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Environmental aspects of sulfate turpentine refining (review)

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The burning of sulfate turpentine, formed as a by-product of pulp and paper mills during the kraft pulping process, causes irreparable environmental damage, as it contains a large number of toxic sulfur-containing compounds generating sulfur dioxide when being combusted. It is for this reason that the search for methods of removing sulfur compounds from the sulfate turpentine, which can make the purified product a valuable source of terpene compounds suitable for industrial processing, is being actively pursued. The problem of complex refinement and rational utilization of turpentine is mainly to establish a waste-free use of feedstock for obtaining useful products. However, the lack of selectivity in the conversion of terpenes which are the main components of turpentine, and the complexity of their separation hinder the development of effective methods for refining turpentine. In this regard, the refined turpentine is used mainly as a solvent for varnishes and paints. At the same time, it is a valuable biofuel, capable, with proper approach, of partially replacing fuels produced from mineral oil. Terpenes from turpentine and their derivatives are widely used in the organic synthesis of biologically active substances, antioxidants, pesticides, herbicides, in the perfume industry for producing fragrances (linalool, geraniol, nerol, citronellol), and also for obtaining compounds with a pronounced insecticidal , repellent, antimicrobial, anti-inflammatory, hypoglycemic and other types of biological activity. Sulfur-containing compounds can achieve widespread use in organic synthesis to manufacture solvents, ion-exchange resins, dyes, in the synthesis of detergents and reagents for the chemical industry (sulfochlorides, thiosulfonates, sulfoxides).

Keywords: sulfate turpentine, α- and β-pinenes, sulfur compounds, terpenes, terpenoids.

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Экологические аспекты очистки сульфатного скипидара

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Сжигание сульфатного скипидара, образующегося в качестве побочного продукта целлюлозно-бумажных комбинатов в ходе сульфатной варки целлюлозы, наносит непоправимый экологический вред окружающей среде, так как он содержит в составе большое количество токсичных серосодержащих соединений, образующихся при горении диоксида серы. Поэтому активно ведутся поиски методов удаления сернистых соединений из состава сульфатного скипидара, способных сделать очищенный продукт пригодным к промышленному использованию.

Проблема комплексной переработки и рационального использования скипидара заключается главным образом в налаживании безотходного использования сырья с целью получения полезных продуктов. Однако отсутствие селективности превращения терпеновых соединений, являющихся основными компонентами скипидара, и сложность их разделения препятствуют разработке эффективных методов переработки скипидара. В связи с этим очищенный скипидар применяется в основном в качестве растворителя для лаков и красок. Терпены и их производные находят широкое применение в органическом синтезе биологически активных веществ, антиоксидантов, пестицидов, гербицидов, в парфюмерной промышленности для получения душистых веществ (линалоол, гераниол, нерол, цитронеллол), для синтеза соединений, обладающих выраженной инсектицидной, реппелентной, антимикробной, противовоспалительной, гипогликемической и другими видами биологической активности, а серосодержащие соединения могут применяться в органическом синтезе для получения растворителей, ионообменных смол, красителей, в синтезе моющих средств и реагентов для химической промышленности (сульфохлоридов, тиолсульфонатов, сульфоксидов).

Ключевые слова: сульфатный скипидар, α- и β-пинен, серосодержащие соединения, терпены, терпеноиды.

Solving the problems of complex processing and rational use of plant raw materials is especially relevant at the present time. Mass forest cutting and transforming it into wood pulp, in addition to the desired product, lead to a number of environmental problems associated with the formation of a significant amount of the by-product of the pulp and paper industry, sulfate turpentine, most of which is not recycled but simply burned. Sulfur compounds from the sulfate turpentine during combustion generate sulfur dioxide, one of the main pollutants being emitted into the atmosphere, which leads to the formation of acid rains and have a negative impact on the environment. The average content of sulfur-containing components in sulfate turpentine in terms of atomic sulfur is 0.03 mass%, but in some cases it can reach 2–6% [1].

The global production of crude sulfate turpentine increased from 165,970 in 2012 to 191,224 million tons in 2016. The global crude sulfate turpentine market is led by North America, capturing about 60.64% of sulfate turpentine production. Europe is the second largest market with 30.04% global production share. In 2023, the production of crude sulfate turpentine is estimated to be 241,724 million tons [2].

Turpentine is a mixture of organic compounds which possess high toxicity (TC_{Lo} inhalation, human = 175 ppm) [3]. When taken orally in an amount of 15–150 mL, turpentine can cause death [4]. The lethal dose depends mainly on the organosulfur compounds content. When in contact with the skin, it causes dermatitis [5]. Systemic toxicity of turpentine leads to the gastrointestinal tract irritation and the central nervous system depression up to the brain and spinal cord atrophy, anemia, reversible kidney failure, tachycardia, behavioral changes, and as well as causes various cancers of such systems as lung, bone marrow, blood (Hodgkin's disease, leukemia, lymphosarcoma), the digestive system. Additionally, a pattern of neuroblastoma development in children whose parents (more often fathers) were exposed to chemicals of turpentine production was found [4].

The yield of refined sulfate turpentine is approximately 10 kg per ton of pulp and depends primarily on the location and date of the wood harvest as well as the length of the storage period before processing [6]. Significant production of sulfate turpentine and the possibility of removing sulfur compounds allow us to consider it as a large source of terpenes which are a useful feedstock for organic synthesis. But due to the complexity of the composition and the difficulty of separating the main components of turpentine, many pulp mills still prefer burning it.

The present review is a coverage of the works devoted to the refining sulfate turpentine and the isolation of components that are useful for the preparation of substances with valuable properties.

Chemical composition of sulfate turpentine

Depending on the habitat of conifers and their species, the content of the main turpentine components varies greatly. The average content of α-pinene in turpentine isolated from the pine *Pinus silvestris* growing on the territory of Russia ranges between 55–70%. The share of 3-carene is 15–30%, the amounts of β-pinene (2–7%), dipentene (3–6%), and camphene (≈ 1%) are insignificant [7].

Among other terpenic hydrocarbons found in small quantities in sulfate turpentine, it is worth noting such as tricyclene, β-myrcene, α-terpinene (Fig. 1) [8].

Some compounds isolated from sulfate turpentine, for example, 3-carene and β-pinene, have a high optical purity. The optical purity of α-pinene and dipentene varies greatly depending on the source of turpentine. Camphene and tricyclene are always extracted as racemates [7].

The chemical composition of sulfate turpentine is extremely complex but is mainly represented by monoterpenes. When processing some other species of conifers, depending on their species and habitat, sesquiterpenes, for example, cadinene and caryophyllene, may occur, but their amount is usually insignificant [9].

The turpentine refining and processing

In the process of sulfate cooking, by-products, which are volatile organosulfur compounds (methyl mercaptan and dimethyl sulfide) with a sharp unpleasant odor, are formed by eliminating the methoxy groups of lignin and their reaction with sodium sulfide. Their amount usually reaches 0.03% (in terms of sulfur). These compounds are highly toxic: MPC of CH_3SH in the air is 0.006 mg/m^3 [10], MPC of $(CH_3)_2S$ is 0.08 mg/m^3 [11]. During processing, methyl mercaptan is partly dimerized by contact with air oxygen, forming dimethyl disulfide. The presence of sulfur-containing compounds in turpentine limits the areas of its synthetic application due to the poisoning of catalysts used in the transformation of terpenic hydrocarbons [1, 6].

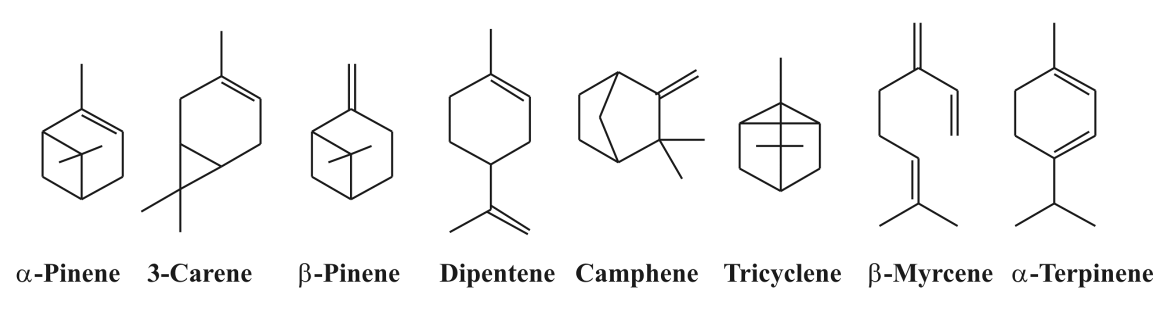


Fig. 1. The main terpenes of sulfate turpentine

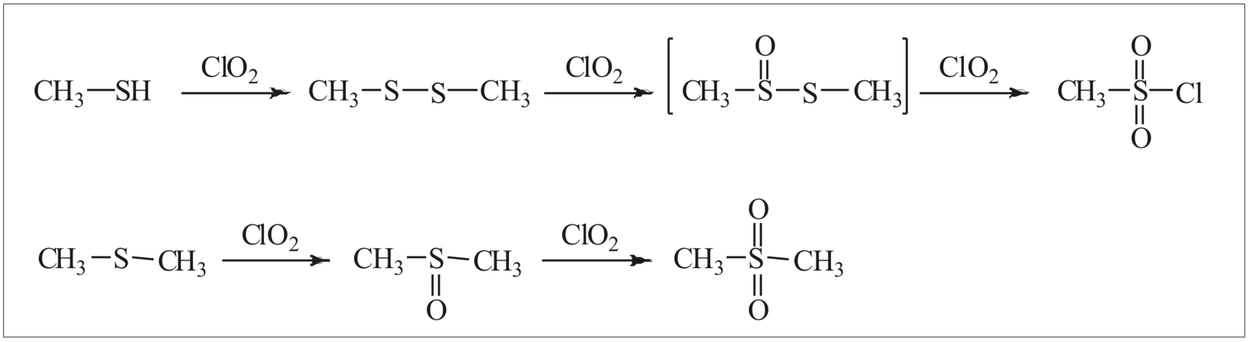


Fig. 2. Oxidation of sulfur compounds from turpentine with chlorine dioxide

To use sulfate turpentine, it is necessary to purify it from sulfur so that its residual content does not exceed 0.005 mass% (TC 13-0281078-36-89). For this purpose, purification methods based on chemical, physical and physicochemical processes are proposed, including rectification (industrial purification method), extraction, application of adsorbents, chemical interaction [12], and distillation with water vapor [13]. Oxidizers such as air oxygen [14–16] and inorganic peroxides [17], treatment with aqueous alkali solutions [18, 19] and other methods are used as chemicals to purify sulfate turpentine from sulfur-containing impurities. A method for refining sulfate turpentine with sodium hypochlorite solution in an acidic medium (pH 3.5–5.0) at a temperature of 10–40 °C for 20–60 min, followed by neutralization with an alkali solution [20], is known. To oxidize sulfur compounds, it has been proposed a way to react them with an aqueous solution of sodium hypochlorite with preliminary removal of the highly volatile sulfur compounds by an inert gas current (for example, nitrogen) at a temperature of 10–50 °C [21]. However, this method was unsuitable for refining turpentine with a high sulfur content. There were also attempts to desulfurize turpentine on nickel-palladium [22] and cobalt-molybdenum [23] catalysts. It should be noted that these methods are either ineffective and do not allow to reduce the total sulfur content below 0.005 mass % or require additional production costs for obtaining reagents.

The Institute of Chemistry of the Komi Scientific Center of the Ural Branch of the RAS has developed a highly effective method for purifying sulfate turpentine in which chlorine dioxide ClO_2 that is a large-capacity product applied in pulp and paper production for bleaching cellulose is used as an oxidizer [24, 25]. As a result of reacting methyl mercaptan and dimethyl disulfide with ClO_2, methane sulfonyl chloride [26] or thiosulfonate [27] is formed. Oxidation of dimethyl sulfide leads to the formation of dimethyl sulfoxide and dimethyl sulfone (Fig. 2) [28, 29].

The sulfur compounds of sulfate turpentine isolated in pure form can be used as odorants of natural and liquefied gas. The products formed during their oxidation find application in organic synthesis. Sulfonyl chlorides are widely used in the synthesis of detergents, ion-exchange resins, elastomers, drugs, dyes, herbicides; thiosulfonates possess bactericidal and fungicidal activities. Dimethyl sulfoxide is a universal organic solvent, forms the basis of the medicine "Dimexide" which exhibits an anti-inflammatory effect [30]. Dimethyl sulfone is a part of various dietary supplements for the prevention of osteoarthritis. Its activity against cancer cells was investigated, however, these studies were completed with a negative result, dimethyl sulfone do not show toxicity, and is almost not metabolized in the human body [31].

After removing sulfur compounds, the composition of sulfate turpentine becomes approximate to the composition of gum turpentine and usable. The turpentine is currently used mainly as a solvent for varnishes and paints [32], and also there are data of using it as an extragent, for example, of gutta-percha from *Eucommia ulmoides* barks [33].

Terpenes and terpenoids find application as high-value chemicals across the food, cosmetic, fragrance, pharmaceutical and biotechnology industries [34–36].

The presence of double bonds and strained cycles in the structure of terpenic hydrocarbons makes them extremely reactive and enables to use in the addition, alkylation, isomerization, and polymerization reactions [8] which are the main directions of turpentine processing.

It is known that in the presence of acid catalysts, α-pinene and other monoterpene hydrocarbons, which are part of turpentine, undergo significant isomerization transformations. The composition of the isomerization products strongly depends on conditions under which the process is performed. Therefore, changing the conditions can direct the same reaction in different pathways [7].

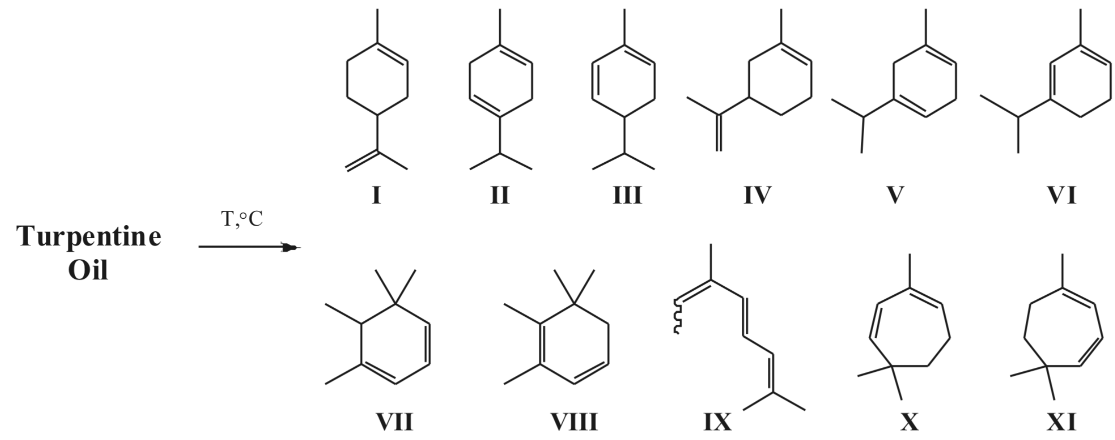
The isomerization of terpenes can also occur in the absence of catalysts. When sulfate turpentine is heated (533–693 K) at a pressure (40–280 atm.), its isomerization takes place to form a mixture with variable composition which mainly depends on the temperature. As the temperature in the mixture increases, the amount of α-pinene decreases until it disappears completely. At the same time, the content of dipentene, α- and β-pyronenes, alloocymenes increases.

Among the other thermolysis products, there found volatile compounds such as di- and monoalkylbenzenes (methyl, ethyl, isopropyl, isopropenyl), trimethylcycloheptadienes and trimethylcycloheptatrienes, *p*- and *m*-menthadienes (terpinenes, terpinolene, fellandrenes), dimethyloctadienes, turpentine monoterpenes (camphene, fenchen, tricyclene), dimeric products (C17–C20) [37] (Fig. 3).

The menthadienes, in contrast to turpentine, have a better solvent power. They are oxidized by air oxygen to form colorless products and for this reason are more promising as solvents for paint and varnish materials. In addition, conjugated menthadienes can relatively easy react with various dienophiles to form Diels-Alder products which are used effectively to improve the quality of some sealants and rubbers [38].

In industry, most of α-pinene is isomerized on TiO_2 at 100 °C to form a mixture of products with a total yield of 75–80% in which the main components are limonene and camphene [39]. Camphene is a widely employed fragrance in perfumery, a precursor to camphor, and an additive in the formulation of insect repellents, explosives and plastics [40–42]. Limonene finds large scale application in the perfume and pharmaceutical industries as a flavoring and antimicrobial agent [42, 43].

Titanium catalysts for the isomerization of turpentine, however, do not exhibit a high



I - Dipentene (limonene), **II** - γ-Terpinene, **III** - α-Phellandrene, **IV** - Sylvestrene, **V** - *m*-Mentha-1(6),4-diene, **VI** - *m*-Mentha-1(6),3-diene, **VII** - α-Pyronene, **VIII** - β-Pyronene, **IX** - Alloocimenes, **X** - 2,5,5-Trimethylcyclohepta-1,3-diene, **XI** - 1,5,5-Trimethylcyclohepta-1,3-diene

Fig. 3. Major products of turpentine thermolysis

selectivity. Therefore, alternative catalysts such as clays, zeolites, sulfated zirconia, heteropolyacids, which are able to increase the selectivity of isomerization and the conversion of α-pinene, were proposed [39].

A very effective direction of processing turpentine is the production of polyterpene resins, both liquid and solid. The liquid polyterpene resins are used as lubricants for fiberglass and added into fat-liquoring agents for treating natural leather products. In addition, they are a part of film-forming compositions for manufacturing dielectrical and varnish-and-paint materials [44].

The main producer of solid polyterpene resins is the USA turpentine enriched with β-pinene as a raw material. Russian turpentine consists mainly of α-pinene, the polymerization of which is difficult due to the peculiarities of the spatial structure. Therefore, the production of high-melting polyterpene resins based upon α-pinene remains a pressing challenge. The polymerization of α-pinene in the presence of Friedel-Crafts catalysts ($AlCl_3$–$SbCl_3$), heteropolyacids ($H_3PW_{12}O_{40}$ and $H_4SiMo_{12}O_{40}$) and Me_3SiCl additives was studied in [45]. It should be noted that the production of high-melting polyterpene resins is greatly facilitated when dipentene obtained by α-pinene isomerization is used as a raw material for the polymerization [46].

Another effective direction of processing turpentine is the acid-catalytic interaction of monoterpenoids, which are part of its composition, with water, alcohols and organic acids. The α-pinene hydration reaction forms the basis for the production of terpineol which possesses effective flotation properties it is also used for the extraction of non-ferrous metals as well as a component of paint-and-varnish compositions [47, 48]. As a result of α-pinene hydration terpin hydrate can also be obtained with a high yield [49], which is used as a substance for the manufacture of medicines and is a starting compound to perfume terpineol [50]. α-Terpineol and its acetate have a pleasant floral odor and possess bactericidal properties, so they find application as soap perfumes, detergents and disinfectants. Terpineol is also used in metallurgy to extract metals from their ores [51]. The preparation of terpineol was studied in [52]. When the hydratation of sulfate turpentine in the absence of catalysts at a temperature of 80–85 °C with the addition of a small amount of acetone occurs, terpineol is formed with a yield of 67–77%.

Much attention is paid to the production of turpentine-based fuel, since the reduction of unsaturated compounds and the opening of rings in terpene molecules leads to the formation of branched hydrocarbons having a structure close to isooctane [53, 54]. The mixture of turpentine and ethanol prior to the beginning of the 19th century was used as a fuel for lighting and was the preferred source of power for internal combustion engines. The attempts to use crude sulfate turpentine as motor fuels after a simple filtration were unsuccessful, leading to fast contamination of the motor oil with metal sulfides and severe corrosion of engine parts [55]. Turpentine has not been used as fuel for almost two centuries because of the limited production and the difficulties caused by its application. However, taking into account the natural advantages of these hydrocarbons, the development of methods for both production and use of terpenes as fuel on an appropriate scale is very convincing.

An approach to produce the fuel materials based on α-pinene, limonene, and camphene, which consists in obtaining unsaturated dimeric molecules and their reduction, was proposed in [56, 57]. There found an effective catalyst to synthesize dimeric products with yields up to 90% that is Nafion (fluorine-containing sulfated polymer), whereas acid catalysts, for example, H_2SO_4, lead to the formation of polymer products [57].

Monoaromatic compounds produced from terpenes are valuable for petrochemical industry [58, 59]. Of these, *p*-cymene is of particular importance as it has potential use in the synthesis of terephthalic acid [40, 41, 60] which is applied in polyester (PET) producing. *p*-Cymene is also used for the synthesis of *p*-cresol [61] and its derivative, 2,6-di-*tert*-butyl-*p*-cresol (BHT), that is a light-resistant antioxidant with a wide range of applications [62]. It comes into use in producing the corresponding hydroperoxide by oxidation with air oxygen, which is an effective initiator for the emulsion copolymerization of butadiene with styrene in the production of appropriate rubbers along with cumene hydroperoxide. *p*-Cymene is also used as a solvent for dyes and varnishes, and as an intermediate for the production of pesticides, fungicides, flavors, and pharmaceuticals [63].

On a large scale, the preparation of *p*-cymene from mono- and bicyclic terpenes has been proposed on metal catalysts such as Pd/C, Pd/Al_2O_3 [64], Pd/Si [65–67], Pt/C, Cu/Cr_2O_3 and ZnO_2/Cr_2O_3 [68]. In [69], zeolites were used to dehydrogenate the terpenes of turpentine, but, as a result of this process, a mixture of *o*-, *m*-, and *p*-cymenes with a total content of up to 25% in the mixture was formed. The hydrogen released during the dehydrogenation process is able to simultaneously reduce unsaturated compounds represented by limonene, terpinolene, α- and γ-terpinene, menthadiene, and menthene to menthane. At 380 °C, the share of menthane in the reaction mixture reaches 20% (Fig. 4).

The dehydrogenation process, as noted by the authors of the same paper [69], can be used for removing sulfur compounds to avoid the additional treatment of sulfate turpentine in the case of achieving selective formation of cymene. The organic sulfur compounds can also act as hydrogen acceptors as they can undergo hydrogenolysis, disproportionation, and reduction.

$CH_3SH + H_2 \rightarrow CH_4 + H_2S$
(hydrogenolysis)
$2CH_3SH \rightarrow (CH_3)_2S + H_2S$
(disproportionation)
$(CH_3)_2S + 2H_2 \rightarrow 2CH_4 + H_2S$
(reduction)

By binding the resulting hydrogen, the sulfur compounds, as believed, can increase the selectivity of cymene formation.

Terpenes and terpenoids are widespread in nature and important for maintaining the ecological balance in interspecies relationships. These compounds act as a means of communication between plants, plant communities, plants and insects, affect the intraspecies structure of insect populations (primarily social ones: ants, bees, and termites) [70–72], participate in the formation of protective systems against enemies, competitors or invasive species [73].

Some terpenic compounds, for example, limonene, terpinolene and α-pinene are natural pheromones of numerous termites. However, the physiological response of insects to other terpenic compounds is possible. For example, the ants *Acanthomyops claviger* respond to citronellol, citronellal and citral, and the mixture of *exo*-brevicomin with β-myrcene attracts *Dendroctonus brevikomis* beetles [74] (Fig. 5). The oxidized with SeO_2 turpentine mainly composed of (−)-borneol and a mixture of (+)-, (−)-1-terpineols, terpinen-4-ol showed a high activity against ticks (*Ixodes ricinus*) [75].

The most complete information on insect pheromones is presented in the review [76].

The use of terpenic compounds in perfumery is associated with having pleasant aromas of most of them. Many of fragrant substances are acyclic monoterpenoids which can be obtained from the cyclic components of sulfate turpentine. One such compound is β-myrcene. The content of β-myrcene in sulfate turpentine is insignificant, but technically, it is easy accessible by short-term heating of turpentine to 400–700 °C. Under such conditions, the selectivity of β-myrcene formation reaches 95%. On the basis of β-myrcene, the fragrances such as linalool, (*R*)-cytronellol, geraniol, and nerol are synthesized (Fig. 3). Their annual production is estimated to be from 4 to 12 thousand tons a year [77].

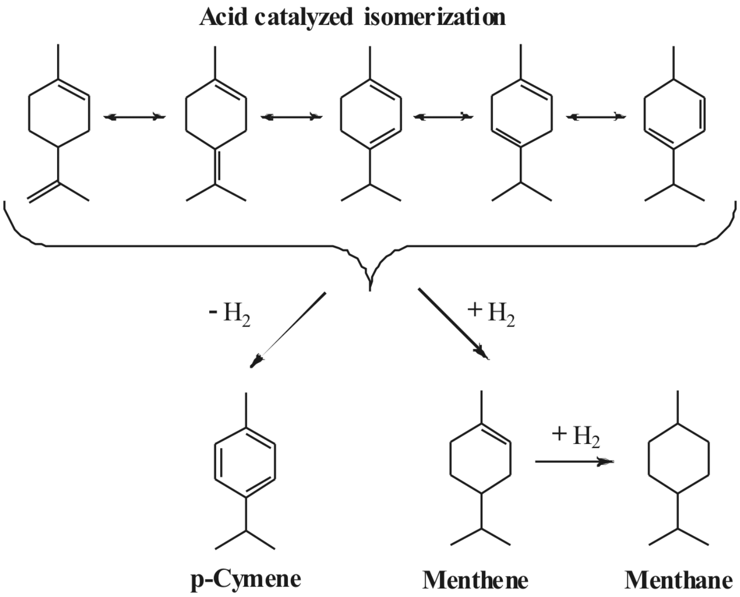


Fig. 4. Usage of dipentenes in *p*-cymene and menthane production

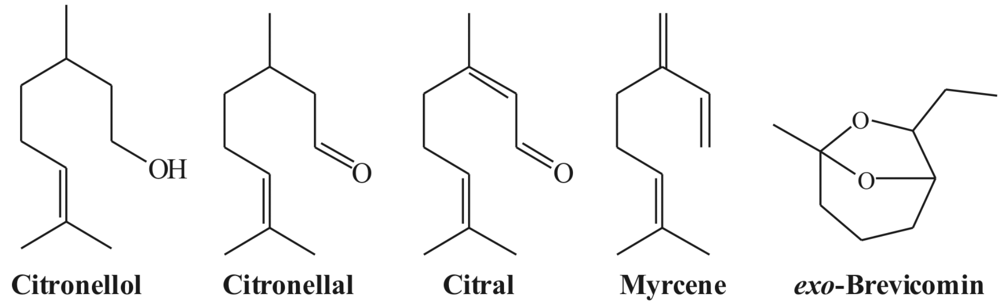


Fig. 5. Some natural pheromones of insects

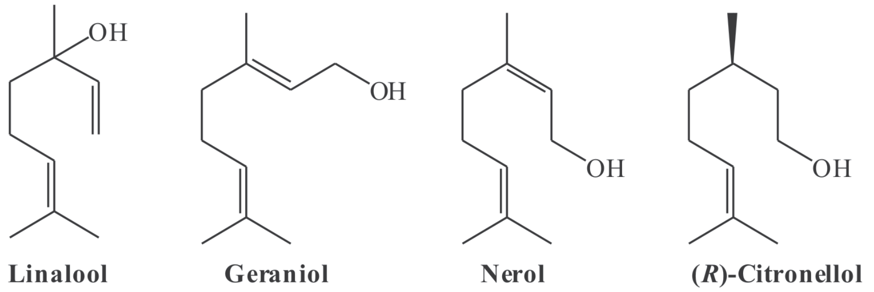


Fig. 6. Fragrances derived from β-myrcene

In summary, sulfate turpentine is the source of many useful substances which are applicable in various fields of industry, agriculture, perfumery and household. The products obtained on the basis of sulfate turpentine are cheaper than synthetically obtained, they require less production costs. The use of natural or semisynthetic products of the terpene series has the main advantage over the synthetic ones – the ability to be involved in the metabolism of bacteria, insects, and plants. This means that there is a high probability that products derived from sulfate turpentine, for example, insecticides, pesticides, will not accumulate in nature.

Biological activity of the main components of turpentine

Turpentine is able to be oxidized by air oxygen, forming a set of oxygen-containing products. The oxidized turpentine exhibits anti-inflammatory activity [78], and its peroxidized form is thought to show a good anti-radical activity [79, 80].

The physiological activity of turpentine, however, is very different from the activity of its individual components, which is associated with the manifestation of a synergistic effect [81].

Studies of pure α-pinene showed the presence of a broad spectrum of biological activity against various bacteria and fungi. α-Pinene shows activity against the gram-negative bacteria *Actinobacillus actinomycetemcomitans, Prevotella intermedia*, *Porphylomonas gingivalis*, *Fusobacterium nucleatum* [82], *Yersinia enterocolitica* [83], *Salmonella typhi* [83], *Proteus vulgaris* [83, 84], and *Acetobacter* spp. [83]; as well as against the fungi and yeast *Candida tropicalis*, *Candida glabrata*, *Aspergillus* spp. [83], *Penicillium notatum* [83], and others. It also exhibits insecticidal activity [85], activity against *Pediculus humanis capitis* [86] and the bark beetles of the species *Pityogenes bidentatus* [87].

α-Pinene is a non-toxic compound used in medicine to increase the absorption of various chemicals, for example, neuroleptics. It also possesses lipophilic, pesticidal, anticarcinogenic, diuretic, immunostimulating, sedative, anti-inflammatory, hypoglycemic, and other activities [88].

β-Pinene, in contrast to α-pinene, shows a narrower spectrum of biological activity, but it is synthetically more desirable due to its greater reactivity which allows to obtain based on it a larger set of useful products. It exhibits antifungal properties [89], especially against *Candida* spp. [83]. When acting on yeast, β-pinene inhibits mitochondrial respiration, proton pump activity and K^+ transport and also increases membrane fluidity [90]. It possesses moderate antimicrobial activity, is capable of antiseptic effect on the oral bacterial flora [82]and active against *Staphylococcus aureus* as well as some other gram-positive and gram-negative bacteria [84, 89].

In [91], the antimicrobial activity of the individual enantiomers of both pinenes was studied, and (+) enantiomers were found to be more active. Thus, (+)-α- and (+)-β-pinene are highly active against the fungi *Cryptococcus neoformans*, *Candida albicans*, and *Rhizopus oryzae*, whereas (–)-enantiomers do not possess the corresponding activity against them.

Both pinenes are readily absorbed through the pulmonary system, skin, and intestines, their lethal dose are ranged from 0.5 to 5 g/kg body weight [5]. The primary metabolism of α- and β-pinenes in the mammals is well studied. When ingested, hydroxylation of pinenes occurs with the formation of terpenic pinane and menthane alcohols [92].

Turpentine, as shown in [93], increases the permeability of the skin. This proper can be used to facilitate the penetration of drugs through the cell membranes, what demonstrated by the example of the delivery of fluconazole through the membranes of liposomes and ethosomes.

The biological activity of caranes has been studied worse. 3-Carene is known to be the most toxic terpene contained in turpentine. This hydrocarbon causes the strongest dermatitis, induces bronchoconstriction, stimulates the development of asthma [94].

In summary, having considered the range of useful properties and biological activities of the major components of turpentine, we can conclude that a waste from the pulp and paper production has broad prospects for obtaining new physiologically active substances based on them. The study of the chemistry of semisynthetic functional derivatives of the terpene series in this connection is topical.

Conclusions

The development of effective methods for processing the major components of turpentine, including sulfur compounds, allows to solve a number of environmental problems associated with the release of sulfur dioxide into atmosphere, pollution of water bodies and soils with sewage from turpentine production. This is of paramount importance not only for the development of the wood chemical industry, but also for the forest complex as a whole, as it contributes significantly to the solution of the problem of rational use of forest resources and the environmental protection.

Prospects for the sulfate turpentine processing mainly depend on the selectivity of the reactions underlying it. The terpenes represented in turpentine have in most cases a related composition of C10 and a structure, so their separation is often difficult. This problem can be partially solved by rectification distillation, but even it does not allow to isolate terpenes with a high purity. Therefore, the search for ways to separate terpenes, and methods for increasing the selectivity of sulfate turpentine processing should be of a high priority.

Terpenes are able to participate in the metabolism of living organisms, this allows them to be used for producing medicines. However, to date, the use of sulfate turpentine for medical purposes is prohibited, as methods for the quantitative removal of sulfur from its composition have not been developed yet. The production of gum turpentine has its drawbacks due to the difficulty of extracting it on an industrial scale, so at a cost it is more expensive than sulfate one. In addition, the industrial gum turpentine production in Russia is not carried out any longer.

Studying these issues can bring turpentine production to a new level, during which both the problem of harmful emissions into the environment and the problem of using turpentine components for creating new biologically active compounds, flavoring agents, pesticides, herbicides, surfactants, antioxidants, etc. will be solved.

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