Development of a New External Groundline Preservative Paste System: WP101-PRO®

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ABSTRACT

The development, testing, and EPA registration of a new groundline remedial paste formulation are described. The formulation has been developed in response to a general interest in remedial paste products that do not contain heavy metals such as copper. Test data indicate the product is effective in controlling wood-destroying insects and decay fungi. The formulation is stable and essentially non-toxic to humans. Concerns regarding the stability of the organic biocide component of the formulation are addressed.

Keywords: WP101-PRO®, groundline remedial paste, propiconazole, tebuconazole, disodium tetraborate decahydrate, Formosan termite, carpenter ant, heavy metals, copper

INTRODUCTION

Wood preservative groundline remedial pastes typically contain a primary biocide containing a boron compound and a secondary biocide containing copper. The primary biocide, generally present in the greatest concentration, rapidly diffuses into the wood to contain and control existing wood decay and/or insect infestation, while the secondary biocide (usually copper-containing) remains at or near the surface to protect against re-invasion.

In response to general interest in a groundline remedial paste that does not contain heavy metals such as copper, Poles, Inc., has developed a formulation containing only organic compounds as the secondary biocides. The organic biocides in the formulation behave similarly to copper compounds in having limited diffusion into wood and remaining primarily at the wood surface to provide prolonged protection.

Poles, Inc., obtained United States Environmental Protection Agency (EPA) registration for WP101-PRO® on December 12, 2017.[1] The EPA Registration Number is 88201-1.

Composition of WP101-PRO®

WP101-PRO® is a gray, semi-solid paste containing three active ingredients and several inert ingredients in order to provide an easily applied product of uniform consistency. The active ingredients are a borate compound and two triazole fungicides.

Borate Component

The borate component of WP101-PRO® is 45.5% w/w disodium tetraborate decahydrate, CAS No. 1303-96-4. Disodium tetraborate decahydrate is a well-known diffusible wood preservative with excellent activity against wood decay fungi and wood destroying insects.[2-5]

Triazole Component

WP101-PRO® contains 0.5% w/w (5,000 ppm) of each of two triazole fungicides: propiconazole (CAS No. 60207-90-1) and tebuconazole (CAS No. 80443-41-0). Propiconazole and tebuconazole are widely used fungicides in agriculture and are known to act synergistically in protecting wood against wood-destroying basidiomycetes, ascomycetes, Fungi imperfecti, molds and staining fungi, and soft-rot fungi.[6]

Based upon an examination of data provided by the NPIRS public database on pesticide registrations,[7] as of November 2017, there were 187 active EPA registrations belonging to 53 companies for products containing tebuconazole. The vast majority of these products have agricultural applications. Similarly, NPIRS lists 173 active registrations for products containing propiconazole belonging to 61 different companies. Like tebuconazole, the majority of products containing propiconazole are used in agriculture.

NPIRS lists 19 active product registrations for formulations containing a combination of both tebuconazole and propiconazole (additional active ingredients may be present). The majority of these formulations are used in wood protection and preservation.

WP101-PRO® Use Patterns

For externally applied treatments, WP101-PRO® is used for preventative and remedial treatment of wood, such as posts, poles, and timbers. The product stops wood decay and insect damage in progress and provides long-term protection against future invasion by wood-destroying organisms. Areas treated externally with WP101-PRO® should be covered with an approved moisture barrier stapled in place after treatment. WP101-PRO® is not applied directly to soil, nor is it applied to wood in direct contact with soil.

For internal treatments, such as internal decay, decay pockets, and voids in poles, posts, wooden bridge joints, and other timbers, WP101-PRO® may be applied by drilling holes in areas where treatment is needed and applying the paste using a pressurized applicator or grease gun. Holes should be plugged with tight-fitting wood or plastic plugs after application.

MATERIALS AND METHODS

Efficacy Testing

WP101-PRO® has been tested for its efficacy against decay fungi and insects, and for its ability to diffuse in wood. In addition, WP101-PRO® has undergone a battery of toxicology, product chemistry, and storage stability tests in order to qualify for EPA pesticide registration. After passing all required EPA reviews, registration was granted on December 12, 2017.

Laboratory Soil Block Decay Test, American Wood Protection Association E10-15, Michigan Technological University

A soil block decay test was conducted according to American Wood Protection Association (AWPA) Standard E10-15 by Michigan Technological University, Houghton, MI.[8] Conditioned (40% - 60% moisture content) southern yellow pine (SYP) soil blocks (19 mm cubes) were treated with three thicknesses of WP101-PRO® (1/16″, 1/8″, and1/4″) and the preservative allowed to diffuse into the treated wood for 30 days. After the diffusion period, any residual preservative was removed from the soil blocks, which were subsequently incubated in the presence of *Gloeophyllum trabeum* (ATCC 11539) for a period of 12 weeks. Control blocks were similarly treated but unexposed to the decay fungus. There were five replicate soil blocks per treatment. Weight losses were recorded and compared to those of appropriate control treatments.

Protection of Douglas-fir pole sections against attack by Carpenter Ants by treatment with WP101-PRO®

Laboratory trials were conducted at Spokane Falls Community College (Spokane, WA) under the supervision of Dr. Laurel D. Hansen, Ph.D., to determine the ability of WP101-PRO® to protect against attack by the western carpenter ant, *Camponotus modoc*.[9] Douglas-fir (DF) pole sections were freshly cut and hand-peeled. Three thicknesses of WP101-PRO® were applied, 1/16″, 1/8″, and 1/4″. There were four (4) pole sections per treatment with 4 poles left untreated as controls. After paste application, the pole sections (excluding the untreated controls) were externally wrapped with 16 lb. kraft paper (2 mil polyethylene on the treatment side of the paper) to mimic a field application. Wrapping prevents the paste from leaving the treated area, encourages diffusion of protectant into the wood, and protects the surrounding soil from contamination. The top and bottom ends of the pole sections were left untreated and unwrapped, leaving approximately one inch of wood exposed at either end of each pole, in order to allow the carpenter ants access to untreated wood. The treated and wrapped pole sections were placed in closed plastic totes and the wood preservative allowed to diffuse for 23 days.

For exposure to carpenter ants, each pole section was individually placed in a 10-gallon plastic waste container containing 4 inches of damp soil in the bottom to mimic an actual field application and to steady the poles, allowing at least 5-10 cm of clearance between the edges of the container and the wood. The soil provided humidity for the ants and poles. The inside upper 10-15 cm of each container was "greased" with mineral oil and petroleum jelly to prevent ants escaping. A satellite nest of worker ants (400) was added to each container and supplied with food (honey and a protein source) and water. Brood (approximately 200 eggs, larvae, and pupae) was added to the soil surface following introduction of the workers. Containers were maintained in the laboratory at room temperature of 68-70°F and monitored weekly during the trial for 10 weeks. Food and water were replaced weekly. Poles and ants were left undisturbed during the 10-week exposure period. When the trial was terminated, each container was disassembled, numbers of live ants counted, and examination of each pole was made. Moisture readings were recorded for each pole and the paper wrappings were removed for examination of damage.

Ability of WP101-PRO® to protect against attack by the Formosan subterranean termites, Coptotermes formosanus

A laboratory "no choice" AWPA E-1 test was used to evaluate the performance of WP101-PRO® in protecting SYP sapwood against attack by the Formosan subterranean termite, *Coptotermes formosanus*. This test can be used to determine the toxicity and repellency of the test substrate toward the termites under study. The test was conducted by the Michigan Technological Wood Protection Group (WPG) Entomology Laboratory in New Orleans, LA (this facility is synonymous with

the City of New Orleans Mosquito, Termite, and Rodent Control Board (CNOMTRCB) Entomology Laboratory).[10] Selected SYP wafers 1″ x 1″ x 1/4″ were conditioned to 40 – 60% moisture content and treated with three thicknesses of WP101-PRO®, 1/16″, 1/8″, or 1/4″. There were 5 replicate wafers per treatment with a diffusion period of 30 days. To prepare for the 4-week exposure to termites, residual paste was removed by scraping. Each test substrate was exposed with and without termites. The exposure without termites tested for weight loss not attributable to termite attack. Test results are reported as % termite mortality, % weight loss, and visual termite attack.

Diffusion of WP101-PRO® active ingredients in SYP and DF sapwood

The Department of Wood Science and Engineering at Oregon State University conducted tests of the ability of the active ingredients in WP101-PRO® (propiconazole, tebuconazole, and disodium tetraborate decahydrate) to diffuse in SYP and DF sapwood.[11] The procedures used generally followed those described in AWPA Preliminary Evaluation Method (PEM) for Accelerated Laboratory Evaluation of Supplemental Preservative Pastes for Protecting Wood Surfaces.[12] SYP and DF sapwood blocks approximately 1-1/2″ x 3-1/2″ x 4″ long were cut from defect-free, kiln-dried lumber. A 25 mm x 5 mm deep well was cut into one wide face of each block. Blocks were conditioned to approximately 60% MC. After the conditioning period, each well was filled with 4, 8, or 12 grams of WP101-PRO®. Wells were covered with tape and the blocks (paraffin coated) placed in plastic bags and incubated at 5°C for 6 and 12 weeks to allow for diffusion to occur. There were 3 replicates per treatment, with chemical sampling conducted at 6 and 12 weeks. Following the incubation periods, residual paste was removed from the wells and zones cut from the well area corresponding to 0-5 and 5-10 mm away from the well surface. Appropriate chemical analyses were performed on wood samples from these zones.

EPA Registration

EPA registration of WP101-PRO® required the performance, submission, and approval of numerous tests dealing with acute toxicology, physical-chemical properties, product stability and corrosion, and enforcement analytical methods.

Toxicology Tests

The battery of acute toxicology tests required for EPA registration of WP101-PRO® were performed according to EPA Guidelines by Product Safety Labs, Dayton, NJ. Tests conducted were Acute Oral Toxicity, Acute Dermal Toxicity, Acute Inhalation Toxicity, Primary Eye Irritation, Primary Skin Irritation, and Skin Sensitization.

Physical-Chemical Properties Tests

Physical and chemical properties tests were carried out on WP101-PRO® according to EPA Product Properties Test Guidelines. The studies were conducted by Product Safety Labs, Dayton, NJ. Tests included color, physical state, odor, oxidation/reduction, pH, and density/relative density.

Product Stability and Corrosion Tests

These tests were performed according to EPA Product Properties Test Guidelines OPPTS 830.6317 and 830.6320. The studies were conducted by Product Safety Labs, Dayton, NJ. Tests included accelerated storage stability and corrosion characteristics. The accelerated storage stability test was carried out with WP101-PRO® in 125 ml white, high density polyethylene (HDPE) bottles. Samples were stored in a 50°C incubator and tested following a two-month storage period. The active ingredient concentrations were determined by High Performance Liquid Chromatography (HPLC). WP101-PRO® was in direct contact with the storage containers throughout the incubation period.

Enforcement Analytical Method

These tests were performed according to EPA Product Properties Test Guidelines OPPTS 830.1800. The studies were conducted by Product Safety Labs, Dayton, NJ. Tests included determination of propiconazole, tebuconazole, and borax (disodium tetraborate decahydrate) by High Performance Liquid Chromatography and Titration.

RESULTS

WP101-PRO® test results show that it is an effective wood preservative exhibiting a very high degree of efficacy against wood-destroying fungi and insects. Acute toxicology and product chemistry reviews conducted by the EPA demonstrate the product is virtually non-toxic for humans and has excellent formulation characteristics.

Efficacy Tests

Laboratory Soil Block Decay Test, AWPA E10-15, Michigan Technological University

The results of the soil block decay test conducted according to AWPA Standard E10-15 by Michigan Technological University are shown in Table 1.

Table 1. WP101-PRO® soil block decay test, SYP, AWPA E10-15; 12 weeks exposure to *G. trabeum*.

Treatment[a]	Application Thickness (inches)	Net % Weight Loss[b]
WP101-PRO®	1/16	0.6
	1/8	0.8
	1/4	0.2
Benchmark[c]	1/16	0.3
	1/8	-1.0
	1/4	-0.8
Control	---	40.4

[a] 5 replications per treatment.
[b] Weight loss adjusted for paste-treated controls unexposed to the decay fungus.
[c] The benchmark treatment is a wood preservative paste in current commercial use.

The results of the soil block test show that WP101-PRO® is highly effective in protecting SYP against attack by the brown rot decay fungus, *Gloeophyllum trabeum*, regardless of applied paste thickness[8]. These results are as expected and comparable to those obtained with a benchmark commercial product.

Carpenter Ant Exposure Test

There was no excavation damage by carpenter ants in any of the treatments, including the untreated controls. No damage occurred to the paper wrap on any of the treated poles. The lack of excavation damage in the untreated controls and the relatively high ant mortality observed in this treatment was attributed to the natural repellency (terpenes present in green poles) of the green DF sections (Table 2). Treatments with the highest rate of WP101-PRO® had the highest average numbers of surviving ants and the lowest numbers of ants observed directly on the pole sections themselves. These effects were attributed to the repellency of the higher application rates of WP101-PRO®.[9] Ants tended to avoid colonizing those post sections with thicker layers of paste and thus were better able to survive the 10-week exposure period.

Table 2. Test results for DF pole sections treated with WP101-PRO® and exposed to carpenter ants (*Camponotus modoc*) for 10 weeks.[a]

Application Thickness (inches)[b]	Average No. Surviving Ants	Average No. Ants Observed on Pole Sections
0 (Control)	268	18
1/16	204	12
1/8	341	11
1/4	421	3.5

[a] Average % Moisture Content for the majority of treated pole sections remained at or above 40% for the trial duration.
[b] Treated poles wrapped with 16 lb kraft paper; pole ends left untreated and unwrapped; controls untreated and unwrapped.

Poles with WP101-PRO® treatment appeared to be highly repellent to ants with the highest application rate showing the highest survival and highest repellency. The lowest application rate (1/16″) produced a higher mortality indicating less repellency and providing for more contact with the treated surface. The non-treated poles had the highest amount of activity by the ants both on the pole surface and on the interior of the nest, accompanied by a high rate of mortality.

*Laboratory "No-Choice" Formosan subterranean termite (*Coptotermes formosanus*) test of WP101-PRO®, AWPA E1-15, Michigan Technological University and City of New Orleans Mosquito, Termite, and Rodent Control Board Entomology Laboratory*

The results of the "no-choice" termite test conducted according to AWPA Standard E1-15 are shown in Table 3, where

weight losses as a result of termite exposure, AWPA E1-15 visual ratings, and % termite mortality are compared. Despite excellent termite vigor and strong termite pressure on the test specimens at the beginning of the test, all termites exposed to wafers treated with WP101-PRO® died. All wafers treated with WP101-PRO® had visual termite attack ratings of nine or higher (10 = no damage). The wafers treated with WP101-PRO® had high visual ratings and low weight losses. Combined with high termite mortality, these results suggest that the WP101-PRO® wood preservative paste acted primarily as a contact poison or repellent and effectively protects SYP wood wafers from *Coptotermes formosanus* attack.[10]

Table 3. Test results for AWPA E1-15 "no-choice" test of WP101-PRO® in protecting SYP against attack by the Formosan subterranean termite, *Coptotermes formosanus*.[a]

Application Thickness (inches)	Average Net % Weight Loss[b]	AWPA E1-15 Visual Rating	% Termite Mortality
0 (Control)	48.9	3.0	32.7
1/16	1.6	10.0	100.0
1/8	2.9	9.4	100.0
1/4	2.0	9.8	100.0

[a] 30-day paste diffusion period followed by 4-week exposure to termites; 5 replicate blocks per treatment.
[b] Weight loss adjusted for paste-treated controls unexposed to termites.

Diffusion of WP101-PRO® active ingredients in SYP and DF sapwood

Results for the diffusion of propiconazole, tebuconazole, and disodium tetraborate decahydrate (presented as % BAE, Boric Acid Equivalent) are shown in Tables 4, 5, and 6, respectively. Although chemical analyses were performed at 6 and 12 weeks, for simplicity only analysis results for the 12-week sampling period are presented.

Table 4. Levels of propiconazole (ppm) detected in SYP or DF diffusion zone 12 weeks after application of 4, 8, or 12 grams of WP101-PRO® paste.[a]

	Southern Yellow Pine			Douglas-fir		
Zone (mm)[b]	4 g	8 g	12 g	4 g	8 g	12 g
0 – 5	939	675	845	989	656	675
5 – 10	0	0	0	0	0	0

[a] Samples paraffin-sealed and incubated 6 and12 weeks at 5°C.
[b] Sampling zone is the distance from a 25 mm diameter x 5 mm deep well cut into the wood where paste was originally applied.

Table 5. Levels of tebuconazole (ppm) detected in SYP or DF diffusion zone 12 weeks after application of 4, 8, or 12 grams of WP101-PRO® paste.[a]

	Southern Yellow Pine			Douglas-fir		
Zone (mm)[b]	4 g	8 g	12 g	4 g	8 g	12 g
0 – 5	266	158	212	219	142	143
5 – 10	0	0	0	0	0	0

[a] Samples paraffin-sealed and incubated 6 and12 weeks at 5°C.
[b] Sampling zone is the distance from a 25 mm diameter x 5 mm deep well cut into the wood where paste was originally applied.

Table 6. Levels of boron (% boric acid equivalent) detected in SYP or DF diffusion zones 12 weeks after application of 4, 8, or 12 grams of WP101-PRO® paste.[a]

	Southern Yellow Pine			Douglas-fir		
Zone (mm)[b]	4 g	8 g	12 g	4 g	8 g	12 g
0 – 5	1.07	0.96	0.96	1.30	1.10	1.24
5 – 10	0.68	0.60	0.51	0.73	0.81	0.69
10 - 20	0.37	0.33	0.25	0.48	0.40	0.40
>20	0.21	0.16	0.13	0.18	0.17	0.19

[a] Samples paraffin-sealed and incubated 6 and12 weeks at 5°C.

[b] Sampling zone is the distance from a 25 mm diameter x 5 mm deep well cut into the wood where paste was originally applied.

Tebuconazole and propiconazole were only detected in the outer 5 mm of the test samples. This is consistent with the tendency for these molecules to migrate more slowly in wood and stay nearer the surface. Tebuconazole and propiconazole levels also tended to vary widely, which reflects inherent variation in wood properties (Tables 4 and 5).

Tebuconazole did not diffuse to the same extent as propiconazole in either DF or SYP. Previous long-term field trials on DF pole sections[13] showed that propiconazole is capable of moving long distances into sapwood. Tebuconazole has not been previously tested for its ability to diffuse when applied as a groundline preservative paste.

Increasing paste dosage appeared to have a negative effect on triazole migration between 4 and 8 g of paste per block but a more positive effect on chemical levels in the wood at the 12 g dosage. Longer incubation periods (6 weeks vs. 12 weeks) were associated with higher chemical loadings indicating that the azoles were moving into the wood over time.

There is no generally accepted threshold value for either of the triazole compounds against soft rot fungi, nor is there a value for the combination. Tebuconazole is used at a retention of 400 ppm to protect wood windows against fungal attack,[14] while propiconazole is primarily used in anti-stain formulations and has a slightly higher threshold of around 1000 ppm[15].

Boron levels in DF and SYP sapwood blocks were both well over the threshold (approximately 0.5% boric acid equivalent) for fungal protection in the outer 0 - 5 mm zone after 6 or 12 weeks (Table 6). There was relatively little difference in boron levels in this zone in blocks incubated for 6 or 12 weeks nor did there appear to be any appreciable difference with respect to dosage applied or wood species. Boron levels 5 to 10 mm inward from the surface declined to about 50 % of the levels found in the outer 0 – 5 mm zone, which is consistent with the diffusion of this system and the relatively short time in test. Boron levels in the 5 to 10 mm zone were still largely above the protection threshold. Boron levels 10 to 20 mm inward from the surface were generally low 6 weeks after treatment, but rose with the additional 6 weeks of incubation, indicating that the boron was continuing to diffuse inward from the surface.

The results demonstrate that both triazole fungicides, along with boron, are capable of diffusing inward from the surface.[11] In principle, the boron should diffuse inward to arrest any fungal attack underway away from the surface, while the azoles move inward for a short distance to limit the potential for renewed attack.

EPA Registration

WP101-PRO® was conditionally registered by the EPA on December 12, 2017. The registration submission included test reports for acute toxicology, physical-chemical properties, product stability and corrosion, and enforcement analytical methods.

Toxicology Tests

EPA reviewed and approved the reports submitted for the battery of acute toxicology studies required for registration. In a review document issued November 1, 2017,[16] the EPA concluded that all studies were acceptable and assigned Toxicity Categories for each study. EPA Toxicity Categories for acute toxicology tests are shown in Table 7.[17] WP101-PRO® was assigned Toxicity Category IV (least toxic) for all but one study. In the Primary Eye Irritation study, WP101-PRO® was assigned to Toxicity Category III.

Physical-Chemical Properties

EPA reviewed and approved the reports submitted for the battery of product chemistry studies required for registration.[18] WP101-PRO® is a gray, semi-solid paste with a mild, faint odor. The product is not flammable and contains no explosive ingredients. WP101-PRO® has a pH of 9.0 and a density of 1.192 g/ml.

Table 7. EPA Label Review Manual, Chapter 7, Table 1, Toxicity Categories.

Study	Category I	Category II	Category III	Category IV
Acute Oral	Up to and including 50 mg/kg	>50 thru 500 mg/kg	>500 thru 5000 mg/kg	>5000 mg/kg
Acute Dermal	Up to and including 200 mg/kg	>200 thru 2000 mg/kg	>2000 thru 5000 mg/kg	>5000 mg/kg
Acute Inhalation	Up to and including 0.05 mg/liter	>0.05 thru 0.5 mg/liter	>0.5 thru 2 mg/liter	>2 mg/liter
Primary Eye Irritation	Corrosive (irreversible destruction of ocular tissue) or corneal involvement or irritation persisting for more than 21 days	Corneal involvement or other eye irritation clearing in 8-21 days	Corneal involvement or other eye irritation clearing in 7 days or less	Minimal effects clearing in less than 24 hours
Primary Skin Irritation	Corrosive (tissue destruction into the dermis and/or scarring)	Severe irritation at 72 hours (severe erythema or edema)	Moderate irritation at 72 hours (moderate erythema)	Mild or slight irritation at 72 hours (no irritation or slight erythema)

Product Stability and Corrosion

In a report dated November 7, 2016, Product Safety Labs determined that WP101-PRO® was stable and retained its active ingredient levels after storage at 50°C for two months.[19] No significant weight change in the containers or changes in physical appearance of the product was noted. No corrosion of the storage containers was observed.

Enforcement Analytical Method

In a report dated November 30, 2016, Product Safety Labs provided an Enforcement Analytical Method for the determination of propiconazole, tebuconazole, and borax (disodium tetraborate decahydrate) by High Performance Liquid Chromatography and Titration.[20] Propiconazole and tebuconazole were determined by high performance liquid chromatography. Borax, disodium tetraborate decahydrate, was determined by a titration method. The report provided detailed analysis procedures and a summary of the validation parameters. Acceptable linearity, accuracy, and precision (repeatability) were demonstrated.

DISCUSSION

The development of WP101-PRO® is in response to a general interest in remedial groundline pastes that do not contain heavy metals such as copper. Until now, wood preservative groundline remedial paste formulations have almost invariably contained a combination of a borate and a copper compound. The primary biocide, the borate compound, can be considered the "shock and awe" component, diffusing relatively rapidly into the wood to kill existing fungal and insect infestations. The secondary biocide, usually a copper compound, may diffuse to a limited extent but essentially remains near the treated surface to provide prolonged protection against reinfestation. WP101-PRO® is unique as a groundline remedial paste because it does not contain copper nor any heavy metals; the secondary biocide components are totally organic. The organic biocides in WP101-PRO®, propiconazole and tebuconazole, are known to act synergistically against a wide variety of wood destroying fungi, including basidiomycetes, ascomycetes, Fungi imperfecti, and soft rot fungi.[6] Furthermore, the work by Konkler *et. al.* has demonstrated that the triazole components of WP101-PRO® have, like copper, limited ability to diffuse in wood and can be expected to remain at or near the treated wood surface to provide continuing protection.[11]

A legitimate concern is whether the organic biocides of WP101-PRO® can adequately substitute for the more widely used copper compounds typically employed as secondary biocides in groundline remedial paste formulations. Below we address such concerns:

- WP101-PRO® is not applied to soil, nor to wood in direct contact with soil where the active ingredients would be directly exposed to soil bacteria; rather, it is applied as a paste and isolated from soil exposure by use of an approved moisture barrier stapled in place over the treated area.

- Tebuconazole has a high intrinsic resistance to breakdown by soil bacteria. An EPA Data Evaluation Record (DER) was prepared in response to an Aerobic Soil Metabolism study of tebuconazole.[23] The aerobic soil metabolism study, EPA OPPTS Test Guideline 835.4100, exposes the test substance, in this case tebuconazole, to ideal conditions for bacterial breakdown.[24] The aerobic soil metabolism study is used for chemicals that are directly applied to soil or that are likely to reach the soil environment (neither of which applies to the tebuconazole in WP101-PRO®). The study review concluded that the ½-life of tebuconazole in soil was concentration dependent, with a ½-life of 22 to 47 days when the fungicide is present at a concentration of 0.06 ppm. At 1 ppm, the ½-life increased to 155 days, while at 50 ppm the ½ life of tebuconazole was 343 to 375 days. To put these numbers in perspective, it should be recalled that the concentration of tebuconazole in WP101-PRO® is 0.5%, or 5,000 ppm, and the fungicide is not in contact with soil but rather in a paste matrix protected from direct soil contact and consisting largely of borax, disodium tetraborate decahydrate.
- Propiconazole is also naturally resistant to breakdown by soil bacteria. In 2006, the EPA published its Reregistration Eligibility Decision (RED) for propiconazole.[25] In the section dealing with the Environmental Fate and Transport of propiconazole, the RED document concluded as follows:
  - Propiconazole appears to be persistent and moderately mobile to relatively immobile in most soil and aqueous environments.
  - In soil environments, propiconazole dissipation appears to be dependent on incorporation or binding to soil organic matter.
  - Laboratory and terrestrial field dissipation data indicate that propiconazole is stable in soil and aqueous environments. Propiconazole was stable to hydrolysis, aqueous photolysis, soil photolysis, aerobic aquatic metabolism, aerobic soil metabolism, and anaerobic aquatic metabolism.
- WP101-PRO® contains borax (disodium tetraborate decahydrate), which is in continuous equilibrium with small quantities of boric acid when exposed to acidic conditions. In fact, borax is one of the starting materials used in the commercial production of boric acid.[21] Boric acid is both antifungal and insecticidal. More significantly, boric acid is both bacteriostatic and bactericidal, and can be expected to provide a degree of protection against bacterial breakdown of the triazole fungicides. Houlsby *et. al.* showed that a minimal salts medium buffered with a combination of borax and boric acid exhibited significant antibacterial activity against 15 *Pseudomonas* strains, 12 strains of enteric bacteria, and 7 strains of *Staphylococci*.[22]
- The WP101-PRO® formulation is highly stable; the active ingredients undergoing no degradation after storage at 50°C for two months.[19]

CONCLUSION

WP101-PRO® is a new and unique wood preservative groundline remedial paste. The active ingredients are a boron compound, disodium tetraborate decahydrate, and two organic triazole fungicides: propiconazole and tebuconazole. The formulation is highly effective against wood-destroying fungi and insects. Acute toxicology and product chemistry studies demonstrate that WP101-PRO® is virtually non-toxic for humans and possesses excellent formulation and storage stability characteristics. WP101-PRO® provides an alternative to users of groundline remedial paste products who desire a formulation free of copper.

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