# Diatomaceous earth: Advantages and limitations

Paul G. Fields[1]

*Abstract*

The grain industry needs to reduce its reliance on synthetic pesticides because of insecticide deregulation, resistant populations and consumer concerns over insecticide residues. Diatomaceous earth (DE)-based insecticides are finding increased use as stored commodity protectants because of these concerns DE is obtained from geological deposits of diatomite, which are fossilized sedimentary layers of microscopic algae called diatoms. DE, made up mainly of $SiO_2$, works as an insecticide through physical mechanisms. The fine DE dust absorbs wax from the insect cuticle, causing death due to desiccation.

The main advantages of DE are its low-toxicity to mammals and its stability. However, several problems limit its widespread use: reduction of the bulk density and flowablity of grain, dusty to apply, low efficacy against some insects and reduction in efficacy at high moisture contents. Finally there has been concern that DE will increase wear on machinery, but there are no data to support or refute this hypothesis.

The purpose of the workshop on diatomaceous earth is to provide people with enough information to be able to use DE effectively We have divided the workshop into five presentations covering: Introduction (this paper), Efficacy (Subramanyam), Evaluations and Standardized Testing (Korunic and Ormesher), Application (Bridgeman), and Safety (Desmarchelier and Allen)

## Concerns with Insecticides

In the last 60 years, the story of insect control has been written predominantly by the chemists and the toxicologists. The stunning successes of the organochlorines, organophosphates and fumigants in controlling insects in the 1950's led to a dramatic increase in the number and quantity of insecticides used in agriculture (Ware, 1988). With the publication of 'Silent Spring' by Rachel Carson (1962), the public, scientists and the agricultural community began to examine the hidden costs of chemical pesticide control

The costs or disadvantages of the chemical insecticides fall into one of two categories. One, insecticides have negative effects on non-target organisms Insect parasites and predators, which would normally keep pest insect populations in check, can be killed by insecticides. Also insecticides can be toxic to fish, birds, or mammals. Some insecticides (eg. malathion, chlorpyrifos-methyl, pirimiphos-methyl or deltamethrin; Snelson, 1987; White, and Leesch, 1995) used to control stored-product insects must be applied directly to the grain, and therefore residues can be ingested by consumers. Given that the effects consuming low levels of insecticide residues for many years are unknown and effects may only appear after years of exposure, there is a desire to have foods free of pesticide residues. Two, the widespread use of a single insecticide or a class of insecticide can lead to resistance with the pest populations (Subramanyam, 1995)

These two factors have caused a reduction in the number and quantity of chemical insecticides used in stored grain A case in point; at present two grain fumigants, phosphine and methyl bromide, remain in common use, yet Bond (1984) listed 13 such materials only 15 years ago Even methyl bromide will soon be severely restricted or discontinued because of its contribution to stratospheric ozone depletion (Watson et al. 1992).

In response to these concerns, alternative methods, many in use before the arrival of chemical insecticides are seeing a renaissance. Physical methods of pest control in grain storage are becoming increasingly important. Physical control of insect pests involves the manipulation of physical factors to eliminate pests or reduce their populations to a tolerable level. Temperature, relative humidity, atmospheric composition, impact, desiccation, physical exclusion, removal, and ionizing radiation all may be employed separately or in combination. It is likely that physical methods of pest control will become the method of choice for advanced systems of grain handling and storage (Banks and Fields, 1995)

## Diatomaceous Earth

Inert dusts have a long history of use for grain protection (Ebeling, 1971; Ross, 1981; Korunic, 1997; 1998). There are four basic types of inert dusts:

- clays, sands and earths that are used as top dressing in traditional grain stores;
- synthetic silica aerogels that are light, fine powders made

[1] Agriculture and Agri-Food Canada, Cereal Research Centre, 195 Dafoe Rd, Winnipeg, MB, R3T 2M9, Canada, pfields@em agr ca

up of 100% $SiO_2$;

- non-silica dusts such as pulverised phosphate rock and calcium hydroxide; and
- diatomaceous earth (DE) (Fig. 1).

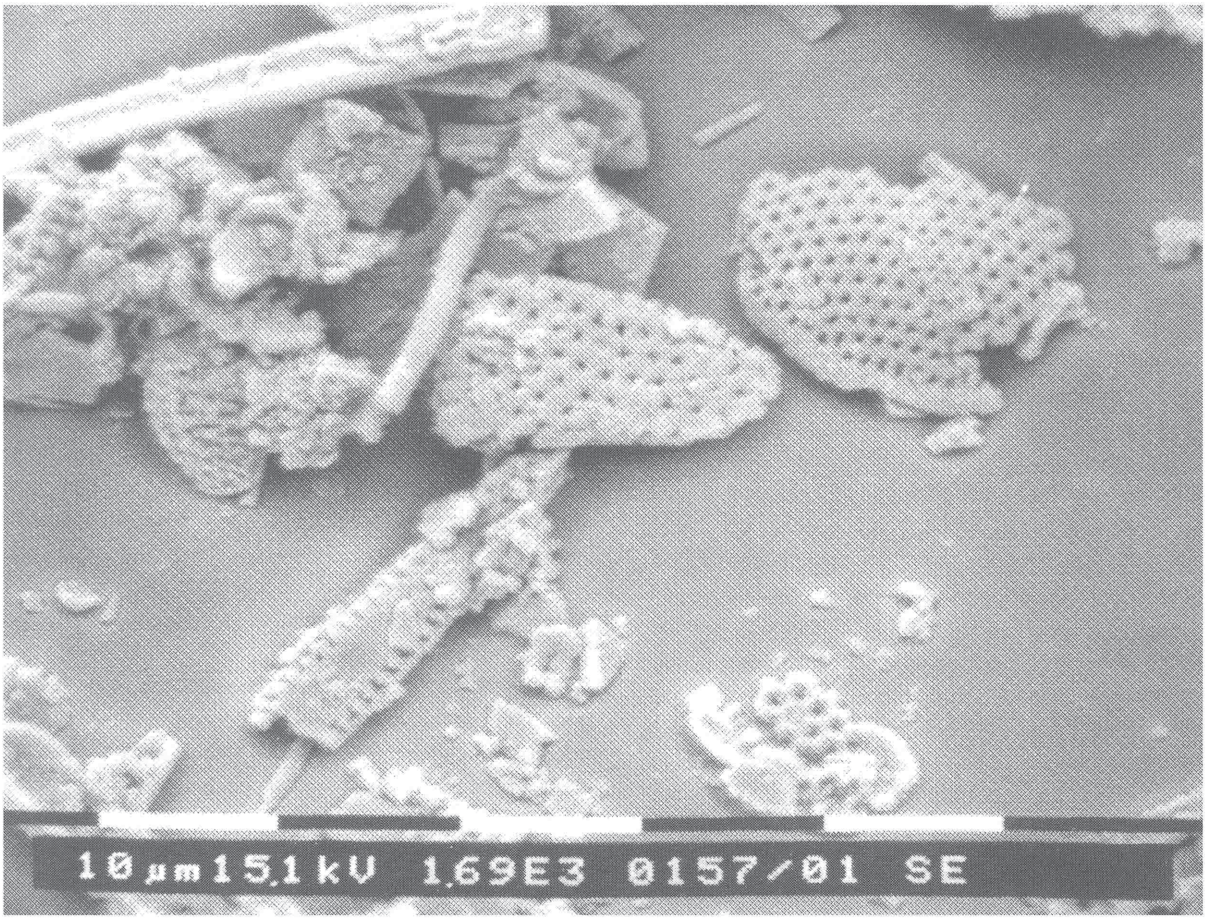


**Fig. 1.** Scanning electron micrograph of diatom remains in the DE, Celite 209.

DE is a light weight, porous sedimentary rock made up of the prehistoric remains of diatoms (Round et al., 1990), which are microscopic, unicellular, aquatic-plants that have a fine shell made of amorphous hydrated silica. There are three types of commercial deposits; marine DE found on the continental margins, freshwater DE from diatoms from lakes or marshes, and sediments from present day water bodies. Geological deposits of DE can be hundreds of metres thick (Ross, 1981). Many of these sedimentary layers originated 20 to 80 million years ago. After quarrying, crushing and milling, a fine light dust is obtained. The main constituent of these deposits is silica ($SiO_2$) although there are small amounts of other minerals (aluminum, iron oxide, lime, magnesium, and sodium). DE is actively mined around the world, with the main producers being Untied States (705 t/yr), Russia (100 t/yr), Denmark (96 t/yr), France (85 t/yr) and Korea (80 t/yr). The world production of DE in 1997 is estimated at 1.4 million t (Anon., 1998). It has many uses: filters in food processing and swimming pools, cosmetics, insulation, anti-caking agents, filler and absorbent. Several proprietary insecticidal formulations are available, some of which contain additional materials, e.g., ammonium fluorosilicate, silica aerogel or attractants, that are said to enhance their potency.

## Advantages

There are several advantages to using DE to control stored-product insect pests. The low mammalian toxicity of DE makes it simpler for applicators to apply (see paper by Bridgeman). Phosphine and methyl bromide are acutely toxic and require specialized training, licencing and protective equipment and storage. Pesticide residues are a concern throughout the grain and food processing. In the USA and Canada, DE is registered as a feed additive. Amorphous silicon dioxide is considered Generally Recognized as Safe (GRAS), and is a registered food additive in the USA and Canada. Most of the DE registered as insecticides are more than 90% amorphous silicon dioxide. Silicon dioxide has low mammalian toxicity (3160 mg/kg LD50, rat oral; NIOSH, 1977, see paper by Desmarchelier and Allen).

As DE is inert, it provides long-lasting protection as long as the grain or structure remains dry (White et al , 1975). In Australia DE is used extensively as a pre-harvest structural treatment (see paper by Bridgeman), because organophosphates degrade rapidly in the heat, but the DE remains effective for long durations. Unlike the fumigants which are used as curative treatments, DE is applied as a preventative treatment, as a structural treatment before grain is placed in storage and as a residual on freshly harvested grain as it goes into storage The long lasting protection provided by DE makes it ideal to be used in this capacity In addition to Australia, DE is registered as a grain protectant or for structural treatment in Canada, China, Croatia, Germany, USA and some other Asian countries

Extensive testing has shown that there is no effect on end use quality; baking, malting or pasta production (Desmarchelier and Dines, 1987; Aldryhim, 1990; Korunic, et al. 1996).

## Limitations

The main limitations of DE are; reduction in the flowability of grain, reduction of the bulk density of grain, ineffective in some situations, discomfort due to air borne dust and health concerns due to crystalline silica

DE sticks to the surface of the kernels and increases friction between grains. This causes increased angles of repose and decreased bulk densities (Korunic et al , 1998). DE at 500 ppm decreases bulk density by about 6 kg/hl in wheat, barley, oats, rye or corn Also the source of DE affects how much the bulk density is reduced There can be as much as a four-fold difference in reduction in bulk densities between DE sources (Korunic et al, 1998; see paper by Korunic and Ormesher). Unfortunately, the DE that are the most effective insecticides, are also the ones that reduce the bulk densities the most (Korunic, 1997)

As desiccation is the mode of action, DE does not control insects in moist grain as well as in dry grain (le Patourel, 1986; Aldryhim, 1993). Unlike a fumigant, it will not control the immature stages that remain within the grain kernel eg Sitophilus spp Efficacy will be covered in detail in the paper by Subramamyam.

Application of inert dusts can be undesirable because of the dust generated. To alleviate this, aqueous applications for surface treatments are used in Australia (see paper by Bridgeman), although this somewhat reduces the effectiveness of the inert dusts (Maceljski and Korunic 1972). DE can be used as a mild abrasive and there is concern over increased wear on grain handling machinery. However DE is relatively soft having a Moh's hardness index of 2, which is softer than gold (2.5 – 3), copper (2.5 – 3), nickel iron (5) and quartz (7) and diamond (10) (Glover, 1997). Tests need to be conducted to determine if DE does increase on the actual wear on grain handling and milling equipment.

Depending upon the source and processing, DE can contain from 60 to 0.1% crystalline silica. The DE registered as insecticides generally have less than 7% crystalline silica For other uses, DE is heated or calcined and the crystalline silica content can increase to more than 60% Crystalline silica has been shown to be carcinogenic if inhaled (IARC, 1997) However, the use of proper dust masks, or the use of low crystalline silica DE can protect against this health risk (see paper by Desmarchelier and Allen).

To overcome some of these limitations DE can be used as a top dressing or applied in layers in the granary. This method has been used in the USA. In Australia, DE has been used in combination with low dose, long duration phosphine treatment (SIROFLO; Winks and Russell, 1994) or with aeration (Nickson et al , 1994). These methods of application reduce the amount of DE needed and hence would reduce the cost and the reduction in bulk density. Finally, DE is one tool of many and it should be used not in isolation but as part of an integrated pest management program.

## Acknowledgments

I am grateful to Suvira Prashar for taking the SEM photograph and Zlatko Korunic for reviewing the manuscript.

## References

Aldryhim, Y. N 1990. Efficacy of the amorphous silica dust, Dryacide, against *Tribolium confusum* Duv. and *Sitophilus granarius* (L ) (Coleoptera: Tenebrionidae and Curculionidae). Journal of Stored Products Research, 26, 207 – 210

Aldryhim, Y. N 1993. Combination of classes of wheat and environmental factors affecting the efficacy of amorphous silica dust, Dryacide, against *Rhyzopertha dominica* (F.) Journal of Stored Products Research 29, 271 – 275.

Annon., 1998, Mineral Commodity Summaries. United States Geological Survey, Washington, 197 p

Banks, H. J and Fields, P 1995. Physical methods for insect control in stored-grain ecosystems. In Jayas, D S., White, N D. G. and Muir, W. E, ed Stored Grain Ecosystems, Marcel Dekker Inc, New York 353 – 410.

Bond, J 1984 Manual of fumigation for insect control. Food and Agricultural Organization, Plant Production and Protection Paper No 54. Rome, Italy. 432 p.

Carson, R. 1962 Silent Spring. Fawcett Crest Books, CBS Publications, New York, 304 p

Desmarchelier, J M., and Dines, J C 1987 Dryacide treatment of stored wheat: its efficacy against insects, and after processing. Australian Journal of Experimental Agriculture, 27, 309 – 312

Ebeling, W. 1971. Sorptive dusts for pest control Annual Review of Entomology, 16, 123 – 158.

Glover, T J. 1997. Pocket Ref. Sequoia Publishing, Inc. Littleton, CO, USA, 554 p.

International Agency for Research on Cancer (IARC), 1997. Silica, some silicates, coal dust and para-aramid fibrils. Volume 68, IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, Lyon, 506 p.

Korunic, Z. 1997 Rapid assessment of the insecticidal value of diatomaceous earths without conducting bioassays. Journal of Stored Products Research, 33, 219 – 229

Korunic, Z 1998. Diatomaceous earths, a group of natural insecticides. Journal of Stored Product Research, 34, 87 – 97.

Korunic Z., Fields, P. G , Civics, M. I. P , Noll, J. S., Lukow, O. M., Demianyk, C. J., and Shibley, K J 1996. The effect of diatomaceous earth on grain quality. Postharvest Biology and Technology, 9, 373 – 387.

Korunic Z , Cenkowski, S. and Fields P 1998. Grain bulk density as affected by diatomaceous earth and application method. Postharvest Biology and Technology 13, 81 – 89.

le Patourel, G. N. J 1986. The effect of grain moisture content on the toxicity of a sorptive silica dust to four species of grain beetles. Journal of Stored Products Research, 22, 63 – 69

Maceljski, M , and Korunic, Z 1972 Trials of inert dusts in water suspension for controlling stored-product pests. Zastita Bilja, 22, 377 – 387.

National Institute of Occupational Safety and Health (NIOSH) 1977. Registry of Teoxic effect of Chemical Substances. U. S. Department of Health Education and Welfare DHEW Publication Number. (NIOSH) 78 – 104 – A. Government Printing Office, Washington, D C

Nickson, P.J., Desmarchelier, J.M. and Gibbs, P 1994. Combination of cooling with a surface application of Dryacide to control insects In: Highley, E., Wright, E. J., Banks, H. J and Champ, B R. Eds., Proceedings of the 6th International Working Conference on Stored Product Protection. pp 646 – 649 CABI, Cambridge.

Snelson, J. T 1987. Grain Protectants. Monograph no. 3, Australian Centre for International Agricultural Research, Canberra, Australia, 448 p.

Ross, T. E 1981 Diatomaceous earth as a possible alternative to chemical insecticides. Agriculture and Environment, 6, 43 – 51.

Round, F. E., Crawford, R. M. and Mann, D. G 1990. The diatoms Cambridge University Press, Cambridge, 747 p.

Subramanyam, Bh 1995. Resistance measurement and management., In Subramanyam, Bh. and Hagstrum, D ed Integrated Management of Insects in Stored Products, Marcel Dekker, New York, 331 – 398.

Ware, G. W., 1988. Complete guide to pest control: with and without chemicals. Thomson Publications, Fresno, 304 p.

Watson, R. T , D. L. Albritton, S. O. Andersen, and L. Lee-Bapty. 1992. Methyl bromide: its atmospheric science, technology and economics. United Nations Environment Programme, Nairobi. 42 p.

White, G. D , W. L. Berndt, and J. L. Wilson. 1975. Evaluating diatomaceous earth, silica-aerogel dusts, and malathion to protect stored wheat from insects. Marketing Research Report United States Department of Agriculture, No 1038 18 p

White, N. D. G., and Leesch, J. G. 1995 Chemical Control, In: Subramanyam, Bh and D. Hagstrum, D ed., Integrated Management Of Insects In Stored Products, Marcel Dekker Inc , New York, 287 – 330.

Winks, R G. and Russell, G.F. 1994. The effectiveness of SIROFLO in vertical silos In: Highley, E , Wright, E. J., Banks, H J. and Champ, B.R. Eds., Proceedings of the 6th International Working Conference on Stored Product Protection. pp. 1245 – 1249. CABI, Cambridge.