Chilean Nitrate

for use in
Spirulina aquaculture production

Executive Summary[1]

A petition is under consideration with respect to NOP regulations, section 205.602 (h):

Petitioned: **Annotation to section 205.602(h), that allows for unrestricted use of Chilean (sodium) nitrate for *Spirulina* production where media is recycled and no run-off to soil or ground water occurs.**

Chilean nitrate is a mined source of highly soluble nitrogen. It is used in agricultural production systems as a fertilizer where traditional methods of cover cropping, rotations, and composting are considered inadequate sources of nitrogen in terms of timing, solubility, and/or form. Currently, the NOP restricts its use to not more than twenty percent of the total nitrogen budget per cropping cycle.

There are currently two petitions submitted to the NOSB pertaining to the use of Chilean nitrate in organic crop production. These two petitions have been considered separately. **This TAP evaluation addresses the petition that requests the unrestricted use of Chilean nitrate in a closed-loop *Spirulina* production system.**

The TAP reviewers were not in agreement over the use of Chilean nitrate in *Spirulina* production. Two reviewers thought it should be prohibited from *Spirulina* production, and one reviewer was in favor of a conditional phase-out of the substance whereby time would be granted to transition to a new source of nitrogen.

Of the two reviewers who favored prohibition, both expressed concern over supply-side environmental degradation and the integrity of the system as a closed-loop. Neither reviewer suggested specific alternatives to the use of Chilean nitrate. The reviewer in favor of a gradual phase-out expressed similar concerns over environmental contamination at mining sites and production areas, while also suggesting that nitrogen fixation be explored as a potential alternative nitrogen source. All three reviewers conceded that there may not be a viable alternative to Chilean nitrate for organic *Spirulina* production.

Summary of TAP Reviewer Analyses

Synthetic/ Nonsynthetic	Allowed or Prohibited	Notes/suggested annotations:
Synthetic (0) *Nonsynthetic (3)*	*Allowed (1)* *Prohibited (2)*	***Reviewer 1:*** *Prohibition of Chilean nitrate from organic* Spirulina *production* ***Reveiwer 2:*** *Continued allowance of Chilean nitrate during a three to five year transition period, conditional upon a reduction or elimination of dependence on the substance depending on the success of implementing nitrogen fixation or alternative nutrient delivery systems* ***Reviewer 3:*** *Prohibition of Chilean nitrate from organic* Spirulina *production*

Identification

Chemical name: Sodium nitrate
Trade name: Chilean nitrate, Bulldog Soda
Other names: Nitrate of soda, Chilean saltpeter, soda niter, nitric acid sodium salt

CAS Number:
sodium nitrate: 7631-99-4

Other Codes:
EPA PC Code: 076104
DOT # NA 1487 Oxidizer
NOES 1983: HZD 69220; NIS 249; TNF 40765; NOS 152; TNE 557740; TFE 110040
EINECS 231-554-3
ICSC #0185
RTECHS # WC5600000
UN #1498
WHMIS: C, D2B

[1] *This Technical Advisory Panel (TAP) review is based on the information available as of the date of this review. This review addresses the requirements of the Organic Foods Production Act to the best of the contractor's ability, and has been reviewed by experts on the TAP. The substance is evaluated against the criteria found in section 2119(m) of the OFPA [7 USC 6517(m)]. The information and evaluation presented to the NOSB is based on the technical evaluation against those criteria, and does not incorporate commercial availability, socio-economic impact or others factors that the NOSB and the USDA may consider in making decisions.*

Characterization

Composition:
sodium nitrate $NaNO_3$

Physical Data:

Melting point:	308°C
Boiling point:	380°C (decomposes)
Specific Gravity:	2.26
Solubility:	Approx. 480 g/L @ 25°C
Stability:	Stable
Hazardous Polymerization:	Will not occur

Properties:
Pure sodium nitrate is an odorless, colorless to light yellow crystalline salt. It is available in synthetic form or from mined sources. The chemical structure remains the same for both cases. The naturally occurring form, known as Chilean nitrate, is derived from *caliche* ore, a crude mineral conglomerate of salts comprised of nitrates; sulfates; chlorides of sodium; calcium and potassium; magnesium; and various micronutrients including borate, iodate, and perchlorate (Ericksen, 1983). Dissolution is endothermic. The aqueous solution is neutral (Merck 2000).

How Made:
Chilean nitrate is mined from natural deposits of *caliche* ore found in the extremely arid Atacama desert of northern Chile (avg. precip >2mm). These deposits are mined primarily from saline mineral deposits that form veins and irregular masses in the bedrock. The ore is extracted by first drilling or blasting the soil overburden covering the deposits, then transported to the extraction plant. The overburden, usually 1 to 2 m thick, is removed mechanically and left on-site (Collings 1950). During refinement, crushed ore is dissolved at 35°C to extract nitrates, sulfates, potassium, and iodine. Nitrate precipitates are removed, crystallized, dried, and prilled. The purified grade contains at least 97% $NaNO_3$ (Stoddard and Silberman, 1995).

Specific Uses
The material is used as a technical grade nitrogen fertilizer. It can be broadcast, drilled, used as a sidedress, or dissolved and applied as an aqueous solution.

Status

History of Use:
Commercial development of Chilean nitrate deposits first occurred on extremely arid islands off the coast of Chile and Peru around 1840. These island deposits – derived from whole cliffs of seabird excrement, or guano, deposited over thousands of years – were quickly depleted and by 1870 markets turned to more expansive deposits located in the nearby Atacama Desert in northern Chile. These so-called *caliche* deposits are sporadically located in a band 30km wide by 700km long. Unlike the guano deposits, this mined substance is a crude mineral conglomerate of salts possibly formed from nitrogen fixation by microorganisms in playa lakes and associated soils approximately 10 – 15 million years ago (Ericksen 1983). Currently, Chilean nitrate constitutes 0.14% of the total US fertilizer application, and is used primarily by niche markets (Urbansky et al., 2001).

Functionality

Spirulina platensis is a thermophilic, alkalophilic, non-heterocystous filamentous cyanobacterium. It is a specialty product, mass cultured in shallow (>20cm), open outdoor ponds one hectare in size, under intense sunlight. These ponds are infused with carbon dioxide (C source) and calcium bicarbonate (baking soda) to maintain an exceptionally alkaline solution (pH 10) necessary for cultivation. A lined, offsite holding pond is used to premix the calcium bicarbonate solution, after which it is pumped into individual production ponds. All other minerals and nutrients necessary for growth, including Chilean nitrate, are mixed directly into water supply inputs at each pond. Ponds are inoculated with pure strains of *Spirulina* at the start of the growing season. Since light penetration becomes severely limited at depths >2cm, paddle wheels continuously stir the media to ensure even exposure to sunlight. One "season" lasts 3-4 days, after which the algae are harvested, rinsed intensively to remove residual media contaminants, and dried. *Spirulina* is sold as a feed additive for aquaculture and as a dietary supplement.[2]

Although classified as a cyanobacterium, the commercially produced *Spirulina platensis* strain does not contain a heterocyst necessary for nitrogen fixation. Thus, it must absorb nitrate from the media. The finished product contains over 60% protein by weight, and cultivation requires substantial inputs of soluble nitrogen. The Petition claims that exclusive use of Chilean nitrate is essential for production because of its high concentration of high solubility nitrate.

[2]*Sources: www.cyanotech.com, www.spirulina.com*

USDA Final Rule:
The USDA final rule lists sodium nitrate for crop production at 205.602(h). It is not allowed for use, "unless its use is restricted to no more than 20% of the crop's total nitrogen requirement" (NOSB 1995). This annotation is derived from a review by the National Organic Standards Board, detailed in Addendum Number 27, as follows:

> The use of Chilean Nitrate (16-0-0) in Organic crop production is limited to not more than 20 percent of total nitrogen supplied to a crop. The producer's Farm Plan shall contain specific provisions and strategies designed to substantially reduce the use of Chilean Nitrate over time. The amount and timing of these reductions will be consistent with documented site-specific constraints. The Farm Plan will seek to explore each and every alternative to the routine use of Chilean Nitrate in the farming system. These alternatives include, but are not limited to: composting, improvement of compost, leguminous cover crops, interplanting, rotations, microbial enhancements, animal manures, varietal selections, planting date alterations, and reducing amounts of applied supplemental nitrogen. The timing and efficiency of Chilean Nitrate applications shall be optimized and documented in the Farm Plan. Certifiers will monitor progress in the reduction of Chilean Nitrate use and will decertify farmers that develop long term dependence on this material. Strong farmer commitment, aggressive action, and measurable results are all necessary elements of this special use of Chilean Nitrate.

Per current USDA organic standards, producers may use Chilean nitrate for no more than twenty percent of their total nitrogen budget per cropping cycle. Currently, at least one producer named in the Petition uses Chilean nitrate exclusively, maintaining that it is the only viable option for production of a certified organic product. As a result, the producer has been cited with non-compliance by their organic certification agency. This designation allows a producer to continue production and retain their certified organic status provided that "corrective actions" are taken. In this case, the *Spirulina* producer has elected to follow the NOP TAP Review process as its corrective action, and hence will acquiesce to the NOSB's final decision when it goes into effect. In the opinion of the certifying agency, the TAP Review process is a reasonable choice of corrective action because it represents the first comprehensive analysis of the substance in regard to organic agriculture (QAI 2002). The Petitioner feels that an annotation to the national organic standards is the only option.

Regulatory

U.S. certifiers that prohibit any use of Chilean nitrate include Maine Organic Farmers and Gardeners Association (MOFGA), Northeast Organic Farming Association (NOFA) -New Jersey, NOFA-New York, NOFA-Vermont, NOFA-Massachusetts, and Oregon Tilth Certified Organic. Currently, the Organic Trade Association's (OTA) American Organic Standards recommends that sodium nitrate be phased out by Jan 1, 2003.

International certifiers that prohibit use include the European Union (EU), Organic Crop Improvement Association (OCIA), International Federation of Organic Agriculture Movements (IFOAM), Farm Verified Organic (FVO), National Association for Sustainable Agriculture Australia (NASAA), UN-FAO Codex Alimentarius, and the Japanese Organic Standards (JOS). Producers currently shipping products to Europe or Japan must have their certifiers specifically verify that Chilean nitrate was not used in production.

EPA *Sodium nitrate:* registered under the Toxic Substances Control Act, currently exempt from reporting under the Inventory Update Rule.
Nitrate/nitrite: Clean Water Act, Section 304, 40 CFR 418.32; Safe Water Drinking Act National Primary Drinking Water Regulations; with limits set at 10mg/L NO_3^- -N and 1mg/L NO_2^- -N.

NIEHS National Toxicity Program database does not list any regulatory limits for sodium nitrate.

FDA does not regulate sodium nitrate

DOT classifies the substance as a hazardous material, and misuse may increase risk of explosion.

Section 2119 OFPA U.S.C. 6518(m)(1-7) Criteria

1. ***The potential of the substance for detrimental chemical interactions with other materials used in organic farming systems.***

   No information was found detailing adverse chemical interactions with other organic inputs. Nitrate is a highly energetic oxidizer, and hence the substance is generally incompatible with combustible materials and strong reducing agents.
2. ***The toxicity and mode of action of the substance and its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.***

   Acute Toxicity:

Inhalation:	Mild irritant. May cause irritation to upper respiratory tract, headache, nausea, vomiting, dizziness, weakness; may lead to rapid ineffective breathing, cyanosis, loss consciousness, death. Use in well-ventilated area.
Ingestion:	Large doses (15-30 g) fatal, smaller doses may cause gastro-enteritis, headache, abdominal pain, vomiting, muscular weakness, irregular pulse, convulsions and collapse.
Eye Contact:	Mild irritant. Safety goggles if dust is expected or if handling large quantities.
Skin Contact:	Mild irritant. Gloves should be worn when handling.
LD_{50} =	4.3 g/kg (oral, rat)
LD_{Lo} =	200 mg/kg (oral, rat)
LD_{Lo} =	500 mg/kg (oral, human)

Breakdown products/contaminants:
Substance is a naturally occurring, inorganic mineral salt. It has no complex metabolites. Substance is quickly ionized into sodium (Na^+) and nitrate (NO_3^-) in water.

Sodium (Na^+) is persistent in the soil profile in that it is relatively immobile. It tends to accumulate in semi arid and arid environments.

Nitrate (NO_3^-) is highly mobile and tends to leach into groundwater supplies if not used by plants or soil microorganisms. It is a common non-point source water contaminant, particularly in agricultural areas, and is regulated as a contaminant under the Clean Water Act. High nitrate concentrations can be toxic to soil and aquatic organisms. Increases in soluble soil nitrates caused decreases in earthworm populations at Rothamsted (Edwards and Lofty 1975). Nitrate contamination of freshwater streams and rivers in also a concern. One study by Scott and Crunkilton (2000) found ambient levels of surface water nitrate in areas of intensive agricultural cultivation to be toxic to channel catfish, *Ceriodaphnia dubia*. Nitrates have also been linked to numerous human health issues.[3]

Due to extremely high evapotranspiration rates in areas of *Spirulina* cultivation, open holding ponds tend to concentrate sodium carbonate, a by-product of the use of large amounts of calcium carbonate needed to maintain alkalinity. The following section details disposal of this and other by-products of production.

3. The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.

As noted earlier, nitrate contamination is a common problem in agricultural areas. Potential environmental impacts of Chilean nitrate stem from point source pollution of nitrates at mining sites, and non-point source pollution in areas of application. It should be noted that all ecosystems tend to leach nitrate to a certain degree.

The extraction and processing of Chilean nitrate has adverse ecological consequences. Information on Chilean *caliche* mining operations is scarce, but general conditions are assumed to be no different than those in the United States. The extraction of nitrates from northern Chilean deserts has caused serious environmental damage through the removal and concurrent dumping of sand and rock tailings (Muniz 1996). Primary concerns are soil degradation due to excavation of overburden, leaching of tailing piles, health risks to mine workers, contamination of downstream water sources due to increase sediment and nitrate load, and air pollution due to extracting/processing activities. In 1994 the Chilean government passed one of the more complete and strict environmental laws in the Americas, with two Articles of the law directed specifically at the mining industry. Remarkably, the Ministry of Mining took the position that sustainable development of mining operations is necessary in order to ensure investment security (Muniz 1996). No further information is available about the effectiveness of this legislation. Currently, nitrate extraction totals over 900,000 tons $year^{-1}$, of which 75,000 tons $year^{-1}$ is sold to US farmers (Urbansky et al. 2001).

The high solubility of Chilean nitrate virtually ensures that any nitrate not immediately assimilated by plants or soil organisms will leach down the soil profile and potentially enter the water table. The extent to which this happens is dependent on the balance that exists between the biological demand and the active pool of available nitrogen in the system. Nitrates are not locally persistent, and are quickly utilized, leached, or denitrified. Point-source nitrate contamination due to application will vary greatly depending on soil type, biological nitrogen demand, and depth to the water table. Contamination due to sodium buildup will depend upon timing of application and potential evapotranspiration.

The Petition to allow unrestricted use of Chilean nitrate in *Spirulina* aquaculture presents a unique situation. The fate of nitrogen in a nutrient rich, aqueous solution with a high biological N demand will differ substantially than its fate in a soil cropping system. The majority of information regarding toxicity and environmental side effects relate to the use of Chilean nitrate in soil media. Due to high leaching potential inherent in land-based aquaculture systems, contamination from large scale holding ponds is of considerable concern. In Texas, one of the nation's leaders in aquaculture in terms of total acreage, seepage is the major cause of water loss from most production ponds, usually exceeding the evaporation rate (Davis

[3] *See* Effects on Human Health*, below.*

et al. 1990). The Petition lists the following "unique features" of outdoor *Spirulina* production that limit environmental contamination:

- ♦ Growth ponds are lined with Hypalon or similar material such that there is no contact of the medium or the alga with the soil.
- ♦ The culture system is a closed-loop system where the nutrients are recycled continuously throughout the growth season. The only loss from the system is water from evaporation. All inputs are recycled completely and no nutrient-laden water is discharged to the environment.
- ♦ Due to that fast growth rate of the algae, nitrates are stripped off the medium at a very fast rate leaving virtually no detectable levels at the time of harvest.
- ♦ Since the ponds are harvested every day the nutrient input is equal to the removal by the algae such that nutrient accumulation is minimized.

A field visit was made to one of the Petitioner's *Spirulina* production facilities by the contractor staff to observe management practices and to substantiate these claims. The following observations were recorded:

- While the liners in use were patent, isolated seepage remains a concern. Areas of seepage are identified as soft areas under a pond or localized ballooning of a liner. Once identified they are immediately corrected. Large rips/tears are repaired immediately *in situ*. No measurements are made to determine the extent of any given seepage area, and this may be physically impractical. The producer is in the process of implementing voluntary water quality monitoring at four wells surrounding the production facilities. Until now, there has been only occasional testing at one well that is not proximal to any of the organic food grade *Spirulina* production ponds.
- Production closely resembles a closed-loop system. Upon harvesting, the *Spirulina*-laden solution is pumped out of the ponds and the product is removed via filtering through a series of fine mesh screens. The solution is then directly recycled into the growing ponds for use by the next crop. This process continues throughout the growing season. At the end of the season, residual pond water is discharged into an adjacent unlined, "natural" production pond used to cultivate non-organic *Spirulina* for use in aquaculture, animal feed, and pigment extraction.
- The nitrogen demand of *Spirulina* is closely monitored to avoid additions of Chilean nitrate in excess of demand. Although "virtually no detectable levels" of nitrate are left at the time of harvest, it is likely that this is due at least in part to denitrification of soluble N, in addition to N uptake by *Spirulina*. No monitoring is done to evaluate potential off-site contamination of soils or groundwater specifically from food grade production ponds.
- While the system minimizes nutrient accumulation, residual substances (e.g., sodium bicarbonate, dust, and other precipitates) remain after ponds have been drained and evaporated at the end of the season. The following year these substances are cleaned from the pond surfaces and the effluent is discharged into the "natural" ponds. Exact soil types underlying these ponds were not determined but appear to be predominantly heavy 2:1 clays, which is advantageous in terms of leachate containment.

4. The effects of the substance on human health.

Extraction and application of sodium nitrate for agricultural purposes has possible detrimental human consequences.

Nitrate contamination. In the absence of an adequate biological nitrate demand, nitrates have a high leaching potential and commonly migrate into groundwater sources. Nitrate *per se* is not of particular concern to human health. However, nitrate in the human body is endogenously reduced to nitrite, which has been linked to methemoglobinemia, a potentially fatal condition whereby nitrites interfere with oxygen uptake (Kross et. al 1992). Medical complications due to exposure to nitrate-containing substances have resulted from absorption though burned skin (Harris 1979) and ingestion (Grant 1986). Nitrites can be further reduced to nitrosamines. These compounds are some of the strongest known carcinogens (NAS 1981), can act systemically (Tricker et al. 1991), and have been found to induce cancer in a variety of organs in more than forty animal species, including higher primates (Bogovski and Bogovski 1981). A recent study of contaminated municipal drinking water in rural Iowa linked nitrates to a higher risk of bladder cancer in older women (Weyer et al. 2001). Elevated nitrate concentrations may also increase the incidence of non-Hodgkin's lymphoma (Weisenburger 1991; Ward et al. 1996). In California, nitrates are the largest non-point source pollutant, with levels frequently exceeding drinking water standards (USGS 1998).

Residual contaminants. The chemical composition of an average *caliche* deposit is difficult to estimate due to localized variations in relative amounts of saline constituents. The measurements at left were based on monthly combined averages from the two largest extraction plants in the Atacama desert (Grossling & Ericksen, 1971). According to the packaging, a bag of fertilizer grade Chilean nitrate[4] was composed of the following:

Average content of ionic saline constituents in mined caliche

ion	%
SO_4^{2-}	10
Na^+	6.9
NO_3^-	6.3
Cl^-	4.6
Ca^{2+}	1.8
K^+	0.7
Mg^{2+}	0.5
$B(OH_4)^-$	0.5
IO_3^-	0.06
ClO_4^-	0.03

$NaNO_3$	98.11%
$NaCl$	1.11
Na_2SO_4	0.41
H_2O	0.1
H_3BO_4	0.1
$KClO_4$	0.09

During processing, the dissolution process homogenizes impurities. Among these constituents, perchlorate is of particular concern. At sufficiently high concentrations, perchlorate interferes with iodide uptake in the thyroid gland (EPA 1998, Clark 2000). Since 1997, perchlorate contamination has been discovered in a number of US water supplies, prompting the EPA to add it to its Contaminant Candidate List (CCL, Perciasepe 1998) and the Unregulated Contaminants Monitoring Board (UCMR; Browner, 1999). The ecological impact of perchlorate is not well known. While perchlorate contamination in potable water is difficult to treat (Urbansky & Schock 1999), microbes capable of reducing the anion appear to be abundant (Logan 1998, Coates et al. 1999, Nzengung & Wang 2000). Preliminary risk assessment has focused on quantitative analyses to determine perchlorate content in fertilizers. Current analyses put perchlorate anion concentrations at 0.5-2 mg g^{-1} of sodium nitrate derived from *caliche*. However, a recent letter to the EPA from SQM North America, the sole source of Chilean nitrate, indicated that SQM had modified its refining process to produce fertilizer containing less than 0.01% perchlorate (0.1 mg g^{-1}). The same report indicated that since Chilean nitrate accounts for only 0.14% of US fertilizer application, it cannot be considered a significant anthropogenic source of perchlorate nationwide (Urbansky et al. 2001). Noting that the use of this fertilizer is highly localized in some areas, the authors indicate the need for further research into guidelines for application rates that are relevant to site-specific watersheds or ecosystems.

5. ***The effects of the substance on biological and chemical interactions.***

In a system described by the Petition in which no runoff occurs to soil and/or groundwater, adverse biological or chemical interactions on the surrounding environment are insignificant. Denitrification of N sources, if occurring, can contribute to localized atmospheric pollution and general ozone depletion through the release of NO_x gases. However, given the relatively small scale of the industry, this is not likely to be a significant concern.

No information is available on potentially adverse effects on the growth and development of *Spirulina* when using Chilean nitrate.

6. ***Alternatives to using the substance in terms of practices or other available materials***.

There are few organically approved alternatives that are as versatile and as soluble as Chilean nitrate. As described previously, the fact that the material provides an instantly available source of mineral nitrogen gives it a distinct advantage over organically complexed nitrogen sources. The Petitioner claims that "there is virtually no substitute for sodium nitrate for use in our kind of production where the water has to be stirred continuously by paddlewheels." Furthermore, "crop rotation is not feasible with *Spirulina* production" due to quality control concerns. It was suggested to the Petitioner that N-fixing *Anabaena* may have potential for use in an aquaculture crop rotation system. The Petitioner asserts that this is not feasible for the following reasons:

- *Anabaena* contains human toxins that appear as residual contaminants in *Spirulina* crops;
- Inputs of nitrogen from an *Anabaena* cover crop are inadequate in form and amount to sustain a *Spirulina* crop. Most of the N released would be in the form of proteins, which *Spirulina* cannot use, and any extracellular N would be consumed by bacteria.
- Harvesting *Anabaena* biomass for use as a soluble compost would require the capture of ammonia gas, which can be toxic for *Spirulina*.

According to a producer named in the Petition, these conclusions are not based on actual experimentation. Rather, they represent a combination of theoretical knowledge of *Spirulina* production ecology combined with experience in *Spirulina* production using good manufacturing processes (GMPs). No other information was found regarding the use of cover cropping practices in algae aquaculture.

According to the Petitioner visited by the contractor, Chilean nitrate has constituted the sole source of nitrogen for organic Spirulina production since they first became certified in 1996. While there are a number of soluble nitrogen fertilizer sources approved for use in organic production, little information exists on effective management of these materials. In

[4] 50lb bag, Peaceful Valley Farm Supply, Grass Valley, CA.

general, they "cannot fully sustain the algae and are not considered enough nor preferred sources" (Lorenz and Belay 2001). Specifically, optimum form and timing of application is lacking. In addition, variability in composition of organic fertilizers is a serious problem limiting their efficient use (Gaskell 1999), as are solubility and pH control when used in aqueous solutions (Peet 2002). Nonetheless, there are a number of substances that are often used to provide supplemental, readily usable nitrate-nitrogen. A short list is presented below. No information was found regarding the use of these fertilizers in large-scale aquaculture systems. This is consistent with the Petition's insistence that alternatives to the use of Chilean nitrate in organic *Spirulina* production are severely limited. One of the producers named on the Petition indicated that limited laboratory research had been done into the use of fish emulsion – considered by the producer to be the only promising alternative – but it was rejected after preliminary assessment due to poor solubility and residual contamination of the finished product.

Material	Manufacturer / Source	Advertised Analysis	Cost / lb N
Bloodmeal	Peaceful Valley	(14 - 0 - 0)	$4.30
Pelleted Chicken Manure	Integro	(3.5 – 1 – 7)	$6.50
Fish Meal	Peaceful Valley	(10 – 6 – 2)	$5.50
Liquid Fish	EcoNutdent	(3.4 – 2 – 0.5)	$6.00
Phytamin 800	Peaceful Valley	(7 – 0 – 0)	$7.50
Feather Meal	Calif. Organic Fertilizers	(7 – 1 – 7)	$5.50
Seabird Guano	Verditech	(11 – 8 – 2)	$6.25
Chilean nitrate	Dirt Works	(16 - 0 - 0)	$3.00

Adapted from Gaskell, 1999

7. ***The compatibility of the substance with a system of sustainable agriculture***

The premise of the Petition is that cultivation of this product represents a highly unique agroecological system, and hence problems associated with production are not addressed by standard organic research and principles. As mentioned previously, the use of Chilean nitrate allows for a source of concentrated, highly mobile nitrate-nitrogen necessary for *Spirulina* cultivation. Traditional methods of maintaining fertility in organic crop production (cover cropping, rotations, composting) may not be applicable in an aquaculture production system. Alternatives to Chilean nitrate in aquaculture are limited, and they are not as effective in terms of solubility and control of pH, both of which are essential factors in algae production. In addition, the purity of inputs greatly influences the purity of the finished product, a significant concern since *Spirulina* is marketed as a specialty crop.

Another consideration pertains to the extremely high nitrogen content of dry *Spirulina*, making it a highly concentrated source of protein. It could be argued that since most of the US population's protein is derived from animal meat – a highly resource intensive industry by comparison – the utility of a plant-derived alternative confers greater value on the product, both in terms of an individual's diet and the broader goal of sustainability. While the cost per gram of meat and poultry is lower than *Spirulina*, these prices do not take into account numerous externalities associated with meat production.

Given that past restrictions governing the use of Chilean nitrate have emphasized detrimental environmental effects, it may be argued that the Petition to allow unrestricted use in *Spirulina* production is predicated on the integrity of the operation as a closed-loop aquaculture system. Such use presents unique concerns about potential hazards in terms of groundwater leachate. Since the system relies on a continuous recycling of media, and given that production facilities are open and outdoors, concentration of residual contaminants and unused nutrients over the course of a growing season should be expected. Hence, full containment of any potential source of contamination such as effluent or seepage is necessary. The Petition claims that there is little to no potential for off-site contamination because *Spirulina* production takes place in lined holding ponds and all inputs are recycled. The Petitioner does not provide clear evidence about the discharge of exhausted media solution at the end of the growing season. One may argue that since this effluent is channeled into another production pond where residual nutrients are utilized, it is essentially recycled and thus is fundamentally different than tailwater discharged into the environment from an open field. A counter argument may be that since no information is presented regarding the composition and fate of this effluent, any assertions of environmental safety cannot be confirmed.

It would appear that the organic *Spirulina* industry has been built around the use of Chilean nitrate, which is contrary to the guidelines set forth in NOSB Addendum 27. However, it is the exact position of the Petitioner that the uniqueness of its product and production system should exempt it from use restrictions. Currently, there are no industry-specific prohibitions/allowances pertaining to use of a given substance. A strong argument can be made against the decision to begin allowing line-item exemptions to the use of substances in organic standards, as this could lead to a de facto weakening of organic regulations over time. Furthermore, if acceptable use of a substance must be based on assurances that the substance will not enter the ecosystem, one may question the suitability of that substance for organic agricultural production in the first place, since the assurances imply a hazard inherent in use. On the other hard, virtually every organically approved substance is potentially toxic if managed inappropriately. Thus it remains the function of regulatory agencies to ensure that approved substances are managed in accordance with their accepted use, regardless of the nature and extent of that use.

TAP Reviewer Discussion

Investigator's note: The following responses have been reprinted verbatim.

Reviewer 1 *[West coast, Ph.D. in Horticulture, 19 years experience as Extension Vegetable Specialist in Texas and California, specialization in nutrient and irrigation management]*

I have no expertise in this area, so I can make no judgment regarding the claim that no practical alternative exists. However, since my objections to the use of Chilean nitrate in field production are in large part related to the way the material is mined and manufactured, consistency requires that I oppose its use in organic aquaculture. If allowed to choose from any mineral N form, the petitioning aquaculturalist would undoubtedly choose a product other than sodium nitrate; they would settle for sodium nitrate only if that would enable them to retain the all important 'organic' marketing designation. If no suitable organic alternative exists, I conclude that hydroponic *Spirulina* production may not be a viable organic enterprise.

I offer a few other points to consider. The declaration that this production system is completely closed is suspect, because the algae is not likely to take up sodium and nitrate in equal amounts; combined with the concentrating effects of evaporative losses it seems unavoidable that release of waste waters will periodically be necessary. Also, the contention that *Spirulina* can be an important source of protein in vegetarian diets is unconvincing; the price of *Spirulina* at the health food store I checked was $4.00 per 50 grams, an order of magnitude greater per unit of N than other plant sources of protein.

In summary, if the only way to produce this highly specialized product is to exclusively rely on a mined, processed, mineral form of nitrate, calling this scheme 'organic' makes that designation meaningless.

Recommendation: The petition should be denied.

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Reviewer 2 *[West coast, Ph.D. .in Crop and Soil Science, specializing in soil fertility and sustainability of managed and natural ecosystem, carbon and nitrogen cycling processes]*

Evaluation of the Petition against Organic Farming Production Act Section 2119 U.S.C. 6518(m)(1-7) Criteria:

1. *The potential of the substance for detrimental chemical interactions with other materials used in organic farming systems.* In the manner it is used for the production of *Spirulina*, minimal detrimental chemical interactions will occur. This assumes that all nitrate taken up by the *Spirulina* has been reduced and converted to protein at harvest. However, there may be significant leaching volatilization losses of the added nitrate. (see below)

2. *The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.*
   The description of *Spirulina* production indicates minimal potential to contaminate the environment assuming the closed system has integrity. However, as stated in the petition, potential loses are not currently examined. A significant amount of the nitrate is no doubt denitrified and would be a source of nitric and nitrous oxides. In addition, the high pH (pH 10) of the production system may lead to substantial loses of ammonia. Ammonia volatilization can occur from the living organism and through their turnover in the production system. However the scale of production indicates small total emissions compared to other sources. As indicated in the TAP Review, nitrate is highly mobile and prone to leaching into groundwater and this will probably need to be eventually examined at the site.
   The discharge of the waste from *Spirulina* production may eventually lead to sodium affected soils at the disposal point. As stated in the petition, the system accumulates residual substances (e.g., sodium bicarbonate, dust, and other precipitates), which are discharged into the "natural" ponds. Regardless of the soil type, the soils in the discharge ponds will most likely degrade to a sodic soil.

3. *The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.*
   I am unfamiliar with the mining operations for Chilean sodium nitrate and therefore cannot give an appropriate response. Assuming that the Chilean sodium nitrate production is no different that conditions in the United States, there will be environmental impact at the mining site. The use of water to manufacture the nitrate suggests potential movement of nitrate to groundwater and surface water at the mining site. However the magnitude of nitrate loss cannot be determined with the information supplied.

4. *The effects of the substance on human health.*
   Most of the constituents stated in the analysis should not be a problem. Boron health effects are not well researched. Boron studies normally examine the benefits of increasing uptake. Over the United States, atmospheric concentrations of boron average about 0.5 ng/m3 of air. Boron concentrations in the surface waters of the United States average less

than 0.3 mg/l, but can range as high as 15 mg/l in regions draining boron-rich soils. A survey of 100 U.S. drinking water supplies showed a median boron concentration of 0.03 mg/l.

In foods, boron ranges from a low of 0.16 µg/g dry weight in red meat to about 160 ppm in quince. The average U.S. diet contains 2.5 to 3 µg/g of boron and provides a dietary intake in humans of about 1.5 mg boron/day.

Since the system used to produce the *Spirulina* is closed, the accumulation of boron may be a possibility. However, since little is known of the health effects of excess boron intake so no conclusions can be made.

The perchlorate content in of the Chilean sodium nitrate fertilizer is the other potential concern. However, the system employed to produce the *Spirulina* no doubt consumes the perchlorate through intense metabolic processing in the Spirulina and other organisms in the production process. The perchlorate content in of the Chilean sodium nitrate fertilizer is the other potential concern. Overall the low level of perchlorate should not pose human health problems at the recommended application rate.

5. *The effects of the substance on biological interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including salt index and solubility in the soil (crops, and livestock).*
   The effects of the Chilean sodium nitrate on *Spirulina* should be growth promoting. The excess salts probably do not bioaccumulate in the *Spirulina* and therefore should pose little risk to end users, such as cattle or humans. Possible loss of greenhouse gases from denitrification losses was mentioned in Criteria 2. The disposal site where the residual salts are disposed of may adversely impact the soil ecology through salt accumulation.

6. *The alternatives to using the substance in terms of practices or other available materials.*
   Few available if any organic nitrogen sources would behave as Chilean sodium nitrate does in the described *Spirulina* production systems. Most organic sources of nitrogen have low nitrogen content and in addition have considerable other constituents, many that are insoluble. These constituents may accumulate other undesirable components. If the current system can not be changed, there are few or no alternatives to Chilean sodium nitrate.

   It was stated that the commercially produced *Spirulina platensis* strain does not fix nitrogen but absorbs nitrate from the media. Is there a possibility to use a strain that fixes nitrogen? Nitrogen fixation seems an elegant approach to reducing the reliance of mined nitrates. If this could be done, a reduction in the use of Chilean sodium nitrate down to 20% may be possible. However, the complexity in prompting biological nitrogen fixation may be economically challenging unless the organic market is willing to pay the premium associated with technology conversion.

7. *Its compatibility with a system of organic agriculture.*
   The system for the production of *Spirulin*a was not thoroughly described. Therefore, the fate of the constituents in the waste from the recirculated nutrients cannot be assessed. The waste may presumably have a high salt concentration and therefore raises questions on its disposal. These whole systems aspects are not discussed in the petition (area of disposal, frequency of disposal, makeup of residual salts, etc.). The petition states that the production system is a "closed loop" implying high nutrient conversion efficiency into biomass. These claims must be substantiated since leaching and volatilization loses of nitrogen can be significant in a high pH environment. Simple stable isotope analysis of the input versus the output nitrogen would provide a realistic estimate of loss and not require extensive and costly sampling.

   Many organic certifying organizations are currently in the process or have already disallowed the use of mined nitrates. The success of the exemption to use 100% in the *Spirulina* production depends on market viability, which seems to be decreasing. It seems inevitable that different methods to produce *Spirulina* will have to be considered.

<u>Conclusion:</u>

I suggest a 3 to 5 year conversion period where the dependency of mined nitrate would be reduced or eliminated depending on the success of implementing nitrogen fixation or alternative nutrient delivery systems.

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<u>Reviewer 3:</u> *[Organic Vegetable grower, 20 years experience; Doctoral candidate in Environmental Studies, specializing in history and sociology of alternative agriculture]*

- **Evaluation Against Criteria**

1. *The potential of the substance for detrimental chemical interactions with other materials used in organic farming systems.*
   not applicable

2. *The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.*
   As noted, use of Chilean nitrate tends to leave a residue of sodium that could be problematic over the long run. But the most important concern is the transport of excess nitrate into the water table, thus leading to potential downstream contamination.

3. *The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.*
   Chilean nitrate is a mined substance. The mining process itself creates environmental degradation. Byproducts of the mining and processing can be sources of pollution. In agricultural systems, excessive use can lead to non-point source pollution of water table. In an aquaculture system such as Spirulina, if for some reason the closed system/containment were breached, a serious pollution problem could occur.

4. *The effects of the substance on human health.*
   There would seem to be strong potential for danger to human health if this substance contacted food or water supplies in high enough concentrations.

5. *The effects of the substance on biological interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including salt index and solubility in the soil (crops, and livestock).*
   This is a particularly important concern. Any accidental leakage from an aquaculture system could lead to toxic effects in nearby or downstream biota.

6. *The alternatives to using the substance in terms of practices or other available materials.*
   I see no reason for allowing Chilean nitrate in organic production, even restricted to 20% of a crop's total nitrogen. In aquaculture for *Spirulina* the petitioners claim that there are no comparable alternatives found in traditional organic practices. This may or may not be true. It is probably true that Chilean nitrate is the most *convenient* source of nitrogen for algae production. But organic production systems are not predicated on convenience. All organic production systems, whether terrestrial or aquatic, are known to require a great deal of effort, innovation and intelligence to foster and maintain a healthy and consistently productive ecosystem.

7. *Its compatibility with a system of organic agriculture.*
   Given the points mentioned above, it is my opinion that Chilean nitrate is not compatible with organic agricultural systems.

- **Concluding Remarks**

It does not make sense to me to alter the definition of organics in order to accommodate algae production in aquatic systems. With further research it should be possible to design a *Spirulina* system that would be sufficiently productive without using Chilean nitrate.

- **Specific Recommendations**

With regard to specific use proposed *Spirulina* production, the substance should be **prohibited**.

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