Application technology and usage patterns of diatomaceous earth in stored product protection

Barry Bridgeman[1]

Abstract

Use of diatomaceous earths (DEs) as insecticides for the protection of stored products has increased significantly during the last 5 to 10 years This increase has been primarily due to the convenience of a physical control agent in a bag DE has satisfied the need for a cost effective, non-chemical control strategy compatible with modern integrated pest and resistance management

DEs are used as both wet and dry treatments admixed directly with the grain mass by hand or via screw augers as the grain enters the storage DEs also an important role in the disinfestation of grain storage structures In Australia, surface application and top dressing of grain bulk with DE has proven a successful component of integrated control strategies based on cooling with aeration and flow through fumigation. Work in Australia has also shown there is a significant synergistic response to DE and grain protectant mixtures in target pests Recent work in the USA has integrated the use of DE with heat to replace methyl bromide fumigation as a disinfestation process for flour mills.

While the insecticidal properties of some diatomaceous earths have been well researched and known to industry for many years, it has been the innovative development of suitable application technology which has accelerated the eventual acceptance of this control agent. Many of the developments in application methods and systems for DE have involved only minor alterations to standard application equipment.

Introduction

The primary challenge in pest management in the grain industry has altered very little over the past three decades, however, the rules and conditions under which this challenge must be met have changed significantly The primary task is still to provide long term insect free storage. How freedom from insect infestation is achieved is now a much more complex issue than in the 1960s. Markets have dictated that this task must now be achieved without using residual chemical (grain protectants) admixture. In addition, the demise of the fumigant, methyl bromide, due to the international phase out of ozone depleting substances, and reports of the development of resistance to phosphine in target pests, have added further to the complexity of the task It is clear that the traditional control tactics are no longer the easy, reliable solution they once were.

Experience has shown that integrated pest management (IPM) is the most effective way that the grain protection industry can deliver its charter in a future where product must be out-turned insect and residue free, without the use of fumigants such as methyl bromide (Bridgeman and Collins 1994). It is as a component of IPM that diatomaceous earths (DE) have found a major role to play (Bridgeman 1994; Nickson et al 1994). The recent successes of DE in control strategies have been in synergy with other controls. For example, DE have been used to enhance the efficacy of aeration, fumigation and heat in trials in the US and in Australia (Golob 1997, B Bridgeman Unpublished Data 1996, Winks and Russell 1994, Fields et al 1996)

While the introduction of several formulations of DE onto the marketplace has confused the issue of the efficacy these materials, application techniques are the same for all formulations There is now a variety of DE formulations for application to grain and grain storages (Golob 1997; McLaughlin 1994) They have similar modes of action and the same deficiencies (Golob 1997). Some are much more efficacious than others (McLaughlin 1994; Allen and Desmarchelier 1998). The activated formulations are the more efficacious (McLaughlin 1994; Golob 1997), however, good results can be achieved from the unmodified dust of the right particle size (McLaughlin 1994; Golob 1997; Allen and Desmarchelier 1998)

At the previous conference in this series (Highley et al. 1994), DE received a modest response for papers and average interest in the session The field demonstration was impressive and following on from that, the interest in DE continued to increase particularly in the US. Since that conference we have seen many developments in the use of DE. It would appear that the development of techniques for applying DE that has been the primary driving force behind the increased diversity of use of these materials

[1] Grainco Ltd; PO Box 136, Toowoomba, Queensland, 4350, Australia

Direct Admixture to Grain

DE was initially developed as a non-chemical grain protectant. Laboratory experiments confirmed that DE controlled all species but its effectiveness was dependent on moisture content (Desmarchelier and Dines 1987). In the field DE was successful as a grain protectant when admixed to grain However, because it significantly altered the handling characteristics of the grain, it was banned from grain being delivered to grain handling institutions of the time (Jackson and Webley 1994).

Application technology

The application technology for admixing DE to bulk grain ranged from a variety of elaborate 'shakers' to simple hand application into a screw auger. Much of the research looked at the evenness of application and the efficacy in the field Work on applicators lost its priority when the problems in handling the DE treated product were realised

Advantages

A reduction in the use of residual chemicals to protect grain in storage has been the desire of consumer groups for some time. The primary advantage proposed by using DE add-mixed to the bulk in this manner was that it was not a residual chemical The mode of action offered by DE is novel. Abrasion of the cuticle and desiccation causing death over a period of time is a physical control. The bonus of having the dust in a bag made this physical control agent readily accessible and very cost effective. DE is long lasting and does not decay over time as do the residual grain protectant chemicals, so retreatments were not necessary. DE is a cost effective physical control agent in a bag

Disadvantages

Despite the considerable advantages offered by DE, it does have major disadvantages when admixed to grain (Jackson and Webley 1994; Golob 1997).

Problems are caused by the DE altering the physical characteristics of the grain when admixed at the recommended rate. The DE changed the angle of repose of the grain which resulted in the grain not flowing. Auguring the treated product became almost impossible and as the angle of repose was changed the bulk became difficult to handle These issues resulted in the Australian Wheat Board (AWB) banning the delivery of the DE treated grain into the central handling system (Jackson and Webley 1994) DE is still registered for application to grain in Australia and is used on farm for feed grains and seed as well as on some niche market products such as organic grains

Structural Disinfestation and Protection of Bulk Storages

While considerable problems were experienced in admixture applications, the issues of significance in use of DE on structures involved occupational health and safety, application techniques, and effectiveness of the application In Australia, the use of DE to disinfest grain, pulse and oilseed storages is widespread The DE is used extensively in situations where chemical residues are a major issue.

The effectiveness of DE is dependent on ambient relative humidity (Desmarchelier and Dines 1987). The presence of humidity above 70% will result in significant survival This has been well established both in the laboratory and in the field Conversely use of DE in areas of low humidity is highly effective In Queensland, Australia, DE is used extensively in the drier grain growing areas where it is found to be very effective However, DE is not used at all in the ports, where the humidity is often quite high, because it is noticeably less effective (B. Bridgeman, unpublished data).

Application techniques for structural disinfestation can be divided into two major categories; Wet and Dry.

Dry/Dust Application of DE

Application of DE as a dust is relatively straight forward. The aim is to cover the storage fabric with a minimum of $2g/m^2$ coating of DE on all surfaces. The achievement of an adequate and even coverage of DE on all surfaces within a storage is almost impossible, however, DE application is much more effective dry than it is as a wet application (J Desmarchelier, personal communication). The are a number of dust applicators on the market which can apply the dust satisfactorily In Australia, the application method of preference for dry DE is the 'blowvac' a hand-held inexpensive venturi which relies on a small air compressor to achieve the dusting action Hand-held blowers have been used effectively to disperse the dust as well Aeration systems have also been employed to disperse the DE throughout empty storages

Advantages

It is cost effective and easy to apply as a dust. No specialised equipment is required and it requires a much smaller application to be efficacious

Disadvantages

DE as a dust poses significant environmental and worker safety issues (Desmarchelier and Allen 1998). The thick cloud of dust generated during application requires personal protective equipment to be worn and extreme care to be taken as vision is restricted to less than one meter The problem re-emerges during hygiene activities as the dust is disturbed by broom or compressed air. The significance of

the health effects of DE have yet to be confirmed, even so it would be foolish to disregard the obvious hazards common to most dusts regardless of any long-term effects they may have. All applications of DE are influenced by the moisture available at the treatment site. In areas of high relative humidity (eg wet floors) DE is generally ineffective (Bridgeman 1994)

Wet/Slurry Application DE

Although less efficacious when applied as a slurry, wet/slurry application of DE is widespread in Australia Several techniques are practiced. These involve atomising, spraying or squirting the DE/water 10% w/v mixture onto the storage structure to achieve 6 to 10 g/m^2. In accessible areas, results with most methods appears uniform and adequate. The equipment required with each technique varies considerably There is equipment for applying slurry commercially available

Atomising the mixture with high pressure pumping system

High pressure slurry pumps are commonly used in Australia to apply an atomised mist of DE and water on to the storage (Bridgeman 1991). These pumps are off the shelf items and need only minor modification to make them suitable for application of DE slurry. Results with this system were reported at the previous conference in this series (Bridgeman 1994).

Spraying the mixture

Conventional spraying systems designed for grain protectants have also been used While application of the slurry can be successfully achieved with this equipment the DE tends to be very abrasive This results in accelerated wear and tear on the pump and maintenance problems. This equipment was not designed to pump slurries and it is not recommended for this purpose.

Squirting the mixture with pump and compressed air

Compressed air can be used to blow and disperse a stream of DE and water mixture as it is hosed out of a mixture vat with a high volume water pump. This system gives a good effective coverage were the squirt reaches. The distribution of DE particles on the surface is uneven but adequate This system gains favour where the equipment required (large air compressor and water pump) is already at hand and used for other tasks The cost of providing this gear for the sole purpose of applying DE would be prohibitive. It must also be noted that high volume water pumps are not recommended for pumping slurries

Advantages

The major advantage slurry application has over dry dusting methods is the improved occupational safety. The only area where dust is generated is at mixing. The DE applied as a slurry adheres to the surface much better allowing a heavier application to be applied. Application on the structure is more even and the recommended rate can be more accurately applied Once on the structure, the DE tends to stay on longer, however field studies to confirm long term efficacy of treated structures have not been carried out.

Disadvantages

Wet applications must be applied at four to five times higher concentrations than dry applications to be efficacious. The equipment required for wet application is significantly more costly than that required for dry dust As with the dry application, the dust generated during hygiene activities is a significant problem

Integration with Aeration

The cooling of grain using aeration is used throughout Australia as a quality maintenance strategy. It is well recorded that controlling insect populations with aeration alone is not completely effective Trials using refrigeration or aeration with DE have indicated that reductions in populations of insects is possible if managed effectively (Nickson et al 1994) The process involved admixing DE to grain in the top of the silo This procedure gives a treated buffer of grain that will control immigrant insects in addition to those herded to the top of the silo by the cooling front. It was apparent from field trials that success is dependent on a number of factors. Initial population size, grain temperature, grain moisture content and insect species present in the bulk all appear to influence efficacy. Nevertheless, by ensuring nil detectable levels of insects at intake; a receival limit on grain moisture of 12% or less; early aeration to reduce temperatures as soon as possible, and at least 300mm of DE treated grain on top of the bulk significant (detectable) insect populations can be avoided. Control can be maintained if the grain temperature remains below 20℃ It is unlikely that these temperatures would be achieved during normal harvest period in tropical and subtropical environments Although control in these trials (Nickson et al 1994) was incomplete, it is encouraging that insect population development was significantly restricted. The use of DE and aeration is an area which will continue to evolve.

Integration with Fumigation

The use of DE as a dust to cap the grain surface in low flow phosphine fumigations is industry practice in bulk handling companies in Eastern Australia The use of low flow

technology has enabled insect free and residue free storage in poorly sealed or unsealed storages (Bridgeman and Collins 1994; Bridgeman and Davis 1998) The capping process has improved the success of these fumigations by ensuring retention of target concentrations of the fumigant in the top layer of the grain The DE is usually applied using a 'blowvac' (other dust application systems are also satisfactory) over the surface of the grain. The concentration to apply is difficult to quantify, however the application needs only to restrict air flow through the inter-grain spaces Four to five kilogram is enough to cover the surface of a 10 meter diameter bin Data collected during CSIRO tests of this process have indicated that use of DE in this manner gives superior results to covering the grain surface with a PVC cover (Winks and Russell 1994). In South Australia, the South Australian Cooperative Bulk Handling (SACBH) has successfully trialed the use of a slurry capping process in fumigation of open topped storages to reduce worker exposure to dusts. While the application requires specialised equipment, it is reported that the capping achieved by the process effectively seals the surface of the storage (G. Masters, personal communication, 1998).

Disadvantages of Surface Applications

In some areas the use of DE on the surface has caused problems with the grain flow (B. Bridgeman, unpublished data, 1997). This has been primarily due to the concentration of DE on the top of the grain being high enough to alter the flow characteristics of that top layer. The top layer comes down through the grain first and as it flows much less effectively it can cause the grain flow to backup and cause a blockage. This problem can be minimised by ensuring that the silo operator regulates the flow of grain. Once the treated partition of grain has moved the rest of the bulk behaves normally. It is also possible that some clients may question the presence of the dust in their grain if they were not aware of the use of the product in the storage strategy.

Worker safety with the dust is an issue with both these applications and comments on the safety of DE are relevant in this context.

Integration with Heat

Early trials on the efficacy of DE highlighted effectiveness increased with decreasing humidity The effect of temperature on insects is also well documented and heat disinfestation processes are utilised elsewhere in the industry with considerable success. It makes perfect sense from this point to test the synergies evident from existing data. Trials in the US have indicated that integrating the use of heat and DE to disinfest food processing facilities could be used to replace methyl bromide fumigations (Fields et al. 1997) These synergies of heat and DE, and low humidity and DE will in no doubt stand further exploitation

Concluding Comments

Diatomaceous Earth (DE) has enjoyed a significant increase in popularity within the Stored Product Protection Industry during the past several seasons. This increase has been primarily due to the non-chemical nature of the product and the need within the industry for a cost effective physical control agent in a bag is consistent with IPM and resistance management programs. It is in this role as an IPM tactic that DE will increase its usefulness in the future.

The challenge for the future of DE is to further the integration of DE other control tactics. It is more than likely that DE will be used in conjunction with other non-chemical controls rather than with a chemical solution. The relationship between DE and temperature (heat) and humidity will be explored further. It is this type of synergy which provides the results required.

Application methods are being developed at present to minimize the worker safety issue. It is essential the safety issues be resolved for this product to evolve further. The convenience of DE will also see the problems in handling treated grain revisited. Is DE treated grain a problem because it is difficult to handle, or is it a problem that existing machinery is inadequate and requires modification for a new age product?

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