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Predicting the concentration of phosphine and insect mortality with Computational Fluid Dynamics; Validation with field trials in cylindrical grain silos and shipping containers

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ABSTRACT

In the present work, a Computational Fluid Dynamics (CFD) model was used to predict the distribution of phosphine gas in metal shipping containers and metal silos. The model results were compared with available data from phosphine sensors. The CFD model solves the equations for air velocity, temperature, gas transport, phosphine sorption, and their respective implementation in porous media. Weather conditions were used as boundary conditions and the phosphine gas release as a source term. Additionally, insect mortality was calculated as a function of their exposure to phosphine gas. For each fumigated facility, wireless sensors were placed to monitor the concentration of phosphine, along with vials with phosphine-susceptible and -resistant insect populations. The insect species used were *Rhyzopertha dominica* (F.) and *Oryzaephilus surinamensis* (L.), two of the most common species found in stored products. The first facility was a 12.2 m (40 ft) shipping container loaded with currants. Three Mg_3P_2 plates were used for the fumigation process. There was a time delay for phosphine to reach the sensors that were submerged inside the fumigated commodity, at the rear side of the container. The second facility tested was a metal silo (530 tonne capacity). Aluminum phosphide bags were placed to produce the phosphine gas and a recirculation system was used to improve the diffusion of phosphine throughout the grain bulk. The predictions of the computational model were in accordance with the phosphine concentration as recorded by the sensors. Concerning insect mortality data, in most of the cases, for both species, complete control was noted, regardless of the resistance level of the population tested. As results indicated that the CFD model correlated well with the phosphine concentration and insect mortality, a methodology for precision fumigation can be established.

Keywords: Shipping container, Metal silo, Fumigation, Phosphine, Wireless sensors, Stored-product insects, Monitoring, Computational fluid dynamics, Mathematical modeling