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EXECUTIVE SUMMARY

Azole resistant strains of Aspergillus fumigatus have been shown to be hampering efforts to manage the infectious diseases this fungus causes. Recent publications have associated the presence of resistant strains with the traces of azole containing products in sawmills in France and the presence of treated wood chips in compost.

Industry associations of wood preservatives manufacturers and wood preservation have, over the years, developed and implemented best practice guidelines for the safe and sustainable design of operations, which span from the creation of techniques to avoid the exposure of the environment to preservatives during treatment and storage, to the correct management of waste with the exclusion of the use of treated wood chips in compost.

Through EWPM and WEI-IEO all the participants in the wood treatment chain remain vigilant and fully committed to proactively work to help limit the emergence of azole-resistant Aspergillus fumigatus and contribute to the management of infectious diseases caused by it.

INTRODUCTION

The emergence of azole-resistant Aspergillus fumigatus is hindering the management of infectious diseases caused by it. Recent publications have associated the presence of resistant strains with exposure to traces of azole containing products in sawmills in France and the presence of treated wood chips used in compost.

This document offers a summary of the best practices the wood preservative industry is promoting to prevent environmental emission pathways along the whole process chain, from the treatment of fresh wood to the disposal of waste, and limit the emergence of resistant strains.

WOOD PRESERVATION (BPR PRODUCT TYPE 8)

Wood preservatives regulation and standardization

Wood preservatives are a category of biocidal active substance containing products intended to destroy or control harmful or unwanted organisms such as fungi and insects, that have detrimental effects on wood and are used in a wide variety of ways by both industrial and professional users as well as by the public.

Poorly treated timbers used in construction, landscaping, garden or engineering, that fail due to decay or insect attack, can have multiple unwanted consequences such as the unexpected collapse of timber structures, injuries and costly and time-consuming remedial work.

Wood preservatives are regulated by under the EU Biocidal Products Regulation[1] (BPR) product type 8 and are consequently considered to be effective and show acceptable risk according to use recommendations. The BPR regulation imposes approval at EU level of active substances such as fungicides and insecticides with authorisation at national level of wood preservative formulations (water-based and solvent-based mixtures and emulsions) that incorporate one or more approved active substances.

BPR also imposes rules on the placing on the market of treated articles aimed at ensuring the safe handling of treated wood (art. 58 of BPR).

[1] Biocidal Products Regulation (EU) No. 528/2012.

European Standard EN 335[2] describes five use classes for wood characterised by the risk of them becoming wet in service and susceptible to biological attack and the differing organisms that can degrade wood in each class.

Table 1: EN 335 use classes

Use class	Description
1	Interior dry (e.g. internal construction timber)
2	Interior but with risk of wetting (e.g. roof timbers)
3	Exposed to weather but not in ground contact (e.g. fence rails and boards)
4	In ground or freshwater contact (e.g. electricity poles)
5	In seawater (e.g. marine piling)

In use class 1, fungi do not pose a decay hazard. In use class 2, protection is required against fungi as wood may become wet. In both these use classes, protection against insects (beetle larvae and/or termites) may be required. Application methods can cover brushing, dipping, spraying and both double vacuum and vacuum pressure impregnation.

In use class 3 timber is exposed to the weather and far fewer products are available. Fungal deterioration tends to be higher as timber is frequently wetted. Application is generally limited to those that lead to penetration of timber and vacuum pressure (industrial) is predominantly used.

In use class 4 industrial application is necessary and is almost exclusively a vacuum pressure process due to the penetration and retention requirements. Bio-deterioration is more extreme as treated wood is in permanent ground contact and almost always permanently wet. Timber may be structural such as transmission poles, walkways, bridges, decking supports etc and safety is paramount.

No wood preservative is currently approved within the BPR for use in use class 5.

In addition to these five use classes, wood preservatives may also be developed and applied as anti-sapstain products. These provide protection to freshly sawn poles, posts, and lumber from staining fungi which can develop in the wood after felling and before the timber dries down to a moisture content too low to support fungal growth.

Azole-based biocides used as wood preservatives

Azole-based wood preservatives have played a large part in wood preservation globally over the last 30 years, as highly efficient and cost-effective solutions. Propiconazole and Tebuconazole are used as biocides, with and without other biocides such as copper, to provide the required spectrum of efficacy whilst optimising product use and fulfilling requirements of the various quality schemes such as NTR[3] and CTB-P+[4].

The combination of copper with propiconazole and tebuconazole offers excellent protection against wood destroying organisms, including brown rot decay, the most common cause of failure to decay. Two of the most common fungi responsible for decaying softwood timbers are the brown rots Coniophora puteana and Rhodonia placenta. Propiconazole is particularly effective against Rhodonia placenta whereas Tebuconazole is particularly effective against Coniophora puteana, the combination of propiconazole and tebuconazole being highly complementary.

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2 CSN EN 335. Durability of wood and wood-based products - Use classes: definitions, application to solid wood and wood-based products.

[3] Nordiska Träskyddsrådet Nordic Wood Preservation Council Quality Scheme

[4] CTB-P+ scheme administered by FCBA (French Institut Technologique Foret Cellulose Bois-construction Ameublement)

Azole-based solutions also play a dominant role in the protection of wood against sapstain.

Table 2. EU triazole-containing wood preservatives by dip treatment

Solutions	Actives
Triazoles + Insecticide	Propiconazole/Tebuconazole/Permethrin
IPBC + Triazoles	IPBC/Propiconazole
	IPBC/Propiconazole/Tebuconazole
IPBC + Triazoles + Insecticide	IPBC/Propiconazole/Permethrin
	IPBC/Propiconazole/Cypermethrin
	IPBC/Propiconazole/Tebuconazole/ Cypermethrin
Triazoles + Boric acid	Propiconazole/Boric acid
Triazole	Propiconazole

Table 3. EU triazole-containing wood preservatives by pressure treatment

Solutions	Actives
Copper + Triazoles	Basic copper carbonate/Propiconazole/ Tebuconazole
	Basic copper carbonate/copper/ granulated copper/propiconazole/ tebuconazole
Copper + Triazoles + Quats	Basic copper carbonate/Granulated copper/Propiconazole/Tebuconazole/ DDACarbonate
	Basic copper/Propiconazole/ Tebuconazole/ DDAChloride

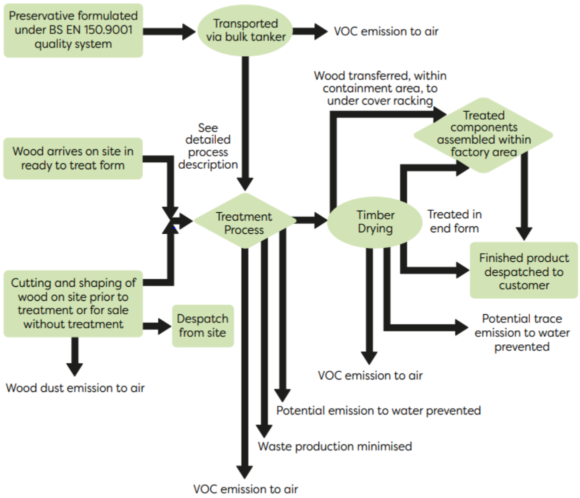
Figure 1. Staining fungi can seriously detract from the value of timber.

Wood preservation lifecycle and application methods

The process for the treatment of timber against sapstain starts with the initial conversion (debarking and sawing) of the log into the form in which it will be dried. The anti sapstain preservative is then applied to protect the wood until the drying process is complete.

Wood preservatives to protect the wood in use are applied after sawing of the wood to the desired size and shape. Depending on the destination of use of the treated article, the wood is treated on site with the preservative that was previously transported via bulk tanker or IBC containers using different application techniques. After treatment the wood is transported in a containment area for drying and then stored until it is dispatched to the customers (i.e. construction companies or domestic users).

Figure 2. Lifecycle diagram flux of treated timber[5]



Source: European Code of Practice for their Safe Design and Operation 2021.

Wood preservatives protecting wood in service are applied by a range of processes depending on the end use requirement, including superficial processes such as dipping and pressure impregnation.

Dipping Treatments

Freshly harvested timbers, pallet and packaging timbers, general construction timbers.

Controlled treatments are generally utilized where anti-sapstain protection is required for freshly harvested and sawn timbers. In some markets dipping treatments can be used for Use Class 1, 2 and 3 (coated) construction timbers. Dipping facilities may be open or encapsulated, equipped with vapour trapping and air emission control.

Dip Tanks

Both automatic and manual dipping/immersion are batch processes. The wood (single piece or pack) is loaded on automatic equipment (e.g. hydraulic elevator) and submerged into a dipping tank containing the anti-sapstain solution. Wood remains there for a period usually between a few minutes and an hour. Cold soaking or steeping can extend over several days. Dipping baths can be heated in cold climate conditions. The treated wood is held over the dipping vat, usually for 30 minutes to an hour to drain the excess of the preservative solution, and drips are usually collected and recycled into the process. The treated wood is then removed to storage.

Continuous green chain dip process

These systems are generally integrated with the sawmill process prior to timbers being placed in to finished packs. Timbers on the chain drive system are submerged through a shallow tank containing the anti-sapstain product. The size of the tank and the speed of the line then controls the residence time and amount of product absorbed. The exit from the systems are generally inclined and fitted with drip trays under the chain drive system to promote product run off from the timbers and this product is recovered back in to the tank and prevents contamination of the surrounding area.

[5] WOOD TREATMENT INSTALLATIONS. European Code of Practice for their Safe Design and Operation 2021. European Wood Preservative Manufacturers Group EWPM European Institute for Wood Preservation (WEI-IEO) Issue 2 2021.

Environmental emissions pathways for dipping/spraying treatments are summarized in the table below.

Table 4. Emissions pathways dipping treatments

	Emission pathways
During treatment	Dip systems potential for splashing / dripping from timbers immediately after treatment
Post treatment	Dripping during draining time above the dipping tank
Post treatment	Contamination of moving equipment (chain dip systems) with products in the vicinity of the dip bath
Post treatment	Residue drying on to floors in plant areas can through movement of Fork Lift trucks (FLTs) can create dust / air born particulates through movement
Storage	Run-off water from paved storage into adjacent surface water body after rain event

In a recent publication[6] resistant strains of *Aspergillus fumigatus* were isolated in sawmills in Eastern France. Sawmill treatments aim to preserve wood in the short-term, freshly cut wood is treated with fungicides to prevent the discoloration caused by blue stain forming fungi.

According to the study, the presence of these strains is associated with exposure to azole-fungicide products close to the dipping tank and from import and storing of wood treated with azoles-fungicides. The time to allow treated wood to drain above the tank was extremely variable between sawmills and potentially correlated to the higher concentration found in some sawmills, especially in area treatment and near the processing tank.

Overall the report indicates the creation of azole capture techniques in treatment and storage areas in sawmills and the use of products with lower content of tebuconazole as potential solutions to prevent the emergence of resistance.

Figure 3. Dipping tank.

[6] A. Jeanvoine, S. Rocchi, G. Reboux, N. Crini, G. Crini and L. Millon. Azole-resistant Aspergillus fumigatus in sawmills of Eastern France, 2017, Journal of Applied Microbiology ISSN 1364-5072.

Source: Métallerie du Sud Lorrain dipping tank pdf from website.

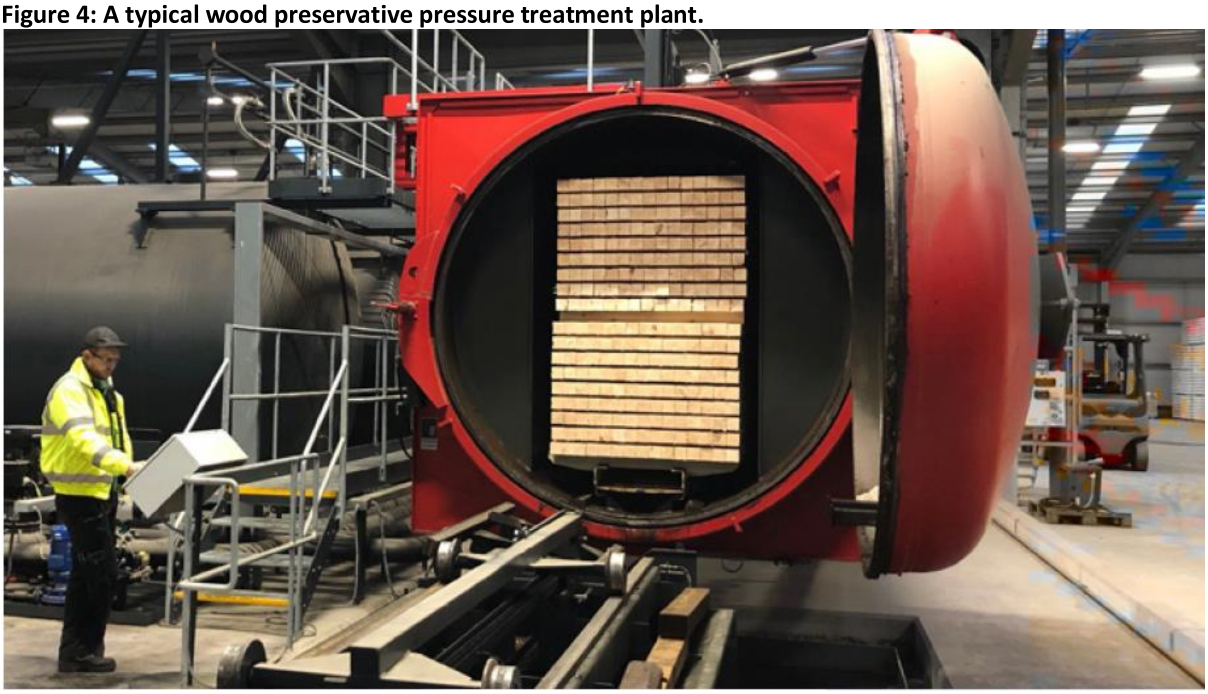
Pressure treatments

General building timbers, claddings, truss rafters, carcassing and timber frame material, joinery components, engineered timbers.

Use Classes 1, 2 and 3 (coated) timbers can be effectively protected using low pressure/double vacuum treatment process. These treatments use water based micro emulsion type preservative products that leave the appearance almost unchanged, however, colour dyes or pigments can be added at the point of treatment to aid treatment identification.

High pressure preservative treatments can generally be used for all Use Classes from 1-4. These treatments utilise copper organic water-based products that generally leave the treated timbers with a pale green colouration that slowly weathers to a silver grey over time. Again colourants can be added at the time of treatments to produce different treated timber options for different markets. Water repellents can also be included to add extra weathering protection to decorative external timbers.

Figure 4: A typical wood preservative pressure treatment plant.



Source: WPA Code of Practice: Industrial Wood Preservation | 2nd Edition: June 2021

In most cases, for industrial use applications by vacuum pressure impregnation, the product (concentrate) is supplied and delivered directly to a concentrate storage tank on site. In other cases it is supplied in 1000 liter intermediate bulk containers (IBCs). At most sites dilution uses dosing systems which automatically draw concentrate and water together and add the resulting solution to the storage tank. Timber is treated in closed system vessels and the treatment plant operator has no exposure to the treatment solution throughout the process. Modern plants have fully automated handling systems and timbers are stored withing the controlled plant area until dry before release to be put in final storage for dispatch.

Emissions pathways for low/high pressure treatments are summarized in the table below.

Table 5. Emissions pathways low/high pressure treatments

	Emission pathways
Post treatment	Residue drying on to floors in plant areas can through movement of fork lift trucks create dust / air born particulates
Post treatment	Loss of chemical to floor during maintenance activities
Post treatment	Loss of preservative chemical in the plant bund from recovered liquid from drip areas, leak from pump seals, door seal passing
Storage	Post treatment storage of timber prior to dispatch, potential for very small amount of wash off into environment
Storage	Run-off water from paved storage into adjacent surface water body after rain event
Storage	Dripping of product from treated timbers in to contained post treatment timber storage areas

Management of wood waste

Every year over 4 millions tonnes of wood waste[7] are collected with the majority destined for biomass energy generation followed by panel board manufacture, animal bedding, reuse and recycling. All producers of waste, including householders, have a duty of care to ensure their waste is passed on to an authorised person.

The cycle of the management of wood waster starts with the disposal of timber from individuals (pruned gardens, treated garden wood), municipalities (pruned gardens), timber is then collected and sorted (for example by gardeners, contractors) and then sold to recycling (chipboard and paper industry), composting companies, or power plants (biomass plants and waste incineration plants).

The Wood Recyclers' Association (WRA) classifies waste wood into four grades depending on the origin and content. Whether preservative treated wood is classified as hazardous or non-hazardous depends on the treatment that was used, retention rates, and is assessed in accordance with The Waste Framework Directive (Directive 2008/98/EC).

Table 6. WRA Classification of waste wood

WRA grade	Description	Typical sources
A	Clean untreated wood and board products *Clean un-treated*	Wood product manufacturing and packaging.
B	Business waste wood *Treated non-hazardous*	Construction, demolition and skip operations.
C	Municipal waste wood *Treated non-hazardous*	Municipal collections, transfer stations and Hazardous Waste Recycling Centres.
D	Hazardous waste wood *Treated hazardous*	Agricultural fencing, industrial applications, telegraph poles & railway sleeps.

Clean/untreated waste wood is suitable for processing into animal bedding, panel board feedstock, landscaping or equestrian surfaces and biomass. Treated, but non-hazardous waste wood is suitable for processing as a feedstock for panel board or energy recovery, hazardous waste wood can only be disposed of in a facility licensed for this purpose.

Waste of processed wood is collected and stored. This wood is a mixture of several kinds of wood varying from railway sleepers, wooden boxes to wooden fences. The presence of traces of azole fungicides could be explained by the use of these fungicides in some wood preservation culture.

In a recent study commissioned by the Dutch Ministry of Health to investigate the specific conditions and sites which are thought to facilitate the emergence, amplification and spread of triazole-resistance mutations in *Aspergillus fumigatus*, **wood chipping** was identified as a hotspot were the

[7] WPA (Wood Protection Association) TW 14, 2021.

the critical factors that facilitate resistance selection in *Aspergillus fumigatus* (ability to complete the growth cycle and presence of azoles)[8]. The study indicates that composting practices (i.e., stockpiling of plant waste) are key to resistance selection in *Aspergillus fumigatus*, rather than mere application of azole fungicides to protect against phytopathogenic fungi, and suggests the creation of conditions that preclude the growth of *Aspergillus fumigatus* as a way to turn the hotspot into a coldspot.

INDUSTRY BEST PRACTICES FOR THE PREVENTION OF SURGENCE OF RESISTANT STRAINS OF ASPERGILLUS FUMIGATUS

The importance of ensuring that treatment procedures do not compromise the health and safety of humans and the environment along the whole process cannot be over-emphasised.

Environmental hotspots are the main route for *Aspergillus spp*. to acquire azole resistance. Recent discussions have indicated the use of treated wood chipping in compost and exposure in sawmills to azole-fungicide products close to the dipping tank and from import and storing of treated wood as steps in the wood preservation lifecycle potentially linked to the development of resistant strains.

Through the work of the European Wood Preservatives Manufacturers (EWPM) and the European Institute for Wood Preservation (WEI-IEO) the wood preservation industry has, over the years, developed and implemented best practice guidelines for the safe and sustainable design of operations.

The aim of the EWPM is to promote, the correct use of wood preservatives including production, transportation, utilisation and disposal. It acts as an official representative of the industry when approaching authorities, institutions and any other competent body on a European or international level. EWPM members work towards the improvement of technical guidelines within the industry for the benefit of consumers, specifiers and other stakeholders recognised by it.

The IEO-WEI promotes the benefits of treated wood whilst representing the wood preservation industries within the European Union. The activities of the WEI-IEO are based around wood preservatives, environmental and technical issues and the marketing of finished wood products.

In the following sections we explain how industry best practices can help prevent the creation of the conditions for the development of resistant strains of *Aspergillus fumigatus* and transform a hotspot into a coldspot.

General advise on treatment operations

The process of wood treatment requires that consideration is given to the whole operation. Effective health and safety policies, arrangements and procedures for the use and maintenance of plant equipment and the health of operators are prepared and properly implemented.

Operators are trained and conduct regular maintenance and correct operations including the cleaning of installations. A system of regular checks should be implemented to ensure that standards are being maintained and sufficient time should be allowed for employees to carry out the necessary housekeeping work. Records should be kept of all routine maintenance, periodic servicing, examinations and remedial work.

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[8] Schoustra SE, Debets A, Rijs A, Zhang J, Snelders E, Leendertse PC, et al. Environmental Hotspots for Azole Resistance Selection of Aspergillus fumigatus, the Netherlands. Emerg Infect Dis. 2019;25(7):1347-1353.

Best practices to minimize environmental exposure during dipping

The table below summarizes the industry best practice guidelines aimed at reducing potential environmental released of preservatives. Information is provided to the treater by the manufacturer in product treatment guideline documents or, in some case, attached to the side of the dip tank.

Table 7. Management of emission pathways

	Emission pathways	**Best practice guideline**
During treatment	Potential for splashing / dripping from timbers immediately after treatment	Timber treatment plants are closed systems with no losses to the environment be that via water, land or air.
Post treatment	Dripping during draining time above the dipping tank	After dipping the timber must be allowed to drain to remove excess treatment solution. Large dimension timber stickered on each layer will require shorter dip times. Pallet timbers, tightly banded and stickered, will infrequently require a longer dip time. Cover drip dry areas should be available in the treatment plant. Where this is not available, ALL rainwater falling on that surface is collected and then stored for reuse in the system. Fully automated plants remove this as a emission route.
Post treatment	Contamination of moving equipment (chain dip systems) with products in the vicinity of the dip bath	Chain drive systems on the outlet of the chain dip tanks are generally inclined to maximise free run off from the timber pieces and fitted with a drip tray underneath to recover free product back in to the dip system
Post treatment	Residue drying on to floors in plant areas can through movement of FLTs create dust / air born particulates	Good / regular housekeeping to clean down machinery and floor areas to minimise sawdust accumulation. Wear a dust mask and, whenever possible, perform these operations (sawing of the wood) outdoors to avoid accumulations of airborne sawdust. Avoid frequent or prolonged inhalation of sawdust. Consult local regulatory authorities for further information on workplace exposure limits for wood dust.
Storage	Run-off water from paved storage into adjacent surface water body after rain event	The treated wood is dry and drip free.

Best practices to minimize environmental exposure during pressure treatments

Timber treatment vessels are closed systems with no losses to the environment be that via water, land or air.

The plant should be equipped with a mechanism to ensure the process is not started until the door is fully closed and locked, and to control the internal pressure and presence of liquid in the vessel before the door is opened once the treatment cycle is complete. Pressure vessels should have a safety relief valve fitted to enable them to be operated safely.

The table below summarizes the relevant best practice guidelines in relation to the relevant emission pathways identified.

Table 8. Management of emission pathways

	Emission pathways	**Best practice guideline**

Post treatment	Residue drying on to floors in plant areas can through movement of FLTs create dust / air born particulates	Timber treatment plants are closed systems with no losses to the environment be that via water, land or air. If a plant does not have a covered drip dry area ALL rainwater falling on that surface is collected and then stored for reuse in the system. Drag out is covered under IED (Industrial Emission Directive 2010/75/EU) and wash systems or dedicated Fork-Lift Truck being forced. Fully automated plant removes this as a emission route. Wear a dust mask and, whenever possible, perform these operations outdoors to avoid accumulations of airborne sawdust. Avoid frequent or prolonged inhalation of sawdust. Consult local regulatory authorities for further information on workplace exposure limits for wood dust. Minimised through good housekeeping practices.
Post treatment	Loss of chemical to floor during maintenance activities	A planned written scheme of maintenance should be prepared by a competent engineer and followed. It is advisable that this written scheme should cover all protective devices, pressure valves and pipe work that could give rise to danger in the event of failure. Records should be kept of all routine maintenance, periodic servicing examinations and remedial work. Entry into treatment vessels may be necessary, for example, to retrieve pieces of wood or other debris from the treatment vessel. A documented permit to work system should be operated and any person who enters a vessel should be trained and competent in the procedures and use of equipment necessary to work safely inside the treatment vessel. Treatment vessel entry should be done with a minimum of two trained personnel.
Post treatment	Preservative chemical in the plant bund from recovered liquid from drip areas, leak from pump seals, door seal passing	
Storage	Post treatment storage of timber prior to dispatch, potential for very small amount of wash off into environment	Freshly treated timber should be stored under cover and protected from rainfall and snow for a minimum of 12 hours or until touch dry or free from surface liquid. This storage should be in a designated drip-dry area, protected from rainfall and direct sunlight. The drying time will depend upon weather conditions, species, specification, timber dimensions, pack size and whether the timber is sawn, planed or sanded. Freshly treated timber should not be tightly wrapped in polythene. Treated packs should be tilted to promote preservative drainage and prevent surface ponding. It is advisable to stack packs evenly to prevent dripping onto lower packs.
Storage	Run-off water from paved storage into adjacent surface water body after rain event	
Storage	Dripping of product from treated timbers in to contained post treatment timber storage areas	

Best practices for the safe handling of treated wood delivered to customers

General advise on for the safe handling of the treated wood is provided to the customers (i.e. construction companies, domestic users) for the management of this risk of exposure to airborne particles from debriefs and sawdust of treated wood.

Table 9. Handling and on-site precautions and personal hygiene

Handling Precautions	When power-sawing and machining, wear a dust mask and, whenever possible, perform these operations outdoors to avoid accumulations of airborne sawdust. Avoid frequent or prolonged inhalation of sawdust. Consult local regulatory authorities for further information on workplace exposure limits for wood dust.
Personal Hygiene	After handling or working with treated timber, all exposed skin should be washed before commencing other activities, especially eating, drinking, smoking or going to the toilet. If sawdust accumulates on clothes, clean them before reuse. Launder heavily soiled clothes separately from other household wash items.
On-Site Precautions	All sawdust and construction debris should be cleaned up and disposed of after construction. Timber should be free from debris and sawdust prior to treatment.

Best practices for the safe disposal of waste

General advise for the safe management of waste is included in the technical material and product Safety Data Sheet (SDS) provided by the manufacturer of the wood preservative to the final customer via the treating company. The aim of these recommendations is to avoid the conditions giving rise to the resistance selection, including composting practices.

The use of treated wood chips as mulch and or compost is NOT allowed. Domestic end users should dispose any waste treated timber, sawdust or ash through special waste treatment.

CONCLUSIONS

Environmental hotspots are the main route for *Aspergillus spp*. to acquire azole resistance. Recent discussions have indicated the use of treated wood chipping in compost and exposure in sawmills to azole-fungicide products close to the dipping tank and from import and storing of treated wood as steps in the wood preservation lifecycle potentially linked to the development of resistant strains.

Industry associations of wood preservatives manufacturers and wood preservation have, over the years, developed and implemented best practice guidelines for the safe and sustainable design of operations, which span from the creation of techniques to avoid the exposure of the environment to preservatives during treatment and storage, to the correct management of waste with the exclusion of the use of treated wood chips in compost.

Through EWPM and WEI-IEO all the participants in the wood treatment chain remain vigilant and fully committed to proactively work to help limit the emergence of azole-resistant Aspergillus fumigatus and contribute to the management of infectious diseases caused by it.