Hydrogen Chloride

Crops

Identification of Petitioned Substance

Chemical Names:
hydrogen chloride, HCl

Other Names:
anhydrous hydrochloric acid; chlorane; chlorohydric acid; hydrogen chloride solution; muriatic acid.

Trade Names:
none

CAS Numbers:
7647-01-0

Other Codes:
EC number: 231-595-7

Summary of Petitioned Use

This limited scope technical report provides updated information to the National Organic Standards Board (NOSB) in support of the sunset review of hydrogen chloride, listed at 7 CFR 205.601(n), where it is allowed for use in delinting cotton seed. Hydrogen chloride was originally petitioned for use in 2002 (Wedel, 2002). It was recommended by the NOSB in 2004 (NOSB, 2009b) and added to the National List of Allowed and Prohibited Substances (hereafter referred to as the "National List"), effective in 2006 (71 FR 53299). As part of the sunset review process, it was reviewed again by the NOSB in 2009, 2015, and in 2019 (NOSB, 2009a, 2015, 2019). In all these meetings, hydrogen chloride was deemed the only available solution for organic farmers needing to delint cotton seed. In the most recent sunset review in October 2019, a motion to remove hydrogen chloride from the National List was unanimously rejected by all 13 attending voters. The NOSB noted (NOSB, 2019):

> public comments were universally supportive of relisting hydrogen chloride as essential and asserted that failure to do so would irreparably harm the U.S. organic cotton industry. Allowing the limited use of hydrogen chloride for seed preparation accrues economic and environmental benefits by supporting domestic organic cotton production and avoiding associated impacts of heavy pesticide use on conventional cotton. The need for additional specialized research to support alternatives to hydrogen chloride, a caustic and potentially harmful material, were emphasized, and is supported by the NOSB.

This technical report focuses on updates to the availability of alternative substances and practices for cotton seed delinting.

Background

At cotton (*Gossypium hirsutum*) maturity, the outermost layer of the cotton seed coat has two types of fibers: long lint fibers and short "linters" (see Figure 1, below). Linters are darker, shorter, more nearly cylindrical, and have thicker walls and narrower central canals than the fiber cotton (Hock, 1947). Cotton ginning removes most of the cotton lint fibers (see Figure 2, below) but some fuzz (short fibers or linters) stays. The fuzz can capture moisture that stays in contact with the seed, thus creating conditions conducive for fungal infection (Afzal et al., 2020). In addition, the fuzz can interfere with grading, handling and mechanical planting (Delouche, 1986).[1] Delinting is a necessary process to improve storage and flowability of cotton seeds through equipment (Holt et al., 2017).

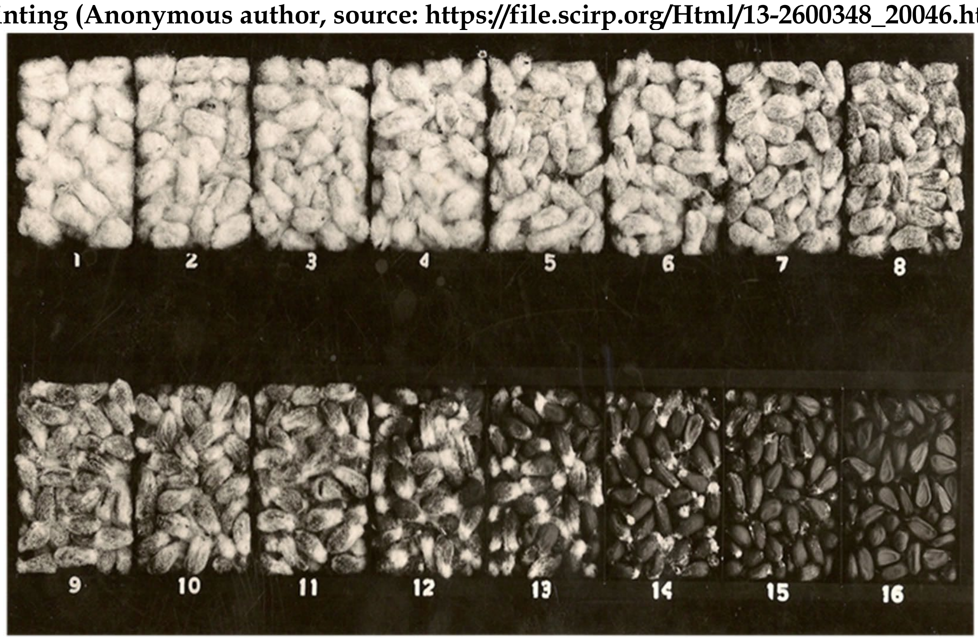
The delinting process has only a very slight effect on the germination rate. Ryavalad et al. (2009) observed that the germination rate of fuzzy seeds after nine months of storage was 66.3% as opposed to 68.3% for acid delinted seed. McMichael et al. (2004) noticed that mechanical and acid delinting resulted in the same

[1] *Grading is a process used by seed companies or storage facilities to classify seed based on physical characteristics such as size, shape, moisture content, color, texture, foreign matter, etc. This process ensures seed consistency.*

germination rate and yield. Similarly, earlier research has shown that delinting does not necessarily affect yields (Wilkes & Corley, 1968). An up-to-date account of cotton seed germination requirements is adequately provided in Maeda et al. (2021). The importance of the delinting process is thoroughly discussed by Atique-ur-Rehman et al. (2020). Historically, cotton seed has been delinted through chemical or mechanical approaches (Delouche, 1986).

Figure 1: Linted cotton seed. Photo credit: Ashraf Tubeileh

Figure 2: Variable degrees of cotton seed delinting. Fully delinted seed (16) is likely achieved using acid delinting (Anonymous author, source: https://file.scirp.org/Html/13-2600348_20046.htm).



Allowed process: hydrogen chloride

The gas-acid or dry acid delinting method uses hydrogen chloride (anhydrous hydrochloric acid) to degrade the linters, which are then separated from the seed (Ardashev, 1933). This method is the most common method in Texas (Hopper & Hinton, 1979). It is most suitable when the cottonseed moisture content is <9%, as hydrogen chloride is a gas with a high affinity for water, and its penetration through the seed coat into the embryo increases with higher seed moisture content (Delouche, 1986). In addition, high humidity accelerates equipment corrosion, making the gas-acid method less adapted to humid regions (Delouche, 1986).

The process is as follows (Delouche, 1986):

1) Seeds with 5-7% moisture content are placed in a rotating drum at 60-70°C before injection of the gas-acid at a concentration of 0.5-2.0% of seed weight.
2) Seeds remain in the drum between 5 and 20 minutes, depending on the temperature, seed moisture content, concentration of the gas-acid and variety.
3) The degraded linters are removed by passing the seed through a perforated reel to allow the drop of the linters.
4) The acid is neutralized using ammonia, resulting in flowable seed ready for planting or storage.

Gas-acid delinting uses less acid and is generally less expensive than another process, the wet acid method (Delouche, 1986). This method is discussed below, in *Evaluation Question #11*. However, the gas-acid method requires sophisticated equipment, close monitoring, and stringent control of the various operations for effective delinting without injury to the seed. Seed injury from the process can cause a drastic drop in germination and vigor. Seed injury can occur due to excessive temperature, gas-acid concentration, reaction duration, or too-long exposure to ammonia during neutralization. Poorly controlled gas-acid delinting can cause a drastic reduction in germination and vigor (Delouche, 1986).

Evaluation Questions for Substances to be used in Organic Crop or Livestock Production

Evaluation Question #11: Describe all natural (non-synthetic) 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)).

Nonsynthetic Alternatives for Delinting

Given the extremely low pH (1.5-3) required for effective acid delinting, no non-synthetic substances are available as alternatives to synthetic acids for cotton seed delinting. However, alternative allowed practices are available and detailed in the answer to *Evaluation Question #12* (below).

Synthetic Alternatives for Delinting

Aside from hydrogen chloride, no other synthetics on the National List are allowed for cotton delinting. Sulfuric acid (H_2SO_4) is the most common material used for delinting (Afzal et al., 2020). However, sulfuric acid is not currently an allowed material for delinting organic cotton. The NOP allows this material to be used to adjust the pH of liquid fish or liquid squid organic fertilizer products, provided that the amount used does not exceed the minimum needed to lower the pH to 3.5 (7 CFR 205.605(j)(8) & (10)).

In addition to sulfuric acid, other synthetic substances used in conventional cotton seed delinting include acids such as anhydrous hydrochloric acid (gas) and alkanesulfonic acid (Borst & Zack, 2015).

Non-allowed process: wet-acid method (sulfuric acid)

This method uses sulfuric acid, which is not allowed in organic production for cotton delinting. As detailed by Maeda et al. (2021), cotton seed producers can use concentrated or diluted sulfuric acid.

In the concentrated wet-acid method (Delouche, 1986; Tostes et al., 2022):

1) Gin-run seeds are wetted with concentrated (93-98%) sulfuric acid at a dose of 80-140 mL/kg seeds with linters, with an acid/seed turning time of 7-8 min (Biradarpatil & Macha, 2009; Tostes et al., 2022).
2) Seeds are washed with water for 2 min. After washing, seed is placed in water with a ratio of 1:10 for removal of floaters.
3) Seeds are immersed in a neutralizing solution for 10–15 min using one of the following basic compound: sodium hydroxide (NaOH), sodium carbonate (Na_2CO_3), calcium hydroxide [$Ca(OH)_2$] (Tostes et al., 2022), calcium chloride ($CaCl_2$) (Atique-ur-Rehman et al., 2020) or different types of lime (Lima et al., 2023).
4) Seeds are dried before moving to the cleaning, grading, treating, and packaging line.

In the dilute wet-acid method:
1) Dilute (~10%) sulfuric acid is used to wet the linters.
2) The wet seeds are then dewatered by centrifugation and dried with heated air to evaporate water, increasing the concentration of the acid.
3) The degraded (hydrolyzed) linters are removed by frictional forces in a rotating buffer-drum.
4) Residual acidity is neutralized with ammonia or by adding lime in the seed treatment process (Delouche, 1986).

The advantages of the dilute wet-acid delinting process are:
- Reduction in the quantity of sulfuric acid required (due to lower quantity used and recovery during dewatering).
- Elimination of the effluent produced in wet-acid delinting.
- Production of by-products (hydrolyzed linters removed during the buffer-drum step) that have potential value in ethanol production and as an animal feed additive (Delouche, 1986).

Non-allowed process: alkanesulfonic acid
Alkanesulfonic acid is another synthetic material that has been recently reported for cotton delinting. Like sulfuric acid, this method is not allowed in organic production. BASF applied for a patent for this material in 2015 (Borst & Zack, 2015). This method comprises:
1) Applying alkanesulfonic acid to surfaces of linted cotton seeds, and optionally heating the linted cotton seeds. A surfactant and water are added to the acid.
2) Applying mechanical force to the surfaces of the linted cotton seeds.

No experimental evidence of the use or efficacy of this material is available in scientific literature. Acid delinting, however, can easily cause damage to seed viability with improper acid exposure time. It has also been reported to reduce seed shelf life and is a relatively expensive process.

Evaluation Question #12: Describe any alternative practices that would make the use of the petitioned substance unnecessary (7 U.S.C. § 6518 (m) (6)).
Historically, three different methods have been used to delint cotton seeds: mechanical, flaming and chemical (Delouche, 1986). Mechanical and flaming methods were more common before the development of acid delinting methods (Bourland, 2019). Earlier researchers found that although fuzzy seeds tended to emerge more slowly, little difference in stands or yields existed between fuzzy, acid-delinted, and mechanically delinted seed (Wilkes & Corley, 1968).

Mechanical delinting
Mechanical delinting is another method to minimize the amount of lint on the seed. In the mechanical process, physical abrasion removes the fuzz from the surface of seed (Holt et al., 2017). This method requires effort and time but it preserves the seed from chemical injuries (Armijo et al., 2006).

Mechanical delinting can reduce the lint amount down to 1.5% (weight/weight) (Olivier et al., 2006). The original weight/weight of lint is not provided. The duration of mechanical delinting can affect cottonseed quality. Hopper et al. (2003) reported that mechanical delinting for 10 minutes was generally equal to or superior to 20- and 60-minute delinting times. The USDA cotton research group in Texas has successfully built a commercial scale mechanical delinter. However, up to the date of writing this report, there has been no industrial partner ready to manufacture it (Greg Holt, personal communication). Seed handling and planting flowability of mechanically delinted seed can be further improved by seed coating, which can be done using natural or synthetic compounds. This is a practice that has been used in preparing cottonseed as animal feed. Natural compounds used include plant starches (maltodextrins) and gum Arabic (Afzal et al., 2020). Corn starch has been successfully used for cotton seed (Hopper et al., 2003).

In one study, researchers evaluated two cotton cultivars: one that involved mechanically-treated seed coated with gelatinized corn starch (called EasiFlo), versus another that was delinted with an undisclosed acid (Olivier et al., 2006). The mechanical delinting process reduced the residual linters on the seed to about 1.5% by weight. Three seed-vigor tests (warm germination test, cool germination test, and cool warm vigor index) resulted in similar results for both seed treatments. Moreover, three commercial-scale field experiments showed that lint yield was not statistically different between the two treatments (Olivier et al., 2006).

Flame delinting

Flame delinting or zipper delinting is a process used by seed processing facilities on mechanically delinted seed which are dropped through an intense flame to singe or burn off loose linters. Flowability of the cotton seed is substantially improved, but not sufficiently for precision cleaning and conditioning methods which separate despined cocklebur s and immature, low density seeds (Delouche, 1986). The seeds exposed to flaming need to be cooled down quickly to avoid damage to the embryo that might affect germinability and vigor (Delouche, 1986).

Chemical (acid) delinting

Acid delinting was developed in response to the drawbacks of mechanical delinting. Mechanical processes damaged the seed physically or by the heat generated from repeated friction with the seed, therefore weakening or killing the embryo (Delouche, 1986). In addition, mechanical delinting alone was not very efficient at removing the linters off the seed (Delouche, 1986). Acid delinting also has the added benefit of reducing microbial contamination and seed-borne pathogens (Chohan et al., 2020; Delouche, 1986). As a result, most cotton planting seed in the U.S. are acid delinted using either hydrochloric acid (dry acid method) or dilute sulfuric acid (wet acid method) (Pilon et al., 2016).

Breeding fuzzless seed

A fuzzless upland cotton mutant (9023 n_4^t) was developed from the cultivar 'SC 9023' through chemical mutagenesis by the Texas USDA cotton research group and Texas Tech University in Lubbock (Bechere et al., 2012). This mutant strain gins faster and with less energy when compared to other conventional and transgenic cultivars (Bechere et al., 2011). Early breeding efforts have continued to show that another fuzzless genotype is possible through identification of genes controlling fuzz fiber production (Erpelding, 2016b). Until 2016, four fuzzless genotypes have been identified in the USDA *Gossypium arboretum* collection, which would suggest the presence of multiple genes for the fuzzless trait in this germplasm collection (Erpelding, 2016a). These genotypes could be potential breeding candidates to develop fuzzless cotton cultivars that would remove or reduce the need for cottonseed delinting.

Focus Questions Requested by the NOSB

Focus Question #1. What new alternative substances or practices, if any, have become available since the last limited scope report in 2014? Are there any updates regarding the mechanical cottonseed delinter made by the USDA and referenced in the 2014 report on hydrogen chloride?

Researchers at the USDA-ARS Cotton Production and Processing Research Unit in Lubbock, Texas, describe construction of a prototype small-scale benchtop mechanical cotton seed delinter (Holt et al., 2017). The researchers evaluated different drum linings and different roller brush combinations for "scrubbing" lint from the cotton seed. In addition, two processing times (five and ten minutes) were evaluated. Researchers measured the following parameters:

- lint loss (i.e., residual lint remaining on the seed after processing)

- germination
- visible mechanical damage of the seed
- visual observations of durability

The researchers found that an alternating brush pattern of half nylon and half steel wire bristle brushes is the best drum material using either one or two roller brushes (Holt et al., 2017). The best processing time in terms of the lint loss values was ten minutes. Lint loss values of the seed with one or two roller brushes at ten minutes were 0.95% and 0.88%, respectively. Germination rates for seed delinted using this system at five and ten min were not statistically different (89.3% and 88.4%, respectively). The brush material used (42N42W) appeared to be the most durable and was one of the easiest materials evaluated to clean out between samples (Holt et al., 2017).

Based on the bench-top prototype detailed in (Holt et al., 2017), the group built an 8-ft commercial scale prototype that could delint approximately 1000 lb./hour of fuzzy upland cottonseed (Figure 3, Figure 4) (Greg Holt, personal communication). The delinter will be tested at a commercial cotton gin in New Mexico during the 2023-2024 ginning season. To complement the mechanical delinter, a cottonseed preconditioning system was also developed to handle several tons of seed per hour. The preconditioning system is designed to remove 4 to 6% of residual lint from fuzzy upland cotton prior to the mechanical delinter to improve the processing throughput (Greg Holt, personal communication). Preliminary tests have shown that lint percentage dropped from 12.4% in initial fuzzy seed to 8.4% with two passes in the delinter (Holt et al., 2022). A larger version of the 8-ft mechanical delinter could be developed if a manufacturing company decides to adopt it. However, as of the development of this report, no such arrangements are planned (Greg Holt, personal communication).

Other techniques to improve cotton seed germination

Seed plasma treatment is a new, non-chemical approach to sanitize seeds and protect against fungi and bacteria (de Groot et al., 2018). Plasma is formed by an electric discharge in a gas. In the case of an air plasma it consists of ions, energetic electrons, neutral species, reactive oxygen species and reactive nitrogen species, and produces electromagnetic radiation such as UV. Cold plasma treatment of cotton seeds significantly improved water absorption and germination parameters, including the four-day warm-germination and metabolic-chilling tests, and seed imbibition. This method could be promising in providing protection during storage to conserve or improve germination of seed delinted mechanically or using other organically-approved methods (de Groot et al., 2018).

Figure 3: Mechanical delinter developed by USDA-ARS in Lubbock, Texas. Photo credit: Greg Holt.

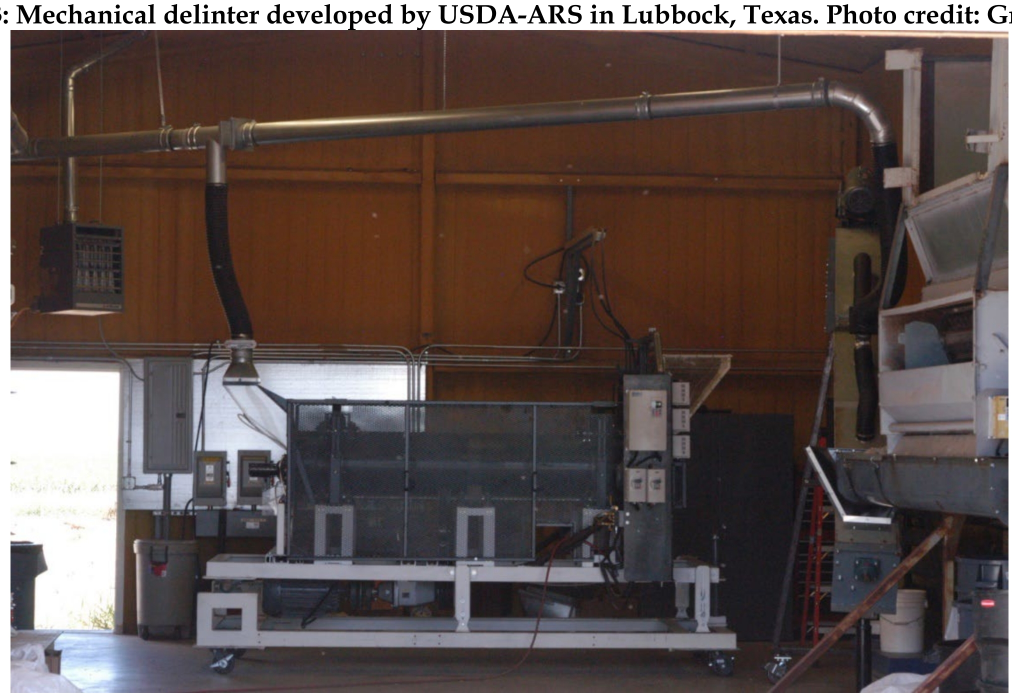


Figure 4: Lint discharge end of the machine. Photo credit: Greg Holt.

Report Authorship

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

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