sunlight.^{69–72} Scoured wool is essentially pure protein which, although the protein has different structures and compositions throughout the fibre, is all referred to as [keratin](#). The fluorescence from wool is primarily that from [tryptophan](#), the excited state of which is influenced by nearby polarizable groups in the protein.⁷³

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Other Organic Chemicals

Sidney M. Gospe Jr., in [Clinical Neurotoxicology](#), 2009

STYRENE

Styrene monomer is used extensively in both the plastics and the **synthetic rubber** industries. Applications of styrene include **polystyrene** plastic packaging materials for foods and numerous commercial products; expanded polystyrene foam, which is a ubiquitous material used for insulated shipping containers, disposable coffee cups, and many other purposes; and the production of resins such as styrene–butadiene polymer used for synthetic rubber and unsaturated **polyester resin** (fiberglass). As is the case with the other chemicals discussed in this chapter, styrene is volatile and a mucous membrane **irritant**. Human contact is primarily via **inhalation**, while gastrointestinal and skin exposures also lead to absorption of the chemical.⁴³ Presently, the TLV for styrene is 20 ppm on a TWA for an 8-hour workday.³²

There is limited epidemiological evidence for carcinogenic and **hepatotoxic** effects of styrene. Clinical studies of volunteers and workers exposed to styrene have demonstrated toxicity to both the central and the **peripheral nervous systems**; however, the number of studies of styrene clinical **neurotoxicity** is small when compared to those of other organic chemicals. Acute exposure to styrene via inhalation at 376 ppm for 25 minutes resulted in **nausea**, a sense of inebriation, and headache, along with abnormal performance on the Romberg test.⁴⁴ Similar exposure conditions resulted in an insignificant reduction in reaction time with no change in manual dexterity or perceptual speed.⁴⁵ In a study of workers in a plant that manufactured fiberglass and **reinforced plastics**, workers who were exposed to 22 ppm of styrene had no specific acute or chronic symptoms related to their exposure, but when compared to unexposed control workers, they did have significant alterations in the **continuous performance test** and **vibration** threshold, suggesting an adverse effect of styrene on both central and **peripheral nervous system** function, respectively.⁴⁶ In contrast, a study of normal volunteers exposed to various styrene exposure scenarios that adhered to local industrial standards failed to demonstrate either symptoms of altered mood and neurological function or abnormal performance on neuropsychological testing.⁴⁷

Chronic exposure to styrene has been noted to result in alterations in neurobehavioral and neurophysiological measurements. For example, in a study of employees involved in fiberglass boat construction that compared former workers exposed to higher styrene concentrations, current workers exposed to lower styrene concentrations, and matched control unexposed workers, the duration of exposure and the interaction between exposure duration and exposure concentration were noted to be the best predictors of impaired visuomotor and perceptual speed performances. This study suggested that less than 10 years of exposure to 37 ppm of styrene may lead to chronic neurotoxic effects.⁴⁸ Abnormal **electroencephalogram** (EEGs), including localized slow activity, diffuse **θ-activity**, and bilateral **spike and wave** discharges were noted in 24% of 96 workers chronically exposed to styrene in plants producing reinforced plastic products, with abnormal **EEGs** being present in more than

one-third of workers who had high-level exposures. Those with low-level styrene exposures had the same frequency of abnormal EEGs as were found in a normal population. [Electrodiagnostic](#) studies were performed on 40 of the subjects who noted the most neurobehavioral symptoms, but there was no evidence of motor or [sensory nerve](#) conduction slowing.^{49,50} A [neurophysiology](#) study of styrene workers exposed to 22 ppm demonstrated abnormal conduction of myelinated sensory fibers, as well as reduced variability of the R–R interval of the [electrocardiogram](#), indicative of [autonomic dysfunction](#); motor conduction velocity and short-latency [somatosensory evoked potentials](#) were not affected by styrene exposure.⁵¹ Similarly, mild [sensory nerve conduction](#) slowing was recorded in 23% of fiberglass workers exposed to less than 50 ppm of styrene and in 71% of workers exposed to more than 100 ppm of styrene. Sensory nerve conduction slowing was not present in five workers exposed to more than 100 ppm of styrene who had been on the job for less than 4 weeks, suggesting that duration of exposure was also a factor in the development of peripheral neurotoxicity. [Central nervous system](#) effects were evaluated by assessing reaction time. This measurement was slower in workers with high styrene exposure burdens but did not specifically depend on the overall length of exposure.⁵² Decreased color discrimination due to styrene exposure has been documented in several studies, and assessment of alterations in color vision may be a sensitive indicator of styrene toxicity. Significant differences in the color confusion index and other assessments of color discrimination have been reported in workers exposed to styrene at levels spanning the range of the current TLV of 20 ppm.⁴³ In particular, one study estimated that impaired color vision could be detected at exposure levels of 4 ppm, with a 95% upper confidence interval of 26 ppm.⁵³

Workers involved in the synthesis of resins and the [fabrication](#) of various products that contain plastics and “synthetics,” as well as some users of the final products, are at risk of exposure to neurotoxic organic compounds. At present, we have only a partial understanding of the basic toxicological mechanisms that underlie the effects of these substances on the nervous system. In many circumstances, the [epidemiology](#) of occupational exposures and the clinical toxicity of these chemicals have been studied on a limited basis. Additional research is clearly needed in each of these fundamental areas.

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Wastes from Industries (Case Studies)

Woodard & Curran, Inc., in [Industrial Waste Treatment Handbook \(Second Edition\)](#), 2006

Wastes Generation

The generation of wastes at manufacturing facilities engaged in the production of [synthetic rubber](#) is dependent to an unusually high degree on how well the entire facility is managed to prevent such generation. Raw materials are delivered as bulk liquids, and the delivery process can be pollution-free if there are no spills and fumes are contained. The entire process, except for clarification and decant steps, is contained within tanks, pumps, piping systems, and mixing vessels; therefore, the only opportunities for air pollution are from leaks and sloppy handling. The only solid material involved in the production process that is of significant volume is the product rubber itself. Any loss of this material to solid waste is a loss of valuable product.

Solid Wastes

Solid wastes requiring management at a typical synthetic rubber production facility should be only nonproduction-related wastes, such as packaging and shipping wastes and construction debris from plant maintenance, modifications, expansions, and periodic facility upgrade projects. In addition, sludges from [wastewater treatment](#) and waste resins from process water [deionization](#) require management.

Airborne Wastes

The many [scrubbers](#) and strippers used at synthetic rubber production facilities are potential sources of air [pollutants](#). Vents on tank farm storage facilities are also potential sources.

Waterborne Wastes

Figures 10-14 through 10-16 show principal sources of wastewater from (1) the [emulsion](#) crumb production process, (2) the solution crumb production process, and (3) the emulsion latex production process, respectively. As shown in these figures, essentially every major processing unit is a source during the normal processing schedule. For instance, Figure 10-14 shows that as the [monomers](#) are being transferred from storage to the [polymerization](#) reactors, they are passed through the [caustic](#) scrubbers to effect removal of the polymerization inhibitors. There is a blow-down of spent caustic wash solution, contaminated with the polymerization inhibitor material, entering the wastewater stream. What is not shown is that each of these processing units is a source of wastewater as a result of periodic washdown. However, these figures do show that additional areas of the plant are at least potential sources of wastewater as the result of spills or overflows. When these largely

unnecessary events occur, they must be managed properly to avoid damage to the environment.

The sources of wastewater from the emulsion crumb production process, as illustrated in Figure 10-14, are presented in Table 10-19.

Table 10-19. Summary of Potential Process-associated Wastewater Sources from Crumb Rubber Production via Emulsion Crumb Production

<i>Processing Unit</i>	<i>Source</i>	<i>Nature of Wastewater Contaminants</i>
Caustic soda scrubber	Spent caustic solution	•High pH, alkalinity, and color•Extremely low average flow rate
Monomer recover	Decant water layer	•Dissolved and separable organics
Coagulation	Coagulation liquor overflow	•Acidity, dissolved organics, suspended and high dissolved solids, and color
Crumb dewatering	Crumb rinse water overflow	•Dissolved organics and suspended and dissolved solids
Monomer strippers	Stripper cleanout and rinse water	•Dissolved organics and high suspended and dissolved solids •High quantities of uncoagulated latex
All plant areas	Area washdowns	•Dissolved and separable organics and suspended and dissolved solids

The sources of wastewater from the solution crumb production process, as illustrated in Figure 10-15, are presented in Table 10-20.

Table 10-20. Summary of Potential Process-associated Wastewater Sources from Crumb Rubber Production via Solution Polymerization Processing

<i>Processing Unit</i>	<i>Source</i>	<i>Nature of Wastewater Contaminants</i>
Caustic soda scrubber	Spent caustic solution	

		<ul style="list-style-type: none"> •High pH, alkalinity, and color •Extremely low average flow rate
Solvent purification	Fractionator bottoms	<ul style="list-style-type: none"> •Dissolved and separable organics
Monomer recovery	Decant water layer	<ul style="list-style-type: none"> •Dissolved and separable organics
Crumb dewatering	Crumb rinse water overflow	<ul style="list-style-type: none"> •Dissolved organics and suspended and dissolved solids
All plant areas	Area washdowns	<ul style="list-style-type: none"> •Dissolved and separable organics and suspended and dissolved solids

The sources of wastewater from the emulsion latex production process, as illustrated in Figure 10-16, are presented in Table 10-21.

Table 10-21. Summary of Potential Process-associated Wastewater Sources from Latex Production via Emulsion Polymerization Processing

<i>Processing Unit</i>	<i>Source</i>	<i>Nature of Wastewater Contaminants</i>
Caustic soda scrubber	Spent caustic solution	<ul style="list-style-type: none"> •High pH, alkalinity, and color •Extremely low average flow rate
Excess monomer stripping	Decant water layer	<ul style="list-style-type: none"> •Dissolved and separable organics
Tanks, reactors, and strippers	Cleanout rinse water	<ul style="list-style-type: none"> •Dissolved organics, suspended and dissolved solids •High quantities of uncoagulated latex
Tank cars and tank trucks	Cleanout rinse water	<ul style="list-style-type: none"> •Dissolved organics, suspended and dissolved solids •High quantities of uncoagulated latex
All plant areas	Area washdowns	

- Dissolved and separable organics and suspended and dissolved solids

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Cyanide Waste

Mukesh Doble, Anil Kumar, in [Biotreatment of Industrial Effluents](#), 2005

[Cyanide](#) is used in the production of organic chemicals such as [nitrile](#), nylon, acrylic plastics, and [synthetic rubber](#). It is also used in the [electroplating](#), metal processing, steel hardening, and photographic industries. The wastes from such industries not only contains [cyanide](#) but also significant amounts of heavy metals such as copper, nickel, zinc, silver, and iron. Since cyanide ions are highly reactive, metal complexes of variable stability and toxicity are readily formed. Ore processing in gold and silver mining operations uses dilute solutions of sodium cyanide (100 to 500 ppm), which is inexpensive (\$1.75/kg, 2003 price) and highly soluble in water, and under mildly oxidizing conditions, dissolves the gold contained in the ore. Each year 2 to 3 million tons of cyanide are industrially produced. [Food processing industries](#) that handle crops such as [cassava](#) and bitter almonds also generate considerable quantities of cyanide waste because of the presence of the cyanogenic [glucosides](#) that are present in the plant material.

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Combined Exposures to Noise and Chemicals at Work

M. Sliwinska-Kowalska, in [Encyclopedia of Environmental Health](#), 2011

Styrene

Styrene is a volatile liquid with a low pressure value that is widely used in the production of various plastics, [synthetic rubber](#), resins, and insulating materials. It is a building block for the manufacture of a broad range of materials used in thousands of products throughout the world. Probably the most recognizable material is [polystyrene](#), often encountered as expanded polystyrene foam. Other styrene-based materials include [acrylonitrile butadiene styrene](#), styrene acrylonitrile,

styrene butadiene rubber, and unsaturated [polyester resin](#), which is better known as fiberglass.

The substance can be absorbed into the body by [inhalation](#) and through the skin. It irritates eyes, skin, and [respiratory tract](#). Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis.

Repeated or prolonged contact with skin may cause [dermatitis](#), skin sensitization, and asthma. The substance may have effects on the [central nervous system](#). This substance is possibly carcinogenic to humans.

Ototoxic effects

Like for [toluene](#), evidence for styrene ototoxicity comes mainly from animal studies although more and more human studies prove the animal results. In rats, styrene is more harmful to the [cochlea](#) than toluene. Elevated auditory brain stem thresholds were found in rats after inhalation exposure to xylene or styrene, and loss of OHCs have been observed in rats exposed to styrene.

Chronic occupational exposures seem to influence hearing thresholds over a wide range of frequencies. Some workers in a plastics boat plant with chronic exposure to styrene showed distorted speech and poor performance on cortical response audiometry tests.

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