Technical Paper
by Alys Bradshaw
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Tyre Wear Particles

Chemistry, Hazards and Regulations of the tyre additives Mercaptobenzothiazole (MBT) and Diphenylguanidine (DPG)

1.0 Introduction

Chemical additives are used to improve the performance characteristics of tyre rubber. Two compounds, mercaptobenzothiazole (MBT) and diphenylguanidine (DPG) play a huge role in making tyres strong, flexible and long-lasting- all of which affect a vehicle's safety and maintenance. Yet, as vital as these chemicals are, growing research shows the environmental and health concerns that come with them.

2.0 Vulcanisation and Role of Accelerators

To transform rubber into something durable and improve its physical properties, manufacturers use the process of vulcanisation. This uses sulphur to create a cross-linked molecular network and gives rubber:

- Higher durability and strength
- Better elasticity and flexibility
- Improved resistance to heat, abrasion and wear

However, sulphur reacts too slowly by itself to be considered practical for industrial tyre manufacturing. Accelerators enable vulcanisation to occur more rapidly, with greater control and efficiency, and at lower temperatures.

Two chemical accelerators commonly used worldwide in rubber manufacturing are thiazoles and guanidines, specifically mercaptobenzothiazole (MBT) and diphenylguanidine (DPG).

3.0 Chemical Profiles

3.1 Mercaptobenzothiazole

Common name: MBT

Chemical formula: $C_7H_5NS_2$

The organosulfur compound has been used as the primary vulcanisation accelerator in rubber production since 1925. This is the main accelerator in this process that starts and drives the reaction and lessens the energy usage during curing. MBT is used in treads, sidewalls and bead compounds, where it is crucial for the tyre to be strong and heat resistant.

Mercaptobenzothiazole can exist in both dissolved and particulate-bound phases within stormwater. MBT can absorb onto sediment particles depending on the environmental conditions of the specific sediment and water, like pH, other pollutants and the organic matter present. However, MBT is typically found more

in the dissolved phase rather than being bound to particles. This affects how it behaves in aquatic environments.

3.2 Diphenylguanidine

Common name: DPG

Chemical formula: $C_{13}H_{13}N_3$

The organic compound DPG is the secondary vulcanisation accelerator, used to enhance the efficiency of the MBT. DPG helps achieve an equilibrium between processing safely and fast cure times, which leads to consistent quality, performance and design life for rubber tyres.

A study which analyses urban watershed samples discovered that DPG doesn't remain dissolved in water but rather associates with sediments to become particulate-bound.

3.3 Other Additives

Many other different tyre additives exist and are used globally in the industry. Research into these chemicals and where they end up have been emerging more in recent years as long-lasting effects have been revealed. Tesni Hyett has researched into the chemical compound 6PPD-quinone (6PPD-Q) for 3P Technik (Toxic Tyres? A study of 6PPD in Stormwater - 3P Technik UK Ltd). This short study revealed a long list of toxic effects for humans, fish and mammals that the antioxidant additive has because of its use in rubber manufacturing.

4.0 Health and Environmental Impacts

The benefits these chemicals have on the process and ultimately the product have made it indispensable to the process of rubber manufacturing.

However, tyres wear down constantly on road surfaces; therefore, the unreacted compounds that are present within the finished rubber are also worn off as tyre wear particles (TWP). But what potential effects can MBT and DPG have?

4.1 Human and Animal Health effects of MBT

- Skin sensitiser: Capable of causing allergic contact dermatitis
- Thyroid interference: Laboratory studies suggest MBT may inhibit thyroid peroxidase which affects the production of thyroid hormones in humans
- Carcinogenic potential: International Agency for Research on Cancer (IARC) has classified MBT as 'probably carcinogenic to humans' based on animal studies (IARC Group 2A)
- Cancer: An increase in bladder cancer was observed when workers were exposed to high concentrations of MBT in two studies
- Tumours: Rats and mice that were orally exposed to MBT saw more incidences of tumours

4.2 Environmental Effects of MBT

MBT is toxic to aquatic life due to the potential leaching into aquatic environments from stormwater runoff. This affects the rate of algae growth for both marine and freshwater algae in a water body and therefore available oxygen levels for marine organisms decreases *(Obanya et al., 2025)*. This potentially affects marine food webs as organisms cannot survive in these new conditions.

As MBT is found predominantly in a dissolved phase, the chemical is more bioavailable and can more easily penetrate biological membranes which increases the possibility of further ecological risk to aquatic organisms.

MBT is resistant to natural biodegradation processes and can remain in aquatic environments for long periods of time. The half-life of MBT can reach up to 280 days *(Redox Ltd, 2022),* which is dependent on water conditions such as sunlight exposure, temperature, pH and oxygen levels and microbial activity. Bioaccumulation takes place which further contaminates the water body, affecting organism growth and development in the environment for years.

4.3 Human and Animal Health effects of DPG

- Irritation: Can cause irritation to human skin and eyes
- Skin sensitisation: May cause contact dermatitis
- Harmful if swallowed
- Respiratory issues: Upper respiratory tract through inhalation is affected
- Hormonal activity interference
- Hinders reproduction and development: reported to cause neurological disorders as well as being damaging to fertility and development (ANSES) (ECHA, H361)

4.4 Environmental Effects of DPG

ECHA (European Chemicals Agency) has determined that DPG shows inherent but not rapid biodegradability, indicating some persistence in aquatic systems. This means that DPG has low bioaccumulation potential. However, studies in Canada, China and Australia show that even at low concentrations, DPG's contamination in aquatic environments is long-lasting *(Hutchins, 2025),* with the chemical also being detected in water bodies near urban area and indoor dust *(Wang et al., 2025)*.

A study completed in 2025 discovered that DPG can be moderately toxic to fish, with lethal concentration values (LC50) typically between 4 and 11mg/L, confirming that even at low concentrations DPG can be harmful to aquatic life.

The growth of tiny marine algae known as diatoms in water is also negatively affected by tyre derived chemicals polluting water bodies. A study completed in 2025 found that tyre-derived chemical compounds (DPG, MBT and 6PPD-Q) suppress the growth of diatoms in aquatic ecosystems *(Obanya et al., 2025)*. These microscopic organisms are the foundation of aquatic food webs as they generate oxygen which sustains life and supports entire ecosystems. Suppressed growth results in the destruction of entire food webs, thus affecting the stability and sustainability of aquatic ecosystems. Obanya discovered that DPG and MBT are highly toxic even at low concentrations with DPG being the most toxic to aquatic life with a half maximal effective concentration (EC50) of 0.101µg/L *(2025)*. Hutchins raises a concern about the increase of tyre-derived pollution that is expected with the increasing shift to electric vehicles *(Hutchins, 2025)*. These vehicles are generally heavier; therefore, will generate more tyre wear particles that are released into the environment which will be transported readily in stormwater and urban runoff.

Not only are these chemicals hazardous in occupational settings, but they also persist beyond the factory floor into our environments.

5.0 Pathways and Exposure

These chemicals are predominantly released through the breakdown of tyres. They enter stormwater or wastewater systems or can travel through urban runoff, ending up in water bodies such as rivers, ponds and oceans.

Human consumption from the leaching of these chemicals into soils and water bodies can create an indirect link into the human food chain.

Exposure to these chemicals also include skin contact with rubber products, which risks the health and safety of the public and inhalation of airborne particles, which have been detected in urban air.

People most at risk:

- Rubber industry workers: exposed through skin contact or inhalation. Males are at risk the most as typically they dominate industry work
- Urban population: exposed to the TWP through airborne particles
- Aquatic organisms: exposed through bioaccumulation of the TWPs over time flowing into water bodies by stormwater

6.0 Legislation classifications and regulations

The classification, research and regulatory control measures for both MBT and DPG vary significantly around the world. Each region applies its own framework to register, assess and apply regulations for the risks of harmful chemicals.

6.1 Global Regulatory Overview

6.1.1 EU Framework

If a chemical is recognised under EU REACH (Registration, Evaluation, Authorisation, and Restrictions of Chemicals), it must meet REACH obligations and comply with future restrictions. REACH aims in protecting human and environmental health from chemical risks. Key EU regulatory frameworks under REACH include:

- ECHA which implements REACH and CLP regulations and ensures companies register substances ensuring safe use in commercial and industrial settings.
- SVHC (Substances of Very High Concern)- recognising these chemicals pushes the need for new safer alternatives to be researched and used in practice
- Annex XVII: lists restricted substances due to the potential effects they have on human health or environmental quality
- Annex VI: Lists harmonised classifications and labelling of hazardous chemicals

CLP (Classification, Labelling and Packaging) is a separate regulation structure used for the EU as well. It is based on GHS that identifies the physical chemistry, health and environmental effects of toxic chemicals

- GHS (Globally Harmonised System): this UN framework is implemented for the EU through CLP, and it provides consistent classifications and labelling of chemical substances to aid in protecting human health and environmental quality.
- Annex VI is also a key part of CLP regulation

6.1.2 US Framework

The US Environmental Protection Agency can request tests, reports and restrictions on a chemical under the TSCA (Toxic Substances Control Act) and therefore manage existing chemicals and new chemicals that come into play.

OSHA is also a US federal agency (Occupational Safety and Health Administration), that aims to regulate workplace health and safety.

6.1.3 Canada Regulations

Canada has a pollutant release reporting program- the NPRI, that has been reporting chemicals since the 1990s. This public database informs individuals about risks near them, monitors pollution levels against environmental goals and can therefore help the fight against air and water pollution.

6.1.4 Australian Regulations

AICIS (Australian Industrial Chemicals Introduction Scheme) regulates the manufacturing and importing of chemicals in industrial settings. They contain risk-based categories which companies must comply with their requirements if chemicals are involved in their processes.

HCIS (Hazardous Chemical Information System) classifies and labels chemicals in the workplace that are potentially or known hazards. This is in line with GHS and used in Australia since 2016.

HSIS (Hazardous Substances Information System) is the former chemical database for chemicals in Australia prior to adopting GHS.

6.2 EU Framework

6.2.1 Mercaptobenzothiazole

MBT is registered under REACH and listed in ECHA'S database, therefore the law requires companies to register and manage the risks of MBT that they manufacture or import, while also seeking safer alternatives to MBT for use in rubber manufacturing.

As MBT is not the SVHC list or Annex XIV, authorisation is not currently required.

CLP regulates and classifies MBT as a hazardous substance, which means that any packages must be labelled as hazardous and ensures that hazards are communicated with those handling the packages.

MBT is not currently restricted under Annex XVII, though ECHA is evaluating its risk profile for potential future action.

Under the REACH organisation, the chemical compound MBT is classified under:

- Skin Sensitiser 1 (H317)
- Aquatic Acute 1: Very toxic to aquatic life in the short-term (H400)
- Aquatic Chronic 1: Very toxic to aquatic life with long lasting effects (H410)

Knowing these risks, REACH has produced no universal limit for exposure for MBT.

However, the German Social Accident Insurance has set a legally binding occupational exposure limit of 4 mg/m^3 of MBT inhalable dust to protect workers in the industrial environment.

6.2.2 Diphenylguanidine

Diphenylguanidine is recognised under ECHA and is classified as harmonised under CLP which is generally the minimum classification and may not cover all hazards.

Despite being classified as harmful, it is not included in the SVHC list and has no established exposure limits set by ECHA for the EU.

Any packages containing DPG must be labelled with a hazard pictogram and the signal word 'warning' respectively as a warning for handlers.

From REACH and all its suborganisations, DPG is labelled and classified under:

- Aquatic Chronic 2: Toxic to aquatic life with long-lasting effects for marine and freshwater environments (H411)
- Skin Irritant 2 (H315)
- Eye Irritant 2 (H319)
- Acute Toxicity 4: Harmful if swallowed (H302)
- Reproductive Toxicity 2: Damaging the fertility or the unborn child (H361)
- STOT Single Exposure 3: Respiratory Irritation (H335)

Differently to this, the French Agency for Food, Environmental and Occupational Health & Safety (ANSES), sees the need to strengthen and upgrade this classification to protect against neurological and reproductive toxicity in humans, but currently the chemical is still under evaluation.

The IARC has researched into the effects of MBT- Group 2A (probably carcinogenic to humans), however no research for DPG has been completed by this organisation.

6.3 US Framework

6.3.1 Mercaptobenzothiazole

In the US, MBT is classified under TSCA but sees no restrictions from it or OSHA limits for workers but suggest safety measures of spill handling and the use of PPE.

6.3.2 Diphenylguanidine

Similarly to MBT, DPG is on the TSCA inventory but with no restrictions for use, manufacturing or selling. Specific regulations for DPG under OSHA do not exist as it isn't listed under the main chemical specific standards, so it is suggested that industry workers and managers should adhere to the general OSHA safety requirements for chemicals.

6.4 Canadian Regulations

6.4.1 Mercaptobenzothiazole

MBT has been in NPRI since 1999 and has a MPO (when the chemical is used commercially) reporting threshold of 100kg. Environment and Health Canada are pursuing further risk assessments for MBT and are actively considering stronger restrictions on the manufacturing of rubber using MBT as an additive.

6.4.2 Diphenylguanidine

The Government of Canada concluded that the chemical is not entering the environment at a dangerous or harmful concentrations, and it is not harmful to the public's health currently and therefore does not have restrictions against its use.

6.5 Australian Regulations

6.5.1 Mercaptobenzothiazole

Australia is also evaluating control measures to eliminate risks associated with MBT, but no national ban has taken place yet, even though MBT is classified as a hazardous chemical under H317- skin sensitiser and H410- very toxic to aquatic life with long lasting effects- the same classification as GHS is a UN framework.

Through the Hazardous Chemical Information System (HCIS), AICIS reported that MBT are:

- Carcinogenic 1B (H350: may cause cancer)
- Skin Sensitisation 1 (H317: may cause an allergic skin reaction)
- Skin corrosion 1C (H314: causes severe skin burns and eye damage)

To regulate these risks, workers should not be exposed to the standards for airborne contaminants using ventilation systems and PPE and the release into the environment should be avoided (not specified how to do so).

6.5.2 Diphenylguanidine

No restrictions have been made despite been classified under the Hazardous Substances Information System (HSIS) as:

- Reproduction Category 3 (Xn; R62)
- Acute toxicity (Xn; R22- harmful if swallowed)
- Irritation (Xi; R36/37/38- irritating to eyes/ irritating to respiratory system/ irritating to skin)

Only restrictions against DPG are from the Work Health and Safety (WHS) organisations that mention safe handling and proper waste handling/ spill control, again not specified direct exposure limits.

More research is necessary into the effects from these rubber tyre additives in order to come to a general conclusion of threats to humans, animals and the environment.

7.0 Managing the risks posed

Measures must be taken to decrease the exposure of MBT and DPG to the public and the environment.

Key approaches may include:

- Protection of industry workers: mandatory PPE such as gloves, masks or the installation of ventilation systems
- Improved stormwater treatment: to capture the finer particles (including TWP) and so prevent them from entering water bodies
- Further research into the long-lasting effects these chemicals have on humans, animals and the environment (including terrestrial and aquatic ecosystems and the atmosphere)

In order to remove the chemicals from stormwater runoff, different approaches must be taken. As MBT is found predominantly in a dissolved phase, it affects the behaviour of the chemical in aquatic environments and is more difficult to remove from the stormwater. Sedimentation alone won't be a feasible option for the removal of MBT from stormwater. However, filtration systems may well be able to remove the dissolved particles.

As DPG is a particulate-bound compound, its transport and overall fate in water and aquatic environments are affected and can be resolved by the sedimentation. This means that devices like the 3P HydroShark and other Hydrodynamic Separators will be efficient in removing this pollutant.

As the chemicals- MBT and DPG are used as a synergic pair for rubber tyre additives, it is likely that both are present in water bodies, and a treatment system must be capable to remove both.

3P Technik's HydroSystem allows for sedimentation to take place in the hydrodynamic separator, where any sediments containing DPG will settle and can be collected and removed as usual via the silt trap chamber access pipe. The water is then passed up through a filter element which will capture finer particles and potentially remove dissolved MBT from the water. The DPG is then permanently removed when exchanging the filter, at the required intervals. This HydroSystem treatment system allows for an output of clean water which will better the environment and pose fewer risks to aquatic environments and the organisms that live in them.

8.0 Conclusion

The small chemical compounds- mercaptobenzothiazole and diphenylguanidine have been improving the overall quality of rubber tyres for a century and providing the strong, durable and reliant tyres that drivers rely on every day globally. However, the growing body of research into their effects on human and animal health and environmental quality should not be ignored.

Mitigation of these harmful chemicals aligns with the following UN Sustainable Development Goals:

- SDG 6: Clean water and sanitation
- SDG 12: Sustainable consumption and production
- SDG 14: Life below water
- SDG 15: Life on land

Moving on to a more sustainable and ecofriendly century must see the mitigation and reduction of these chemical additives. If they are to be used in tyres, then effective stormwater treatment measures must be incorporated to remove them for better water quality and less risks for aquatic environments.

9.0 Further Information

3P Technik's technical team can provide project-specific advice and support. Please contact us to discuss your requirements. Tel: +44 (0)1239 623506, Email: sales@3ptechnik.co.uk.

This article is published on the 3P Technik website: Tyre Wear Particles in Stormwater: Why MBT and DPG Chemical Contamination Matters.

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