Preliminary Alternative Analysis Report

Motor Vehicle Tires Containing N-(1,3-dimethylbutyl)-N´-phenyl-p-phenylenediamine (6PPD)

Prepared for

DEESTONE CORPORATION PUBLIC COMPANY LIMITED

July 12, 2024

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Executive Summary

Starting from October 1, 2023, a new regulation enacted by the California Department of Toxic Substances Control (DTSC) under the Safer Consumer Products (SCP) Regulations has come into effect by listing motor vehicle tires containing N-1,3-dimethylbutyl-N´-phenyl-p-phenylenediamine (6PPD) as a Priority Product. Due to concerns about the environment and public health, DTSC has enacted this regulation, mandating tire manufacturers to explore safer alternatives to 6PPD. Manufacturers, both domestic and international, producing motor vehicle tires containing 6PPD and whose products are placed into the stream of commerce in California must submit not only a Priority Product Notification (PPN) for their products by November 30, 2023, but also subsequently a Preliminary Alternatives Analysis Report (AA report). Under the SCP Regulations, this requires tire manufacturers to find safer possible alternatives to 6PPD.

In the point of view of tire durability and driving safety, rubber tires rely significantly on antidegradants such as 6PPD, the most well-known antidegradant used in tires. For decades, 6PPD has been essential in protecting motor vehicle tires from ozone and oxygen-induced degradation, preventing cracks. However, 6PPD poses a significant threat to aquatic ecosystems due to its toxicity to aquatic organisms, particularly coho salmon. When 6PPD reacts with ozone to form 6PPD-quinone, this transformation product becomes acutely lethal to coho salmon and other fish species. Throughout a tire's lifespan, 6PPD migrates to the tire surface, continuously protecting against degradation. However, as tires wear, particles containing 6PPD are released into the environment, especially through road dust carried by runoff and stormwater. The exact mechanisms of 6PPD-quinone formation are not fully understood, but its presence in California waterways suggests its persistence and potential harm to aquatic organisms.

In late 2020, it was first reported that aquatic organisms are exposed to both 6PPD and 6PPD-quinone from motor vehicle tires, posing significant risks to coho salmon populations during their upstream migration for spawning in California. This exposure threatens endangered and threatened species, potentially hindering their recovery efforts. The loss of coho salmon has broader implications, affecting Native American tribes in California who rely on these fish for sustenance, impacting cultural practices, health, and economic stability within tribal communities [1].

In this Stage 1 AA report prepared under the SCP Regulations, several different typed of alternatives to 6PPD were considered as an antidegradant in tires such as 7PPD, IPPD, 77PD, CCPD, TAPDT and Vulcazon AFS. To evaluate potential alternatives to 6PPD, several key factors must be considered to ensure their safety and sustainability. First, a thorough assessment of the toxicity and health risks of the alternatives is necessary, covering both acute and chronic effects on human health and biological organisms. Second, the environmental impact of the alternatives should be evaluated. This is essential to understand how these chemicals interact with ecosystems and their potential ecological risks. Lastly, it is crucial to ensure that the alternatives comply with relevant regulatory standards and guidelines, such as those specified by SCP regulations and international chemical management frameworks.

At this point after all evaluation approaches, four possible alternatives, 77PD, CCPD, TAPDT and Vulcazon AFS were identified as potential alternatives to 6PPD, based on recent available information about the usage and toxicity.

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CERTIFICATION AND SIGNATURES

"I certify that this document and all attachments were prepared or compiled under my direction or supervision to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person(s) directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that submitting false information or statements is a violation of law."

Responsible Entity Signature ______________________________ **Date** July 12, 2024 .

[Mr. Siritape Promsopa]

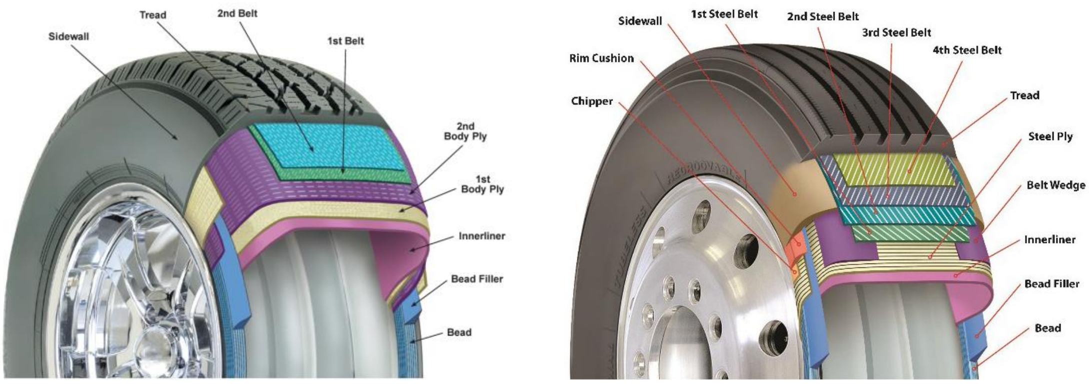
2. Supply Chain

Information regarding supply chain is being submitted to DSC by DEESTONE CORPORATION PUBLIC COMPANY LIMITED as confidential business information and is not included in this report.

3. Priority Product Information

3.1 Tire Construction and Compositions

Tires are a complex composite body made of materials with different physical properties. The radial tire consists of main components such as bead, belt, body plies, inner liner, sidewall and tread, as shown in Figure 1 [2, 3]. Various requirements are placed on each component, which are achieved through optimization of the construction and variation of the elastomer compounds.



(a) Pneumatic radial passenger car tire (b) Pneumatic radial truck/bus tire

Figure 1: Typical structure of pneumatic radial (a) passenger car tire [2] und (b) truck/bus tire [3].

The tire bead ensures the secure fit of the tire on the rim of the metal wheel, with one or more high-strength wire cores embedded in the tire bead. Additionally, it seals the enclosed tire volume from the external environment. The body plies act as a strength carrier and consists of one or more layers of fabric attached to the belt. The belt construction, rotated 90° to the direction of travel, provides a particular rigidity and a stability to the tread area of the tire, which contributes to wear, handling and traction. The outermost layer is the tread. The tread is an important part of the tire, responsible for transferring the forces between the vehicle and the road. Essentially, the tire compounds and the tread profile, which provide grip and abrasion resistance, can be varied significantly and depend on the required application [2, 3].

The typical passenger tires consist of 41-48% rubber, 22-28% carbon black, 13-16% metal, 4-6% textile and 10-12% additives as shown in Table 1 [4]. In addition to rubber, tire compounds consist of various other components, such as fillers, accelerators, activators, aging protection and crosslinking agents, as well as plasticizers. The typical main components of the tire rubber compound are listed in Table 2, with proportions given in phr (parts per hundred rubber) [5].

Table 1: Typical material composition in tire manufacturing [4].

Composition (%)	Passenger car	Truck
Rubber/elastomer	41-48	41-45
Fillers	22-28	20-28
Metal/steel	13-16	20-27
Textile	4-6	0-10
Additives (antioxidants, antiozonants, curing systems etc.)	10-12	7-10

Table 2: Main components of the rubber compound and their general function [5].

Component	Function in compound	Amount [phr]	Characteristic parameters
Rubber	Influences mechanical, thermal, and chemical properties	100	Molecular weight, polarity, chemical resistance, thermal stability, tensile strength, relaxation
Filler	Improves mechanical properties	5-100	Specific surface area, functional groups on surface, interactions with rubber
Plasticizer	Improves processing behavior and elasticity	ca. 10% of filler level	Polarity, molecular weight, viscosity
Curing system	Forms the three-dimensional network	0.5-3.0 for sulfur	Crosslinking structure and its efficiency
Activator	Enhances crosslinking	0.1-1.0	Reaction kinetics
Accelerator	Increases crosslink density and reaction rate	0.2-3.0	Crosslinking structure, reaction kinetics
Antidegradant	Protection against oxidation, ozone and aging	0.2-0.5	Reactivity towards oxygen (O_2) and ozone (O_3)
Processing aids	Improves processing behavior and filler dispersion	0.1-0.2	Processability, viscosity reduction
Coupling agent	Enhances filler dispersion and chemical/physical bonding of fillers to rubber matrix	5-10	Hydrophobicity of filler surface

3.2 Legal requirements for motor vehicle tires

According to regulatory requirements in the United States, the Federal Motor Vehicle Safety Standards (FMVSS) 49 CFR Part 571 outlines specific performance requirements for motor vehicle tires to ensure safety and reliability. All passenger, truck and bus, trailer and motorcycle tires sold and used in the United States must provide reliable performance, safety, and durability under a wide range of conditions and must meet all applicable FMVSS. A summary of these requirements is listed in Table 3. Additionally, the requirements under the Uniform Tire Quality Grading Standards (UTQGS) and FMVSS No. 139 (49 CFR Part 571.139) must be applied to passenger car tires.

Table 3: Tire performance requirements according to FMVSS 49 CFR Part 571

Aspect	In detail what tires must provide
Treadwear and Durability	Demonstrate a minimum level of treadwear and durability, ensuring tires can withstand typical road conditions and usage over time.
High-Speed Performance	Maintain structural integrity and performance when tires are subjected to high speeds, preventing blowouts or failures.
Endurance	Endure prolonged usage without significant deterioration, ensuring tires remain safe and functional over their lifespan.
Low-Pressure Performance	Perform adequately even at lower-than-optimal inflation pressures, providing a safety margin in case of gradual deflation.
Strength	Meet specific strength requirements to resist impacts and punctures, ensuring they can handle typical road hazards.
Bead Unseating Resistance	Resist bead unseating forces, ensuring the tire remains securely mounted on the rim during cornering and other maneuvers.
Road Hazard Impact	Withstand impacts from common road hazards without failing, ensuring safety in typical driving conditions.
High-Temperature Performance	Maintain performance and safety at high temperatures, which can result from prolonged use or high-speed driving.
Rolling Resistance	Be controlled to ensure fuel efficiency while maintaining performance and safety standards.

3.3 Chemical of Concern for the Priority Product

The chemical of concern for the Priority Products is N-(1,3-dimethylbutyl)-N´-phenyl-p-phenylenediamine (6PPD) with CAS. No. 793-24-8. 6PPD is a chemical compound widely used in the rubber industry, particularly in tire manufacturing. Its primary function is to act as an antiozonant and antioxidant. A chemical structure of 6PPD is shown in Figure 2.

As an antiozonant, 6PPD protects rubber from ozone degradation. Ozone (O_3) in the atmosphere can cause cracks to generate in the rubber, a phenomenon known as "ozone cracking." 6PPD reacts with ozone to form a protective film on the surface of the rubber, preventing the ozone from penetrating and damaging the material. This is especially important for tires, which are constantly exposed to varying levels of ozone.

As an antioxidant prevents oxidative degradation of rubber. Rubber chains can degrade over time due to exposure to oxygen, heat, and light, leading to loss of elasticity, brittleness, and eventual failure. 6PPD acts as an antioxidant by neutralizing free radicals and other reactive oxygen species that can cause oxidative degradation. This extends the lifespan of the rubber by maintaining its mechanical properties and flexibility.

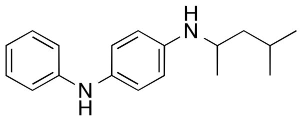


Figure 2: Chemical structure of 6PPD

For decades, 6PPD has served as a crucial antidegradant in motor vehicle tires, protecting rubber from degradation caused by ozone and oxygen, thereby preventing cracks. However, despite its effectiveness, 6PPD poses a significant threat to aquatic ecosystems due to its toxicity to various aquatic organisms, particularly coho salmon. When 6PPD reacts and forms 6PPD-quinone, as shown in Figure 3, the resulting transformation product proves acutely lethal to coho salmon and other related fish species, such as brook trout and steelhead/rainbow trout, with potential impacts on Chinook salmon as well.

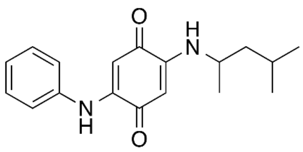


Figure 3: Chemical structure of 6PPD-Quinone

Throughout a tire's lifespan, 6PPD migrates to the tire's surface, offering ongoing protection against degradation. However, as tires wear down, tire wear particles containing 6PPD are released into the environment, particularly through road dust carried by surface runoff and stormwater. Although the exact mechanisms of 6PPD-quinone formation, a toxic transformation product of 6PPD, are not fully understood, its presence in California waterways indicates its persistence and potential harm to aquatic organisms, especially coho salmon.

In late 2020 [1], it was first reported that aquatic organisms face exposure to both 6PPD and 6PPD-quinone derived from motor vehicle tires. This exposure poses significant risks to coho salmon populations during their upstream migration for spawning in California, including endangered and threatened species, potentially hindering their recovery efforts. The loss of coho salmon has broader implications, impacting Native American tribes in California that have long depended on these fish for sustenance. Such losses not only affect cultural practices but also contribute to health issues and economic challenges within tribal communities.

3.4 Function of the Chemical of Concern in the Priority Product

6PPD is a crucial additive in tire manufacturing, providing essential protection against ozone and oxidative degradation. Its use enhances the durability, safety, and lifespan of tires, contributing to better overall performance and reliability of vehicles. In summary, antidegradants such as 6PPD must provide the following functions:

- **Enhanced Durability**: By protecting against ozone and oxygen-induced degradation, 6PPD helps in maintaining the structural integrity and performance of tires over their lifetime.
- **Improved Safety**: Tires with 6PPD are less likely to develop cracks and other forms of degradation, which can lead to blowouts or other failures. This improves the overall safety of vehicles.
- **Extended Service Life**: Tires treated with 6PPD have a longer service life, reducing the frequency of replacements and thereby saving costs for consumers and reducing environmental waste.
- **Compatibility with manufacturing processes**: 6PPD is typically incorporated into the rubber compound during the mixing stage of tire manufacturing. It is uniformly dispersed throughout the rubber matrix to ensure consistent protection.
- **Compatibility with other aspects of tire performance**: The concentration of 6PPD used in tire compounds is carefully controlled to balance the protective effects with other performance characteristics of the tire, such as grip, rolling resistance, and wear resistance.

4. Scope of Relevant Comparison Factors

4.1 Purpose and Approach for this Stage 1 AA

The purpose of a preliminary (Stage 1) Alternatives Analysis is to identify and evaluate potential alternatives to 6PPD used in the tire industry, based on literature review. This report is driven by concerns over the environmental and health impacts associated with 6PPD, particularly its degradation product, 6PPD-quinone, which has been linked to aquatic toxicity. The goal is to find safer antidegradants that provide comparable protective properties without the associated risks, ensuring that tire performance and safety are not compromised.

4.2 Alternatives under the SCP regulation

According to the SCP regulation [6], an alternative may include any of the following [7]:

- Removal of a Chemical of Concern from a Priority Product, with or without the use of one or more replacement chemicals.
- Reformulation or redesign of a Priority Product and/or manufacturing process to eliminate or reduce the concentration of a Chemical of Concern in the Priority Product.
- Redesign of a Priority Product and/or manufacturing process to reduce or restrict potential exposures to a Chemical of Concern in the Priority Product.
- Any other change to a Priority Product or a manufacturing process that reduces the potential adverse impacts or potential exposures associated with the Chemical of Concern in the Priority Product, or the potential adverse waste and end-of-life effects associated with the Priority Product that also meets the Priority Products function.

4.3 Approach for Identification of Alternatives

The approach for the Stage 1 AA report involves several key steps:

- **Literature review and data collection**: Conduct a comprehensive review of existing literature on 6PPD and its alternatives and gather data on the chemical properties, performance characteristics, and environmental and health impacts of potential alternatives.

- **Identification of potential alternatives**: Identify a list of candidate chemicals that could potentially replace 6PPD, firstly based on considering commercially available alternatives

- **Screening and prioritization**: Screen the identified alternatives based on initial criteria such as chemical structure, known performance characteristics, and preliminary safety data and prioritize alternatives for further evaluation based on their potential to meet the performance and safety requirements.
- **Performance evaluation**: Assess the performance of prioritized alternatives in laboratory tests, focusing on their ability to prevent oxidative degradation, maintain tire durability, and perform under various conditions (e.g., heat, pressure, and environmental parameters).

4.4 Relevant Factors

According to the SCP regulation, § 69505.5 (c) [6], several relevant factors need to be considered, focusing on exposure pathways and life cycle segments to identify alternatives to 6PPD in the tire industry. The possible relevant factors listed in Tables 3-1A and 3-2B of the DTSC AA Guide (2017) [7] were be considered and reported by U.S. Tire Manufacturers Association (USTMA) [8]. The summary of the possible relevant factors is listed in

To evaluate potential alternatives to 6PPD, it is essential to consider several relevant factors to ensure the safety and sustainability of the selected alternatives. First, the toxicity and health risks associated with alternatives must be rigorously assessed, encompassing both acute and chronic health effects. This involves a comprehensive analysis of the potential for immediate and long-term harm to human health and biological organisms upon exposure. Second, the environmental impact of these alternatives should be thoroughly evaluated, with a particular focus on their environmental persistence, bioaccumulation potential, and overall toxicity (PBT characteristics). This evaluation is crucial for understanding the interactions of these chemicals with ecosystems and their potential ecological risks. Lastly, ensuring that alternatives comply with relevant regulatory standards and guidelines, such as those specified by SCP regulations and international chemical management frameworks, is unavoidable. Regulatory compliance not only guarantees that the alternatives meet safety and environmental criteria but also facilitates their acceptance and implementation within the industry, thereby promoting a transition to safer alternatives.

By systematically considering these factors related to exposure pathways and life cycle segments, it should be identified safer alternatives to 6PPD that minimize environmental and health risks while maintaining tire performance and safety.

Life cycle segments
Raw material extraction
Resource inputs and other resource consumption
Intermediate materials production processes
Product manufacture
Packaging
Distribution
Use
Operation and maintenance
Waste generation and management
Reuse and recycling
End-of-life disposal

Adverse air quality impact
California Toxic Air Contaminants (e.g. benzene, Cr[VI])
Carbon dioxide (CO_2) emission
Hydrofluorocarbons
Methane
Nitrogen trifluoride,
Nitrous oxide
Perfluorocarbons
Sulfur hexafluoride
Other global warming potential gases
Particulate matter
Ozone-depletion substances
Sulfur oxides
Tropospheric ozone forming compound

Adverse ecological impacts
Impact on aquatic, avian or terrestrial animal, plant organisms, or microbes
Impact on aquatic and terrestrial ecosystems

Adverse soil quality impacts
Compaction or other structure changes
Erosion
Loss of organic matter
Soil sealing

Adverse water quality impacts
Introduction/ Increase in chemicals with MCLs
Increase in chemicals in drinking water public health goals
Exceedance of a standard relating to the protection of the environment

Note: Color and term definition to identify that a factor is relevant when 6PPD and Alternatives are materially different.

No	A considered factor is not relevant, indicating with expected or available data.
Unclear	Data were not available to give an indicator of whether a factor would be relevant or not.
Unlikely	Available Data were too limited.
Potentially	Available Data were too limited but leaned towards one direction.
Yes	A considered factor is relevant, indicating with expected or available data.

Figure 4: Consideration of relevant factors under the SCP regulation (modified from [8]).

Adverse public health impacts
Carcinogenicity
Developmental toxicity
Reproductive toxicity
Cardiovascular toxicity
Dermatotoxicity
Ocular toxicity
Respiratory sensitization
Skin sensitization
Organ sensitization
Endocrine toxicity
Epigenetic toxicity
Genotoxicity
Hematotoxicity
Hepatotoxicity and digestive system toxicity
Immunotoxicity
Musculoskeletal toxicity
Nephrotoxicity and other urinary system toxicity
Neurodevelopmental toxicity
Neurotoxicity
Ototoxicity
Reactivity in biological systems
Exceedance of a standard relating to the public health
Respiratory toxicity

Waste and end-of-life effects
Volume or mass generated
Any special handling needed
Effects on solid waste and wastewater disposal and treatment
Discharge to storm drains or sewer adversely affecting wastewater treatment facilities
Release into the environment

Environmental fate
Aerobic and anaerobic half-lives
Aqueous hydrolysis half-life
Atmospheric oxidation rate
Bioaccumulation
Mobility in environmental media
Persistence
Photodegradation

Materials and resource consumption impacts
Renewable resources consumption
Nonrenewable resources consumption

Physicochemical properties
Combustion facilitation
Explosivity
Flammability
Physical state
Molecular weight
Density
Vapor pressure
Melting point
Boiling point
Flash point
Water solubility
Lipid solubility
Octanol-water partition coefficient
Octanol-air partition coefficient
Organic carbon partition coefficient
Diffusivity in air and water
Henry's Law constant
Sorption coefficient for soil and sediment
Redox potential
Photolysis rates
Hydrolysis rates
Dissociation constants
Reactivity including electrophilicity

Product function and performance	
The useful life of the product	The functional acceptability of the product
The functional and performance of the product	The technical feasibility of the product

Economic impacts
Cost impacts to consumers or other users

Figure 4 (cont.): Consideration of relevant factors under the SCP regulation (modified from [8]).

5. Scope and Comparison of Alternatives

The possible alternatives for comparison and further evaluation in Stage 2 AA report should be selected not only with less hazard profile, but also with potential for use in tire manufacturing. Based on the review process and a recommendation according to the Preliminary (Stage 1) Alternative Analysis (AA) Report submitted by the U.S. Tire Manufacturers Association (USTMA) [8], six potential alternatives to 6PPD were selected for this AA report. Their chemical names and Chemical Abstracts Service Number (CAS No.) are listed in Table 4.

Table 4: Possible Alternatives to 6PPD.

Chemical Name	Acronym	CAS No.
N-(1,4-dimethylpentyl)-N'-phenyl-p-phenylendiamine	7PPD	3081-01-4
N-isopropyl-N'-phenyl-p-phenylenediamine	IPPD	101-72-4
N,N'-bis(1,4-dimethylpentyl)-p-phenylenediamine	77PD	3081-14-9
N,N'-Dicyclohexyl-p-phenylenediamine	CCPD	4175-38-6
2,4,6-tris{N-1,4-dimethylpentyl-p-phenylenediamino)-1,3,5-triazine	TAPDT	121246-28-4
3,9-dicyclohex-3-enyl-2,4,8,10-tetraoxaspiro[5.5]undecane	Vulcazon AFS	6600-31-3

5.1 Methodology and supporting information

According to the SCP Regulation [6], a hazard evaluation comparing 6PPD and possible alternatives must include hazard endpoints from the Green Chemistry Hazard Traits (California Code of Regulations, Title 22, Division 4.5, Chapter 54 [9]. The hazard profiles of 6PPD and the possible alternatives were reviewed by using mainly information according to European Chemicals Agency (ECHA), Registration Evaluation Authorization and Restriction of Chemicals (REACH) dossiers [10] and GreenScreen assessment (Appendix A for more detail). Additionally, acute salmonid toxicity was considered as hazard consideration for organisms in the Salmonidae family.

The hazards of 6PPD and possible alternatives were quantitatively scored by using an adaptation of the Chemical Scoring Index (CSI).

The consideration methodology and criteria such as hazard evaluation approach (e.g. human health and environmental endpoints, salmonid acute toxicity), transformation products and results of screening-level performance data were cited from the AA report submitted by USTMA (Chapter 5) [8].

5.2 Result of comparison

Due to a large amount of hazard information of concerned chemicals, the total scores for six possible alternatives were summarized in Table 5.

Table 5: Stage 1 Alternative Analysis report conclusion based on available data (modified from [8]).

Chemical Name	CAS No.	Human health score	Environmental score	Total score	Salmonid toxicity parent (ug/L)	Salmonid toxicity quinone (ug/L)	Performance evaluation	Conclusion
N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylendiamine (6PPD)	793-24-8	125	150	275	140 (96h)	0.041 (24h)		
N-(1,4-dimethylpentyl)-N'-phenyl-p-phenylendiamine (7PPD)	3081-01-4	120	150	270	No data	No data	Comparable to 6PPD	No further evaluation needed
N-isopropyl-N'-phenyl-p-phenylenediamine (IPPD)	101-72-4	150	100	250	No data	>50 (96h)	Comparable to 6PPD	No further evaluation needed
N,N'-bis(1,4-dimethylpentyl)-p-phenylenediamine (77PD)	3081-14-9	80	100	180	24 (96h)	>226 (96h)	Less effective	Further evaluation needed
N,N'-Dicyclohexyl-p-phenylenediamine (CCPD)	4175-38-6	115	150	265	No data	No data	Less effective	Further evaluation needed
2,4,6-tris{N-1,4-dimethylpentyl-p-phenylenediamino)-1,3,5-triazine (TAPDT)	121246-28-4	50	100	150	No data	No data	Good in NR but limited in BR and SBR	Further evaluation needed
3,9-dicyclohex-3-enyl-2,4,8,10-tetraoxaspiro[5.5]undecane (Vulcazon AFS)	6600-31-3	55	35	90	No data	No data	No data	Further evaluation needed

6. Selected Alternatives Conclusion

As described in Chapter 5.2, the hazard assessment of 6PPD and its potential alternatives was conducted as the top priority. Moreover, the possible alternatives for further evaluation in Stage 2 AA report should be selected with potential for use in tire manufacturing currently when the review data recommended them as having promise as an antidegradant compared to 6PPD. This is the reason why alternatives produced from natural resources such as lignin and rambutan peel extract were not considered in this Preliminary AA report. The selected alternatives to 6PPD and rationale are listed in Table 6.

Table 6: Summary of possible alternatives and rationale for selection.

Chemical Name	CAS No.	Rationale for selection
N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylendiamine (6PPD)	793-24-8	Chemical of Concern
N,N'-bis(1,4-dimethylpentyl)-p-phenylenediamine (77PD)	3081-14-9	This chemical has lower hazard scores than 6PPD and possibly effective performance against ozone [8].
N,N'-Dicyclohexyl-p-phenylenediamine (CCPD)	4175-38-6	This chemical has similar hazard scores to 6PPD and possibly effective performance against ozone [8].
2,4,6-tris{N-1,4-dimethylpentyl-p-phenylenediamino)-1,3,5-triazine (TAPDT)	121246-28-4	Despite lack of toxicity data to coho salmon, this chemical has lower hazard scores than 6PPD.
3,9-dicyclohex-3-enyl-2,4,8,10-tetraoxaspiro[5.5]undecane (Vulcazon AFS)	6600-31-3	Despite lack of toxicity data to coho salmon, this chemical has lower hazard scores than 6PPD.

7. Next Steps, Work Plan

7.1 Tasks for Stage 2 AA

According to the SCP regulation and DTSC AA report guideline [7], the Stage 2 of the Alternatives Analysis (AA) involves an in-depth analysis, refining the relevant factors and product function descriptions from the first stage while expanding the scope to include additional impacts, such as life cycle and economic effects, based on new data after submission of the Stage 1 AA. The evaluation and comparison process is iterative, allowing the responsible entity to integrate new and more detailed information as it becomes available. The responsible entity must document its decision in the Final AA Report, which must also include a schedule for implementing the chosen alternative, if applicable.

7.2 Work plan for laboratory investigation of selected alternatives

During waiting period of DTSC approval on Stage 1 AA report, the responsible entity started a research cooperation with National Metal and Materials Technology Center (MTEC) THAILAND to investigate antidegradation efficiency of the selected alternatives to 6PPD and characterize rubber vulcanizates having different antidegradants after aging in laboratory and prototype scales. To better understand the efficiency of alternative antidegradants, a simple model compound is required to eliminate unexpected interference from other components. Principally, natural rubber (NR) will be used as a rubber matrix and carbon black as a filler. In addition, the content (in phr) of other additives such as wax, TMQ, ZnO, stearic acid, curing agents, and antidegradants will be kept constant in all compound formulas. Only the type and proportion ratio of the selected antidegradants will be varied. The work plan for laboratory investigation of selected alternatives is shown in Figure 5.

At the end of this investigation, one or more possible alternatives to 6PPD should be identified that hold promise to replace or materially reduce 6PPD in motor vehicle tires.

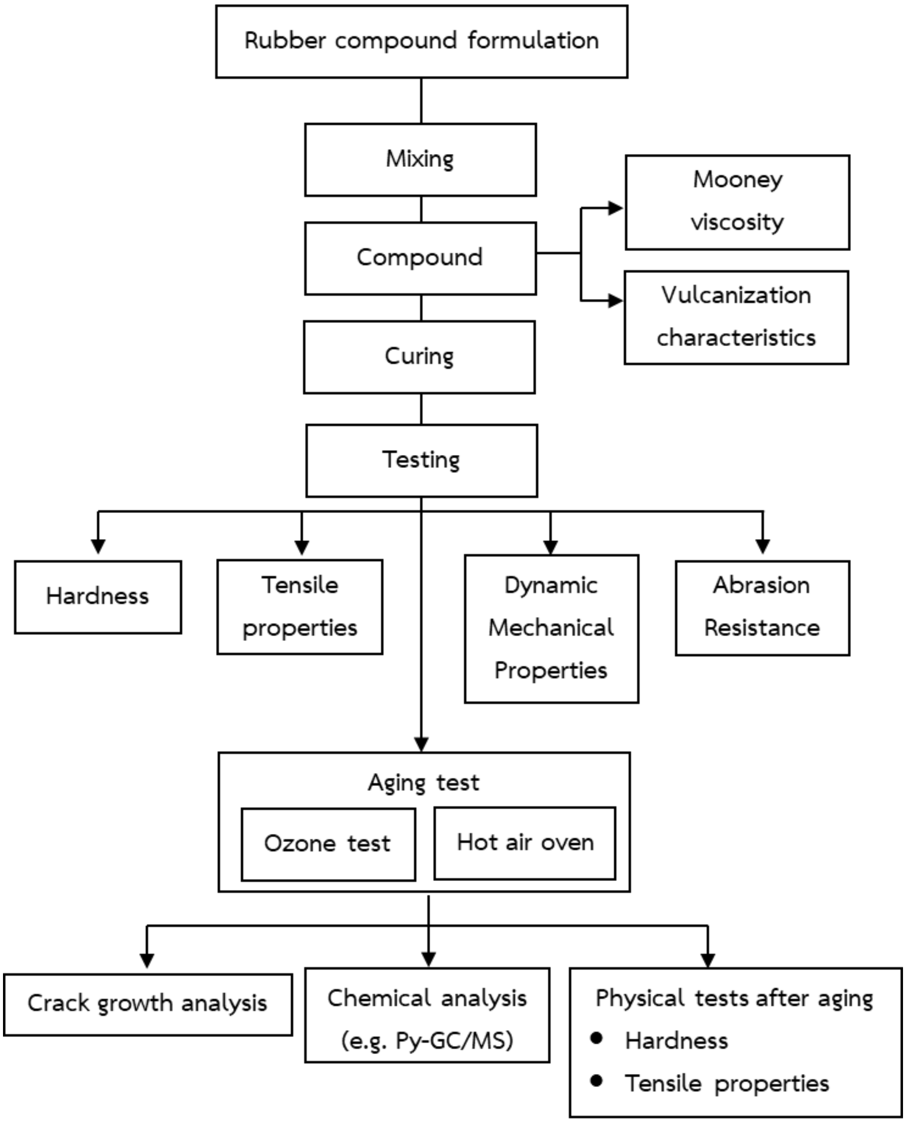


Figure 5: Overall research framework diagram

8. References

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[13] "ToxService LLC: N-Isopropyl-N'-phenyl-p-phenylenediamine (IPPD) (CAS #101-72-4) GreenScreen® for Safer Chemicals (GreenScreen®) Assessment," 14 October 2021. [Online]. [Accessed May 2024].

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[15] "ToxService LLC: N,N'-Dicyclohexyl-4-phenylenediamine (CCPD) (CAS #4175-38-6) GreenScreen® for Safer Chemicals (GreenScreen®) Assessment," 5 November 2021. [Online]. [Accessed May 2024].

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Appendix A: Supporting Information for hazard evaluation of 6PPD and possible alternatives

Chemical Name	CAS No.	ECHA List No.	GreenScreen data and Benchmark Score
N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylendiamine (6PPD)	793-24-8	212-344-0	GS-1204 [11] / BM-1
N-(1,4-dimethylpentyl)-N'-phenyl-p-phenylendiamine (7PPD)	3081-01-4	221-374-3	GS-1203 [12] / BM-1
N-isopropyl-N'-phenyl-p-phenylenediamine (IPPD)	101-72-4	202-969-7	GS-1202 [13] / BM-1
N,N'-bis(1,4-dimethylpentyl)-p-phenylenediamine (77PD)	3081-14-9	221-375-9	GS-1200 [14] / BM-2
N,N'-Dicyclohexyl-p-phenylenediamine (CCPD)	4175-38-6	No data	GS-1201 [15] / BM-1
2,4,6-tris{N-1,4-dimethylpentyl-p-phenylenediamino)-1,3,5-triazine (TAPDT)	121246-28-4	426-150-0	No data
3,9-dicyclohex-3-enyl-2,4,8,10-tetraoxaspiro[5.5]undecane (Vulcazon AFS)	6600-31-3	229-542-8	No data

Note:

- All ECHA data of 6PPD and possible alternatives were review from ECHA website [10].
- The certified GreenScreen assessor compiles hazard data and assigns a score for each endpoint based on criteria developed from the Globally Harmonized System (GHS) for Classification and Labeling of Chemicals and other health and environmental protection agencies (such as Environmental Protection Agency, EPA). They use the compiled data to assign scores included in the complete GreenScreen report.
- Benchmark (BM) score of 1 to 4 for the chemical. A BM-1 stands for “Avoid: Chemical of High Concern” while a BM-4 means “Prefer: Safer Chemical” [16].

Appendix B: List of Products Covered by this Alternative Analysis

Information regarding the list of products is being submitted to DSC by DEESTONE CORPORATION PUBLIC COMPANY LIMITED as confidential business information and is not included in this report.