United States Department of Agriculture
Agricultural Marketing Service | National Organic Program
Document Cover Sheet
https://www.ams.usda.gov/rules-regulations/organic/petitioned-substances

Document Type:

☐ **National List Petition or Petition Update**

A petition is a request to amend the USDA National Organic Program's National List of Allowed and Prohibited Substances (National List).

Any person may submit a petition to have a substance evaluated by the National Organic Standards Board (7 CFR 205.607(a)).

Guidelines for submitting a petition are available in the NOP Handbook as NOP 3011, National List Petition Guidelines.

Petitions are posted for the public on the NOP website for Petitioned Substances.

☒ **Technical Report**

A technical report is developed in response to a petition to amend the National List. Reports are also developed to assist in the review of substances that are already on the National List.

Technical reports are completed by third-party contractors and are available to the public on the NOP website for Petitioned Substances.

Contractor names and dates completed are available in the report.

Perlite

Handling

Identification of Petitioned Substance

Chemical Names:
Perlite

Other Names:
Aragats; Expanded perlite; Filtroperlite; Perfil; Perlite rock

Trade Names:
Europerl® 50M; Perlite; Pearlite Beads Grade 5

CAS Numbers:
130885-09-5 (perlite)
93763-70-3 (perlite, expanded)

Other Codes:
EC. No. (perlite) 603-442-8
EC No. (perlite, expanded) 618-970-4

Summary of Petitioned Use

This full scope technical report provides updated information to the National Organic Standards Board (NOSB) to support the sunset review of perlite, listed at 7 CFR 205.605(a)(22). This report focuses on uses of perlite in organic processing and handling, as a filter aid in food processing (per the substance's annotation).

While authors wrote a Technical Advisory Panel (TAP) report about the substance in 1996, no technical report has been written on perlite since (NOSB, 1996). Perlite was included on the National List of Allowed and Prohibited Substances (hereafter referred to as the "National List") with the first publication of the National Organic Program (NOP) Final Rule (65 FR 80548, December 21, 2000). The NOSB has continued to recommend its renewal in 2005, 2010, 2015, and 2019 (NOSB, 2005, 2010, 2015, 2019).

As perlite is listed at § 205.605(a), only nonsynthetic forms are allowed. The annotation for perlite specifies that it is "for use only as a filter aid in food processing."

Characterization of Petitioned Substance

Composition of the Substance

Perlite is a natural, fused sodium potassium aluminum silicate rock material with 3% - 5% water (U.S. Pharmacopeia, 2023). It has a high silicon dioxide (silica, SiO_2) content, typically between 65-80% (Burriesci et al., 1985; Maxim et al., 2014; Reka et al., 2019). It contains several other oxides such as (in decreasing concentration order) (Burriesci et al., 1985; Maxim et al., 2014):

- aluminum oxide, Al_2O_3 (7.5 − 18%)
- potassium oxide, K_2O (1.4 − 5.5%)
- sodium oxide, Na_2O (2 − 5%)
- magnesium oxide, MgO (0.1 − 1.5%)
- iron oxide or ferric oxide, F_2O_3 (0.5 −3.66%)
- calcium oxide, CaO (0.5 − 3.66%)

Source or Origin of the Substance

Formed from viscous lava, perlite is a volcanic glass of rhyolitic composition that contains between 2 and 5% water.[1] Expanded perlite is produced from three kinds of rock varying in water content; obsidian [< 2% (wt/wt)], perlite (2–5%) and pitchstone (> 5%) (Bush, 1973). The lava that forms perlite is deposited and cooled near the surface and hydrated over time (Denton et al., 2009).

With 1.5 million metric tons (Mmt), China was the top producing country of perlite in 2022, followed by Turkey (1.1 Mmt), Greece (0.71 Mmt) and the U.S. (0.52 Mmt) (Staff of US Geological Survey, 2023).

[1] Rhyolite is a volcanic rock with a high silica content and a glassy or fine-grained texture. It is similar to granite in composition; granite is an igneous rock that forms underground while rhyolite forms from volcanic eruption.

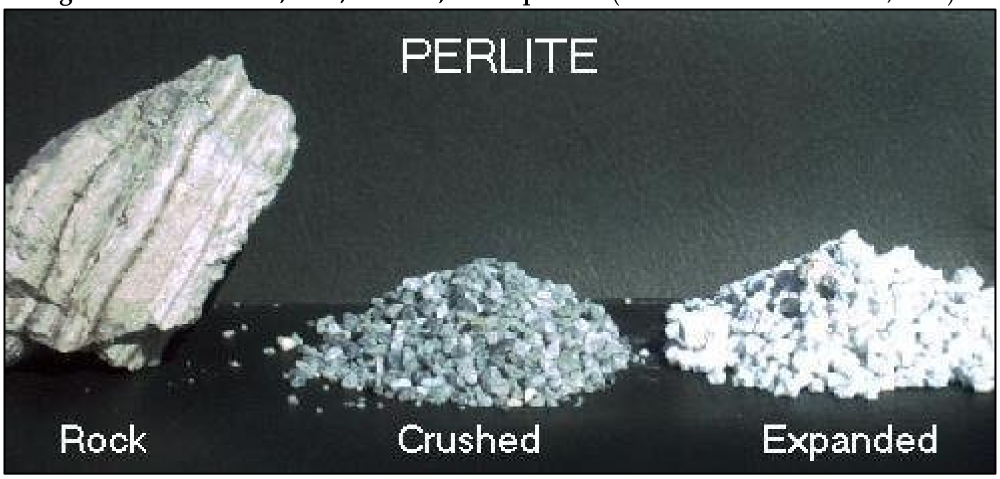
Greece has the largest global reserves, followed by China, Iran, Turkey, and the U.S. Perlite production and reserves in the U.S. are concentrated in the southwestern states (New Mexico, Arizona, California, Utah, Nevada, and Oregon) (Staff of US Geological Survey, 2023).

Properties of the Substance

Physical properties

Perlite is an amorphous natural material from glassy volcanic rock that is formed from the hydration of obsidian or pitchstone (see *Figure 1*). Perlite is known to expand up to 20 times its original volume upon heating [at 1400 to 2000 °F (760–1100 °C)] to produce expanded perlite (Doğan & Alkan, 2004). The resulting frothy, irregularly shaped material is light, highly porous and very low in density. It typically has 2–5% water and its color ranges from translucent to gray.

Figure 1: Perlite forms; rock, crushed, and expanded (Products - Fixmax Perlite, 2024)**.**



The bulk density depends on the parent material, with perlite produced from pitchstone having almost double the bulk density of that produced from obsidian (Sodeyama et al., 1999). The bulk density of obsidian-derived perlite ranges between 0.05 and 0.10 kg/L (Patterson, 2009). Expanded perlite can be manufactured to various densities depending on the specific application (Austin & Barker, 1998), with densities varying from 2 to 12 lbs./ft^3 (32 – 192 kg/m^3) (*Table 1*) (Meisinger, 1985). The grades and nomenclature are usually specific to the application (*e.g.*, horticultural, cryogenic, industrial, and construction) (Meisinger, 1985).

Table 1: Perlite bulk density for main uses (Meisinger, 1985).

End Use	Density (lbs./ft^3)
Plaster and concrete aggregate	7.5 – 8.5
Roof insulation board	4
Filter aids	7– 12
Formed products	3.5
Low-temperature insulation	2 – 4
Masonry and cavity-fill insulation	6
Fillers	7 – 12
Horticultural aggregate	6 – 8

Depending upon the grade, grain sizes range from 20 µm to as much as 10 mm. There are different grades of perlite used for filter aid purposes, which differ in their particle size distribution with some examples provided in *Table 2* (Patterson, 2009).

Table 2: Particle size distribution of expanded perlite particles [adapted from Patterson (2009)].

	Size (microns[2])	0-5	5-10	10-20	20-30	30-50	50-100	100-150	>150
		Particle size distribution (%)							
Grade	A	7	9	29	12	17	12	13	1
	B	3	4	8	6	19	34	14	12

Transmission electron microscopy testing of raw perlite shows that the glassy mass of perlite presents very fine crystalline phases, with dimensions ranging from 10–50 nm (Reka et al., 2019).

Chemical properties

Perlite is acidic, negatively charged, and contains structural hydroxyl groups. The negative charge of the surface is due to (Alkan, Demirbaş, et al., 2005):

- adsorption of ions from the electrolyte solution
- dissociation of the surface hydroxyl groups
- isomorphic replacement of ions of the solid phase by others of a different charge

The negative surface charge of perlite samples increases with an increase in pH (Alkan & Doğan, 1998), which could be due to the ionization of surface silanol groups (Alkan, Karadaş, et al., 2005). [3] Perlite is chemically inert in many environments and hence is considered an excellent filter aid and filler in various processes and materials. Perlite exhibits a slight photocatalytic activity in the presence of solar radiation. Assessing the ability of perlite to remove oxytetracycline from water, Ardhaoui et al. (2023) reported that conducting the experiment in the presence of solar radiation increased the removal efficiency from 81.1% to 99.97%.

Perlite is an anionic adsorbent with a zeta potential ranging between –40 and –50 mV (Alkan et al., 2005).[4] Acid activation has no significant effect on the zeta potential of perlite. Sodium chloride (NaCl), potassium nitrate (KNO_3), sodium nitrate ($NaNO_3$), sodium carbonate (Na_2CO_3), and sodium sulfate (Na_2SO_4) are indifferent electrolytes for perlite, whereas aluminum chloride ($AlCl_3$) and calcium chloride ($CaCl_2$) change the interface charge from negative to positive. The surface charge may be a result of some combination of H+/metal reactions during the adsorption process, which control the number of protons released, or hydroxide ions adsorbed, for each cation adsorbed (Doğan et al., 1997).

Specific Uses of the Substance

Perlite is a lightweight material extensively used in construction products such as insulation boards, plasters, mortars, and ceiling tiles. Other uses of expanded perlite include fillers or extenders in paints, enamels, glazes, plastics, resins, and rubber, as a catalyst in chemical reactions, as an abrasive, and as an agent in mixtures for oil well cementing (Alkan, Demirbaş, et al., 2005). It is also used as a plant-growing medium.

The petitioned use of perlite is focused on its use as a filter aid in food and beverages, including filtration of juices, beer, wine, and vegetable oils. The listing of perlite has been consistently supported by the NOSB and organic stakeholders (NOSB, 2019). Exposure to perlite during preparation or use presents a health hazard of inhalation of fine silica dust (Ampian & Virta, 1992). Personal protective equipment such as a dust mask can minimize this risk (Maxim et al., 2014).

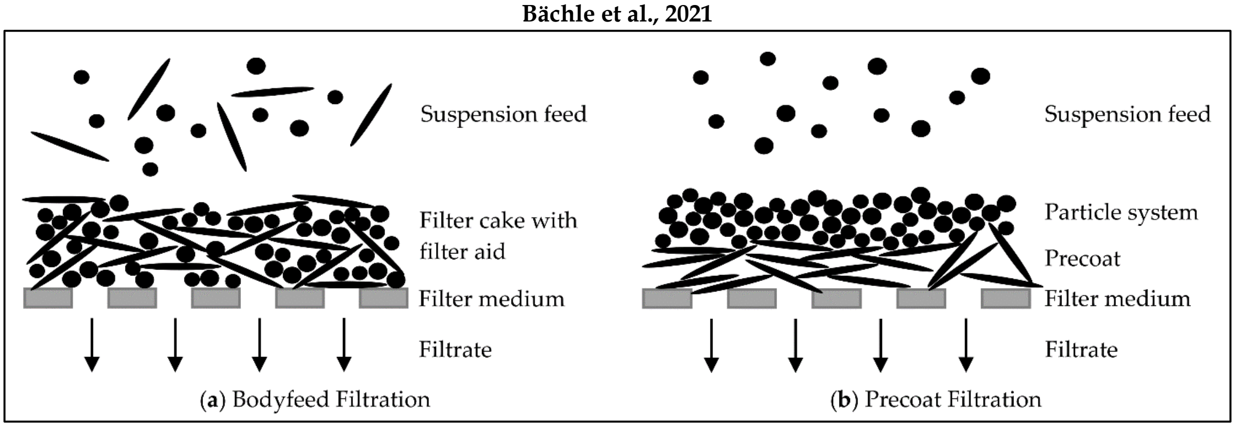
[2] The micron rating refers to the distance between pieces of filter media, which determines the size of particles that the filter will allow to pass through (Dickenson, 1997).
[3] Functional group represented by Si-O-H.
[4] Zeta potential, also known as electrokinetic potential, is a physical property exhibited by any particle in suspension, macromolecule or material surface. It measures the electrochemical equilibrium at the particle-liquid interface. It quantifies the magnitude of electrostatic repulsion/attraction between particles and thus, it has become one of the fundamental parameters known to affect stability of colloidal particles. It can be used to optimize the formulations of suspensions, emulsions and protein solutions, predict interactions with surfaces, and optimize the formation of films and coatings (Shaw, 1980).

The most important factor in selecting the appropriate filter aid is the solid's characteristics (granular, coarse, fine, etc.). Other factors include the settling rate, solids density, and filtrate/filter aid interaction (Perlmutter, 2015). Perlite is used as a low-cost inorganic adsorbent in filters for food, beverage, and pharmaceutical applications due to its inert nature (Doğan et al., 2000). For example, perlite has been successfully used as a filter to remove yeast aflatoxins from milk (Foroughi et al., 2018), metals [*e.g.*, copper (Alkan & Doğan, 2001; Tanaydin et al., 2017)] and impurities in beer (Rögener, 2021). It is also an inexpensive method used to remove heavy metals and radioactive cations (Cecilia et al., 2018). Perlite has also been used as a carrier in bioaerosol filtration. A zinc oxide/perlite filter inactivated (killed) 70% of a bioaerosol (>80% bacteria) (Valdez-Castillo et al., 2019).

Filter aids may be applied either as precoat on the filter material and/or as body feed in the liquid (see *Figure 2*), although in practice a combination of the two approaches is the most common (Perlmutter, 2015). Body feed refers to the filter aid being constantly applied to the suspension (Kuhn & Briesen, 2016). As for precoat, the filter aid forms a thin layer over the filter before the suspension to be filtered is pumped to the filtering apparatus. The precoat and filter beds are deposited on the cellulose sheet and the bed is built up in the inlet frames or chambers on either side of the outlet plate. The filter is cleaned at the end of a cycle and sheets can generally be used again (Sparks & Chase, 2016). Precoat filtration depends upon the flow of liquid through the cake and factors influencing this rate of movement (Illner, 1989). The precoat recirculates the slurry and prevents the particles in suspension from clogging the filter medium and causing excessive resistance (Perlite Institute, Inc., 2020). In other words, the precoat filter aid protects the filter media against the penetration of unwanted solids and premature blinding of the media (Perlmutter, 2015). Furthermore, the precoat layer facilitates the removal of cake from the filter material at the end of the filtration cycle. Other advantages of using precoat include producing immediate clarity when filtering and protecting the filter cloth (Illner, 1989; Svarovsky, 1977). In all cases, the filter aid becomes part of the solids and there is no practical way to separate them, so they add to the amount of solids that must be disposed (Perlmutter, 2015).

The grade of filter aid selected will offer the appropriate performance with respect to clarity and flow characteristics (Illner, 1989). Particles as small as 0.2 µm can be removed by precoat filtration. When a soluble contaminant is present, it must be precipitated prior to filtration; where colloidal matter or dispersed particles are present, precoat filtration alone may not be adequate to reduce the turbidity to desired level (Illner, 1989).

Figure 2: Continuous addition of the filter aid with the suspension (a) and addition as a precoat (b) Adapted from Bächle et al., 2021



Other uses of perlite filter aids that are not approved for organic use have been reported by Onur et al. (2018). They embedded perlite particles into a paper or textile (*e.g.*, cotton, nylon polyamide, polyester, etc.) membrane. Perlite-nanocellulose filters can remove bacteria (1 µm) at higher than 99% efficiency in high flux conditions, which is very promising for cold pasteurization applications (Onur et al., 2018).

Approved Legal Uses of the Substance

When used as a filtering aid, perlite *could* be considered a food additive by the FDA, as defined at 21 CFR 170.3(e)(1). However, perlite is not listed in any sections within 21 CFR specific to food additives or related applications. Perlite is also not listed as *Generally Recognized as Safe* (GRAS) within 21 CFR Part 182, 184, or 186. Despite this, when used as a filter aid, perlite is still considered GRAS, as discussed below.

Under the Federal Food, Drug, and Cosmetic (FD&C) Act, manufacturers are required to obtain premarket approval for new uses of food additives (Gaynor & Cianci, 2006). Substances that are GRAS for specific uses are excluded from the definition of a food additive under the FD&C Act (Gaynor & Cianci, 2006). As such, GRAS substances do not require premarket approval by the FDA for those specific GRAS uses (Gaynor & Cianci, 2006). Unlike food additive safety determinations, which are made by the FDA, GRAS determinations can be made by non-governmental experts (Gaynor & Cianci, 2006). In 2016, the FDA published an updated Final Rule on GRAS substances, which amended the rule so that the GRAS notification program was voluntary (81 FR 54960-55055). The notification program provides a mechanism for a company (or a person) to notify the FDA that a substance is GRAS. However, as the notification is now voluntary, identifying whether a substance is or is not considered GRAS by some experts (such as within food manufacturing businesses) may not always be possible. Furthermore, not all previous GRAS determinations are easily searchable.

Under a contract between the FDA and the Life Sciences Research Office (LSRO), the Select Committee on GRAS Substances (SCOGS; consultants working under the FDA-LSRO contract) reviewed perlite in 1979, and noted that they had no concerns about its use as a filter aid (Federation of American Societies for Experimental Biology, 1979). The FDA reports it as a GRAS substance within the SCOGS database (FDA, 2015).

In 2001, World Minerals, Inc. submitted a GRAS notice to the FDA for a composite filtration media, composed of diatomaceous earth and perlite (Smith, 2001). The FDA had no questions about the GRAS notice (FDA, 2002), which indicates that these materials can be considered GRAS as filtration media.

Action of the Substance

The macroporosity of perlite allows it to host large molecules such as biomolecules, tensoactives (surfactants), or dyes. In addition, the existence of hydroxyl groups in this amorphous aluminosilicate material favors the adsorption of cations and anions (Cecilia et al., 2018).

The adsorbent nature of perlite is due to the silanol groups formed by silicon atoms on the surface of the perlite (see *Properties of the Substance* above). The silicon atoms at the surface tend to maintain their tetrahedral coordination with oxygen. They complete their coordination at room temperature by attachment to monovalent hydroxyl groups, forming silanol groups. One silicon atom can bear two or three hydroxyl groups, yielding silanediol and silanetriol groups, respectively (Alkan, Karadaş, et al., 2005). Silanols are the active sites for physisorption (hydrogen bonding) and condensation of silane molecules. Reaction phase deposition of silane is governed by the available surface area.[5]

In an experiment investigating oxytetracycline removal, Ardhaoui et al. (2023) showed that the adsorption on perlite occurred across multiple layers on the heterogeneous surface of the material. This phenomenon occurs on surface sites which are energetically heterogeneous (Proctor & Toro-Vazquez, 2009), following Freundlich model, which assumes that heterogeneous surfaces with different affinities have multilayer adsorption (Sun & Selim, 2020).

[5] Silanes can be used to prime metals, bind biomaterial, immobilize catalysts, provide crosslinking, and improve polymer and particle dispersions.

Combinations of the Substance

Filter aids applied as pre-coat and body feed additives can employ the same or different grades of perlite (Perlite Institute, Inc., 2020). Food processors may pair layers of perlite as a pre-coat filtration aid with layers of other filtration aids in a food filtering system (Patterson, 2009). These may include diatomaceous earth or cellulose derivatives (Movasati et al., 2014). Processors may use a mix of perlite and diatomaceous earth filter aids (NIHS, 2019).

Some filter aids can be formulated composites of these different filtering materials. There is a GRAS diatomaceous earth-perlite composite filter media approved under GRN No. 87 (FDA, 2002). Composite filters can be further engineered. One study reported the use of a composite filter consisting of a nanocellulose fiber embedded with perlite and added polyamide-amine-epichlorohydrin (PAE) as a wet strengthening agent (Onur et al., 2018).

Per FCC specifications, food-grade, expanded perlite used as a filter aid may have food-grade flow agents added to it, including sodium carbonate and sodium silicate (U.S. Pharmacopeia, 2023).

Status

Historic Use

According to one report from London in 1938, filter aids had been in use for a long time to improve the rate of filtration during the removal of impurities from liquid suspensions (Carman, 1938). The author named diatomaceous earth, brick dust, precipitated calcium carbonate, and paper pulp as examples of filter aids in use at the time. They did not mention perlite as a filter aid.

Human use of perlite may go back millennia. Modern uses, however, developed in the mid-twentieth century (Austin & Barker, 1998). Production of perlite in the U.S. began in 1946 or 1947 in the Southwest (Austin et al., 1996; Austin & Barker, 1998). A material researcher at the time introduced the practice of treating perlite in kilns and mixing it with gypsum for use in plaster (Jaster, 1956). The U.S. construction industry has employed perlite in light-weight aggregates or thermal insulation since then. Around the same time, people began experimenting with "flash popped" perlite, expanding it in gas-fired furnaces, and investigating its different treatments and uses (Jaster, 1956). In 1958, the Socorro perlite plant in New Mexico added a filter aid expansion furnace to the facility.

More recently in the U.S., some perlite sourcing has moved overseas due to the lower cost of ocean transport to production facilities on the East Coast, as compared to the cost of transporting perlite mineral via highways (McLemore & Austin, 2017). In 1997, the bulk of domestic perlite production went to the construction industry, whereas 11% of perlite sourced from Arizona, New Mexico, Nevada and California went to filter aid use (Austin & Barker, 1998).

Organic Foods Production Act, USDA Final Rule

OFPA (1990) does not include any reference to perlite.

For processing and handling purposes, USDA organic regulations include perlite on the National List [7 CFR 205.605(a)(22)]. The annotation specifies that perlite is only for use as a filter aid in food processing. Perlite was originally included in the first publication of the NOP Final Rule (65 FR 80548).

International

Perlite is allowed as a processing aid under several other international organic standards (see *Table 3*, below). Like the USDA Organic standards, the Canada Organic Standards also specify that it be used as a filtering aid. Other standards refer to it more generically as a processing aid.

Table 3: Allowance of perlite in processing and handling applications under a selection of international organic standards

Standard	Applicable regulations	Allowed?	Source and use restrictions (if applicable)
Canada Organic Standards (CAN/CGSB 32.311-2020)	PSL Table 6.5, Processing aids.	Yes	For use as a filtering aid.
European Union Organic Standards (EU No. 2021/1165)	Section A2: Processing aids and other products, which may be used for processing of ingredients of agricultural origin from organic production.	Yes	For use in products of plant origin; gelatin.
Japanese Agricultural Standard for Organic Processed Foods	Appended Table 1-1, Additives (Organic processed foods other than organic alcohol beverages); Appended Table 1-2 Additives (Organic alcohol beverages).	Yes	In Organic foods other than organic alcohol beverages: Limited to the use in processed products of plant origin. In Organic alcohol beverages: no restrictions
Codex Alimentarius Commission—Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods (GL 32-1999)	Table 4: Processing aids which may be used for the preparation of products of agricultural origin referred to in section 3 of these guidelines.	Yes	-
IFOAM-Organics International	Appendix 4, Table 1: List of approved additives and processing/post-harvest handling aids.	Yes	For use as a processing and post-harvest handling aid.

Evaluation Questions for Substances to be used in Organic Handling

<u>Evaluation Question #1:</u> Describe the most prevalent processes used to manufacture or formulate the petitioned substance. Further, describe any chemical change that may occur during manufacture or formulation of the petitioned substance when this substance is extracted from naturally occurring plant, animal, or mineral sources [7 U.S.C. 6502 (21)].

Perlite is produced from glassy volcanic rock raw materials (obsidian or pitchstone) extracted from open pit deposits. The materials are mechanically crushed, which causes them to break in preferential directions along pre-existing fractures or planar structural elements (Weber, 1955). Perlite is known to expand up to 20 times its original volume upon heating [at 1400 to 2000 °F (760–1100 °C)] to produce expanded perlite (Doğan & Alkan, 2004). The process involves heating granulated perlite ore until it becomes molten glass.

Water plays the most important role in the expansion process by expanding the grain during evaporation and by reducing the viscosity of the softened grain (Friedman et al., 1963). During the expansion process the grains start to soften superficially. At the pyroplastic stage, the water trapped into the inner layers of grains starts to evaporate and pushes its way out, resulting in the expansion of grains (Friedman et al., 1963).

Perlite expansion begins in the central part of the sample (Varuzhanyan et al., 2006). Accomplished rapidly and under carefully controlled conditions, this combination of glass liquefaction/water vaporization results in the virtual instantaneous explosive formation of partially fractured, low bulk density macromolecular particles (Bush, 1973). The process is accompanied by a marked strength gain, which impedes any further removal of water (Varuzhanyan et al., 2006). Water release from perlite sharply raises its viscosity, preventing the material from softening, sticking to the reactor wall, or agglomeration (Varuzhanyan et al., 2006).

In addition to the expansion in volume, the heat treatment induces another physical change in the material (Reka et al., 2019). The high percentage of aluminosilicate glass in perlite results in amorphous behavior when undergoing heat treatment. Compared with raw perlite, the expanded perlite shows an increase in the amount of cristobalite, which is one of silica's crystalline forms (polymorphs) (Reka et al., 2019).

Two types of furnaces are used for perlite expansion (Lagaly et al., 2003):

- Tilted horizontal rotary furnaces: the feed material passes in countercurrent flow to the combustion gas.
- Vertical rotary or blast furnaces: the expanding grains and hot gases pass in concurrent flow. This furnace type is more commonly used in perlite expansion.

<u>Evaluation Question #2:</u> Discuss whether the petitioned substance is formulated or manufactured by a chemical process or created by naturally occurring biological processes [7 U.S.C. 6502(21)]. Discuss whether the petitioned substance is derived from an agricultural source.

Synthetic or nonsynthetic classification

Evaluation of perlite against Guidance NOP 5033-1 *Decision Tree for Classification of Materials as Synthetic or Nonsynthetic* (NOP, 2016a) is discussed below.

1. *Is the substance manufactured, produced, or extracted from a natural source?*

Yes. Perlite is a mined mineral of low solubility.

2. *Has the substance undergone a chemical change so that it is chemically or structurally different than how it naturally occurs in the source material?*

No. Material reviewers have historically considered that perlite satisfies the following definition or nonsynthetic mined minerals in NOP Guidance 5034-1: "minerals must not have been heated (calcined) in a way that produces a chemical change in the material."

The main change that happens to perlite after its excavation from natural deposits is the heat-mediated expansion, which is a physical change. The high temperature used results in a mass loss of 3.8% due to the loss of water and hydroxyl groups. Most of this loss (~2.7%) occurs in the temperature interval from 215–477 ºC and is a consequence of the hydroxyl groups release (Reka et al., 2019).

Water in perlite is present in the form of molecular water and hydroxyl groups (Sodeyama et al., 1999). The heating process releases hydroxyl groups bound to silicon atoms (Si–OH bonds) and introduced into the silicate network, a process that contributes to perlite expansion (Roulia et al., 2006; Tazaki et al., 1992). Gas release research shows two different H_2O-species release stages (Heide & Heide, 2011):

- water-release occurs by diffusion between 80 and 800 °C,
- whereas a spontaneous release is observed between 500 and 1450 °C.

This loss of water (including hydroxyl groups originating from water) during perlite calcination does not result in a chemical transformation of the material.

Thus, the material is nonsynthetic according to the decision tree.

Agricultural or nonagricultural classification

Evaluation of perlite against Guidance NOP 5033-2 *Decision Tree for Classification of Agricultural and Nonagricultural Materials for Organic Livestock Production or Handling* (NOP, 2016b) is discussed below.

1. *Is the substance a mineral or bacterial culture as included in the definition of nonagricultural substance at section 205.2 of the USDA organic regulations?*

Yes, perlite is a mineral mined from the ground. Therefore it should be classified as a nonagricultural substance.

<u>Evaluation Question #3:</u> If the substance is a synthetic substance, provide a list of nonsynthetic or natural source(s) of the petitioned substance [7 CFR 205.600(b)(1)].

As discussed above, nonsynthetic forms of the substance exist and are commercially available.

<u>Evaluation Question #4:</u> Specify whether the petitioned substance is categorized as generally recognized as safe (GRAS) when used according to FDA's good manufacturing practices [7 CFR 205.600(b)(5)]. If not categorized as GRAS, describe the regulatory status.

Perlite is categorized as GRAS when used as a filter aid (Federation of American Societies for Experimental Biology, 1979); however this determination is not published within FDA regulations (21 CFR). It is however noted as GRAS within the FDA's SCOGS database (FDA, 2015), as well as within the GRAS Notices Inventory (FDA, 2002).

See *Approved Legal Uses of the Substance* for more details regarding the GRAS status of perlite.

<u>Evaluation Question #5:</u> Describe whether the primary technical function or purpose of the petitioned substance is a preservative. If so, provide a detailed description of its mechanism as a preservative [7 CFR 205.600(b)(4)].

The primary technical function of perlite in food processing applications is not as a preservative, but as a filter aid.

The act of filtration may indirectly affect preservation, depending on the commodity and the impurities filtered. For example, Ergönül & Nergiz (2015) found that using perlite as a filter aid to process vegetable oils during the winterization step helped maintain the oils' oxidative stability.[6]

However, because the action of perlite as a filter aid is to enhance the flow of a solution through a filter matrix, perlite is not itself a preservative. In the study by Valdez-Castillo et al. (2019), the photocatalytically-treated zinc and titanium oxide exerted toxic effects on airborne bacteria, while the perlite functioned as carrier for the metal oxides.

<u>Evaluation Question #6:</u> Describe whether the petitioned substance will be used primarily to recreate or improve flavors, colors, textures, or nutritive values lost in processing (except when required by law) and how the substance recreates or improves any of these food/feed characteristics [7 CFR 205.600(b)(4)].

Perlite is a filter aid and does not itself impart any odor, taste, or color to the food filtered (Movasati et al., 2014; Perlite Institute, Inc., 2020; Termolita®, n.d.). It can be used to clarify food products or beverages.

Movasati et al. (2014) found concentrations of 6.85% heavy perlite and 5% light perlite filter aids to be optimal for decreasing the color and turbidity of date liquid sugar, while maintaining the highest possible levels of Brix.

Manufacturers also employ perlite as a filtration aid to help clarify beer. This clarification process removes yeast cells remaining after fermentation, along with precipitated proteins, dextrins, beta-glucans, and polyphenols (Rögener, 2021).

In oil refining, filtration aids such as perlite assist in the removal of waxes and free fatty acids, thereby reducing turbidity, as well as removing trace metals (i.e., iron and copper), peroxides, aldehydes, mono-

[6] Winterization is a step in the vegetable oil refining process which removes compounds that crystallize at low temperatures and cause oil turbidity (Ergönül & Nergiz, 2015).

and diglycerides, moisture, and other volatile compounds that have negative effects on the sensory properties of the oil (Nedić Grujin et al., 2023). However, the filter aid does not itself affect the flavor or taste of the oil. It may remove some carotenoids – compounds that, while contributing to turbidity, can be nutritionally beneficial due to their antioxidant activity (Nedić Grujin et al., 2023).

Redan (2020) reported on an earlier study from 1985 in which researchers filtered sake with perlite. They observed an increase in iron levels in the sake, which can promote the oxidation of important flavor compounds, thereby adversely affecting product quality. However, we found no other reports of negative effects from perlite filtration on the flavor of filtered product.

<u>Evaluation Question #7:</u> Describe any effect or potential effect on the nutritional quality of the food or feed when the petitioned substance is used [7 CFR 205.600(b)(3)].

Perlite used as a filter aid assists in the removal of unwanted compounds such as solids and sediment, and even contaminants, from liquid suspensions (Wang et al., 2017). For example, Foroughi et al. (2018) used perlite beads as a structure to support immobilized *Saccharomyces cerevisiae*, which they then used to remove aflatoxin contaminants from milk through filtration. However, aside from removing undesirable compounds, perlite does not alter the chemical composition of the materials they filter (Grujin et al., 2023).

<u>Evaluation Question #8:</u> List any reported residues of heavy metals or other contaminants in excess of FDA tolerances that are present or have been reported in the petitioned substance [7 CFR 205.600(b)(5)].

The FDA establishes "action levels" for poisonous or deleterious substances that are unavoidable in human food and animal feed (U.S. FDA, 2000). These include aflatoxin, cadmium, lead, polychlorinated biphenyls (PCBs), and many other substances. The FDA uses different action level tolerances for these substances, depending on the commodity. Commodities are largely food items; however, the FDA also includes tolerances for ceramic and metal items, such as eating vessels and utensils. Perlite is not included on the list of commodities with action levels (U.S. FDA, 2000).

The Food Chemicals Codex specifies limits on impurities in perlite: 10 ppm arsenic and 10 ppm lead (U.S. Pharmacopeia, 2023). The Food Chemicals Codex does not provide specific limit values for other heavy metals or contaminants in perlite, though the Select Committee on GRAS Substances recommended that the FDA add an upper limit for cadmium for food grade perlite (FDA, 2015).

Filter aids can be potential sources of food and beverage contamination by trace metals (Wang et al., 2017). Redan (2020) reported on an early study from 1985 in Japan, where researchers tested the levels of arsenic and lead after filtering sake with diatomaceous earth or perlite. They found the arsenic content of perlite-filtered sake to be 4-5 mg/L (4-5 ppm), but found no detectable lead. More recently, Wang et al. (2017) tested 10 samples of different perlite filter aids for heavy metals, six of which were food grade. They found the arsenic levels of food-grade perlite filter aids to range from 0.16 to 0.89 ppm, lead levels ranging from 0.80 to 3.02 ppm, and cadmium levels from 0.1 to 0.3 ppm. All perlite samples, including those that were not food grade, were within the FCC limits for metal contaminants (Wang et al., 2017).

In contrast, May et al. (2019) found substantially higher lead levels (average of 21 ppm) in the six commercial perlite products they tested. The elevated lead levels reported exceed the FCC specifications for food grade perlite (U.S. Pharmacopeia, 2023). The Select Committee on GRAS Substances determined that the maximum amounts of minerals (presumably including heavy metals) in a filtered liquid that originate from a perlite filter aid do not pose a hazard to public health (FDA, 2015).

Perlite can effectively remove heavy metal contaminants, including copper (Alkan & Doğan, 2001) and cadmium (Mathialagan & Viraraghavan, 2002), from aqueous solutions.

<u>Evaluation Question #9:</u> Discuss and summarize findings on whether the manufacture and use of the petitioned substance may be harmful to the environment or biodiversity [7 U.S.C. 6517(c)(1)(A)(i) and 7 U.S.C. 6517(c)(2)(A)(i)].

Few studies have evaluated the environmental effects of perlite manufacturing on the environment. One study that we located compares the environmental effects of perlite, bentonite and pozzolan production in Milos island, Greece (see *Table 4*) (Goudouva et al., 2018). Comparing the two filter aid raw materials (perlite vs. bentonite), the researchers found that:

- The energy consumption per metric ton produced was similar for the two materials.
- The consumption of mazut (heavy fuel oil) used for milling, however, was more than double the amount per metric ton of bentonite compared to perlite.
- Water consumption in perlite production was considerably lower than that used for bentonite.
- Nitrous oxide gas emissions were higher from perlite production.
- Sulfur dioxide emissions were higher in bentonite production.
- In terms of dust production, perlite produced more than double the dust amount during production. Most of that dust was produced during the mining phase, while dust production during bentonite manufacturing was recorded during the milling phase.

Waste material produced for the two materials, consisting of waste slag and rubble, was 0.83 ± 0.25 m^3/t for bentonite versus 0.39 ± 0.19 m^3/t for perlite (Goudouva et al., 2018). The water use reported here confirms earlier results from the same authors (Goudouva & Zorpas, 2017).

Table 4: Energy consumption and environmental footprint for bentonite and perlite production in the Island of Milos, Greece. Values are averages of three years (2012-2014) calculated from data in Goudouva *et al.* (2018).

	Bentonite	Perlite
Energy consumption		
Diesel oil for mining (L per metric ton)	0.92	1.47
Diesel oil for transportation (L per metric ton)	0.89	0.59
Mazut for milling (kg per metric ton)	7.21	3.13
Electricity for milling (kWh per metric ton)	5.83	6.70
Loading (kWh per metric ton)	0.32	0.21
Water use (m^3 per metric ton)	0.05	0.03
Air emissions[7]		
SO_2 (mg/Nm^3)	5.3	1.3
NO (mg/Nm^3)	96.8	126.8
NO_2 (mg/Nm^3)	2.7	5.1
NOx (mg/Nm^3)	99.5	131.9
Dust concentration in different activities		
Mining (mg/m^3)	0.1	16.1
Milling (mg/m^3)	6.6	0.2
Loading on ships (mg/m^3)	0.5	N/A

<u>Evaluation Question #10:</u> Describe and summarize any reported effects upon human health from use of the petitioned substance [7 U.S.C. 6517(c)(1)(A)(i), 7 U.S.C. 6517(c)(2)(A)(i) and 7 U.S.C. 6518(m)(4)].

Perlite is regulated as a ''nuisance dust'' in most countries (Elmes, 1987). However, early research on health effects of exposure to perlite show little to no effect. For example, Cooper (1975) conducted respiratory health problem tests using chest radiography and measurement of forced vital capacity on 240 perlite mining workers employed for 1 to 23 years in three sites in Colorado and New Mexico. The

[7] Nm^3 or normal cubic meter: amount of gas which when dry, occupies a cubic meter at a temperature of 25 degree Celsius and at an absolute pressure of 1 atmosphere.

results showed no evidence of pneumoconiosis associated with perlite exposure. The researcher reached the same conclusion in another study involving 117 workers (Cooper, 1976).

In Turkey, Polatli et al. (2001) investigated pulmonary function and the risk for silicosis in perlite workers exposed to high levels of perlite dust for more than 10 years. They found that 12 years of perlite exposure did not lead to a decrease in mean pulmonary function test parameters. However, they did observe a change in the carbon monoxide transfer coefficient in nonsmoking perlite workers. [8] The researchers concluded that there is a tendency for transfer factor to decline if perlite dust levels exceed permissible levels. Both perlite workers and office workers that smoke showed significant obstruction to airflow in small airways with respect to predicted values and 4-year change in transfer factor.

Du et al. (2010) followed 24 workers who had acute exposure to perlite dust for 6 months due to a mining accident in Taiwan. Within the first 6 months, the workers developed respiratory tract disorders such as cough, shortness of breath and throat irritation. During this period of time, three of them showed respiratory symptoms for more than 6 months, including signs of reactive airway dysfunction syndrome and a decrease in Forced Expiratory Volume in one second (FEV1) of 20% from the baseline.

A few studies have assessed the effects of perlite on respiratory disease occurrence in production areas. Sampatakakis et al. (2013) conducted a study comparing the prevalence of respiratory diseases and asthma in two locations in Greece, based on the presence of perlite and bentonite mining locations. The morbidity part of the study was conducted in two industrial communities with similar demographic characteristics:

- the island of Milos, which has ambient air polluted by perlite and bentonite mining sites
- the municipality of Oinofita, which has air, water and ground pollution, mostly due to industrial waste

The researchers found that the prevalence of allergic rhinitis, pneumonia and COPD was higher on the island of Milos compared to the municipality of Oinofita, where a statistically significant association was observed (Sampatakakis et al., 2013). The results found for bronchiectasis were similar, despite the small number of observed cases. Regarding asthma, the difference was of borderline significance. They concluded that factors related to the exposure of Milos' permanent residents to perlite and bentonite dust may contribute to their respiratory health related mortality and higher morbidity rates.

As of 2014, no published studies on reproductive toxicity of perlite were found, and such effect is unlikely in view of the likely routes of exposure (Maxim et al., 2014).

<u>Evaluation Question #11:</u> Describe any alternative practices that would make the use of the petitioned substance unnecessary [7 U.S.C. 6518(m)(6)].

Centrifugation is a practice that can complement or replace the use of filter aids for wine clarification (Jackson, 2014). Centrifugation avoids potential health problems related to dust and worker allergy that can be associated with the use and disposal of perlite and other filter aids (*e.g.,* diatomaceous earth).

Centrifugation employs rotation at high speed to expedite settling (Jackson, 2014). It is equivalent to spontaneous sedimentation, but occurs within minutes, rather than months. It often replaces multiple rackings when early bottling is desired. Centrifugation is also useful when the wine is heavily laden with particulate matter. Highly turbid musts and wine are prone to off-odor development if they are permitted to clarify spontaneously. Centrifugation is much more efficient in removing large amounts of particulates than plate filters (Jackson, 2014).

However, the use of centrifugation for other purposes beyond clarification is unclear.

[8] Carbon monoxide transfer coefficient (KCO) is a pulmonary function test. It is also often written as DLCO/VA (diffusing capacity per liter of lung volume) and is an index of the efficiency of alveolar transfer of carbon monoxide.

<u>Evaluation Question #12:</u> Describe all natural (nonsynthetic) substances or products which may be used in place of a petitioned substance [7 U.S.C. 6517(c)(1)(A)(ii)]. Provide a list of allowed substances that may be used in place of the petitioned substance [7 U.S.C. 6518(m)(6)].

Filter aid materials can be classified into organic (carbon-containing) and inorganic materials. Organic (carbon-containing) filter aids, though not necessarily nonsynthetic, include activated charcoal [7 CFR 205.605(b)(2)] and cellulose [§ 205.605(b)(11)]. Because rice hulls are agricultural, rice hull ash would need to be certified organic in order to be allowed for use with organic products. Nonorganic rice hull ash could be used with "made with organic" products.

Besides perlite, other inorganic nonsynthetic filter aid materials allowed by the NOP include bentonite [§ 205.605(a)(5)] and diatomaceous earth [§ 205.605(a)(10)].

Several plant-derived materials have been tested as filter aids in food and beverage applications (see *Table 5*).

Table 5: Some adsorption filter aid materials and details of their use.

Filter aid material	Solution filtered	Material removed	Comments	Reference
Eucalyptus sheathiana bark powder	Water	Methylene blue (MB) dye	Aqueous solution, fixed bed Perspex glass column of 30 cm height with 2.5 cm internal diameter	(Afroze et al., 2016)
Activated charcoal	Diluted spirits; soy sauce	Ethyl carbamate	47% and 45% removal	(S.-R. Park et al., 2009)
Rice hull ash	Beer		Used as a clarifying agent	(Villar et al., 2004)
Sugar cane bagasse ash	Beer; wine		Used as a clarifying agent	(Keogh, 1988)
Kenaf fiber	Kaolin suspension	Kaolin	Body feed filter aid	(Varghese & Cleveland, 1998)
Kenaf core chips	Different solutions	Yeast, bacteria, silica particles	Body feed filter aid	(Lee & Eiteman, 2001)
Kenaf, milled cardboard, cellulose	Bioethanol	**Enzymatically hydrolyzed biomass suspensions**	Body feed and precoat	(Kinnarinen et al., 2013)

Rice hull ash (nonsynthetic)

Rice hull ash is another material used as filter aid (Li et al., 2005). Per guidance NOP 5033-2, rice hulls are agricultural materials. While organic rice hulls are available, certified organic rice hull *ash* is not. Furthermore, rice hull ash does not appear on the National List. Therefore, rice hull ash would only be allowed for use in "made with organic" products.

Villar et al. (2004) tested the effectiveness of rice hull ash as a filter aid for beer filtration in different combinations (percentages) with the standard filter aid Dicalite (diatomaceous earth). They obtained the best results (higher filtrate volume recovery) using a 50%/50% mixture of Dicalite and rice hull ash. The resulting clarity, brightness and sensorial characteristics of the beer (i.e., taste and smell) were similar to those obtained with traditional filter aids. The recovered filtrate volume per time unit (productivity of the process) was also increased by the introduction of rice hull ash. Blending using rice hull ash with Dicalite reduces the cost of the filter aid.

Bentonite (nonsynthetic)

Bentonite clay is a nonsynthetic material allowed for use as a filter aid [§ 205.605(a)(5)]. Bentonite is commonly used as a fining agent in the wine industry to promote beverage clarity (Redan, 2020). However, one drawback of this material is that it can contain elevated levels of metals and trace elements that can subsequently transfer to the processed product (El Youssfi et al., 2023). Nicolini et al. (2004) conducted a study to investigate wine fining with 10 different bentonites (1 g/L) at three pH levels. Bentonite fining resulted in statistically significant increases of the large majority of elements, but in significantly lower levels of copper, potassium, rubidium and zinc.

Diatomaceous earth (nonsynthetic)

In addition to perlite, diatomaceous earth (or diatomite, celite or kieselgur/kieselguhr) is the other most frequently applied inorganic filter aid (Jackson, 2008). Diatomaceous earth is allowed as a food filtering aid only [§ 205.605(a)(10)], in addition to use in pest management.

Diatomaceous earth is made from the skeletons of diatoms, which are fossilized tiny, aquatic organisms (US EPA, 1995). Their skeletons are made of a natural substance called silica. Over a long period of time, diatoms accumulate in the sediment of water bodies, from which they are mined and calcined (heated at high temperature) to get rid of any organic matter and agglomerate the diatoms together. The heat treatment is achieved using rotary calciners (gas- or fuel oil-fired), with or without a fluxing agent. Typical calciner operating temperatures range from 1200 to 2200°F (650 to 1200° C). For straight-calcined grades, the powder is heated in large rotary calciners to the point of incipient fusion. The material exiting the kiln then is further milled and classified. Straight calcining is used for adjusting the particle size distribution for use as a medium flow rate filter aid. The product of straight calcining has a pink color from the oxidation of iron in the raw material, which is more intense with increasing iron oxide content (US EPA, 1995).

Rice hull ash versus diatomaceous earth

One study compared the effectiveness of diatomaceous earth (Celite 577) versus rice hull ash in removing residual ochratoxin A in beer using an immunoaffinity column and high-performance liquid chromatography (Lulamba et al., 2019). The results showed that rice hull ash was more effective (72%) in the removal of ochratoxin A in beer than diatomaceous earth (38%). Adsorption was the major form of ochratoxin A removal using rice hull ash, whereas with Celite 577 it was entrapment (Lulamba et al., 2019).

Perlite versus diatomaceous earth

A comparison of perlite and diatomaceous earth shows several advantages for perlite in terms of filtrate quality for safe human consumption, availability, and performance. Compared to perlite filter aids, diatomaceous earth can contain heavy metals that can be transferred to the beverage or fluid being filtered during processing (May et al., 2019). Diatomaceous earth also contains soluble iron that can dissolve into the material being filtered, thus affecting the quality of edible and drinkable products (Jackson, 2014; Nattrass et al., 2015). Moreover, diatomaceous earth can be toxic depending on its source, with a toxic potential that ranges from unreactive to as haemolytic or cytotoxic as the positive crystalline silica (quartz plus cristobalite) standard DQ12 quartz (Nattrass et al., 2015).[9]

Studies investigating the effect of exposure to silica on lung cancer in diatomaceous earth workers in mining and processing facilities detected a statistically significant increasing trend of lung cancer risk with cumulative exposure to crystalline silica dust (Checkoway et al., 1999; Rice et al., 2001). Similar findings were also reported for non-cancer lung diseases (*e.g.,* silicosis) (R. Park et al., 2002). On the other hand, perlite filter aids contain little to no respirable crystalline silica, making it a relatively healthier and safer product to handle (R. Park et al., 2002).

[9] DQ12 quartz is the standard reference used for crystalline silica biological toxicity studies due to its well-characterized biological activity (Creutzenberg et al., 2008).

From a practicality and efficiency standpoint, perlite presents a 30-50% lower bulk density than diatomaceous earth, therefore requiring less material weight (Cheremisinoff, 1998). Contrary to diatomaceous earth, perlite filter aid is not subject to the strict regulations governing its disposal (Perlmutter, 2015).

Activated charcoal (synthetic)
Activated charcoal is a synthetic material allowed for use as a filter aid option [§ 205.605(b)(2)]. It is used to remove impurities affecting appearance, taste, and odor (Henning & von Kienle, 2021). This material has dozens of uses in food production, pharmaceutical processes, water treatment, and industrial pollution management (Henning & von Kienle, 2021). Activated charcoal filtration is an important step in the production of alcoholic beverages (Christoph & Bauer-Christoph, 2007), fruit juice, oils, and vinegar (Bansal et al., 1988).

For more information see the 2024 technical report *Activated Charcoal* (Handling).

Cellulose (synthetic)
Cellulose is considered a synthetic material allowed as a filter aid for certified organic processing operations (Code of Federal Regulations, 2023). As a filter aid, cellulose has a higher cost and a lower filtration efficiency than diatomaceous earth and perlite, making it less popular. Still, there are some advantages to the use of cellulosic filter aid versus diatomite or perlite. Filter aids consisting of cellulosic fibers have a low density, favorable structure with rough surfaces and high porosity, easy cleaning of filter cloth, and good possibilities for disposal or energy production by combustion (Gerdes, 1997). Cellulose is combustible and is useful in the recovery of valuable metals. Cellulose is also compatible with hot caustic solutions where diatomaceous earth and perlite are not (Cheremisinoff, 1998).

For more information, see the 2016 technical report *Cellulose* (Handling).

<u>Evaluation Information #13:</u> Provide a list of organic agricultural products that could be alternatives for the petitioned substance [7 CFR 205.600(b)(1)].
We found no data suggesting that any certified organic agricultural products offer the same quality as a direct substitute for perlite as a filtering aid for the same range of processed food and beverage products. While availability appears limited (based on a search of the *Organic Integrity Database*), certified organic casein and kenaf exists.

Casein
Casein is one material that has commercially demonstrated limited capacity as an alternative to perlite in the wine industry. Casein is a multipurpose material for wine producers. Casein can clarify wines, but it can also improve color and odor (Ribéreau-Gayon et al., 2006). However, it is not very effective for decolorizing wine (Australian Wine Research Institute, 2023). Although there is one operation producing casein products in the Organic Integrity Database (*Organic Integrity Database*, 2024a), the products of that company are food-industry ingredients, and none is classified as a filter aid (*Milk Specialties Global*, 2024).

Kenaf
Kenaf (*Hibiscus cannabinus*) core chips were studied as a filter aid for three challenge solutions: a yeast solution, a bacterial solution, and a standard silica-particle solution (Lee & Eiteman, 2001). The kenaf and diatomaceous earth both satisfactorily removed all silica particles from the solution without a noticeable flux degradation over the course of the filtration. The kenaf and diatomaceous earth also removed yeast particles. However, the flux loss with time was higher for kenaf precoated filter than with the diatomaceous earth precoated filter. The kenaf precoated filter was more efficient at removing bacterial particles from solution than diatomaceous earth (40% versus 10%, respectively).

In another study, kenaf was used as a body feed filter aid and compared with commercial filter aids (diatomite, perlite, Solka-Floc cellulose) by filtering a dilute (1%) kaolin suspension and obtained a significant improvement in the filtration rate in all cases (Varghese & Cleveland, 1998). The authors concluded that the filter area requirement using kenaf was about 25–30% larger than that required when inorganic commercial filter aids were used. Higher filtrate turbidity was another drawback of kenaf compared to those of diatomite and perlite.

Besides organic kenaf seeds, no certified organic kenaf filter aids are present on the market (*Organic Integrity Database*, 2024b).

Report Authorship

The following individuals were involved in research, data collection, writing, editing, and/or final approval of this report:

- Ashraf Tubeileh, Associate Professor, California Polytechnic State University
- Peter O. Bungum, Research and Education Manager, OMRI
- Tina Jensen Augustine, Technical Operations Manager, OMRI
- Jarod T Rhoades, Standards Manager, OMRI
- Meghan Murphy, Graphic Designer, OMRI

All individuals are in compliance with Federal Acquisition Regulations (FAR) Subpart 3.11—Preventing Personal Conflicts of Interest for Contractor Employees Performing Acquisition Functions.

References

Organic Foods Production Act of 1990, 7 U.S.C. §6501 § 6501 (1990). https://uscode.house.gov/view.xhtml?path=/prelim@title7/chapter94&edition=prelim

Afroze, S., Sen, T. K., & Ang, H. M. (2016). Adsorption performance of continuous fixed bed column for the removal of methylene blue (MB) dye using Eucalyptus sheathiana bark biomass. *Research on Chemical Intermediates*, *42*(3), 2343–2364. https://doi.org/10.1007/s11164-015-2153-8

Alkan, M., Demirbaş, Ö., & Doğan, M. (2005). Zeta potential of unexpanded and expanded perlite samples in various electrolyte media. *Microporous and Mesoporous Materials*, *84*(1), 192–200. https://doi.org/10.1016/j.micromeso.2005.05.023

Alkan, M., & Doğan, M. (1998). Surface titrations of perlite suspensions. *Journal of Colloid and Interface Science*, *207*(1), 90–96. https://doi.org/10.1006/jcis.1998.5694

Alkan, M., & Doğan, M. (2001). Adsorption of copper(II) onto perlite. *Journal of Colloid and Interface Science*, *243*(2), 280–291. https://doi.org/10.1006/jcis.2001.7796

Alkan, M., Karadaş, M., Doğan, M., & Demirbaş, Ö. (2005). Adsorption of CTAB onto perlite samples from aqueous solutions. *Journal of Colloid and Interface Science*, *291*(2), 309–318. https://doi.org/10.1016/j.jcis.2005.05.027

Ampian, S. G., & Virta, R. L. (1992). *Crystalline silica overview: Occurrence and analysis*. U.S. Department of the Interior, Bureau of Mines.

Ardhaoui, N., Sassi, W., Msaadi, R., Rouge, N., Ammar, S., Nafady, A., & Hihn, J.-Y. (2023). Adsorption and Photocatalysis Properties of Perlite During Oxytetracycline Removal. *Water, Air, & Soil Pollution*, *234*(11), 687. https://doi.org/10.1007/s11270-023-06709-7

Austin, G. S., & Barker, J. M. (1998). Commercial perlite deposits of New Mexico and North America. *Las Cruces Country II*, 271–277. https://doi.org/10.56577/FFC-49.271

Austin, G. S., Hoffman, G. K., Barker, J. M., Zidek, J., & Gilson, N. (Eds.). (1996). *Proceedings of the 31st Forum on the Geology of Industrial Minerals – The Borderland Forum*. New Mexico Bureau of Geology and Mineral Resources. https://doi.org/10.58799/B-154

Australian Wine Research Institute. (2023). *Fining agents*. Australian Wine Research Institute. https://www.awri.com.au/industry_support/winemaking_resources/frequently_asked_questions/fining_agents/

Bächle, V., Morsch, P., Gleiß, M., & Nirschl, H. (2021). Influence of the precoat layer on the filtration properties and regeneration quality of backwashing filters. *Eng*, *2*(2), Article 2. https://doi.org/10.3390/eng2020012

Bansal, R. C., Donnet, J.-B., & Stoeckli, F. (1988). *Active Carbons*. https://libra.unine.ch/handle/123456789/13055

Burriesci, N., Arcoraci, C., & Antonucci, P. (1985). Physico-chemical characterization of perlite of various origins. *Material Letters*, *3*(3), 103–110.

Bush, A. L. (1973). Lightweight aggregates. In *United States mineral resources* (pp. 333–355). United States Geological Survey.

Carman, P. C. (1938). The action of filter aids. *Ind. Eng. Chem.*, *30*(10), 1163–1167. https://doi.org/10.1021/ie50346a016

Cecilia, J. A., Autie-Pérez, M. A., ManuelLabadie-Suarez, J., Castellón, E. R., InfantesMolina, A., Cecilia, J. A., Autie-Pérez, M. A., ManuelLabadie-Suarez, J., Castellón, E. R., & InfantesMolina, A. (2018). Volcanic glass and its uses as adsorbent. In *Volcanoes – Geological and Geophysical Setting, Theoretical Aspects and Numerical Modeling, Applications to Industry and Their Impact on the Human Health*. IntechOpen. https://doi.org/10.5772/intechopen.75063

Checkoway, H., Hughes, J. M., Weill, H., Seixas, N. S., & Demers, P. A. (1999). Crystalline silica exposure, radiological silicosis, and lung cancer mortality in diatomaceous earth industry workers. *Thorax*, *54*(1), 56–59. https://doi.org/10.1136/thx.54.1.56

Cheremisinoff, N. P. (1998). 2—Filter media and use of filter aids. In N. P. Cheremisinoff (Ed.), *Liquid Filtration (Second Edition)* (pp. 19–58). Butterworth-Heinemann. https://doi.org/10.1016/B978-075067047-0/50003-9

Christoph, N., & Bauer-Christoph, C. (2007). Flavour of spirit drinks: Raw materials, fermentation, distillation, and ageing. In R. G. Berger (Ed.), *Flavours and Fragrances: Chemistry, Bioprocessing and Sustainability* (pp. 219–239). Springer. https://doi.org/10.1007/978-3-540-49339-6_10

Code of Federal Regulations. (2023). *7 CFR 205.605 – Nonagricultural (nonorganic) substances allowed as ingredients in or on processed products labeled as "organic" or "made with organic (specified ingredients or food group(s))."* United States Code. https://www.ecfr.gov/current/title-7/part-205/section-205.605

Cooper, W. C. (1975). Radiographic survey of perlite workers. *Journal of Occupational Medicine.: Official Publication of the Industrial Medical Association*, *17*(5), 304–307.

Cooper, W. C. (1976). Pulmonary function in perlite workers. *Journal of Occupational Medicine.: Official Publication of the Industrial Medical Association*, *18*(11), 723–729. https://doi.org/10.1097/00043764-197611000-00006

Creutzenberg, O., Hansen, T., Ernst, H., Muhle, H., Oberdörster, G., & Hamilton, R. (2008). Toxicity of a quartz with occluded surfaces in a 90-day intratracheal instillation study in rats. *Inhalation Toxicology*, *20*(11), 995–1008. https://doi.org/10.1080/08958370802123903

Denton, J. S., Tuffen, H., Gilbert, J. S., & Odling, N. (2009). The hydration and alteration of perlite and rhyolite. *Journal of the Geological Society*, *166*(5), 895–904. https://doi.org/10.1144/0016-76492008-007

Dickenson, T. C. (1997). *Filters and filtration handbook*. Elsevier.

Doğan, M., & Alkan, M. (2004). *Some physicochemical properties of perlite as an adsorbent*. http://dspace.balikesir.edu.tr/xmlui/handle/20.500.12462/7482

Doğan, M., Alkan, M., & Çakir, Ü. (1997). Electrokinetic properties of perlite. *Journal of Colloid and Interface Science*, *192*(1), 114–118. https://doi.org/10.1006/jcis.1997.4913

Doğan, M., Alkan, M., & Onganer, Y. (2000). Adsorption of Methylene Blue from Aqueous Solution onto Perlite. *Water, Air, and Soil Pollution*, *120*(3), 229–248. https://doi.org/10.1023/A:1005297724304

Du, C.-L., Wang, J.-D., Chu, P.-C., & Guo, Y. L. (2010). Acute expanded perlite exposure with persistent reactive airway Dysfunction syndrome. *Industrial Health*, *48*(1), 119–122. https://doi.org/10.2486/indhealth.48.119

El Youssfi, M., Sifou, A., Ben Aakame, R., Mahnine, N., Arsalane, S., Halim, M., Laghzizil, A., & Zinedine, A. (2023). Trace elements in foodstuffs from the Mediterranean basin—Occurrence, risk assessment, regulations, and prevention strategies: A review. *Biological Trace Element Research*, *201*(5), 2597–2626. https://doi.org/10.1007/s12011-022-03334-z

Elmes, P. C. (1987). Perlite and other 'nuisance' dusts. *Journal of the Royal Society of Medicine*, *80*(7), 403–404. https://doi.org/10.1177/014107688708000703

Ergönül, P. G., & Nergiz, C. (2015). The effect of different filter aid materials and winterization periods on the oxidative stability of sunflower and corn oils. *CyTA - Journal of Food*. https://www.tandfonline.com/doi/abs/10.1080/19476337.2014.931889

FDA. (2002, February 6). *GRN No. 87. Composite filtration media (diatomaceous earth and perlite)*. https://www.cfsanappsexternal.fda.gov/scripts/fdcc/index.cfm?set=GRASNotices&id=87

FDA. (2015, September 4). *GRAS substances (SCOGS) database - Select Committee On GRAS Substances (SCOGS) opinion: Silicates*. Center for Food Safety and Applied Nutrition. https://wayback.archive-it.org/7993/20171031063508/https://www.fda.gov/Food/IngredientsPackagingLabeling/GRAS/SCOGS/ucm260849.htm

Federation of American Societies for Experimental Biology. (1979). *Evaluation of the health aspects of certain silicates as food ingredients* (FDA/BF-80/11; p. 42). National Technical Information Service.

Foroughi, M., Sarabi Jamab, M., Keramat, J., & Foroughi, M. (2018). Immobilization of saccharomyces cerevisiae on perlite beads for the decontamination of Aflatoxin m1 in milk. *Journal of Food Science*, *83*(7), 2008–2013. https://doi.org/10.1111/1750-3841.14100

Friedman, I. I., Long, W. D., & Smith, R. L. (1963). Viscosity and water content of rhyolite glass. *Geophysical Research*, *68*, 6523–6535.

Gaynor, P., & Cianci, S. (2006). *How U.S. FDA's GRAS notification program works*. U.S. Food & Drug Administration; FDA. https://www.fda.gov/food/generally-recognized-safe-gras/how-us-fdas-gras-notification-program-works

Gerdes, E. (1997). Precoat filtration with organic filter aids. *Filtration and Separation*, *10*(34), 1040–1043.

Goudouva, G. T., Loizia, P., Inglezakis, V., & Zorpas, A. A. (2018). Quarries environmental footprint in the framework of sustainable development: The case study of Milos island. *Desalination and Water Treatment*, *133*, 307–314. https://doi.org/10.5004/dwt.2018.23087

Goudouva, G. T., & Zorpas, A. A. (2017). Water footprint determination by quarry operation in island regions. *DESALINATION AND WATER TREATMENT*, *86*, 271–276. https://doi.org/10.5004/dwt.2017.20814

Grujin, K. N., Lužaić, T., Pezo, L., Nikolovski, B., & Maksimović, Z. (2023). *Sunflower Oil Winterization Using the Cellulose-Based Filtration Aid—Investigation of Oil Quality during Industrial Filtration Probe—ProQuest*. https://www.proquest.com/docview/2829806822/fulltext/CED82118C7424463PQ/1?accountid=28147&sourcetype=Scholarly%20Journals

Heide, K., & Heide, G. (2011). Vitreous state in nature—Origin and properties. *Geochemistry*, *71*(4), 305–335. https://doi.org/10.1016/j.chemer.2011.10.001

Henning, K.-D., & von Kienle, H. (2021). Activated carbon. In *Industrial Carbon and Graphite Materials, Volume I* (pp. 491–531). John Wiley & Sons, Ltd. https://doi.org/10.1002/9783527674046.ch9

Illner, R. (1989). Precoat filtration. In *Water, Wastewater, and Sludge Filtration*. CRC Press.

Jackson, R. S. (2008). 8—Postfermentation treatments and related topics. In R. S. Jackson (Ed.), *Wine Science (Third Edition)* (pp. 418–519). Academic Press. https://doi.org/10.1016/B978-012373646-8.50011-1

Jackson, R. S. (2014). 8—Post-fermentation treatments and related topics. In R. S. Jackson (Ed.), *Wine Science (Fourth Edition)* (pp. 535–676). Academic Press. https://doi.org/10.1016/B978-0-12-381468-5.00008-7

Jaster, M. C. (1956). *Perlite resources of the United States* (Geological Survey Bulletin 1027–I). U.S. Department of the Inerior.

Keogh, B. T. (1988). *Bagasse residue filter materials and activated carbon products and methods of manufacturing the same* (United States Patent US4745096A). https://patents.google.com/patent/US4745096A/en

Kinnarinen, T., Golmaei, M., & Häkkinen, A. (2013). Use of filter aids to improve the filterability of enzymatically hydrolyzed biomass suspensions. *Industrial & Engineering Chemistry Research*, *52*(42), 14955–14964. https://doi.org/10.1021/ie4021057

Kuhn, M., & Briesen, H. (2016). Dynamic modeling of filter-aid filtration including surface- and depth-filtration effects. *Chemical Engineering & Technology*, *39*(3), 425–434. https://doi.org/10.1002/ceat.201500347

Lagaly, G., Tufar, W., Minihan, A., & Lovell, A. (2003). Silicates. In *Ullmanns encyclopedia of industrial chemistry* (6th ed., Vol. 32, pp. 361–426). Wiley-VCH.

Lee, S. A., & Eiteman, M. A. (2001). Ground kenaf core as a filtration aid. *Industrial Crops and Products*, *13*(2), 155–161. https://doi.org/10.1016/S0926-6690(00)00062-5

Li, W., Kiser, C., & Richard, Q. (2005). Quality Test of Rice Hull Ash Filter Aids. *American Filtration & Separations Society*. 2005 International Topical Conferences & Exposition, Ann Arbor, MI. https://static1.squarespace.com/static/597264fcf14aa1811d00f33b/t/59a98f93f5e231241db35f35/1504284564138/Quality+Test+of+Rice+Hull+Ash+Filter+Aids.pdf

Lulamba, T. E., Stafford, R. A., & Njobeh, P. B. (2019). The relative effectiveness of two filter aids in removing ochratoxin A during beer filtration. *Journal of the Institute of Brewing*, *125*(4), 422–432. https://doi.org/10.1002/jib.570

Mathialagan, T., & Viraraghavan, T. (2002). Adsorption of cadmium from aqueous solutions by perlite. *Journal of Hazardous Materials*, *94*(3), 291–303. https://doi.org/10.1016/S0304-3894(02)00084-5

Maxim, L. D., Niebo, R., & McConnell, E. E. (2014). Perlite toxicology and epidemiology – a review. *Inhalation Toxicology*, *26*(5), 259–270. https://doi.org/10.3109/08958378.2014.881940

May, B., Dreifke, T., Patz, C.-D., Schütz, C. L., Schweiggert, R., & Dietrich, H. (2019). Filter aid selection allows modulating the vanadium concentration in beverages. *Food Chemistry*, *300*, 125168. https://doi.org/10.1016/j.foodchem.2019.125168

McLemore, V. T., & Austin, G. S. (2017). *Energy and Mineral Resources of New Mexico: Industrial Minerals and Rocks* (Vol. 50E). New Mexico Bureau of Geology and Mineral Resources and New Mexico Geological Society. https://doi.org/10.58799/M-50E

Meisinger, A. C. (1985). Perlite. In *Mineral Facts and Problems* (pp. 571–577). U.S. Bureau of Mines, US Department of the Interior.

Milk Specialties Global. (2024). Milk Proteins. https://www.milkspecialties.com/human-nutrition/products/milk-proteins/

Movasati, A., Sahraei, E., Vaghari, H., & Jafarizadeh-Malmiri, H. (2014). *Development of a new filter aid formulation based on perlite earth to clarify date liquid sugar*. The 8 th International Chemical Engineering Congress & Exhibition.

Nattrass, C., Horwell, C. J., Damby, D. E., Kermanizadeh, A., Brown, D. M., & Stone, V. (2015). The global variability of diatomaceous earth toxicity: A physicochemical and in vitro investigation. *Journal of Occupational Medicine and Toxicology*, *10*(1), 23. https://doi.org/10.1186/s12995-015-0064-7

Nedić Grujin, K., Lužaić, T., Pezo, L., Nikolovski, B., Maksimović, Z., & Romanić, R. (2023). Sunflower oil winterization using the cellulose-based filtration aid—Investigation of oil quality during industrial filtration probe. *Foods*, *12*(12), Article 12. https://doi.org/10.3390/foods12122291

Nicolini, G., Larcher, R., Pangrazzi, P., & Bontempo, L. (2004). Changes in the contents of micro- and trace-elements in wine due to winemaking treatments. *Vitis*, *43*(1), 41–45.

NIHS. (2019). *Research on the safety evaluation of existing additives*. https://www.nihs.go.jp/dfa/dfa_jp/img/FY2019_research-report-of-existing-additives.pdf

NOP. (2016a). *Guidance 5033-1, Decision tree for classification of materials as synthetic or nonsynthetic*. National Organic Program. https://www.ams.usda.gov/sites/default/files/media/NOP-Synthetic-NonSynthetic-DecisionTree.pdf

NOP. (2016b). *NOP 5033-2, Guidance, decision tree for classification of agricultural and nonagricultural materials for organic livestock production or handling*. National Organic Program. https://www.ams.usda.gov/sites/default/files/media/NOP-Ag-NonAg-DecisionTree.pdf

NOSB. (1996). *Technical Advisory Panel report, processing/handling: Perlite* (p. 12). National Organic Program. https://www.ams.usda.gov/sites/default/files/media/Perlite%20TR.pdf

NOSB. (2005). *Formal recommendation by the National Organic Standards Board (NOSB) to the National Organic Program (NOP)*. National Organic Program. https://www.ams.usda.gov/sites/default/files/media/NOP%20Handling%20Committee%20Sunset%20Rec.pdf

NOSB. (2010). *Formal Recommendation by the National Organic Standards Board (NOSB) to the National Organic Program (NOP); Sunset review of magnesium sulfate*. National Organic Program. https://www.ams.usda.gov/sites/default/files/media/NOP%20Handling%20Final%20Rec%20Magnesium%20Sulfate.pdf

NOSB. (2015). *Sunset 2017 NOSB final review*. National Organic Program. https://www.ams.usda.gov/sites/default/files/media/HS%202017%20Sunset%20Final%20Rvw%20605%28a%29_%28b%29_606_final%20rec.pdf

NOSB. (2019). *Formal recommendation. From: National Organic Standards Board (NOSB). To: The National Organic Program (NOP)*. National Organic Program. https://www.ams.usda.gov/sites/default/files/media/HS2021SunsetReviews.pdf

Onur, A., Ng, A., Garnier, G., & Batchelor, W. (2018). Engineering cellulose fibre inorganic composites for depth filtration and adsorption. *Separation and Purification Technology*, *203*, 209–216. https://doi.org/10.1016/j.seppur.2018.04.038

Organic Integrity Database. (2024a). Casein Products. https://organic.ams.usda.gov/Integrity/CP/OPP?cid=15&nopid=5561006123&ret=Home&retName=Home

Organic Integrity Database. (2024b). Kenaf Products. https://organic.ams.usda.gov/Integrity/Default

Park, R., Rice, F., Stayner, L., Smith, R., Gilbert, S., & Checkoway, H. (2002). Exposure to crystalline silica, silicosis, and lung disease other than cancer in diatomaceous earth industry workers: A quantitative risk assessment. *Occupational and Environmental Medicine*, *59*(1), 36–43. https://doi.org/10.1136/oem.59.1.36

Park, S.-R., Ha, S.-D., Yoon, J.-H., Lee, S.-Y., Hong, K.-P., Lee, E.-H., Yeom, H.-J., Yoon, N.-G., & Bae, D.-H. (2009). Exposure to ethyl carbamate in alcohol-drinking and nondrinking adults and its reduction by simple charcoal filtration. *Food Control*, *20*(10), 946–952. https://doi.org/10.1016/j.foodcont.2009.02.006

Patterson, H. B. W. (2009). Chapter 6—Filtration and Filters. In G. R. List (Ed.), *Bleaching and Purifying Fats and Oils* (Second Edition, pp. 159–188). AOCS Press. https://doi.org/10.1016/B978-1-893997-91-2.50012-2

Perlite Institute, Inc. (2020). *Perlite-filter aids – Explained*. https://hessperlite.com/PDFs/Perlite-FilterAids-Explained.pdf

Perlmutter, B. A. (2015). *Solid-liquid filtration: Practical guides in chemical engineering*. Butterworth-Heinemann.

Polatli, M., Erdinç, M., Erdinç, E., & Okyay, E. (2001). Perlite exposure and 4-year change in lung function. *Environmental Research*, *86*(3), 238–243. https://doi.org/10.1006/enrs.2001.4268

Proctor, A., & Toro-Vazquez, J. F. (2009). Chapter 10—The Freundlich Isotherm in Studying Adsorption in Oil Processing. In G. R. List (Ed.), *Bleaching and Purifying Fats and Oils (Second Edition)* (pp. 209–219). AOCS Press. https://doi.org/10.1016/B978-1-893997-91-2.50016-X

Products – Fixmax Perlite. (2024). [Company]. Fixmax Perlite LLC. http://www.fixmaxperlite.com/en/products

Redan, B. W. (2020). Processing aids in food and beverage manufacturing: Potential source of elemental and trace metal contaminants. *Journal of Agricultural and Food Chemistry*, *68*(46), 13001. https://doi.org/10.1021/acs.jafc.9b08066

Reka, A. A., Pavlovski, B., Lisichkov, K., Jashari, A., Boev, B., Boev, I., Lazarova, M., Eskizeybek, V., Oral, A., & Makreski, P. (2019). Chemical, mineralogical and structural features of native and expanded perlite from Macedonia. *Geologia Croatica*, *72*(3), Article 3. https://doi.org/10.4154/gc.2019.18

Ribéreau-Gayon, P., Glories, Y., Maujean, A., & Dubourdieu, D. (2006). Clarification and Stabilization Treatments: Fining Wine. In *Handbook of Enology* (pp. 301–331). John Wiley & Sons, Ltd. https://doi.org/10.1002/0470010398.ch10

Rice, F. L., Park, R., Stayner, L., Smith, R., Gilbert, S., & Checkoway, H. (2001). Crystalline silica exposure and lung cancer mortality in diatomaceous earth industry workers: A quantitative risk assessment. *Occupational and Environmental Medicine*, *58*(1), 38–45. https://doi.org/10.1136/oem.58.1.38

Rögener, F. (2021). Filtration technology for beer and beer yeast treatment. *IOP Conference Series: Earth and Environmental Science*, *941*(1), 012016. https://doi.org/10.1088/1755-1315/941/1/012016

Roulia, M., Chassapis, K., Kapoutsis, J. A., Kamitsos, E. I., & Savvidis, T. (2006). Influence of thermal treatment on the water release and the glassy structure of perlite. *Journal of Materials Science*, *41*(18), 5870–5881. https://doi.org/10.1007/s10853-006-0325-z

Sampatakakis, S., Linos, A., Papadimitriou, E., Petralias, A., Dalma, A., Papasaranti, E. S., Christoforidou, E., & Stoltidis, M. (2013). Respiratory disease related mortality and morbidity on an island of Greece exposed to perlite and bentonite mining dust. *International Journal of Environmental Research and Public Health*, *10*(10), Article 10. https://doi.org/10.3390/ijerph10104982

Shaw, D. J. (1980). *Introduction to colloid and surface chemistry* (3rd ed.). Butterworths.

Smith, T. (2001). *Notification of GRAS determination for composite filtration media*. U.S. Food And Drug Administration. http://wayback.archive-it.org/7993/20171031055900/https://www.fda.gov/downloads/Food/IngredientsPackagingLabeling/GRAS/NoticeInventory/UCM261673.pdf

Sodeyama, K., Sakka, Y., Kamino, Y., & Seki, H. (1999). Preparation of fine expanded perlite. *Journal of Materials Science*, *34*(10), 2461–2468. https://doi.org/10.1023/A:1004579120164

Sparks, T., & Chase, G. (2016). Section 5—Solid–liquid filtration – Examples of processes. In T. Sparks & G. Chase (Eds.), *Filters and Filtration Handbook (Sixth Edition)* (pp. 297–359). Butterworth-Heinemann. https://doi.org/10.1016/B978-0-08-099396-6.00005-8

Staff of US Geological Survey. (2023). *Perlite* (Mineral Commodity Summaries). U.S. Geological Survey. https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-perlite.pdf

Sun, W., & Selim, H. M. (2020). Chapter Two - Fate and transport of molybdenum in soils: Kinetic modeling. In D. L. Sparks (Ed.), *Advances in Agronomy* (Vol. 164, pp. 51–92). Academic Press. https://doi.org/10.1016/bs.agron.2020.06.002

Svarovsky, L. (Ed.). (1977). *Solid-liquid separation*. Butterworths.

Tanaydin, M. K., Tanaydin, Z. B., İnce, M., & Demırkiran, N. (2017). Removal of copper from aqueous solution using perlite. *AIP Conference Proceedings*, *1833*(1), 020115. https://doi.org/10.1063/1.4981763

Tazaki, K., Tiba, T., Aratani, M., & Miyachi, M. (1992). Structural water in volcanic glass. *Clays and Clay Minerals*, *40*(1), 122–127. https://doi.org/10.1346/CCMN.1992.0400113

Termolita®. (n.d.). *Filter aid solutions – Expanded perlite*. Retrieved December 5, 2023, from https://filteraids.termolita.com/

US EPA, O. (1995). Ch. 11. Mineral products industry. In *AP-42: Compilation of Air Emissions Factors from Stationary Sources* (p. 11.22-1-11.22-5). Environmental Protection Agency. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors-stationary-sources

U.S. FDA. (2000, August). *Guidance for industry: Action levels for poisonous or deleterious substances in human food and animal feed*. U.S. Food & Drug Administration; FDA. https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-action-levels-poisonous-or-deleterious-substances-human-food-and-animal-feed

U.S. Pharmacopeia. (2023). *USP-FCC Perlite*. https://online.foodchemicalscodex.org/uspfcc/current-document/5_GUID-64948811-4C36-490E-B0C0-22DF3437D970_2_en-US?source=Activity

Valdez-Castillo, M., Saucedo-Lucero, J. O., & Arriaga, S. (2019). Photocatalytic inactivation of airborne microorganisms in continuous flow using perlite-supported ZnO and TiO2. *Chemical Engineering Journal*, *374*, 914–923. https://doi.org/10.1016/j.cej.2019.05.231

Varghese, B. K., & Cleveland, T. G. (1998). Kenaf as a body-feed filter aid. *Filtr. Sep. Technol Advances*, *12*, 641.

Varuzhanyan, Av. A., Varuzhanyan, Ar. A., & Varuzhanyan, H. A. (2006). A mechanism of perlite expansion. *Inorganic Materials*, *42*(9), 1039–1045. https://doi.org/10.1134/S0020168506090202

Villar, J., Cañete, R., & Manganelly, E. (2004). Why adding rice hull ash can benefit beer clarification. *Filtration & Separation*, *41*(6), 32–33. https://doi.org/10.1016/S0015-1882(04)00282-4

Wang, A., Jackson, L. S., & Jablonski, J. E. (2017). Factors affecting the level of heavy metals in juices processed with filter aids. *Journal of Food Production*, *80*(6), 892–902.

Weber, R. H. (1955). *Processing perlite: The technologic problems* (Circular 32; p. 3). State Bureau of Mines and Mineral Resources. https://geoinfo.nmt.edu/publications/monographs/circulars/downloads/32/Circular-32.pdf