# Antimicrobials in plastics: a global review

**Antimicrobials are used in a wide range of plastic applications, such as public phones, flooring and escalator rails to control the growth of microorganisms. They are also used in plastic products where infection is a concern, such as hospital furniture. Antimicrobials in plastics form a growing sector of the speciality biocides industry. This sector has now been selected by specialist suppliers, including Agion, Microban, Sanitized and Thompson, as an area for future growth. Niall D'Arcy of the Biocide Information Service at University College Dublin presents some of the most recent statistics and looks at the trends in the plastic antimicrobials industry.**

## *The market by industry*

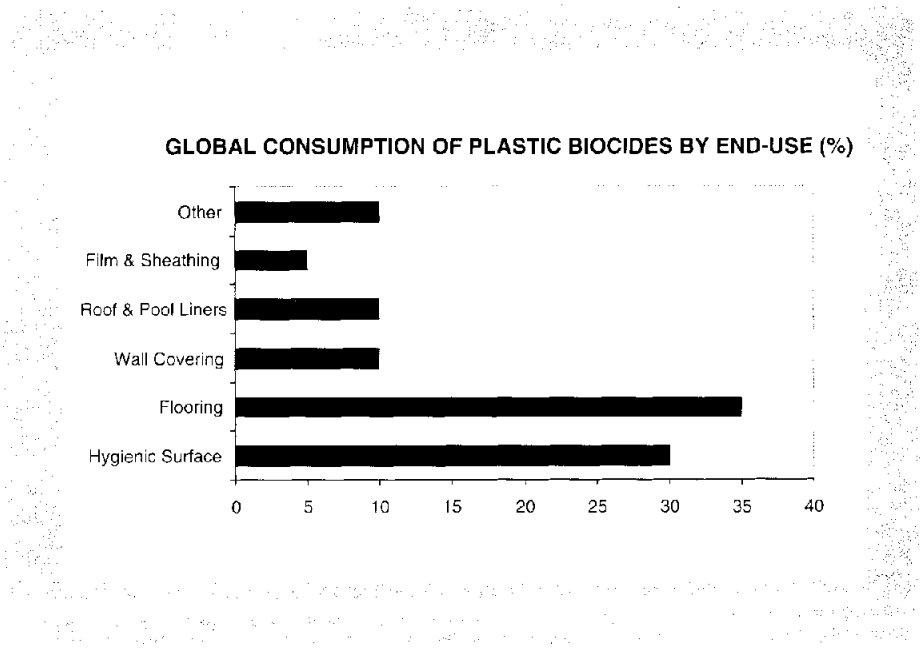
The global market demand for speciality antimicrobials in plastics in 2001 was $130 million at a manufacturing level and $231 million at end-user level. The overall growth of the industry is around 3.5-4% per year. Figure 1 illustrates the main end uses for antimicrobials in 2001 in percentage terms.

The broad range of applications treated would indicate that antimicrobials are used in a broad range of plastics. However, PVC is the dominant polymer for antimicrobials but materials are now being developed for polyamides, polyolefins, polysulphides, polyurethanes, styrenics and many other systems.

## *The market by region*

North America is the leading market for antimicrobials, accounting for nearly 40% of global consumption (see Figure 2). Japan is the largest market on a per capita basis and far exceeds North America and Western Europe. The reason for this difference may be due to three factors. Firstly, products in North America in which a biocide is used must be registered (along with the agent itself) with the EPA. This tends to limit the adoption of biocides in plastics. Secondly, the population density in Japan coupled with major food poisoning scares during the 1990s has made the Japanese highly receptive to antimicrobial products. In Japan, the use of biocides is spread across all resins, while in the other regions, the vast majority of antimicrobials are used in flexible PVC. In Japan 30% of antimicrobials are used in items used in kitchens and bathrooms, 25% in food protection (films, trays, housewares), 20% in appliances, 14% in construction and 12% in other uses.

The antimicrobial type is also different with OBPA being the dominant type in all regions outside Japan, while silver is the dominant antimicrobial in Japan.



## Major antimicrobials used

The market leading antimicrobial product is OBPA (10,10'-oxybisphenox arsine). Although it is seen as the most efficient and cost-effective preservative for plastics and accepted by the Environmental Protection Agency as able to be used safely, concerns with some consumers do exist regarding its safety. Arsenic-based products are estimated to account for 50% of the market, but our research forecasts that there will be a significant shift in consumption patterns. In the future, the demand for non-arsenic based formulations is predicted to rise at 10-20% per year.

The active component of an antimicrobial system can either be organic or inorganic. Organic systems are generally based on small molecules that may contain a metal ion. They are incompatible with the polymer matrix and therefore diffuse to the surface where they interact with microorganisms present. Equilibrium is reached between the antimicrobial present at the surface and that in the body of the polymer. The antimicrobial will only diffuse out of the polymer when the surface is wiped or washed, providing extended antimicrobial performance with the biocide in the polymer acting as a reservoir. The dominant organic antimicrobial used in plastics is 10',10'-oxybisphenox arsine (OBPA) followed by 2-n-octyl-4-isothiazolin-3-one (OIT), 2,4,4'-trichloro-2'-hydroxy diphenyl ether, zinc pyrithione, N-Butyl-1,2-benzisothiazolin-3-one and N-(trichloromethylthio)phthalamide.

Inorganic systems are based on metal ions, stabilized in some way so that they are unreactive until released in association with another agent, such as moisture.

The most common metal ion used is silver, the antimicrobial effect of which has been used for many years. Metal ions interact with many aspects of microbe cellular activity, primarily through interference with enzymatic action. The metal ions as the antimicrobial agent remain stored in the polymer, only being released gradually to the surface, providing continual and long lasting antimicrobial activity.

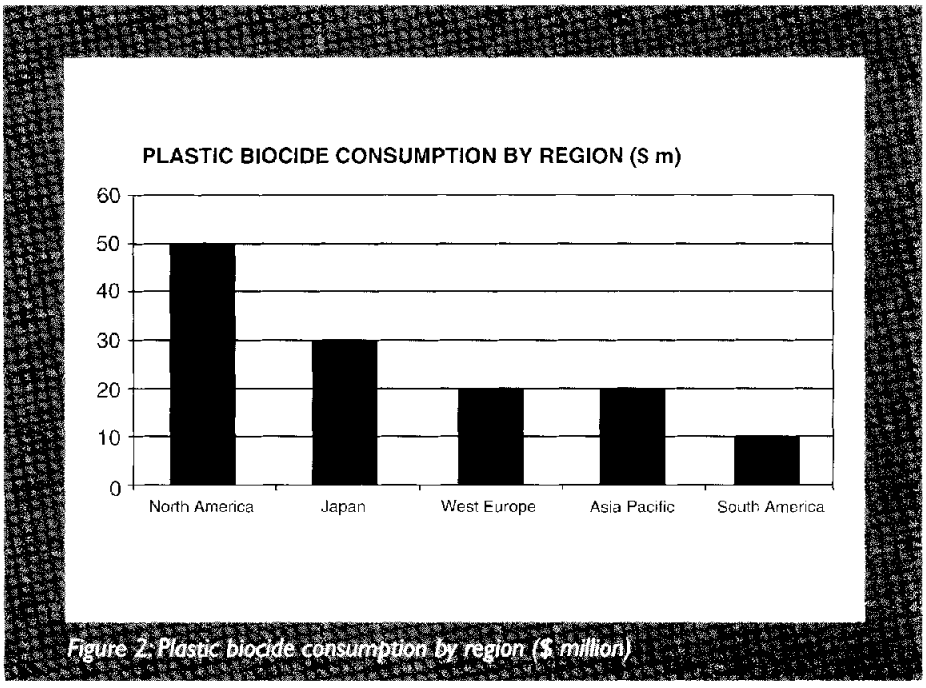



*Figure 2: Plastic biocide consumption by region ($ million)*

Metal ions are typically formulated in a glass or inert material. The antimicrobial activity of the glass formulation results from the presence of silver ions that are encapsulated in a soluble glass matrix. In the presence of moisture the outer layer of the glass matrix is slowly dissolved and silver ions released at the surface. The glass matrix not only protects the silver ions during processing, but its solubility can also be chemically changed to alter the rate of silver ion release. The high heat stability and controlled release of the glass systems make them ideal for use in engineering polymers. Suitable applications include polyester fibres, styrenic and polyolefin mouldings with long life spans, as well as medical devices.

The most common alternative carrier to glass is inert material. With this system the silver is present as a compound stabilized by a chemical association with an inert material. In the presence of moisture the silver dissociates, releasing silver ions at the surface.

## Distribution system

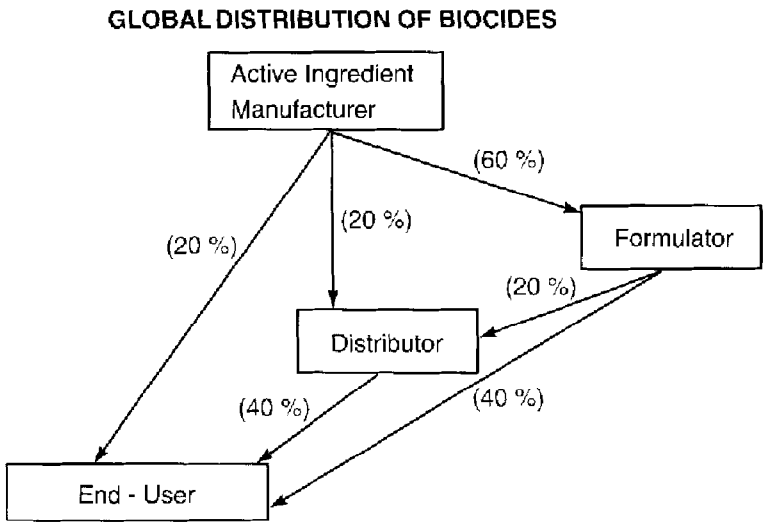
The global plastic antimicrobial industry has a broad range of suppliers to the end users (masterbatch manufacturers), which can be categorized into three distinct groups:

- Biocide active ingredient manufacturers
- Formulators
- Distributors

**Biocide active ingredient manufacturers** sell direct to end-users and also to formulators (blenders) and distributors. The leading biocide manufacturers are Akzo Nobel, Arch, Avecia, Bayer, Ciba Specialty Chemicals, Ishizuka, Johnson Matthey, Rohm & Haas, Toagosei, Troy and Shinagawa.

**Formulators (Blenders)** are defined as companies with a majority of sales arising from purchased antimicrobials that are formulated into their own products. They have achieved high market penetration by providing focused customer service and formulating blends of actives that provide a broader spectrum of control. The leading formulators are Agion, Akcros (Akzo Nobel), Microban, Morton (Rohm & Haas), Ferro, Sanitized and Thompson.

**Distributors** act as agents for both active manufacturers and formulators. They are the most popular choice of supplier for small end users. Distributors sell a range of plastic additives and so will be making deliveries to end users and therefore antimicrobials tend to be combined with




other products, which allows the distributor to be competitive.
The main distribution channel for antimicrobials is via formulators and distributors, which accounts for 80% of biocide consumption as illustrated in Figure 3.

## Active manufacturers

The acquisition of the US speciality chemical producer Morton in 1999 has given Rohm & Haas the position as leading supplier of antimicrobials to the plastics industry. The company has antimicrobials based on 10',10'-oxybisphenox arsine (OBPA) and 2-n-octyl-4-isothiazolin-3-one (OIT).
One manufacturer with a long product history in this field is Akcros Chemicals (owned by Akzo Nobel which is the sole manufacturer of OBPA), which offers a number of biocides in its proprietary Intercide family, based on a range of active agents dispersed in liquid or solid carriers.
An antimicrobial material that has seen large growth recently is triclosan from Ciba Specialty Chemicals. Triclosan is incorporated into the structure of the polymer during compounding, using proprietary technology that introduces the biocide into the empty spaces forming part of the structure. Therefore it is built into the moulded plastics product during the manufacturing process and is designed to last for the useful life of the product. Ciba also supplies inorganic (silver) antimicrobials made by Kanebo Chemical Industries in Japan. Ciba will distribute them outside Asia as Ciba Irgaguard.
The use of silver-based antimicrobials as an alternative technology for biological control is growing. Five companies dominate in the manufacture of silver including Ishizuka, Johnson Matthey, Kanebo, Shinanen and Toagosei. The products are described as potent broad spectrum antimicrobials, based on the controlled release of silver ions. Toagosei supplies its silver-based inorganic antibacterial agent, Novaron, in the USA and Europe, as well as Japan. In the USA, the company cooperates with Milliken, an American textile manufacturer. Shinanen sells its Zeomic antibacterial agent in Japan and the USA, and is now entering the European market. Ishizuka serves the Asian and European plastics industry with inorganic silver in a glass matrix.
Avecia is active in this market and recently launched Vanquish, which is said to provide powerful polymer protection based on the patented active, N-butyl-1,2-benzisothiazolin-3-one (BBIT). Vanquish antimicrobials are developed specifically for the plastics industry. They have a broad spectrum of activity against the microbes that degrade polymers, including PVC, polyurethanes, polyolefins, silicones and others.

## Formulators (Blenders)

AgION Technologies provides an inorganic, ceramic compound that allows the slow release of silver ions from the treated surface to provide long lasting, safe, and durable protection against organic contamination that can cause odours, degrade ventilation equipment, and reduce its efficiency.
Agion recently announced agreements with such companies as DuPont Powder Coatings for its powder coatings; Honeywell Consumer Products for humidifier filters; Mile High Equipment Company for ice makers; AK Steel for industrial and commercial steel products; and C.R. Bard, for urological catheters.
Ferro is a leading US formulator that offers Micro-Chek antimicrobial, which is EPA-registered as an industrial mildewcide for PVC, PU and other polymers, and is particularly suitable in outdoor applications, such as roofing membranes.
Microban offers a triclosan formulation and Ciba and Microban cooperate to offer complete solutions for antimicrobials in plastics. Other formulators active in the plastic antimicrobial industry are Sanitized and Thompson research.

## Requirements of a new biocide

The prevailing attitude among users of antimicrobials is the desire for more

environmentally safe materials driven by Environmental and Health and Safety issues.

In addition, an active ingredient requires the following features:

- Effectiveness against micro-organisms.
- Cost effectiveness in the end product.
- Compatibility with ingredients of the final product.
- Does not discolour the final product.
- Can withstand high processing temperatures.
- Effectiveness over a wide pH range.
- Low toxicity to humans.
- Extensive supporting documentation.
- High biodegradability.

Even if an active ingredient is developed with these characteristics, the cost of bringing a new molecule to the market is high. Manufacturers of active ingredients estimate that the cost for global registration is $5 million. It takes two years to conduct the toxicological testing and another 2-3 years for regional governments throughout the world to grant registration. End users will often want to evaluate the biocide over a 1-5 year test period.

As a result of these requirements and small potential market size, biocide manufacturers are extending product lines by turning to existing active ingredients for new applications instead of developing new molecules.

## Expected growth

The expected growth of the global plastic anitmicrobial industry is 4% per year up to 2005. There are a number of key drivers for this growth. These include:

- The marketing advantages of value added antibacterial products, which have generally met with consumer favour, and the need to ensure hygienic conditions in industrial, commercial, medical and other institutional settings will support further gains.
- Regulatory pressures on traditional antimicrobials, such as OBPA, PCP, TBTO, for example.
- Increasing concerns related to disease transmission will drive demand for surfaces treated with antimicrobials.
- High end-industry growth in particular geographical regions, such as Asia.
- Growing use of antimicrobials as hygiene aids.
- Increasing use of plastics in new applications, including decking.

*The Biocide Information Services (BIS), based at University College Dublin, provides a broad range of support services to the global antimicrobials industry and has recently completed a comprehensive report on the global plastics antimicrobials industry.*

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