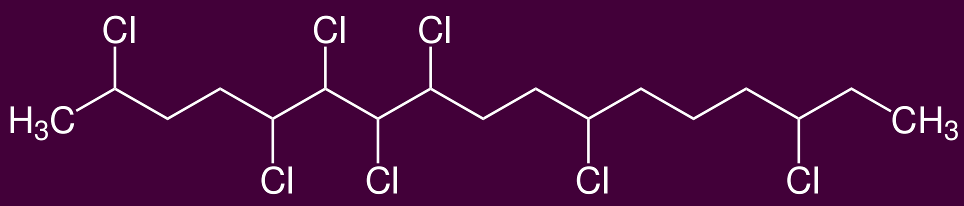
CHLORINATED PARAFFINS

Environmental Concerns and Regulatory Landscape



Toxics Link
for a toxics-free world

About Toxics Link

Toxics Link is an Indian environmental research and advocacy organisation set up in 1996, engaged in disseminating information to help strengthen the campaign against toxics pollution, provide cleaner alternatives and bring together groups and people affected by these problems. Toxics Link has a unique expertise in areas of hazardous, plastic, medical and municipal wastes, international waste trade, and emerging issues of pesticides, Persistent Organic Pollutants (POPs), hazardous heavy metal contamination, etc. We have successfully implemented various best practices and have contributed to policy changes in the aforementioned areas apart from creating awareness among several stakeholder groups.

Toxics Link's Mission Statement - "Working together for environmental justice and freedom from toxics, we have taken upon ourselves to collect and share both information about the sources and the dangers of poisons in our environment and bodies, and information about clean and sustainable alternatives."

Acknowledgment:

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Environmental Concerns and Regulatory Landscape

Abbreviations

CAGR	Compound Annual Growth Rate
CETP	Common Effluent Treatment Plant
COP	Conference of the Parties (to the Stockholm Convention)
CPCB	Central Pollution Control Board (India)
CPs	Chlorinated Paraffins
DGFT	Directorate General of Foreign Trade (India)
EU	European Union
LCCPs	Long-Chain Chlorinated Paraffins
MCCPs	Medium-Chain Chlorinated Paraffins
MLD	Million Litres per Day
POPs	Persistent Organic Pollutants
PVC	Polyvinyl Chloride
REACH	Registration, Evaluation, Authorisation & Restriction of Chemicals (European Union Regulation)
SCCPs	Short-Chain Chlorinated Paraffins
STP	Sewage Treatment Plant
UNEP	United Nations Environment Programme
UNEP POPRC	United Nations Environment Programme Persistent Organic Pollutants Review Committee
USEPA	United States Environmental Protection Agency
WWTP	Wastewater Treatment Plant
ZDHC	Zero Discharge of Hazardous Chemicals (Programme)

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Executive Summary

Chlorinated paraffins (CPs) are a group of synthetic organic chemicals, widely used as flame retardants, plasticisers, and lubricants across different industries such as plastics, textiles, leather, paints, adhesives, and metalworking fluids. Due to their wide range of applicability, the global demand for CPs is increasing. China is the major producer and supplier of CPs, while India holds the second position. CPs, especially Short-Chain Chlorinated Paraffins (SCCPs) and Medium-Chain Chlorinated Paraffins (MCCPs), have persistent, bio-accumulative and toxic properties. Many scientific studies support its widespread occurrence in air, water, sediment, soil and biota.

CPs have been detected in human blood and breast milk and can have toxicological impacts on liver and kidney, cause endocrine disruption, reproductive and developmental abnormalities, neurotoxicity, and immune dysfunction. Because they are fat-soluble, toxic and persistent in nature, they have a long half-life in the body and are therefore extremely bio-accumulative. This accumulation can injure the brain and immune system, interfere with hormones, impact reproduction and development, and damage the liver, kidneys, and other organs.

Thus, globally, the focus is on addressing these chemicals through regulatory measures. In 2017, SCCPs were listed in Annex A of the Stockholm Convention, and recently in COP-12 held from April 28 to May 9, 2025, MCCPs were listed as Persistent Organic Pollutants (POPs) with specific time-limited exemptions for certain uses. This drives a significant global shift towards the elimination of MCCPs as well, while Long-Chain Chlorinated Paraffins (LCCPs) remain under scientific review for potential listing. However, CPs are not likely to be regulated in the country.

In terms of the monitoring process in the country, the downstream management process is inadequate, and the wastewater treatment facilities are not able to efficiently remove the CPs from the wastewater, thereby releasing the CPs into the environment and contaminating soils, sediments and water.

As there is limited data with respect to the Indian context, this report stresses on the urgent need for India to align with the global commitments under the Stockholm Convention and move towards the elimination of SCCPs and MCCPs, while preparing for stricter controls on LCCPs in the future.

Ratification of SCCPs and MCCPs, strengthening regulatory frameworks, adoption of safer alternatives, improving monitoring of production and environmental pathways, enhancing supply chain transparency, and raising awareness are critical steps for the country. India as a significant producer and consumer of chemical products situates itself at the forefront of this global change, necessitating proactive domestic measures to protect public health, preserve the environment, and maintain the competitiveness of Indian companies in markets worldwide.

The Stockholm Convention on Persistent Organic Pollutants (POPs) is a global treaty aimed at protecting human health and the environment from POPs, which are toxic chemicals that persist and spread globally. Annex A lists chemicals that parties to the convention must eliminate, with provisions for specific, time-limited exemptions for production and use under strict conditions.

Chlorinated Paraffins

1.1 Introduction

Chlorinated paraffins are a complex group of synthetic chemicals produced through the chlorination of n-alkanes, resulting in a wide range of compounds with varying carbon chain lengths, degrees of chlorination, number and position of chlorine atoms (Knobloch et al., 2022). There are approximately 10,000 possible isomers of CP (Wang et.al., 2016; Van Mourik, et.al., 2020) (See Figure 1).

Their molecular diversity enables their use in numerous industrial applications, such as high-temperature lubricants, plasticisers, and flame retardants. CPs are commonly found in products like polyvinyl chloride (PVC) flooring, paints, adhesives, rubber, and leather sealants (Ezquer, et.al. 2024) (See Figure 2).

CPs are used for their flame-retardant properties, low-temperature flexibility, stain and chemical resistance. However, they are also bio-accumulative in wildlife and humans, persistent in the environment, can be transported globally, and are toxic to aquatic organisms even at low concentrations.

1.2 Types of CPs

- CPs are generally divided into three groups based on their carbon chain lengths:
- Short-chain chlorinated paraffins (SCCPs, C_{10-13} and a chlorine content of 40-70%).
- Medium-chain chlorinated paraffins (MCCPs, C_{14-17} and a chlorine content of 40-70%).
- Long-chain chlorinated paraffins (LCCPs, $C_{\geq 18}$).

CPs can also be classified as high-chlorinated or low-chlorinated types, depending upon the degree of chlorination. Generally, the chlorine content in CPs range from 30% to 70% by weight (South et al., 2022). These chemicals are complex mixtures with different carbon chain lengths, which differ on the basis of specific product and manufacturer (Chen et.al., 2021; Guida et.al., 2022).

Figure 1: General structure of CPs

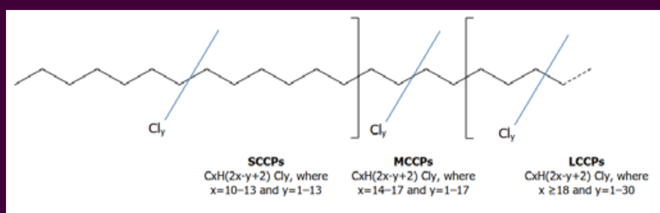


Figure 2: Application of CPs

1.2.1 Short-Chain Chlorinated Paraffin (SCCPs)

SCCPs are man-made chemicals that belong to a group of compounds with complex mixtures known as polychlorinated n-alkanes. These compounds are synthesised by chlorinating straight-chain paraffins derived from petroleum. Their composition can vary based on the degree of chlorination and the length of the carbon chain. Generally, SCCPS contain 10 to 13 carbon atoms and varying levels of chlorine, ranging from 30% to 70% by weight (PubChem, 2025).

The structural complexity contributes to a range of physicochemical properties of SCCPs, including being generally oily, non-volatile, resistant to degradation, and poorly soluble in water. These characteristics helps in making SCCPs the most useful compound in the industrial sector (PubChem, 2025) (Figure 3).

Generally, SCCPs are used as plasticisers in flexible PVC products, as flame retardants in rubbers and plastics, and as extreme-pressure lubricant additives in metalworking fluids, while also finding utility in rubber compounding and leather processing. These properties help in benefiting the product for thermal stability, lubricating properties, and fire resistance.

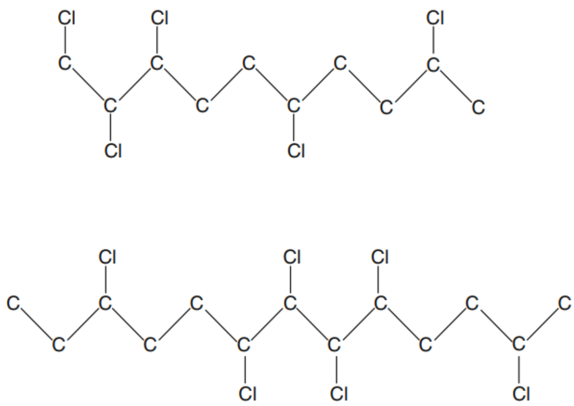


Figure 3: Structure of two SCCP compounds ($C_{10}H_{17}Cl_{5}$ and $C_{13}H_{22}Cl_{6}$)

Some key applications of SCCPs include:

- As a flame retardant in conveyor belts, V belts, and natural and synthetic rubber.
- As a plasticiser in the formulation of PVC compounds and granules used in wires and cables, PVC windows and door profiles, PVC flooring, films and sheets, PVC footwear, etc.
- In polyurethane and polysulfide-based sealants and adhesives.
- As an extreme pressure additive in metal working fluids/cutting compounds.
- As a flame retardant in the paint industry. It is used in the formulation of swimming pool paints and other fireproof paints.
- As a flame retardant in the textile industry. It is used in the finishing of heavy textiles such as military tents.

1.2.2 Medium-Chain Chlorinated Paraffins (MCCPs) and Long Chain Chlorinated Paraffins (LCCPs)

MCCPs and LCCPs are a group of synthetic chlorinated hydrocarbons consisting of straight-chain alkanes with higher carbon chain lengths. MCCPs have a carbon chain of C_{14-17} while LCCPs contain carbon chain of more than $C \geq_{18}$. There are several isomers of MCCPs and LCCPs which differ on the basis of degrees of chlorination and carbon chain distributions.

The chlorine content of MCCPs and LCCPs generally varies between 30% to 70% by weight, which significantly influences their physical properties such as viscosity, density and thermal stability. These compounds are generally oily, viscous liquids that are chemically stable and insoluble in water, though soluble in organic solvents (Glüge, et.al., 2018).

MCCPs and LCCPs are widely used by industries as substitutes for SCCPs. They are primarily used as secondary plasticisers in PVC products such as cables, flooring and roofing. MCCPs also act as flame retardants in plastics, rubber, adhesives and sealants. LCCPs are widely used in lubricants and metalworking fluids due to their stability under high temperatures, and their demand is expected to increase with the shift to electric vehicles. Additionally, they are used in industrial paints, coatings, and, to a lesser extent, in rubber and textile processing (UNEP, 2023a; ECHA, 2021; Government of Canada, 2008).

Some of the applications of MCCPs and LCCPs are as follows:

Flame retardants in plastics, PVC cables, flooring, automotive parts, rubbers, textiles, and paints.

Additives/ lubricants in metalworking fluids to reduce friction and wear during machining.

Plasticisers in PVC to enhance flexibility and durability.

Viscosity modifiers in adhesives and sealants to improve workability and adhesion.

Fat liquors in leather processing for softening and lubricating leather fibres.

1.3 Chlorinated Paraffins Market: Global and Indian Context

The global chlorinated paraffins market was valued at USD 2.16 billion in 2024 and is projected to reach USD 3.00 billion by 2033, with a compound annual growth rate (CAGR) of 3.52% (Valuates Reports, 2023). This growth is steadily increasing due to its increasing demand in metalworking fluids, plasticisers, flame retardants, and construction materials. The Asia-Pacific region accounted for 31.2% of total consumption due to rapid industrialisation (Valuates Reports, 2023).

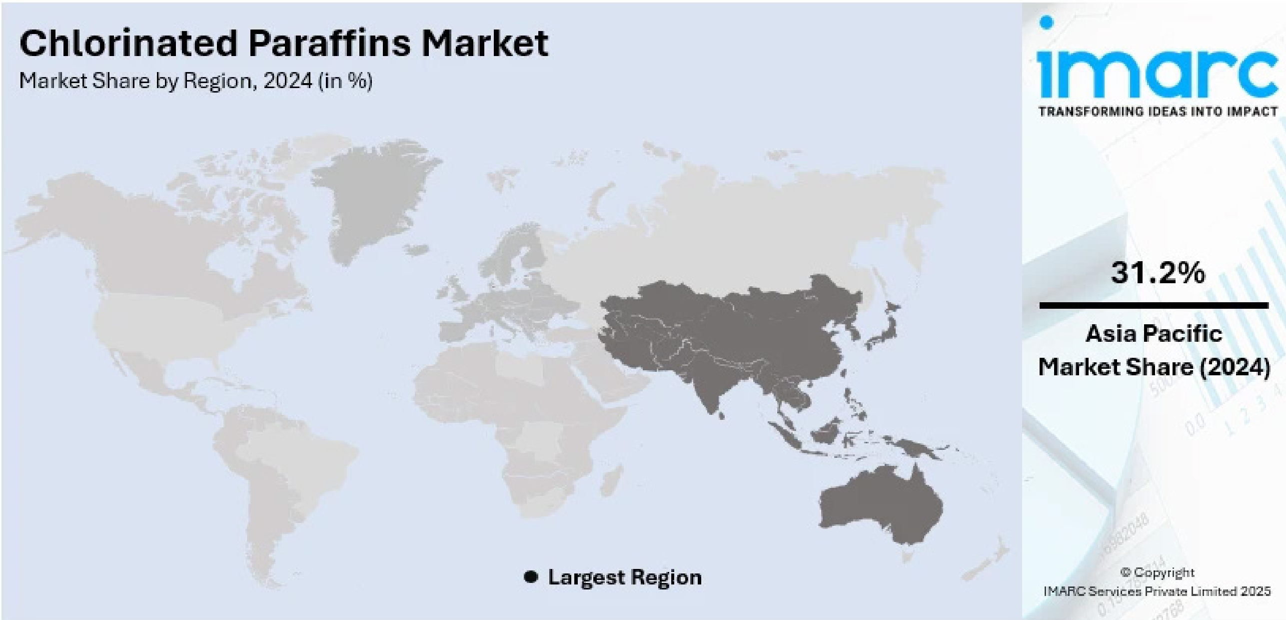
According to another market agency report, China and India are major global producers of CPs (Fortune Business Insights, 2025). The global production of CPs annually is around 2 million tonnes with China leading at around 1.05 million tonnes (Chen et al., 2021), followed by India in the second position. The last reported production volumes of CPs in different countries were reported in the second draft of the risk assessment report for the Stockholm Convention (UNEP, 2023a) (See Table 1).

Table 1: Overview of CP/MCCP production volumes (Adopted from UNEP, 2023a)

Country/Region	Volume (tonnes)	Year	Reported as	Source
China	11,00,000	2014	CPs	Chen et al., 2022
	9,00,000	2020	CPs	WCC 2022 Annex E submission (based on Chinese Chlor Alkali Industry Association)
	6,00,000	2013	MCCPs	Glüge et al., 2018
India	2,26,400	2010	CPs	Chen et al., 2022
	5,00,000–7,00,000	2018	CPs	WCC 2022 Annex E submission
	2,53,000	2020	MCCPs	UNEP, 2023a
Japan	2,507	2020	CPs	Japan Annex F submission [total of production and import]
Europe (12 countries)	33,000	2022	MCCPs	EU 2022 Annex F submission
Russian Federation	27,000	2011	MCCPs	Glüge et al., 2018; ECHA, 2022 (based on WCC 2012)
USA	11,000	2021	MCCPs	WCC-CPIA 2022 Annex F submission
Qatar	30,000	2021	MCCPs	Qatar 2022 Annex F submission
Republic of Korea	3,737	2018	MCCPs	Republic of Korea 2022 Annex F submission
UK	<10,000	2020	MCCPs	WCC/CPIA (pers. comm)
Australia	1,000–10,000	2006	MCCPs	NICNAS, 2020

The CPs production in India was 0.22 million tonnes in the year 2010. It increased to 0.5-0.7 million tonnes in the year 2018 (Guida, et.al., 2020; WWC, 2022; Stockholm Convention, 2023).

The use of SCCPs has declined globally because of regulatory restrictions, with their share in CP production having fallen from over 30% in the 1970s to around 15% by the early 2000s. It stabilised at that level until the 2017 ban in several jurisdictions (Glüge et al., 2016). This has led to an increase in demand of MCCPs (See Figure 3). In India, there is limited information about SCCP and MCCP use in the public domain.



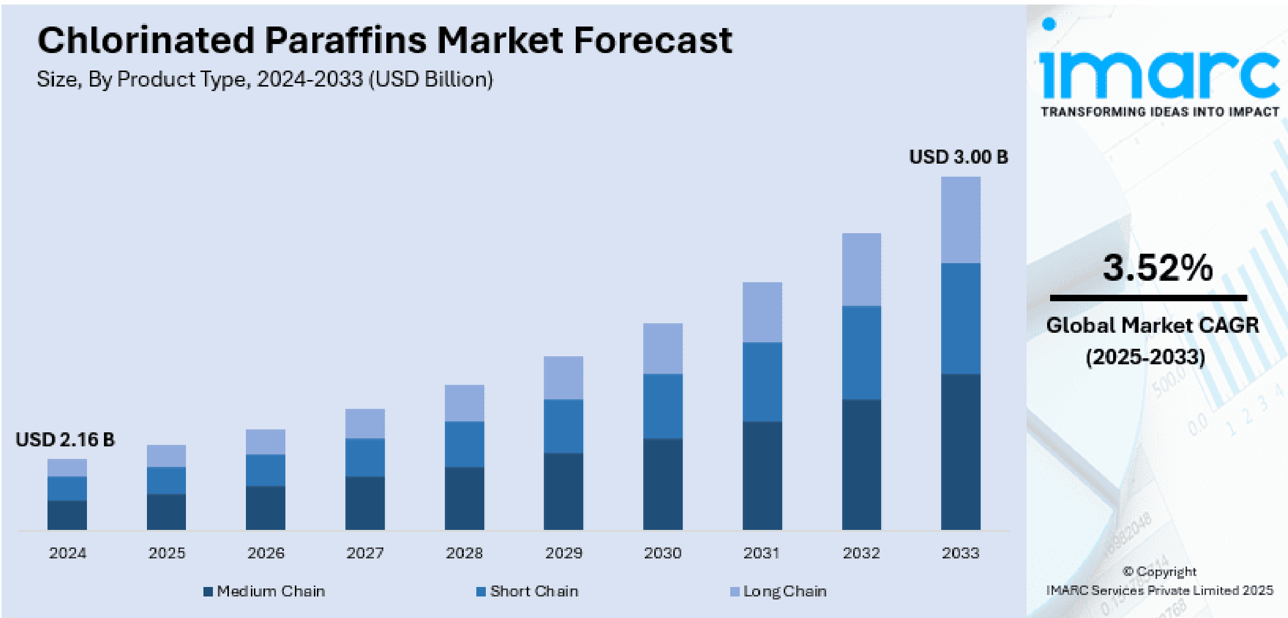


Figure 4: Market Overview of CPs (IMARC, 2025)

1.4 Status of Chlorinated Paraffins in India

India is the second-largest global producer of CPs (IMARC, 2025). Though market share of CP in India is not available in any public platform, the Indian paraffin wax market was valued at USD 741.85 million in FY2024 and is projected to grow at a CAGR of 7.80% to USD 1,352.90 million by FY2032. Paraffin wax is used as precursors for CP production and the growth is attributed to increased applications in coatings, adhesives, cosmetics, pharmaceuticals, and electrical insulation (Allied Market Research, 2022; Markets & Data, 2023; Transparency Market Research, 2025).

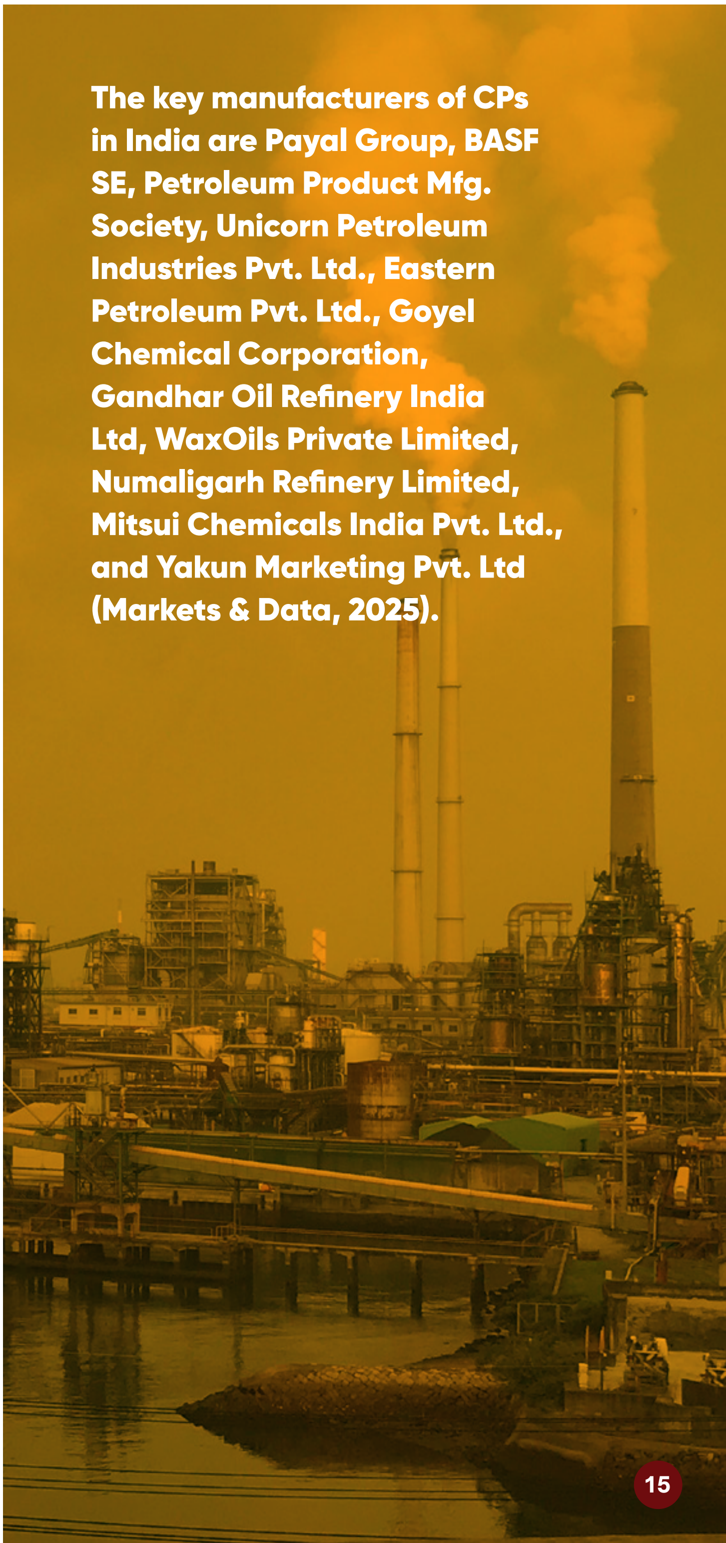
The demand for CPs' from Indian industries is growing rapidly due to their wider applications (KonnArk, 2023). However, unlike China, publicly available data on production volumes by CP type (SCCPs, MCCPs, LCCPs) and sector-specific consumption information remains unavailable.

Specific data regarding individual CP mixture categories (SCCPs, MCCPs, LCCPs) and sector-wise consumption within the country is currently unavailable. However, the data collected by UNEP POPRC (United Nations Environment Programme Persistent Organic Pollutants Review Committee) in 2019 shows sector-specific consumption of MCCPs in which the highest consumption was observed in PVC (40%), rubber (20%), adhesives and sealants (15%), paints and varnish (7.5%) and textiles (5%) (UNEP, 2023b).

India trades CPs under two primary Harmonised System (HS) codes: 27129090 for paraffin waxes and 38122090 for plasticiser compounds (DGFT, 2025). In Financial Year (FY) 2024-2025, India imported 2,527,255 kilograms (kg) of paraffin waxes and 3,48,328 kg of plasticiser compounds from different countries. On the export side, India primarily exports 2,579,724 kg of plasticiser compounds and 72,846 kg of paraffin wax to different countries (DGFT, 2025).

Key observations:

- India imports CPs in the form of paraffin waxes, while exports involve plasticiser compounds (See Figure 5 and 6).
- In 2024-2025, India imported paraffin waxes (CP) primarily from the UAE, China, Thailand, Germany, Spain, Malaysia, and Korea. Conversely, plasticiser compounds (PC) were predominantly imported from Japan, China, Korea, Germany, the Netherlands, and the USA (See Table 2 and Table 3).
- India exports plasticiser compounds to countries like Nepal, Malaysia, Poland, Indonesia and Bangladesh.
- Specific data regarding individual CP mixture categories (SCCPs, MCCPs, LCCPs) and sector-wise consumption within India is currently unavailable.



The key manufacturers of CPs in India are Payal Group, BASF SE, Petroleum Product Mfg. Society, Unicorn Petroleum Industries Pvt. Ltd., Eastern Petroleum Pvt. Ltd., Goyel Chemical Corporation, Gandhar Oil Refinery India Ltd, WaxOils Private Limited, Numaligarh Refinery Limited, Mitsui Chemicals India Pvt. Ltd., and Yakun Marketing Pvt. Ltd (Markets & Data, 2025).

Table 2: Import data of CP in the country (FY 2024-2025)

Country	Import data of CP	
	Paraffin wax	Plasticiser compound
	Quantity (Thousand tonnes)	
UAE	488.236	--
Australia		17.8
USA	29.995	40.917
China	1186.846	227.955
Belgium	4.371	
Malaysia	118.8	2.88
Germany	71.438	12.488
South Africa	120.7	--
Korea	19.56	2.4

Table 3: Export data of CP in the country (2024-2025)

Country	Export data	
	Paraffin wax	Plasticiser compound
	Quantity (Thousand tonnes)	
Australia	11.55	93
Kenya	2.14	69.4
UAE	0.54	288.4
UK	--	-
USA	--	0.4
Belgium	--	-
Bangladesh	0.025	80.1
Brazil	-	46.4
China	-	12
Nepal	-	366.07
Malaysia	-	237.55
Germany	-	--
Uganda	-	--
Kuwait	12	
Sri Lanka	41.7	23.2
South Africa	-	300
Slovenia	-	-
Saudi Arab	--	--
Djibouti	-	138.9
Greece	-	50
Indonesia	-	198.6
Thailand	-	217.4

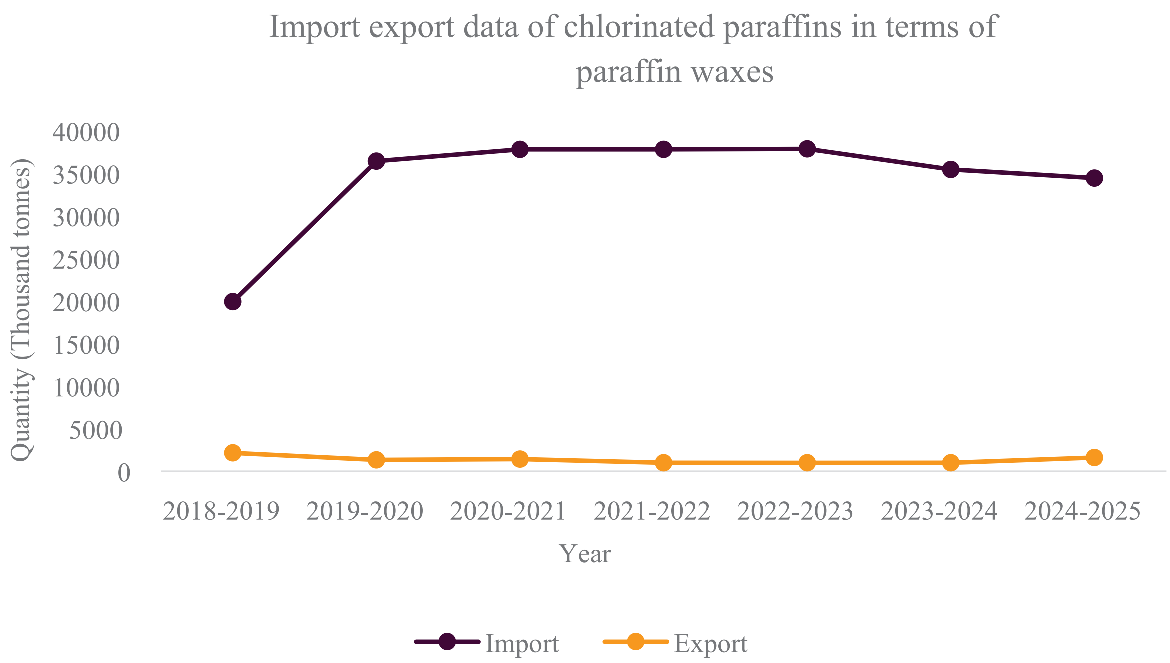


Figure 5: Import export data of CPs (Paraffin wax)

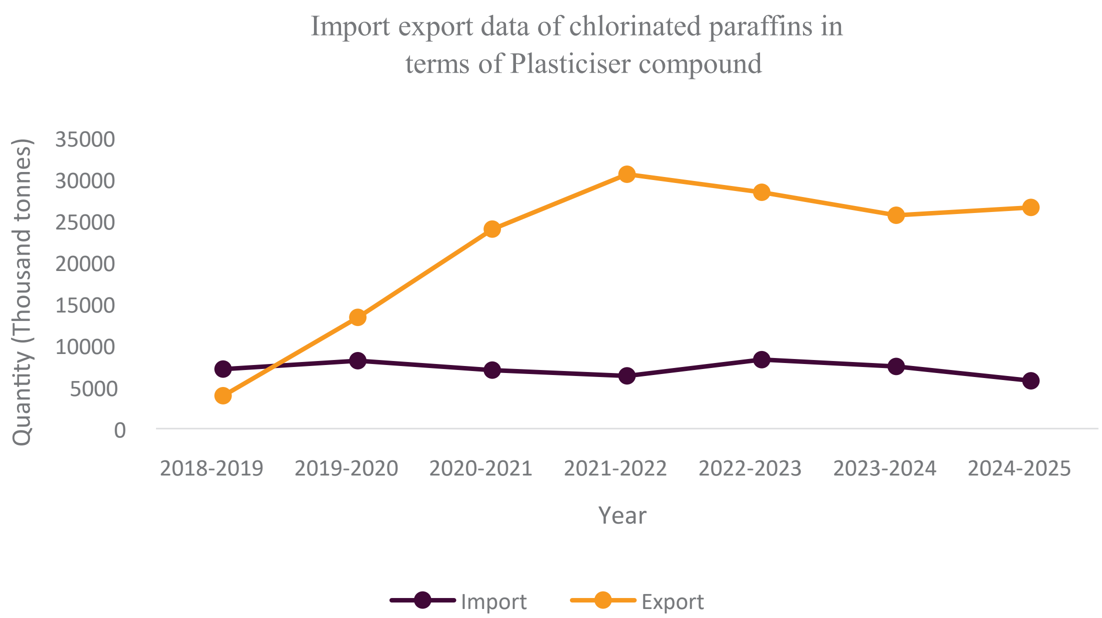


Figure 6: Import export data of CPs (Plasticiser compounds)

1.5 Rationale of the Study

CPs are a group of high-volume industrial chemicals that have been in use for decades across a wide range of applications, including plastics, lubricants, paints, and flame retardants. Their widespread use, despite their qualities of persistence, bioaccumulation and potential toxicity, has raised significant global concern. SCCPs and MCCPs have already been listed as POPs under the Stockholm Convention, reflecting their serious environmental and health risks. LCCPs, often used as substitutes, share similar hazardous characteristics and remain largely unregulated in many jurisdictions. Notably, though India has not ratified SCCPs, it has accepted the enlisting of MCCPs as POPs in Stockholm Convention COP-12.

In India, there is very limited information available on this chemical though India is a major producer and user of CPs. Data on CPs, particularly regarding consumption patterns, environmental distribution, and human health impacts, are not well documented.

Therefore, this report on CPs is critical to consolidate existing knowledge, map regulatory and industrial practices, and identify data gaps. The assessment will provide evidence to help policymakers, researchers, and industry stakeholders to strengthen management strategies, align with global conventions, and advance the transition towards safer alternatives.

Environmental and Health Concerns

CPs, including SCCPs, MCCPs and LCCPs, have been widely utilised in industrial applications since the 1930s. By 2020, their cumulative global emissions were estimated at approximately 5.2 million metric tonnes (Chen et al., 2022; Breivik et al., 2007). CPs have been detected not only in proximity to emission sources but also in remote environments, facilitated by long-range atmospheric and oceanic transport mechanisms (Gluge et al., 2018). Their classification as chemicals of global concern is based on key properties: environmental persistence (Iozza et al., 2008; Yuan et al., 2017), long-range transport potential (Gawor & Wania, 2013; Yuan et al., 2021), bioaccumulation in biota (Houde et al., 2008), and adverse ecological and human health effects (Brooke & Crookes, 2011).

In recognition of these risks, SCCPs were listed as POPs under the Stockholm Convention in 2017 (UNEP, 2017) and MCCPs have been recently listed in the Conference of the Parties (COP-12) to the Stockholm Convention (Stockholm Convention 2025). Many countries have ratified the listing of SCCPs and MCCPs, but India is yet to ratify the listing of these chemicals (Stockholm Convention, 2025).

High environmental concentrations of CPs have been documented in industrialised regions such as China (Yang et al, 2025; Wang et.al., 2025; Gao et.al., 2012; Li et al., 2018), as well as in remote and sensitive environments including the Arctic, Antarctic, and the Tibetan Plateau (Wu et al., 2020). However, available environmental monitoring data remain limited in spatial and temporal coverage. Moreover, the lack of quantitative source-receptor relationships limits understanding of transboundary pollution dynamics (Jiang et al., 2020).

Annex A of the Stockholm Convention lists chemical as POPs that are targeted for elimination by member countries, though specific, registered exemptions for the production and use of some chemicals may apply. Parties must take measures to eliminate the production and use of these intentionally produced chemicals, with the goal of eventual global elimination.

2.1 Potential Sources of Emission

CPs are extensively used in industrial processes and consumer products, resulting in widespread environmental releases. Their persistence and toxicological properties have raised significant regulatory and scientific concerns.

Industrial process

Emissions of CPs arise from multiple sectors. Incineration of CP-containing materials can generate hazardous by-products (International Programme on Chemical Safety [IPCS], 1996). In the United States and the European Union, metalworking fluids account for about 10-31.6% of SCCP emissions (EFSA, 2020). Similarly, PVC manufacturing, metalworking and cutting fluids account for over 28-80% of CP release in China (Stockholm Convention, n.d.; Environmental Science, 2014; RSC Publishing, 2025). In India, studies have detected SCCPs and MCCPs in river sediments and biota near industrial hubs such as the Ganga basin (Ranjan et al., 2021; Sharma et al., 2019) (See Annexure for more information).

Consumer Products

CPs are widely used in PVC, paints, sealants, adhesives, and treated textiles as plasticisers and flame retardants. These products release CPs through volatilisation and leaching during their service life, contaminating indoor air and dust (Science China Press, 2024; PMC, 2023). Although these releases are estimated to be <1% of the total CP content in products, their diffusive nature makes them an ongoing environmental concern (EFSA, 2020).

Waste and Recycling Pathways

Disposal and recycling of CP-containing plastics, rubbers, and electronic waste contribute significantly to secondary emissions, particularly in regions with poor dust control. Studies in China have documented elevated SCCP levels in soils near e-waste dismantling sites (Yuan et al., 2017). Landfilling and incineration of CP-containing materials may also contribute to releases, with incineration sometimes generating additional chlorinated by-products.

Wastewater and Agricultural Practices

Wastewater treatment plants (WWTPs) act as both sinks and secondary sources of CPs. CPs accumulate in biosolids, which, when applied to farmland, may transfer to biota even when not consistently detected in soil (Nicholls et al., 2015). In the EU, production facilities are estimated to release 105 kg of MCCPs annually into wastewater or surface water, a small fraction compared to annual production (44-160 kilotons), while air emissions are negligible (Mackay, 2006; EFSA, 2020).

Environmental Transport and Global Distribution

CPs are subject to long-range atmospheric transport, enabling detection in remote regions such as the Arctic and high-altitude lakes (Stockholm Convention, 2023). This highlights their persistence and mobility beyond point sources. With restrictions on SCCPs under the Stockholm Convention, production and use of MCCPs have increased, making them an emerging concern for environmental monitoring (Stockholm Convention, 2023; Henan Ecology, 2024) (See Figure 7).

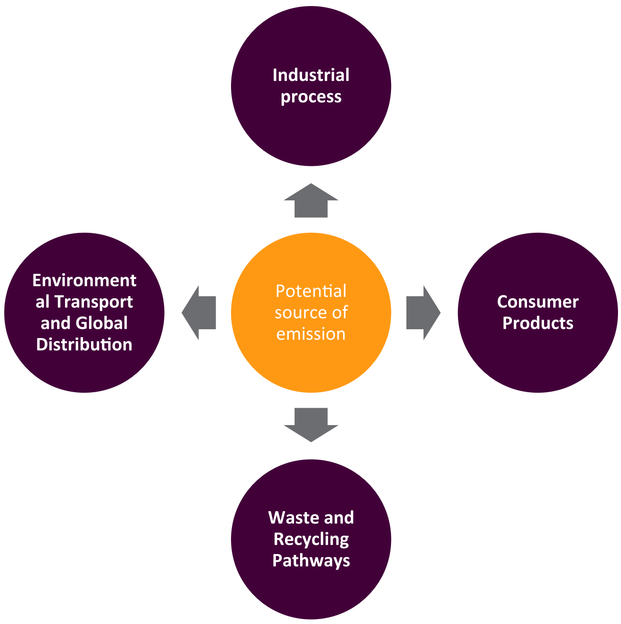


Figure 7: Potential sources of emission of CPs

2.2 Occurrence and Distribution in the Environment

2.2.1 Air

CPs, especially SCCPs, are commonly found in both outdoor and indoor air because they can easily evaporate and attach to tiny particles. In China, studies have measured SCCP levels in air ranging from 3 to 988 ng/m^3 in gas and particle forms, with higher levels near industrial areas and lower levels in cities and indoor environments (Yu et al., 2019; Zhou et al., 2021; Zhang et al., 2021, 2022; Ni et al., 2020). Their widespread presence shows that SCCPs can travel long distances and may pose health risks through inhalation, affecting particularly those near factories and industrial centres. Currently, there is no published study in India that has reported the presence of CPs in air particulate matter.

2.2.2 Soil

Global studies have shown that soils in urban, industrial, and e-waste recycling areas accumulate substantial levels of CPs. For instance, SCCPs and MCCPs have been detected in urban soil of Chinese cities in the range of 188-615 ng/g (Wang et al., 2014; Xu et al., 2023).

Apart from this, in industrial and e-waste dismantling zones, CP contamination was found to be 2,40,000-8,90,000 ng/g in Guiyu, China (Zeng et al., 2016), and nearby emission zones exhibited ranges of 30.4-554,161 ng/g (Zhang et al., 2022). Similarly, elevated concentrations have been measured in Tanzania, where e-waste contaminated soils contained 400-21,300 ng/g SCCPs and up to 65,000 ng/g MCCPs (Haarr et al., 2023) (See Annexure for more information).

These findings underscore the role of atmospheric deposition, industrial discharges, and recycling activities as dominant pathways of soil contamination, raising concerns regarding their persistence, potential leaching to groundwater, and transfer into agricultural systems.

There are no studies pertaining to the occurrence of CPs in the soils of India.

2.2.3 Water

Chlorinated paraffins have been reported in a wide range of surface and wastewater sources globally. Shabbir et al. (2024) found SCCP concentrations from below detection to 19 ng/L and MCCPs from 25 to 55 ng/L in the River Ravi in Pakistan. Zhang et al. (2022) detected SCCPs as high as 4,700 ng/L in emission zone surface waters in China. In Germany, the Stockholm Convention (2009) noted SCCP levels of up to 4.8 µg/L in municipal wastewater effluents. Rubirola et al. (2018) reported SCCPs in 54% of treated wastewater samples in Spain, with concentrations up to 0.13 µg/L. In Lake Ontario, SCCPs and MCCPs were reported at 1,190 pg/L and 0.9 pg/L, respectively (Tomy et al., 2007). Wu et al. (2020) also documented SCCPs in Tibetan Plateau rivers ranging from 0.87 to 9.1 ng/L. CP contamination in water signifies both localised pollution and potential for hydrological dispersion, posing long-term ecological and human health concerns, especially when entering food webs via aquatic organisms (See Annexure for more information).

2.2.4 Sediment

Many studies have reported the occurrence of CPs in sediments, which function both as long-term sinks and as secondary sources through remobilisation processes. In industrial regions, Zhang et al. (2022) observed SCCP concentrations ranging from 32.5 to 350,000 ng/g, reflecting intense localised contamination. Riverine systems show considerably higher burdens, such as in the Pearl River Delta in China, where the concentration ranged from 6,600 to 38,000 ng/g (Pan et al., 2018). Additionally, Li et al. (2023) found much lower levels in marine sediments of the East and Yellow Seas, with concentrations between 0.094 and 13.4 ng/g. CPs have also been detected in lake sediments across Canada, Spain, and the United States, confirming their widespread distribution and persistence (Nipen et al., 2022; Wu et al., 2024; Huang et al., 2020). (See Annexure for more information).

These findings demonstrate that CPs in sediments reflect both historical deposition and ongoing inputs, particularly near industrial discharge zones. Their strong binding capacity for particulate matter facilitates long-term accumulation, while this may enhance bioavailability to benthic organisms and transfer within aquatic food webs.

2.2.5 Biota

CPs have been detected in a wide range of biota, demonstrating their potential for bioaccumulation and trophic transfer. In e-waste recycling areas of China, duck tissues contained concentrations up to 20,000 ng/g lipid (Luo et al., 2015). Evidence of long-range transport has also been observed in the Arctic, where seal blubber contained SCCPs up to 120 ng/g lipid, highlighting their persistence and transboundary movement (Sun et al., 2016). In the Great Lakes region, Tomasko et al. (2021) reported SCCPs and MCCPs in fish at levels reaching 4,500 ng/g lipid, while Braune et al. (2005) documented SCCP concentrations up to 15 µg/g lipid in marine species (See Annexture for more information). Further evidence from the Tibetan Plateau shows biomagnification in fish and birds, with tissue concentrations reflecting ongoing environmental inputs and persistence (Wu et al., 2020). These findings demonstrate that CPs are bio-accumulative and lipophilic, allowing them to concentrate in organisms and magnify across food webs, thereby presenting risks to both ecosystem integrity and human health via dietary exposure.

2.2.6 Food

CPs have been detected in diverse food matrices worldwide, indicating environmental contamination and food chain transfer. The concentration of CPs in different food matrix have been reported in the range of 14 µg/kg- 151,000 µg/kg in Salmon, oil-based supplements, barber fish, fats and oils amongst different countries such as Germany, France and Sweden (Kratschmer et al., 2019; Sprengel et al., 2019; Labadie et al., 2019; Yuan et al., 2017).

In China, much higher levels were observed in meat (up to 129 µg/kg SCCPs), cereals (up to 343 µg/kg), and eggs (up to 1,490 µg/kg fat). Fish from e-waste regions contained exceptionally high SCCPs, reaching 95,000 µg/kg fat (Huang et al., 2018; Wang et al., 2019b; Gao et al., 2018; Zeng et al., 2018; Sun et al., 2017) (See Annexure for more information).

2.3 Ecotoxicological Impacts

CPs exert a range of ecotoxicological impacts on aquatic organisms, birds, amphibians, mammals, and invertebrates, with effects varying by chain length, degree of chlorination, and exposure concentration. Developmental toxicity is one of the most well documented effects. In a study, *zebrafish* embryos exposed to SCCPs (C10, 50–65% Cl) at 10 mg/L showed spinal curvature, pericardial edema, and yolk deformities (Liu et al., 2016), and similar deformities occurred in *medaka* at tissue concentrations of 2-8 µmol/g (Fisk et al., 1999). Amphibians like *Xenopus laevis* embryos exhibited growth inhibition and malformations at 50 mg/L SCCPs (Buryskova et al., 2006). Hepatotoxicity is also prominent. Rats exposed to SCCPs (1000 mg/kg bw/day) developed liver necrosis, inflammation, and enzyme induction (Yang et al., 2021), and zebrafish exhibited metabolic disturbances even at 1–5 µg/L (Ren et al., 2018). Black-spotted frogs with 35–1200 ng/g wet weight of CPs showed reduced liver tissue mass (Du et al., 2019).

Nephrotoxicity includes glomerular hyperplasia and tubular cell edema in rats at 1000 mg/kg bw/day SCCP exposure (Yang et al., 2021). CPs also induce neurotoxic effects: SCCPs reduced swimming distance and social behaviours in zebrafish at 10-1000 µg/L (Yang et al., 2019), and MCCPs caused lethargy and motor coordination loss in rats at high doses (Birtley et al., 1980). Furthermore, CPs are confirmed endocrine disruptors, impairing thyroid hormone (TH) regulation (Wyatt et al., 1993; Liu et al., 2016). Additionally, SCCPs bind with high affinity to transthyretin, displacing thyroid hormones and disrupting endocrine function (Sun et al., 2020).

Immunotoxic effects such as spleen enlargement and immune cell infiltration were observed in mice at 10-100 mg/kg bw/day SCCP exposure (Wang et al., 2019), while epidemiological studies link serum CP concentrations with altered liver and kidney function biomarkers in humans (Liu et al., 2021b; Zhao et al., 2021). Collectively, the ecotoxicological evidence demonstrates that CPs can induce developmental, hepatic, renal, neurological, endocrine, and immune dysfunction across diverse taxa, often at environmentally relevant or bio-accumulative levels.

- CPs cause acute toxicity in aquatic invertebrates, with LC_{50} values as low as 14.1–15.5 µg/L in

Mysidopsis bahia after 4 days of exposure through water.

- Fish larvae exhibit acute toxicity to SCCPs, with LC_{50} values of 34.4 µg/L and 100% lethality at 100 µg/L in zebrafish exposed for 13 days.
- Soil invertebrates like Caenorhabditis elegans show acute toxicity, with LC_{50} values of 0.5 mg/L in waterborne exposure for 2 days.
- Rodents exposed orally to high doses of SCCPs experience acute toxicity, with LD_{50} values around 3750 mg/kg body weight (bw) within 16 days of exposure.
- Chronic toxicity is observed in rainbow trout exposed to SCCPs for 60 days, showing liver damage at 340 µg/L.
- Birds, such as domestic mallards, experience chronic developmental toxicity, including eggshell thinning and reduced embryo survival when fed SCCPs at 1000 mg/kg bw/day.
- Chronic developmental effects are noted in amphibians, like Xenopus laevis, at SCCP concentrations of 50 mg/L, causing growth inhibition and malformations.
- Rodents show chronic hepatotoxicity and nephrotoxicity from repeated oral exposure to SCCPs at ≥100 mg/kg bw/day over 14-28 days of exposure.

2.4 Sources of Human Exposure to Chlorinated Paraffins (CPs)

CPs are used extensively in PVC products, rubber, textiles, sealants, paints, and adhesives. Human exposure to these compounds occurs through multiple pathways. Indoor environments are a major source. SCCPs and MCCPs have been detected in household dust in Canada and Sweden, indicating ongoing emissions (Shang et al., 2019; Washington State Department of Ecology, 2017; Fridén et al., 2011).

Consumer products such as hand blenders, oven doors, and internal oven surfaces have also shown high concentrations of CPs (Zhang et al., 2022; Gallistl et al., 2018; Yuan et al., 2017), as testing of hand wipes revealed SCCP contamination. Dietary intake is another significant route, particularly for MCCPs, which have been found in various fish species from the Rhône River, the North and Baltic Seas, and in both farmed and wild salmon and trout (Labadie et al., 2019; Reth et al., 2005; Krätschmer et al., 2018).

MCCPs have also been detected in palm oil-derived vitamin E capsules, with estimated daily intakes ranging from 38 to 112 µg/person (Sprengel et al., 2019). The European Food Safety Authority (EFSA, 2020) reported dietary exposure to MCCPs between 3.2 and 59 ng/kg body weight/day (95th percentile). Additional exposure occurs through contaminated air, soil, and water resulting from unintentional releases during manufacturing, storage, leaching, and runoff (Xu et al., 2023; Glüge et al., 2018). Inhalation of vapours or contaminated dust and dermal contact with CP-treated materials further contribute to total exposure (Cao et al., 2019; IMAP, 2017) (See Figure 8 & 9).

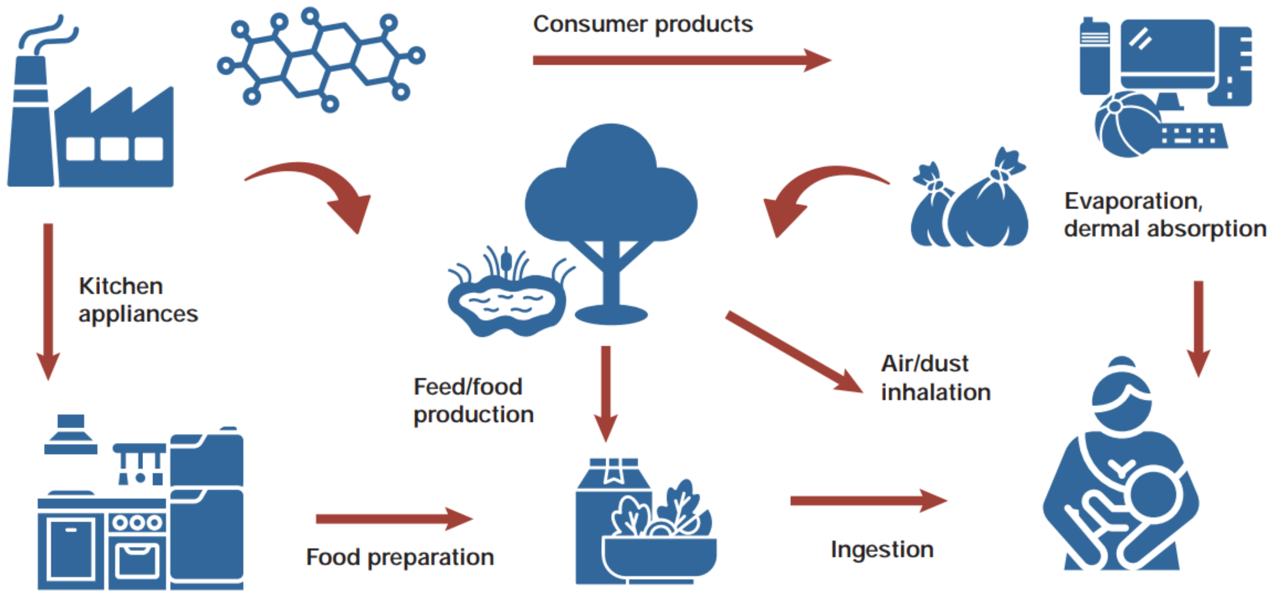


Figure 8: Routes of human exposure of CPs

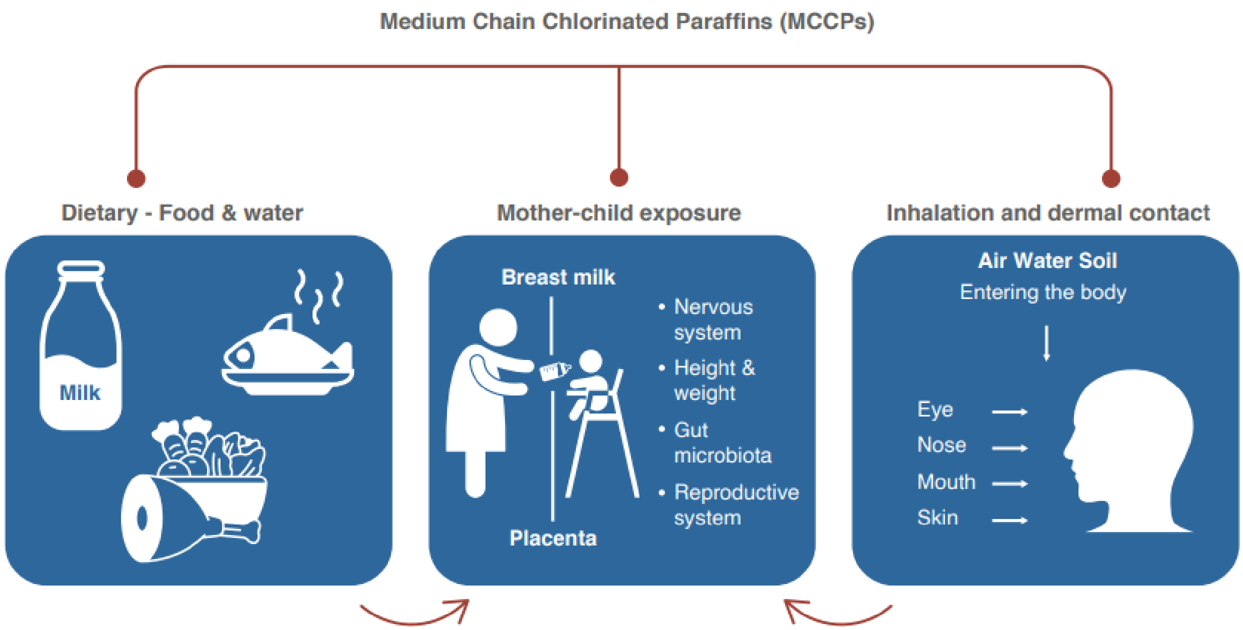


Figure 9: Sources of MCCP exposure to humans

2.5 Human Health Impacts of CPs

CPs are associated with a wide range of adverse health effects. SCCPs have been linked to liver and kidney toxicity, reproductive and developmental toxicity, endocrine disruption, neurotoxicity, and immune dysfunction (Huang et al., 2023; Li et al., 2023; Krätschmer et al., 2023). MCCPs exhibit similar toxicological concerns. Animal studies have demonstrated effects on the liver and thyroid, reproductive and endocrine systems, with bioaccumulation observed in organs such as the liver, kidneys, ovaries, adrenal glands, and adipose tissue (Darnerud & Bergman, 2022). LCCPs have demonstrated systemic toxicity in animal studies, particularly affecting the liver, kidneys, and nervous system (National Research Council, 2000; Huang et al., 2023). Although human evidence for carcinogenicity remains limited, long-term exposure to LCCPs and similar chlorinated compounds may pose cancer risks (EFSA, 2020). LCCPs are also associated with skin irritation, dermatitis, and respiratory infection symptoms such as coughing and wheezing (IMAP, 2017) (See Figure 10).

Biomonitoring studies support these concerns, having detected SCCPs and MCCPs in human blood, breast milk, and umbilical cord blood (Thomas et al., 2006; Sun et al., 2016; Zeng et al., 2011). MCCPs were found in breast milk in Germany at concentrations between 9.6 and 903 ng/g lipid weight (lw) (Hilger et al., 2011). Blood serum samples from China reported levels ranging from 470 to 15,200 ng/g lw, while samples from Australia showed concentrations around 190 ng/g lw (Qiao et al., 2018; Ding et al., 2020; van Mourik et al., 2020). Though limited, available data suggest likely human exposure to LCCPs through indoor dust, contaminated food, and treated consumer products (See Annexure for more information).

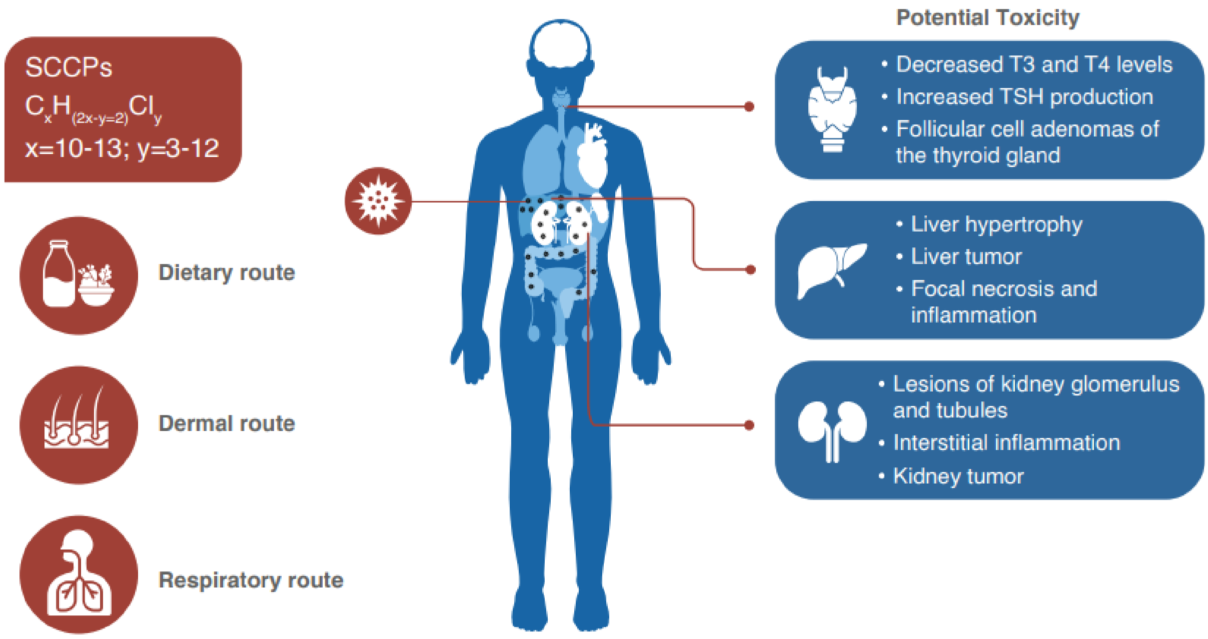


Figure 9: Impact of SCCP exposure on human health

The available toxicological and biomonitoring evidence clearly indicates that human exposure to chlorinated paraffins, particularly SCCPs and MCCPs, is ongoing and widespread, with potential risks to critical biological systems including endocrine, reproductive, hepatic, and immune functions. The detection of CPs in human tissues such as blood, breast milk, and cord blood highlights the urgency of regulatory intervention, improved public awareness, and safer substitution in consumer and industrial applications to mitigate long-term health risks.

2.6 Analytical techniques

Due to the complexity of the mixtures, there are a number of challenges in the analysis of CPs, especially their characterisation and determination. An overview of different techniques used for the analysis of CPs is given in Table 4. (Kratschmer, 2019).

Table 4: Separation and Detection Techniques for Chlorinated Paraffins (CPs)

Technique	Sensitivity	Selectivity	Detection of SCCP, MCCP, LCCP	Chlorine Content of Isomers	Carbon Length/ Chlorine Distribution	Calibration (Response Factors)
GC-ECNI-LRMS	High	Moderate	SCCP, MCCP	$\geq Cl_5$	Yes	Depending on chlorination degree
GC-ECNI-HRMS	High	High	SCCP, MCCP	$\geq Cl_5$	Yes	Depending on chlorination degree
GC-MS/MS (EI mode)	High	Low (much fragmentation)	SCCP, MCCP	No congener- and homologue-specific info	Not possible	Less critical for chlorine and carbon variation
LC-APCI-qTOF-MS (HRMS)	High	High	SCCP, MCCP, LCCP (esp. MCCP/LCCP)	Cl_2–Cl_x	Yes	Less critical for chlorine and carbon variation
GC×GC-TOF-MS (ECNI)	High	High	SCCP, MCCP	$\geq Cl_5$	Yes	Depending on chlorination degree
GC×GC-ECD	High	High	SCCP, MCCP, (LCCP)	Cl_2–Cl_x	Yes	Depending on chlorination degree
GC-FID and GC-MS (carbon skeleton method)	Moderate	High (if alkanes removed)	SCCP, MCCP, LCCP	No congener- and homologue-specific info	No	Good calibration based on hydrocarbon number only

CPs in Industrial sectors

3.1 Textile & Leather

3.1.1 Application

CPs, including SCCPs, MCCPs and LCCPs, are used in the textile and leather industries mainly as plasticisers, flame retardants and hydrophobic agents. In textiles, they are applied during finishing stages, particularly in PVC and PU coatings for products like rainwear, tarpaulins and upholstery, to improve flexibility and flame resistance (UNEP, 2016; IEEP, 2010) (See Table 5).

The chemical is also used in back coating and padding to enhance mechanical strength and abrasion resistance, especially in industrial textiles (OSPAR Commission, 2001). Additionally, they serve in water- and oil-repellent finishes, applied by padding or spraying followed by thermal curing (European Commission, 2005).

In leather processing, SCCPs are used in fat liquoring, where they are emulsified in oils to soften and strengthen the leather post-tanning (UNEP, 2015). They are also added as plasticisers in topcoats or binders during leather finishing, improving elasticity and durability (Umweltbundesamt, 2015; Oekopol GmbH, 2014). SCCPs are present in flame-retardant coatings for leather used in transport sectors requiring high fire safety (BIPRO, 2005). MCCPs and LCCPs are widely used as flame retardants in textiles and leather. They offer similar technical performance as SCCPs, which makes them more favourable for the application in this sector (DHR, 2025).

Table 5: Use of CPs in textile and leather

Sector	Process	Why CPs are Used	Reference
Textile	PVC/PU Coating	Plasticiser, flame retardant	(UNEP 2016, IEEP 2010)
Textile	Back coating/Padding	Strength, flame retardancy	(OSPAR 2001)
Textile	Water/Oil Repellent Finish	Hydrophobic, oleophobic	(EC 2005)
Leather	Fat liquoring	Softness, flexibility	(UNEP 2015, ILTA Journal)
Leather	Finishing & Coating	Plasticiser, gloss, crack resistance	(UBA Germany, Oekopol 2014)
Leather	Flame Retardant Treatment	Fire resistance (automotive/ aviation use)	(BIPRO 2005)

3.1.2 Market Overview of CPs in Textiles & Leather in India

India's textile industry is one of the oldest and most established sectors in the country, with a legacy that spans centuries. It is also one of the largest textile producers in the world. The industry is projected to grow at a 10% compound annual growth rate (CAGR) from 2019-20, reaching USD 350 billion by 2030. It is at present contributing around 2.3% to India's GDP (IBEF, 2024) (See Figure 11).

The leather industry is another key contributor to India's economy. India ranks as the second-largest exporter of leather garments, third-largest in saddlery and harnesses, and fourth-largest in leather goods globally (IBEF, 2024). As per a Statista market analysis, the leather goods segment in India is projected to reach USD 2.4 billion in 2024 and is expected to grow at a CAGR of 3.51% between 2024 and 2029 (Statista, 2024a).

Since both industries are growing rapidly and CPs are used as an additive in both the industries, the demand for CPs will also increase in the future, leading to increase in risks to human health and environment.

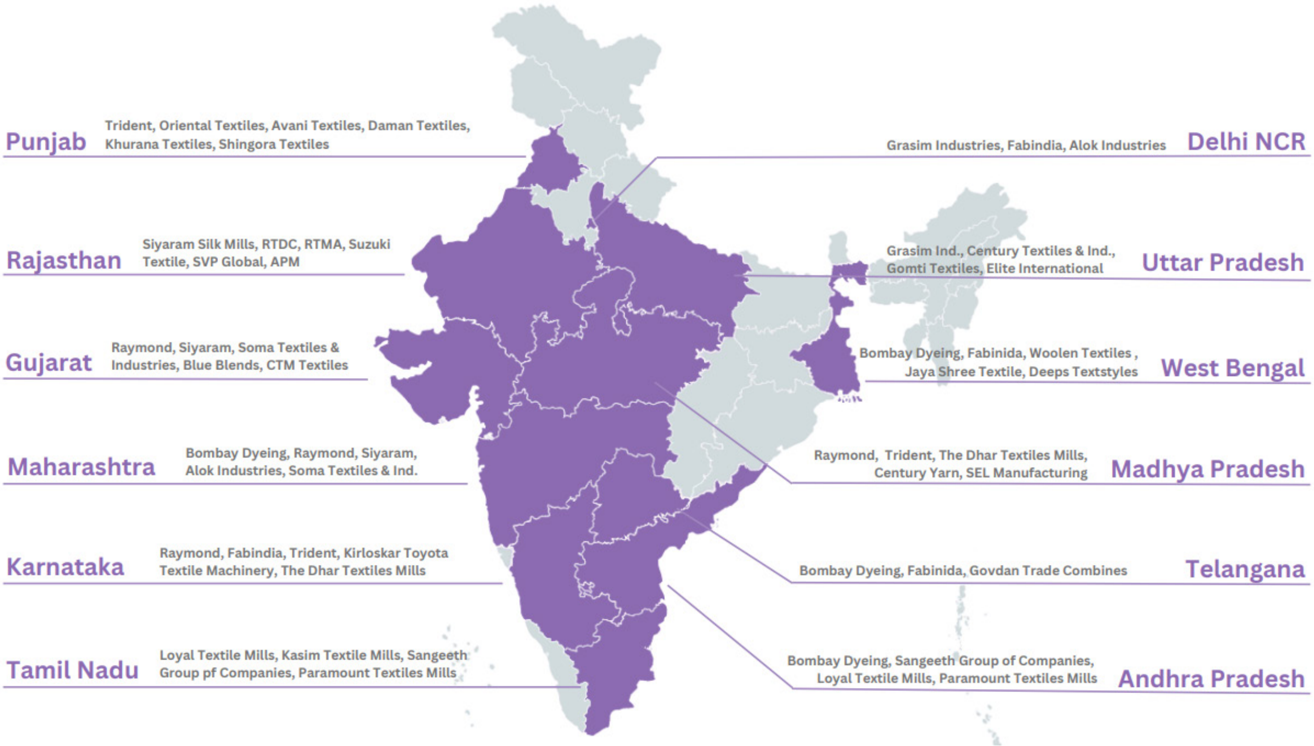


Figure 11: Major Textile manufacturing players in India (Completecircle, 2023)

India is one of the leading producers of chlorinated paraffins, with an estimated production capacity of over 110,000 tonnes per annum across approximately 20 manufacturers, although this includes all chain lengths (CSE, 2020). The domestic availability and relatively low cost of CPs have contributed to their continued use in textile applications, particularly in informal or small-scale manufacturing units.

However, India's textile export industry, which supplies to markets with strict chemical safety standards such as the European Union, faces increasing regulatory pressure. SCCPs and MCCPs are listed under Annex A of the Stockholm Convention for global elimination due to their persistence, bioaccumulation, and toxicity (UNEP, 2017). Consequently, export-oriented manufacturers like Raymond and Welspun are gradually shifting towards alternative substances to meet compliance requirements under frameworks like REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) and ZDHC (Zero Discharge of Hazardous Chemicals).

However, many small and medium enterprises that supply to the domestic market continue using SCCPs due to low cost and limited regulatory enforcement in the country (CSE, 2022; IPEN, 2016).

3.1.3 Inference from Scientific Research

Scientific research demonstrates that SCCPs and MCCPs are prevalent in textile and polymeric consumer products, pointing to their intentional use during manufacturing for properties such as plasticisation, flame retardancy, and water resistance.

In one comprehensive study, SCCPs and MCCPs were detected in 28 textile samples, including T-shirts and socks with concentrations reaching up to 33.9 to 5,940 ng/g, particularly in garments made from synthetic fibres, which contained up to seven times higher levels than those made from cotton (Tomasko, Parizek, & Pulkrabova, 2023). High concentration of SCCP and MCCPs (450 to 14,000 mg/kg) has been reported in artificial leather (Guida et al., 2020; Khan et.al., 2025) (See Annexure for more information).

There is limited evidence that LCCPs are used in the textiles and leather industries. According to the UK Environment Agency (2009), in leather processing, formulations may contain 5-15% LCCPs per kg of leather. However, no scientific studies have directly measured LCCPs in finished textile or leather products, indicating a major research gap. In addition, the research studies for the presence of CPs in Indian textiles and leather are limited.

3.2 PVC and rubber industries

3.2.1 Application

CPs are widely used in plastics and rubber for their plasticising and flame-retardant properties. In PVC processing, SCCPs act as secondary plasticisers, enhancing flexibility, durability, and thermal stability, making them suitable for applications such as wire and cable insulation, flooring, and artificial leather (UNEP, 2016; OSPAR Commission, 2001). They also improve flame resistance and chemical stability in flexible PVC products.

Beyond PVC, SCCPs are used in polyolefins, polystyrene, and rubber compounds, serving as both plasticisers and flame retardants in automotive parts, conveyor belts, and construction materials (European Commission, 2005; Umweltbundesamt, 2015). MCCPs and LCCPs share similar applications, including use in PVC, textiles, sealants, adhesives, coatings, and metalworking fluids (Yu et al., 2025). Unlike SCCPs, MCCPs and LCCPs offer higher thermal stability and lower volatility, making them preferable for high-temperature applications such as heat-resistant cables, electrical insulation, and power transmission.

3.2.2 Market Overview

The plastics and rubber products market has witnessed significant growth in recent years, increasing from $1,508.6 billion in 2024 to $1,621.51 billion in 2025, with a CAGR of 7.5%. This rise is largely driven by rapid industrialisation, expanding automotive and consumer goods sectors, and growing use in healthcare and packaging (See Figure 12). The market is expected to further expand to $2,087.48 billion by 2029 at a CAGR of 6.5%, propelled by the push for electric vehicles, lightweight materials, circular economy initiatives, and aerospace applications.

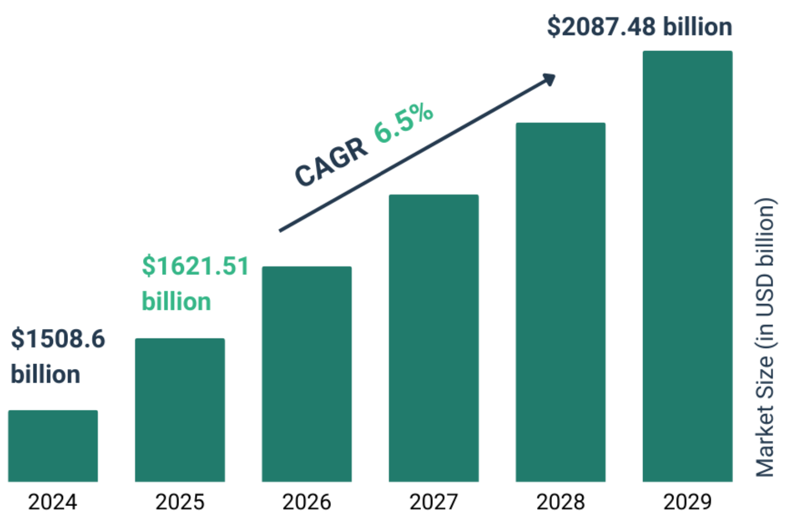


Figure 12: Plastics and Rubber Products Global Market Report 2025 (The business and research company, 2025)

India's plastics and rubber industries are experiencing robust growth, fuelled by rising demand across automotive, packaging, construction, healthcare and consumer goods sectors. The Indian plastics market was valued at US$ 43.68 billion in 2023 and is projected to grow at a CAGR of 6.6%, reaching US$ 68.33 billion by 2030 (Maximise Market Research, 2024) (Figure 13). Exports remain strong, crossing US$ 11 billion in FY 2022–23 (IBEF, 2023). Since CPs are widely used in these industrial sectors as a plasticiser and flame retardant, the demand for CPs will increase gradually.

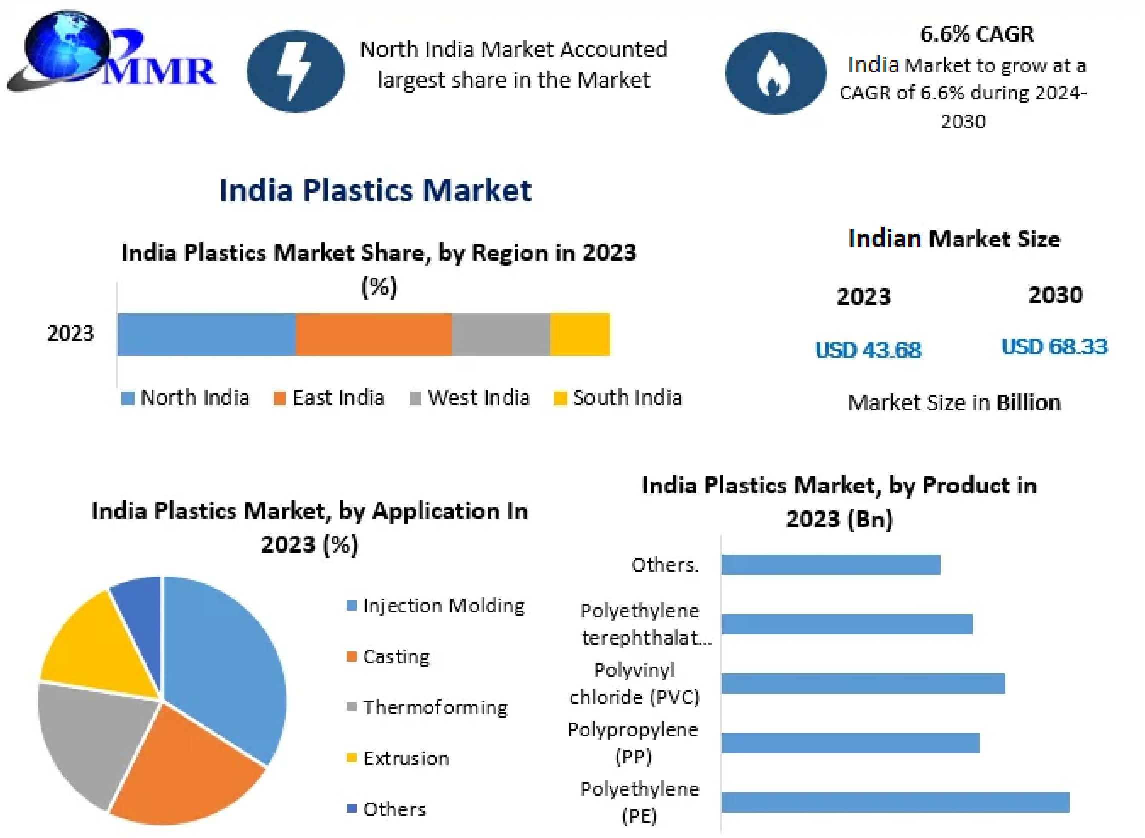


Figure 13: India's Plastic Market (MMR, 2024)

3.2.3 Inference from Scientific Research

Recent studies report widespread SCCP use in consumer products such as PVC pipes, plastic toys, children's items, and rubber-based food contact materials. High concentrations of SCCP were detected in children's products in Japan (up to 120,000 mg/kg; Guida et al., 2022) and toys from ten countries (up to 60,400 mg/kg; Karlsson & Miller, 2023). SCCPs were also found in rubber-based food contact materials in Germany (Vetter et al., 2023), PVC pipes in South Africa (Nevondo et al., 2025), and toys in Canada (Kutarna et al., 2022), indicating both intentional use and legacy contamination.

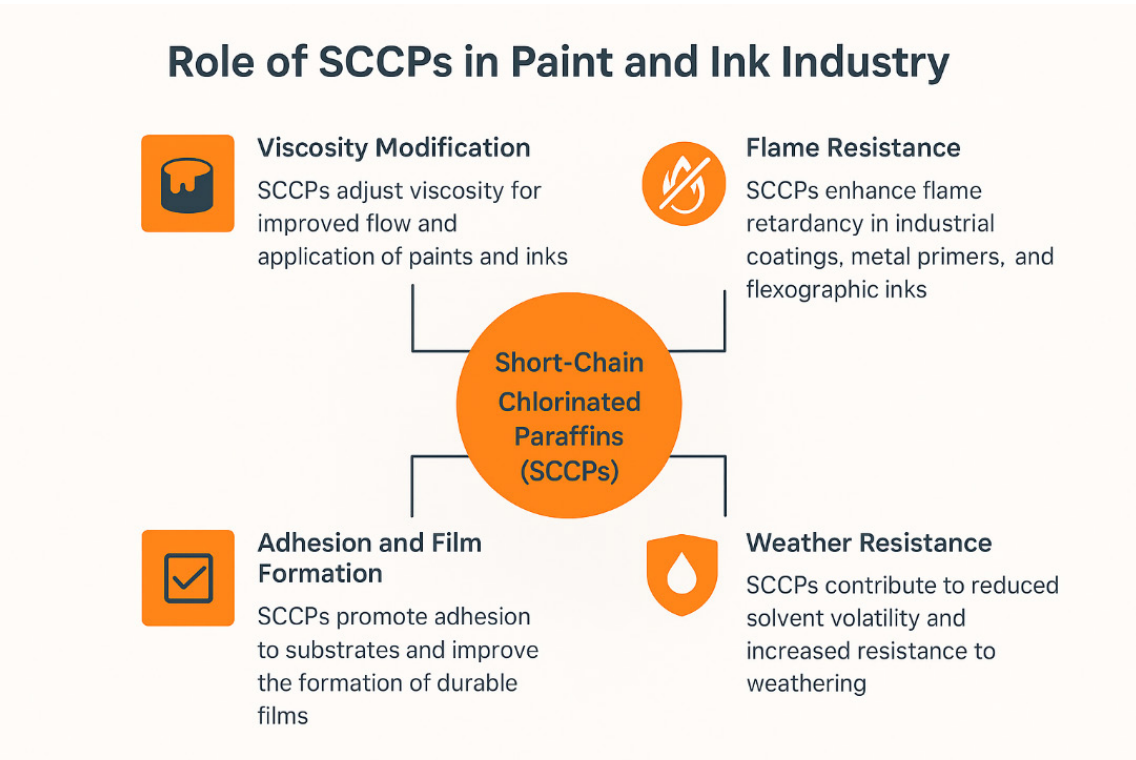
MCCPs and LCCPs have likewise been detected in a variety of polymeric products. In Germany, MCCPs reached 112,000-341,000 mg/kg in rubber food contact materials (Vetter et al., 2023), while in Belgium, toys and PVC/rubber products contained up to 3,500 mg/kg (McGrath et al., 2021). In Canada, LCCPs were found in plastic-coated electrical cables (up to 5.79 mg/g) and foam toys (0.14 mg/g) (Kutarna et al., 2023) (See Annexure for more information).

Recycled rubber also carried LCCP congeners (C_{18}–C_{29}), as observed in playground tiles and tyre granulates in the Netherlands, pointing to potential environmental contamination from degraded rubber materials. These findings suggest that polymeric consumer products can act as significant sources of human exposure, particularly for vulnerable populations such as children (Brandsma et al., 2019). The studies pertaining to the presence of SCCPs, MCCPs and LCCPs in the Indian context are not available in the public domain.

3.3 Paint and Ink

3.3.1 Application

CPs are widely used in the paint and ink industries as multifunctional additives due to their favourable physical and chemical properties. They serve primarily as flame retardants and water-repellent agents, contributing to the modification of viscosity, improved flexibility, and enhanced flame resistance in formulations (Oekopol GmbH, 2014; UNEP, 2012), while also minimising solvent volatility and boosting weather resistance, making them particularly useful in high-performance and outdoor applications (Yuan et al., 2021). Their cost-effectiveness and compatibility with a wide range of solvents and binders have supported their continued use across various types of paints and coatings. Common applications include anticorrosive coatings for metal surfaces, intumescent paints for fireproofing, swimming pool coatings, decorative paints for both interior and exterior surfaces, and primers for polysulphide expansion joints. SCCPs are also used in cross-linkable polyester systems designed for long-term road markings and in unsaturated polyester resins found in fibre-reinforced composites. These diverse applications reflect the adaptability and performance-enhancing value of SCCPs in industrial and commercial paint and ink formulations (Zarogiannis and Nwaogu., 2010).



3.3.2 Market Overview

In 2024, the global paints and coatings market was valued at approximately USD 202 billion, marking a 2.5% increase in value from 2023 (ChemQuest Group, 2025). It is projected to grow to USD 282 billion by 2034, with a compound annual growth rate (CAGR) of about 4.3% from 2025 to 2034 (Precedence Research, 2025).

The market size was reported at USD 211.3 billion in 2024, with expectations to hit USD 280.2 billion by 2030 at a 5.0% CAGR (Grand View Research, 2024) (See Figure 14). In India, the paints and coatings sector has been expanding rapidly as part of regional growth, with the printing inks industry valued at USD 1.07 billion in 2024, supported by rising demand in the packaging and publishing sectors (Market Research Future, 2024). Since CPs are widely used in this industrial sector, the demand for CPs will increase gradually.

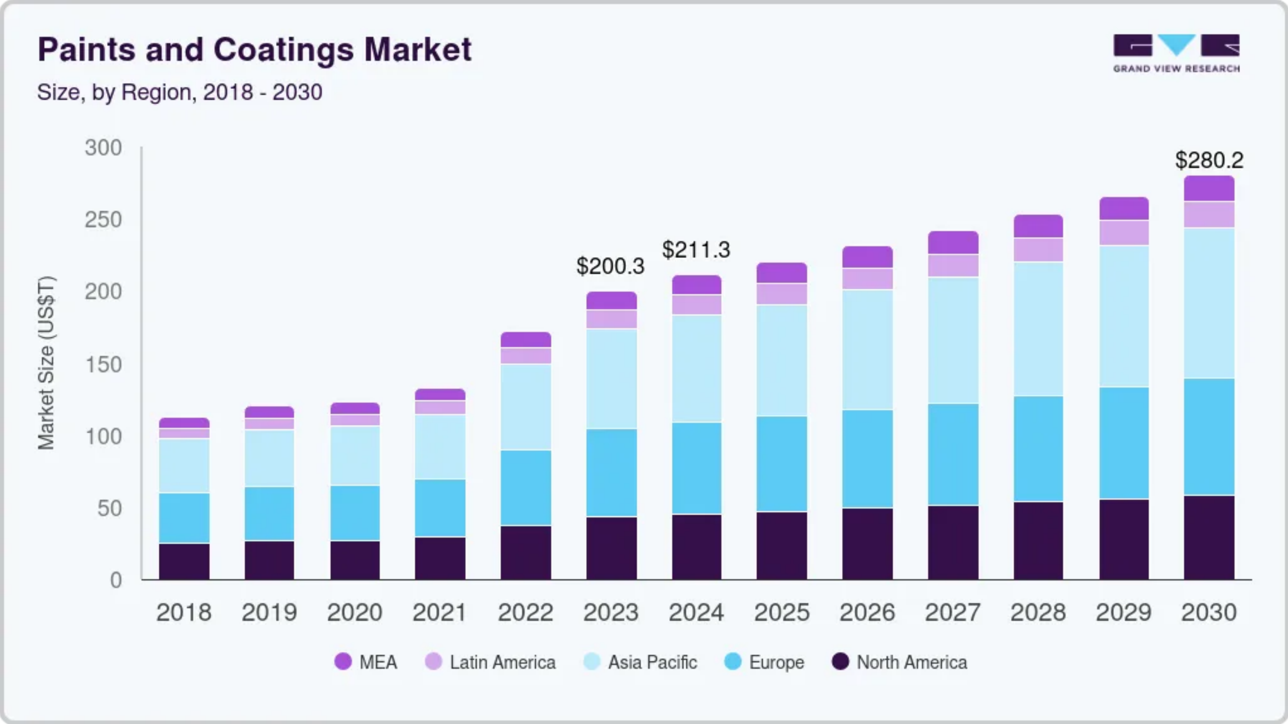


Figure 14: Paints and Coatings (Grand View Research, 2024)

3.3.3 Inference from Scientific Research

Scientific studies confirm that SCCPs are still used in paint formulations. Zarogiannis and Nwaogu (2010) reported SCCP concentrations of 2.5-10% in intumescent coatings, <1-10% in road marking paints, and 10-15% in anticorrosive/protective coatings, with dried films reaching 5-20%, and in some cases up to 50-70% by weight across several European countries. More recently, Kuramochi et al. (2023) detected SCCPs at 5.07-14.32 µg/g in indoor paints from Canada. While data on MCCPs and LCCPs in paints and ink remain scarce, Wang et al. (2023) reported MCCPs up to 7,020 µg/g (≈0.7% w/w) in wax coatings on ceramic tiles.

There are no studies pertaining to the Indian context, underscoring a major knowledge gap and the need for more investigations on MCCPs and LCCPs in modern paint and ink products in the country.

3.4 Adhesives and Sealants

3.4.1 Application

SCCPs are widely used as plasticising agents to enhance elasticity and spreadability, particularly in construction adhesives, sealant tapes, and weatherproof coatings (BIPRO Umweltberatung, 2005). Their inclusion improves both workability during application and durability after curing. In surface coatings for metals, wood, and leather, SCCPs also contribute to gloss, hardness, and chemical resistance, thereby extending product longevity under harsh environmental conditions (UNEP, 2015). Similarly, MCCPs and LCCPs are applied in adhesives and sealants as plasticisers and to improve water resistance and flame retardancy. These uses are comparable to SCCPs and are found in a variety of sealant and adhesive applications, including those for electrical and electronic equipment (UK Environment Agency, 2003; ECHA, 2021; Brandsma et al., 2015; UK Environment Agency, 2009).

3.4.2 Market Overview

The global adhesives and sealants market was valued at USD 121.27 billion in 2023 and is projected to reach USD 237.07 billion by 2030, growing at a CAGR of 10.1% from 2024 to 2030. Asia Pacific led the market with a 41.3% revenue share in 2023, driven by strong industrial growth. In the US, increased automobile production has contributed to market expansion. Among applications, the furniture and woodworking segment is expected to grow at the fastest pace, with an 11.6% CAGR. Acrylic-based adhesives dominated the market by product type, accounting for a 36.7% share in 2023 (Market Analysis Report, 2025) (See Figure 15). As the global and Indian metalworking fluids market grow, the demand for CPs, which are commonly used as additives and lubricants in these fluids, is also expected to rise.

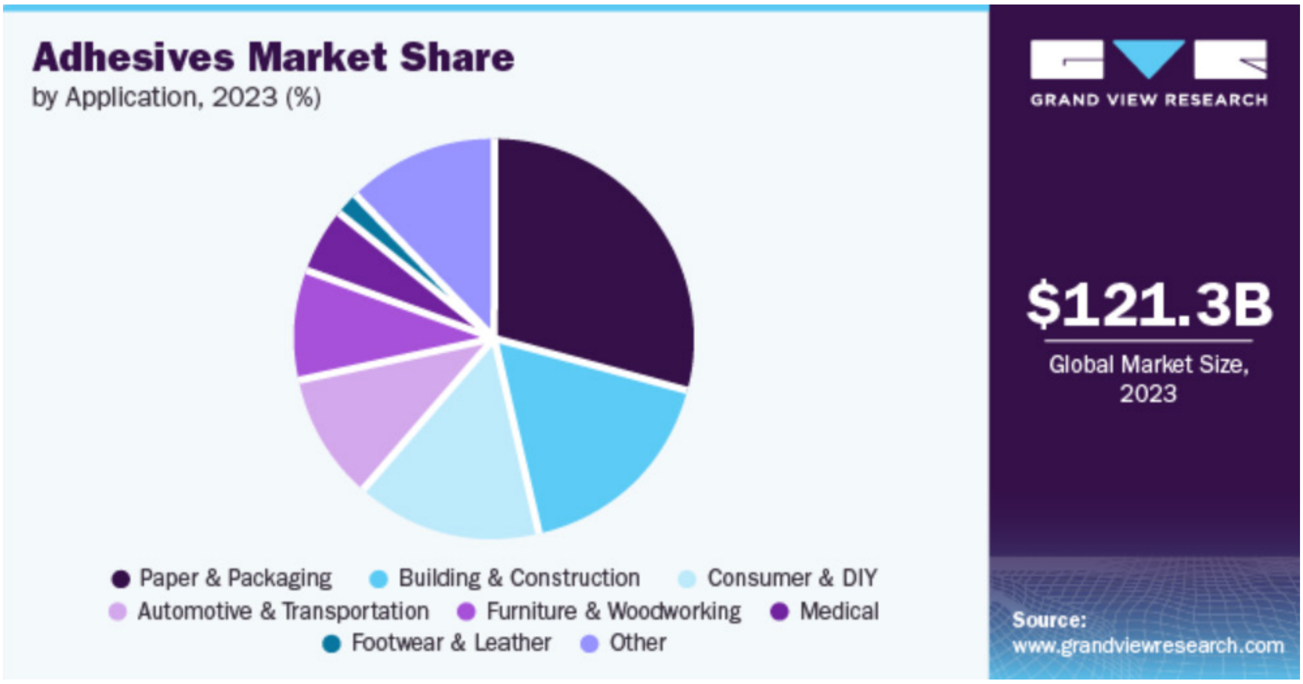


Figure 15: Market share of Adhesives (Grand View Research, 2024)

3.4.3 Inference from Scientific Research

Research studies showed that SCCPs are used in adhesives and sealants mainly as plasticisers and flame retardants (UNEP, 2016; ECHA, 2021). Studies by Zeng et al. (2011) and Yuan et al. (2022) found SCCPs in air and dust samples, likely from construction materials like sealants in China. Similarly, Xu et al. (2019) reported MCCP concentrations of 41,400 µg/g (4.1% by weight) in adhesives used in rubber track products, indicating they are a major source of MCCPs in finished goods. EFSA (2020) also reported possible migration of SCCPs from adhesives in food packaging, raising health concerns. There are no studies that have shown the presence of MCCPs and LCCPs in finished adhesives and sealants, but their detection in indoor dust and treated materials suggests widespread use in building and electronic applications (Glüge et al., 2021; IPCS, 1996). There are no studies on the presence of MCCPs and LCCPs in the Indian context.

3.5 Metal working Fluids

3.5.1 Application

SCCPs are used in metalworking fluids as effective lubricants and coolants in metal cutting and forming processes. They reduce friction, improve surface finish, and extend tool life. Their chlorinated structure provides excellent extreme pressure (EP) properties, thermal stability, and compatibility with various base oils, making them suitable for high-load and high-temperature machining operations (USEPA, 2009). MCCPs and LCCPs are also used in metalworking fluids as extreme pressure additives, lubricants, and corrosion inhibitors, offering similar properties and performance to SCCPs. They effectively reduce friction, wear, and corrosion during machining operations (Glüge et.al., 2018).

3.5.2 Market Overview

The global metalworking fluids market was valued at USD 12.17 billion in 2023 and is projected to reach USD 17.45 billion by 2030, growing at a CAGR of 4.9% from 2024 to 2030. Asia Pacific led the market with over 42% share in 2023, while North America is expected to see notable growth. The mineral oil-based segment dominated by product type, and machinery and construction were the leading end-use sectors (Grand View Research, 2025) (See Figure 16).

In India, the metalworking market is set to grow steadily, driven by the expanding automotive, aerospace, and machinery manufacturing sectors, with projected annual growth around 17% and a CAGR of 3.3% from 2024 to 2029 (Technavio, 2025).

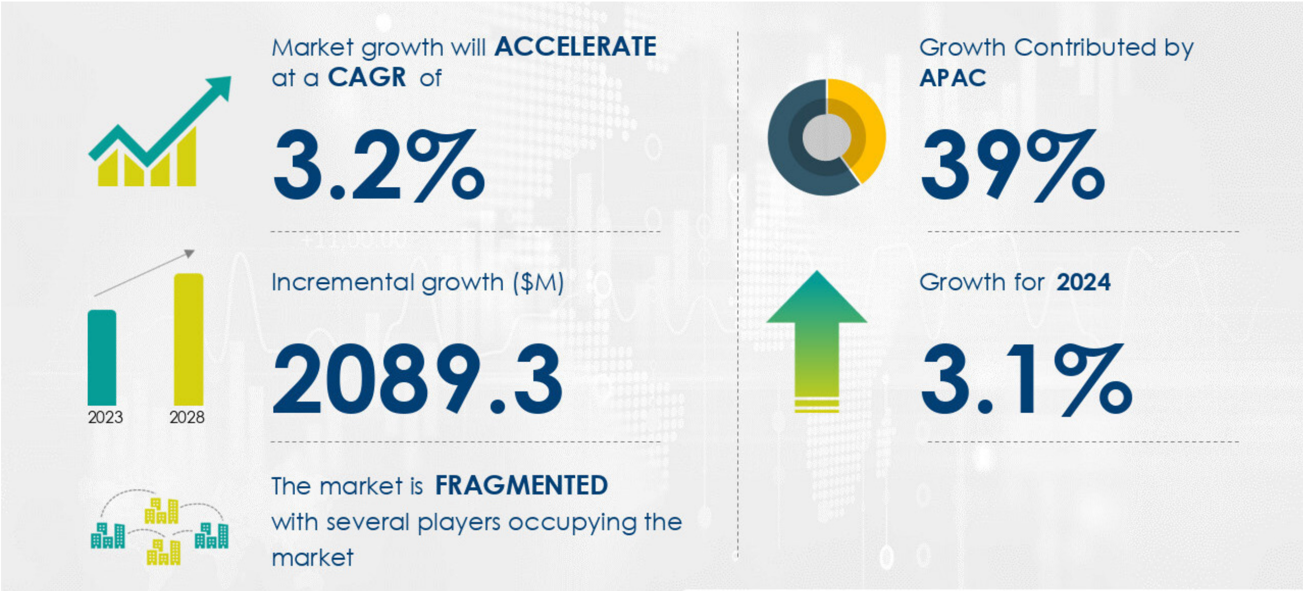


Figure 16: Metalworking Fluids Market (Technavio, 2024)

3.5.3 Inference from Scientific Research

Scientific studies showed that metalworking fluids are a major source of SCCP emissions, with estimated releases of 246-412 tonnes per year (Xu et al., 2014). SCCPs are also reported to be emitted from gear oils, mining fluids, and marine equipment (CPIA, 2002). The USEPA (2009) estimated releases from metalworking operations at 2,400 kg/site/year to wastewater and 900 kg/site/year to landfills or incinerators, emphasising the need for better waste management. The improper disposal of SCCP-containing waste oils, often reused as fuel, poses environmental and corrosion risks. The oils with halogen content above 1,000 mg/kg are classified as hazardous waste, while those above 10,000 mg/kg may require incineration (PDEP, 2019; European Commission, 2010).

Although most studies focus on SCCPs and MCCPs, LCCPs continue to be used in industrial fluids (Glüge et al., 2021; Straková et al., 2022). In India, data on the presence or use of SCCPs, MCCPs, or LCCPs in MWFs are currently lacking.

Downstream Challenges and Management

CPs are released into the environment during manufacturing, usage, and disposal. Their high persistence, hydrophobicity, and resistance to biodegradation enable them to accumulate in different environmental compartments including water bodies, soils, sediments, and biota. CPs can enter aquatic environments through direct industrial discharge, leaching from landfills, and most significantly through effluents from sewage and common effluent treatment plants. CPs are not effectively removed during conventional wastewater treatment processes (Guida et.al., 2020).

Many studies from industrial hubs such as China, Germany and South Korea have confirmed the frequent detection of SCCPs and MCCPs in influent and effluent samples of wastewater treatment plants (Zeng et.al., 2012). In China, SCCP concentrations have been found to range between 1.6 to 12.3 µg/L in influents and 0.4 to 3.1 µg/L in effluents, indicating partial but inadequate removal (Wang et al., 2022). MCCPs were reported in wastewater sludge in Germany at concentrations ranging from 0.23 to 1.87 mg/kg (Wluka, et al., 2021). In South Korea, MCCPs were detected in effluents at levels between 0.87 and 5.7 µg/L, while SCCPs ranged from 1.3 to 8.6 µg/L (Lee et al., 2020). Similarly, in Taiwan, SCCPs and MCCPs were found in WWTP sludge at 5.4 ± 1.8 µg/g and 7.3 ± 2.2 µg/g dry weight, respectively (Lee et al., 2022). These findings clearly demonstrate that traditional treatment technologies used in sewage treatment plants (STPs) and common effluent treatment plants (CETPs) are not designed to eliminate CPs effectively, leading to their continuous discharge into the environment.

In India, effluents from CETPs in industrial clusters such as Vapi (Gujarat) and Kanpur (Uttar Pradesh), associated with textile and leather processing industries, have shown detectable levels of SCCPs and MCCPs (Dubey & Srivastav, N.A.). Soil samples collected from agricultural areas irrigated with treated effluents in these regions have revealed SCCP concentrations ranging from 180 to 860 ng/g and MCCPs ranging from 210 to 1,120 ng/g (Dong et.al, 2020). This suggests that irrigation using wastewater, along with land application of sewage sludge, is a significant pathway through which CPs accumulate in soil. Their strong sorption to soil organic matter and low mobility also facilitate long-term persistence. In sediment samples from water bodies adjacent to plastic manufacturing zones and e-waste recycling clusters, CPs have been recorded at concentrations exceeding 2.1 mg/kg (Mowla, et al., 2021), highlighting their transport and deposition downstream from pollution hotspots. Studies from Germany and China have also confirmed the accumulation of SCCPs and MCCPs in urban-industrial sediments, while LCCPs though less frequently monitored due to analytical limitations have been found in WWTP sludge and plastic-contaminated sediments up to 1.6 µg/g dry weight (UNEP, 2020).

The presence of CPs in effluents and sludge, despite existing treatment, is attributed to the limitations of current technologies. Traditional STP processes such as biological degradation, sedimentation, sand filtration, and chemical coagulation are largely ineffective for removing highly hydrophobic and persistent compounds like CPs. Their strong binding to particulate matter allows them to evade treatment stages and be discharged with effluent or accumulate in biosolids. The Central Pollution Control Board (CPCB) estimates that India generates approximately 72,368 million litres of wastewater per day (MLD), while the national treatment capacity is only 31,841 MLD, leaving around 40,527 MLD of wastewater untreated (CPCB, 2023). Even among the treated portion, there is no CP-specific removal infrastructure, which results in persistent environmental release. For instance, in the Ganga River basin, CPCB data indicates that while towns generate about 3,558.5 MLD of sewage, the operational STP capacity is only 2,325.7 MLD, again highlighting a major treatment gap.

In response to increasing evidence of CP persistence in treated effluents, several research efforts are being made to identify feasible removal technologies. Studies have shown that the use of activated carbon, both powdered and granular, can significantly improve the removal efficiency of SCCPs and MCCPs when added to secondary or tertiary treatment stages, achieving removal efficiencies of up to 85% under optimal conditions. Advanced oxidation processes (AOPs) such as UV/H_2O_2, ozonation and Fenton-based treatments have also demonstrated the ability to degrade CP molecules, though these require high energy inputs and are not yet widely deployed. Furthermore, experimental technologies such as molecularly imprinted polymers and cyclodextrin-based sequestration materials are being investigated for their ability to selectively adsorb and remove CPs from wastewater with greater specificity. Integrated methods combining bioaugmentation and chemical oxidation are also being explored as cost-effective and scalable solutions, though most remain in the pilot or research phase.

Regulatory Status of CPs

5.1 SCCPs

5.1.1 Status of SCCPs in Stockholm Convention

SCCPs are formally designated as persistent organic pollutants (POPs) and listed under Annex A (elimination) of the Stockholm Convention in May 2017 (Guida et al., 2020; Stockholm Convention on POPs, 2017a, 2017b). Despite this general prohibition, specific exemptions were granted for their use in certain applications within the mining and forestry industries, leather production, as lubricant additives, and as plasticisers in polyvinyl chloride (PVC), with the express exclusion of toys and children's products (Guida et al., 2020; Stockholm Convention on POPs, 2017a, 2017b). Furthermore, the Stockholm Convention's listing permits SCCPs to be present at concentrations up to 1% by weight in mixtures of other chlorinated paraffins (Stockholm Convention on POPs, 2017a).

According to the Basel Convention General Technical Guidelines on the Environmentally Sound Management (ESM) of Waste consisting of, containing, or contaminated with POPs (UNEP 2023b), waste with low POP content limit for SCCPs at or above [100 mg/kg] [1500 mg/kg][10,000 mg/kg] must be disposed of in such a way that the POP content is destroyed or irreversibly transformed.

Indian Scenario

India's chlorinated paraffins manufacturing capacity stands at around 110,000 tonnes annually, produced by approximately twenty manufacturers (OMAL, 2025). Despite this large-scale production, the country lacks specific national regulations for the use and distribution of SCCPs. This regulatory void is particularly concerning given that SCCPs are listed for global elimination under the Stockholm Convention. The continued unregulated presence of SCCPs could threaten India's export potential, especially to countries with stringent import restrictions on such hazardous chemicals.

5.1.2 Regulatory status of SCCPs

Table 6: Regulatory framework of SCCPs (Global vs India)

Year	Country	Regulation	Remark
2024	Australia	Industrial Chemicals Environmental Management Standard	Australia has prohibited SCCPs from July 2024 in Industrial Chemicals Environmental Management Standard (IChEMS Register Schedule 7).
2023	China	Chinese Ministry of Ecology and Environment (MEE)	Restricted the use of SCCPs from January 1, 2024 (Chinese Ministry of Ecology and Environment (MEE), 2023).
2023	Vietnam	National Technical Regulation on Thresholds for Persistent Organic Pollutants (POPs)	Vietnam has proposed a draft version to restrict SCCPs in certain items. (1% in substances or mixtures)
2018	Singapore	National Environment Agency (NEA)	Singapore banned the production, import, export, and use of Short-Chain Chlorinated Paraffins (SCCPs).
2018	Japan	Ministry of Environment (MoE)	Japan designated SCCPs as Class I Specified Chemical Substances in 2005 under its Chemical Substances Control Law (CSCL), with a full ban on production and import implemented in 2018 (NIP, 2020).
2017	South Korea	Ministry of Government Legislation	South Korea has ratified the Stockholm Convention and regulates SCCPs as POPs under its POPs Control Act.
2012	European Union (EU)	EU Regulation No 519/2012	Included SCCP in Annex I of Stockholm Convention on POPs. However, specific exemptions for production and market use of up to 1% was granted for certain uses of SCCPs.
India		No regulation	

5.2 MCCPS

5.2.1 Status of MCCPs in Stockholm Convention

In its ninth meeting held in October 2023, POP RC-19 Committee of the Stockholm Convention recommended for the listing of MCCPs in Annex A, with several specific exemptions, such as for metalworking fluids, PVC, adhesives, sealants, and tape used for non-structural bonding in aerospace and defence products (UNEP, 2023a).

During the 12th Conference of the Parties (COP-12) to the Stockholm Convention, which took place from April 28 to May 9, 2025 in Geneva, parties agreed to list MCCPs in Annex A (Elimination) of the Convention, with specific, time-limited exemptions (UNEP, 2025).

5.2.2 Global Regulations on MCCPs

Moreover, MCCPs have been classified under the harmonised classification of the EU Classification, Labelling and Packaging (CLP) Regulation (ECHA 2019) as it "may cause harm to breastfed children".

Several countries are imposing restrictions or regulations on MCCPs due to their Persistent, Bio-accumulative, and Toxic (PBT) properties. Table 7 outlines the current status of the regulatory framework for MCCPs.

Table 7: Regulatory status of MCCPs Global vs India

Year	Country	Regulation	Remark
2025	Japan	Ministry of Economy, Trade and Industry (METI)	In Japan, MCCPs are under consideration for designation as Class I Specified Chemical Substances under the Chemical Substances Control Law (CSCL).
2024	Singapore	Environment Protection Management Act (EPMA) and Environment Protection and Management (Hazardous Substances)	Singapore notifies proposal to regulate the MCCPs in products. The regulatory measures will be promulgated in the official gazette by June 2024 (Nao, 2024).
2023	China	Ministry of Ecology and Environment of China	The Ministry of Ecology and Environment of China issues a notice for collecting information on production, usage, import-export, alternative substances and alternative technologies of MCCPs for POP RC-19 of the Stockholm Convention (Yake, 2023).
2022	European Union	ECHA	ECHA updated the information for their intentions for restricting medium-chain chlorinated paraffins. ECHA will update the intention to submit an Annex XV restriction dossier on medium-chain chlorinated paraffins to include uses in PVC as well as other substances that contain chloroalkanes with carbon chain lengths within the range C14 to C17.
2022	UK	UK Government	UK has proposed to enlist MCCPs under the Stockholm Convention as Persistent Organic Pollutants (POPs) (UNEP, 2023a; Guida et.al., 2022).
2020	Australia	The Australian Department of Health published a hazard assessment	MCCPs meet the domestic PBT criteria, and that some congener groups may meet the Annex D screening criteria for Persistent Organic Pollutants under the Stockholm Convention (NICNAS, 2020).
2019	Canada	Canadian Environmental Protection Act, 1999	Canada classified medium-chain chlorinated paraffins as toxic substances under paragraph 64 (a) and 64 (c) of the Canadian Environmental Protection Act, 1999 (Government of Canada, 2019).
2015	United States	United States Environmental Protection Agency (US EPA)	USEPA regulating medium-chain chlorinated paraffins (MCCPs) under Toxic Substances Control Act's (TSCA) new chemical review programme. Detailed risk assessment has been performed under TSCA 5 new chemical review programme (USEPA, 2015).
India	No Regulation		

5.3 LCCPs

5.3.1 Status of LCCPs in Stockholm Convention

Long-chain chlorinated paraffins are not yet listed under the Stockholm Convention; however, scientific studies have demonstrated that they are persistent, bio accumulative, and toxic (PBT), particularly posing risks to aquatic organisms.

5.3.2 Global Regulations on LCCPs

The regulatory status of LCCPs varies globally. Table 8 presents the various regulatory statuses and actions taken by different countries for the management of LCCPs.

Table 8: Regulatory status of LCCPs Global vs India

Year	Country	Regulation	Remark
2022	European Union	European Chemicals Agency (ECHA)	ECHA is regulating LCCPs REACH regulation, which mandates registration, evaluation, potential authorisation, and restriction of LCCPs based on their hazardous properties and usage within the European Union.
2019	Canada	Canadian Environmental Protection Act, 1999	Canada classified long-chain chlorinated paraffins as toxic substances under paragraphs 64 (a) and 64 (c) of the Canadian Environmental Protection Act, 1999 (Government of Canada, 2019).
2016	United States	US EPA	EPA is regulating LCCPs Significant New Use Rules (SNUR), under TSCA section 5(a)(2), (LCCPs—alkyl chain length of C_{21} and above) (US EPA, 2016).
India	No Regulation		

5.4 Regulatory Impact on Global Supply

The global market is undergoing significant changes due to the imposition of stricter regulations on chemicals, particularly chlorinated paraffins. Governments worldwide are introducing tighter controls on manufacturing, imports, and trade because of growing environmental concerns over persistent pollution. These measures are disrupting supply chains while simultaneously driving the search for safer and more sustainable substitutes.

In September 2024, under Notification No. 2024-571, the South Korean Ministry of Environment officially designated SCCPs as POPs. This regulation restricts their production, import and use, thereby affecting global supply chains for plasticisers, lubricants, and flame retardants. As a result, the market is witnessing a shift towards alternative materials, forcing manufacturers to go for sustainable alternatives. This is also impacting the global trade flow. In the long-term, the transition would be towards adopting Best Available Technology (BAT) and Best Environmental Practices (BEP) (IMARC, 2025).

Alternatives

6.1 Alternatives to SCCPs

Non-chlorinated paraffins such as alkyl phosphates and Sulfonated fatty-acid esters can be used in the following applications:

- Leather production: Natural, animal and vegetable oils.
- Paint and coating: Polyacrylic esters, diisobutyrate and phosphates.
- Flame retardant: Aluminium hydroxide and phosphate-containing compound.
- Metalworking fluid: Alkanol amides, isopropyl oleate, long-chain chlorinated paraffins (C18+) (LCCPs), Medium-chain chlorinated paraffins (C14-17) (MCCPs), Nitrated compounds and overbased calcium sulphonates.
- Phosphorus-based compounds: alkyl phosphate esters, phenol, isopropylated, phosphate, tributyl phosphate, Triaryl phosphate, bis(2-ethylhexyl) hydrogen phosphate, didodecyl phosphite, dimethyl hydrogen phosphite, 2-ethylhexyl hydrogen phosphate, polyethoxy oleyletherphosphate, zinc dialkyl dithiophosphates and zinc dialkyl dithiophosphate.
- Sulphur-based substitutes: Sulphurised polyisobutene, polypropylene, polystyrene, tertiary nonyl polysulfide, polyolefin sulphide, sulfonated fatty acid esters, polysulphides, alkyl sulphide, sulphurised alkenes/olefins, and sulphurised hydrocarbons.

6.2 Alternatives to MCCPs

Aluminium hydroxide, aluminium phosphate, zinc borate and antimony trioxide containing compound as flame retardants.

- Natural animal and vegetable oils in leather production.
- Alkyl phosphates and sulfonated fatty-acid esters.
- Polyacrylic esters, diisobutyrate and phosphates in paint and coating (ZDHC, 2025).
- Triethyl Citrate, diisononyl cyclohexane-1,2-dicarboxylate, diisononyl adipate as plasticisers.

6.3 Alternatives to LCCPs

At present, there are many alternatives to LCCPs. Some of them are listed below:

- Alkanol amides (e.g., 2:1 di-ethanolamine (DEA) tall oil fatty acid alkanol amide)
- Isopropyl oleate
- Overbased calcium sulphonates
- Alkyl phosphate esters
- Phenol, isopropylated, phosphate (ITAP) (3:1)
- Tributyl phosphate (TBP)
- Triaryl phosphate
- Sulphurised polyisobutene, polypropylene and polystyrene
- Polyolefin sulphide

Chlorinated paraffins and Circular economy

CPs are widely used by different industrial sectors. However, integrating this forever chemical with the circular economy system poses significant challenges due its persistence, toxicity and bio-accumulative properties.

Studies have shown that CPs are very commonly used in many products, such as PVC, textiles, and leather, which are recycled into new products. However, the recycling of materials containing CPs can lead to contamination of the entire supply chain, with the possibility of high CPs-containing products. For instance, recycling of plastic material may cause accumulation of CPs in recycled material and may act as a barrier in the circular economy. Therefore, phasing out CPs from the upstream sector is the best option. Else, it will remain in the waste stream forever and impact human health and the environment. Some other solutions that may help, include improving waste-sorting technologies to exclude CP-laden materials and adopting closed-loop industrial systems to prevent environmental leakage. Thus it is essential for India to ratify these chemicals to reduce the health and environmental burden, both upstream and downstream.

Recommendations and Future Outlook

CPs are widely used across various industrial sectors globally, including plastics, rubber, textiles, lubricants, paints, sealants, and metalworking fluids. These sectors are also major industries in India. The dispersive use and significant environmental release of CPs, particularly SCCPs and MCCPs, which are listed as POPs have led to widespread contamination both in India and globally. The major concerns include their persistence, bio-accumulative nature and toxicity, potential to disrupt the endocrine system and cause long-term harm to aquatic and terrestrial ecosystems. LCCPs, though not yet classified as POPs, have demonstrated similar hazardous properties and are increasingly being evaluated by international regulatory bodies.

Many developed countries and multinational corporations have taken regulatory or voluntary action to restrict or phase out the use of SCCPs and MCCPs. The European Union have listed SCCPs and MCCPs under the Stockholm Convention and is moving towards restrictions on LCCPs, while China has imposed limits in certain applications. Multinational companies often exclude CPs from their products in countries with strong regulations, but may continue to use them in markets like India, where restrictions are lacking.

Although several safer and technically feasible alternatives to CPs have been developed and commercialised, transitioning to these substitutes presents multiple challenges. These include high costs, limited awareness among stakeholders, and the need for significant modifications in industrial infrastructure and manufacturing processes.

In India, there is limited data on the production, use and emissions of CPs across industries. Therefore, there is a need to adopt suitable policy and regulations to manage these chemicals. Notably, ratification of these chemicals are key for the suitable management of these chemicals. Some key actionable recommendations for the countries are:

8.1 Strengthening Regulatory Framework

- There is scope to develop more comprehensive and targeted regulations for the management of CPs, particularly SCCPs and MCCPs, which have been identified as POPs under the Stockholm Convention. International experiences for regulatory approaches in the EU, US, and Canada may help India build a framework that supports both environmental safety and global trade alignment.
- Adopting relevant international standards can offer valuable direction for shaping national policies. This could also help ensure that Indian industries remain competitive in global markets while encouraging a shift towards safer alternatives.
- There is a need for time-bound milestones for the reduction or gradual substitution of certain CPs, especially in key sectors like plastics, textiles, leather processing and metalworking, which can support a smoother transition. Such timelines can allow industries to plan ahead, adapt technologies, and invest in safer substitutes without undue burden.
- Industrial effluent standards can be reviewed to assess and potentially limit the release of CPs into the environment.
- Standards or guideline values for CPs in drinking water and food may be developed to support human health protection and environmental safety.

8.2 Promoting the Adoption of Safer Alternatives

- Encouraging the development of safer alternatives to CPs, could involve providing targeted financial incentives and subsidies. Fostering collaboration between industry and research institutions may help drive innovation and support the identification of cost-effective substitutes.
- Small and Medium Enterprises (SMEs) could benefit from tailored support such as grants, technical guidance, and improved access to affordable alternatives. Such efforts may assist them in transitioning to safer chemical practices while maintaining economic stability.
- Voluntary, industry-led initiatives that promote the use of safer chemicals, such as certification schemes and sustainability reporting, can be encouraged. These actions may help strengthen responsible industry practices and contribute to long-term environmental and human health protection.

8.3 Potential Innovations

- Investment in research and development of safer alternatives to CPs can help reduce their long-term environmental and health impacts.
- With increasing global attention on the regulations of CPs, India could explore the potential to participate in emerging markets for safer chemical substitutes.
- Enhancing industrial processes and adopting advanced treatment technologies such as green chemistry innovations or improved remediation systems may contribute to minimising environmental releases.
- Collaborative efforts involving government agencies, industry stakeholders, and scientific institutions can catalyse innovation and support progress towards a more sustainable chemical management framework.

8.4 Overcoming Data Gaps and Need Analysis

- There is an urgent need to enhance data collection on environmental levels of CPs (e.g., SCCPs, MCCPs and LCCPs) in air, soil, water, sediment, and biota across industrial zones.
- A comprehensive inventory of CP production, import, and use across sectors is essential to understand the supply chain and regulatory gaps.
- Information on occupational exposure and consumer products containing CPs is also lacking and needs to be addressed.
- There is a need to establish long-term environmental monitoring programmes to track CPs in different environmental matrices

8.5 Adopting International Best Practices

Countries such as the EU member states, Canada, and Japan have stringent regulatory controls or restrictions on certain groups of CPs, particularly SCCPs and MCCPs, due to their persistence, bioaccumulation, and toxicity. These international efforts offer insights that could help inform broader chemical management in the country.

- Experiences from other regions highlight the usefulness of phased implementation timelines, technical assistance mechanisms, and dedicated support for small and medium enterprises (SMEs) during regulatory transitions.
- International practices emphasise the value of multi-stakeholder collaboration among regulatory bodies, research institutions and industry for developing and adopting safer alternatives effectively.
- In some jurisdictions, industries have proactively engaged in voluntary programmes, including certification schemes and the adoption of safer chemical standards, offering practical examples of enhanced corporate social responsibility.
- Building on global phase-out timelines and implementation strategies can help shape context-appropriate actions that align with domestic regulatory and industrial capacities. Offering policy incentives and technical support to SMEs can facilitate their transition to safer substitutes, especially considering the resource constraints they often face.
- In addition, recognising companies that voluntarily reduce the use of CPs or adopt safer alternatives can encourage industry leadership and foster a

culture of positive competition, ultimately driving broader compliance and innovation in chemical safety

8.6 Strengthening Supply Chain Transparency and Management

The widespread use of CPs across diverse sectors makes it essential to strengthen supply chain accountability.

- Information on the sourcing, use, and disposal of CPs is often fragmented or inaccessible.
- Adopting supply chain traceability tools can enhance risk management and foster safer substitution.
- Promote full disclosure of CPs use in the supply chains of consumer and industrial goods.
- Encourage public procurement policies that favour CP-free materials and products.
- Develop chemical safety criteria in procurement guidelines for government and public sector undertakings.

8.7 Encouraging Innovation and Market Development

India has the potential to develop safer alternatives to CPs, which could open new opportunities for eco-friendly products in both domestic and export markets.

- Innovation in substitute materials and processes is crucial to reduce dependency on CPs.
- Raising consumer awareness about CP-free products can increase market demand and drive change.
- Invest in R&D through public-private partnerships to identify technically viable and affordable alternatives to CPs.
- Launch eco-labelling schemes and awareness campaigns to help consumers make informed choices.
- Support export-oriented industries in complying with international CP-related regulations, avoiding trade disruptions.

8.8 Promoting Sectoral Collaboration and Exchange

Transitioning away from hazardous substances like CPs requires shared knowledge and coordinated action across sectors.

- Facilitate collaboration among industrial associations, research institutes and civil society for safer chemical management.
- Promote inter-sectoral dialogues to share best practices and lessons learned in reducing CP use.
- Align India's domestic goals with international chemical safety initiatives and conventions to remain competitive globally.

8.9 Enhancing Industry Awareness and Capacity Building

Lack of awareness and technical know-how can be significant barriers to reducing CP use, particularly among small and medium-scale industries.

- Conduct awareness campaigns about the environmental and health risks of CPs and the advantages of using safer substitutes
- Organise sector-specific workshops to build technical capacity for evaluating and adopting alternatives
- Create accessible knowledge portals featuring case studies, substitution tools, and regulatory updates

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Annexure

Annexure represents the published data on CPs in different products, environmental matrices, and human health data.

i. Presence of CPs in Plastic & Rubber:

Year	Title	Author	Matrix	Country	Findings	Reference
SCCPs						
2025	Analytical insights into shortchain chlorinated paraffins in consumer products, leachates, and sediments in Gauteng, South Africa	V. Nevondo, M. F. Morethe, R. Okwuosa O. J. Okonkwo	PVC Pipe	South Africa	76.77-36.21 ng/g	(Nevondo, et.al., 2025)
2023	Are Your Children's Toys Hazardous Waste? High levels of chlorinated paraffins in plastic toys from ten countries	Therese M. Karlsson and Pamela Miller	Children toys	Global	1-60,400 mg/kg	(Karlsson and Miller, 2023)
2023	Chlorinated paraffins in food contact materials made of rubber from the German market	Walter Vetter, Tobias Schulz, Sina Schweizer, Sebastian Zellmer				
2022	Widespread presence of chlorinated paraffins in consumer products	Steven Kutarna, Xuan Du, Miriam L. Diamond, Arlene Blumde and Hui Peng	Plastic Toys	Canada	0.005–2.02 mg/g	(Kutarna, et.al., 2022)
2022	Short- and medium-chain chlorinated paraffins in polyvinyl chloride consumer goods available in the Japanese market	Yago Guida, Hidenori Matsukami, Natsuko Kajiwara	Children product	Japan	SCCPs and MCCPs were detected in children's products (up to 120,000 mg/kg SCCPs)	(Guida, et.al., 2022)

MCCPs						
2023	Chlorinated paraffins in food contact materials made of rubber from the German market	Walter Vetter, Tobias Schulz, Sina Schweizer, Sebastian Zellmer	Rubber samples	Hohenheim	Rubber sample: 112,000 mg/kg to 341,000 mg/kg	(Vetter, et.al., 2023)
2021	Short- and Medium-Chain Chlorinated Paraffins in Polyvinylchloride and Rubber Consumer Products and Toys Purchased on the Belgian Market	Thomas J. McGrath,Giulia Poma, Hidenori Matsukami, Govindan Malarvannan, Natsuko Kajiwara and Adrian Covaci	Polyvinyl Chloride (PVC) and Rubber Consumer Products, Toys	Belgium	MCCPs were detected in 5 out of 28 samples, with concentrations ranging from below the limit of quantification to 3500 µg/g. MCCP patterns were consistent with industrial mixtures, suggesting inadvertent incorporation into polymeric materials.	(McGrath et.al., 2021)
LCCPs						
2023	Widespread presence of chlorinated paraffins in consumer products	Steven Kutarna, Xuan Du, Miriam L. Diamond, logo Arlene Blumde and Hui Peng	Plastic toys (foam), toy packaging, electronic cables	Canada	LCCPs detected in 96 products: most in plastic-coated cables (up to 5.79 mg g^{-1} LCCP) and toys (foam toy: 0.14 mg g^{-1}; packaging: 0.002 mg g^{-1}). Indicating hand-to-mouth and dermal exposure pathways for children.	(Kutarna, et.al., 2023)

2019	Chlorinated Paraffins in Car Tires Recycled to Rubber Granulates and Playground Tiles	Brandsma, S. H., Brits, M., Groenewoud, Q. R., Van Velzen, M. J., Leonards, P. E., & De Boer, J.	Car-tire granulates, playground tiles	Europe & Brazil	Identified LCCP congeners (C_{18}–C_{29}) in rubber derived from tires and playground materials. Notable presence of wax-grade (C_{25}/C_{26} LCCPs). Highlights potential environmental exposure from recycled rubber.	(Brandsm, et.al., 2019)

ii. Presence of CPs in Textile & Leather

Year	Title	Author	Matrix	Country	Findings	Reference
SCCPS						
2023	Short- and medium-chain chlorinated paraffins in T-shirts and socks	Jakub Tomasko, Ondrej Parizek, Jana Pulkrabova	T-Shirt and Socks	Czech Republic	SCCPs were observed in the range of 17.1 to 4040 ng/g	(Tomasko, et.al., 2023)
2019	Determination of Short Chain Chlorinated Paraffins in Textile Samples by GC-MS	Zheng Z., Shao Y., Li X., Du J.	Textile Fabrix	China	SCCPs detected at limits down to 10 mg/kg; method recoveries 82–107%, RSD 3–8%	(Zheng, et.al., 2019)
2020	Chlorinated paraffins in the technosphere: A review of available information and data gaps demonstrating the need to support the Stockholm Convention implementation	Yago Guida, Raquel Capella , Roland Weber	Leather (Artificial)	-	SCCPs were obtained to be in the range of 1100-14000 mg/kg	(Guidaet.al., 2020).

2023	Short and medium chain chlorinated paraffins in T-shirts and socks	Jakub Tomasko, Ondrej Parizek and Jana Pulkrabova	T-shirts & socks (textiles)	China	SCCPs detected in 100% of samples (33.9–5,940 ng/g); synthetic-fiber garments had ~22× more SCCPs than cotton; washing effects varied	(Tomasko, et.al., 2023)
MCCPs						
2023	GC-NCI-MS determination of short- (C10-13) and medium-chain (C14-17) chlorinated paraffins in textile, leather, and polymeric consumer products	Khan, U., Uzman, M., Hayat, K., Khan, A., Qureshi, M., Fatima, M., Tariq, S., Khalid, S., Ijaz, Z.	Synthetic Leather, PVC-based footwear	Pakistan	MCCPs dominated in synthetic leather goods, with concentrations up to 450 ng/g.	(Khan et.al., 2025)
2023	Short- and medium-chain chlorinated paraffins in T-shirts and socks	Jakub Tomasko, Ondrej Parizek and Jana Pulkrabova	T-shirts and socks (Textiles)	China	MCCPs were detected above quantification limits in all 28 samples, with concentrations ranging from 33.9 to 5940 ng/g. Samples with a substantial proportion of synthetic fibers contained 7 times higher mean MCCP concentrations than cotton garments. Washing effects varied, leading to emission, contamination, or retention of CPs.	(Tomasko, et.al., 2023)
LCCPs						
	Limited studies					

iii. Impact of CPs on Human Health

Year	Title	Author	Matrix	Country	Findings	Reference
SCCPs						
2024	Evaluation of the Body Burden of Short- and Medium-Chain Chlorinated Paraffins in the Blood Serum of Residents of the Czech Republic	Denisa Parizkova, Aneta Sykorova, Jakub Tomasko, Ondrej Parizek and Jana Pulkrabova	Blood Serum of Residents	Czech Republic	Ceske Budejovice: <120–210 ng/g lw Ostrava: <120–650 ng/g lw	(Parizkova, et.al., 2023)
MCCPs						
2024	Evaluation of the Body Burden of Short- and Medium-Chain Chlorinated Paraffins in the Blood Serum of Residents of the Czech Republic	Denisa Parizkova, Aneta Sykorova, Jakub Tomasko, Ondrej Parizek and Jana Pulkrabova	Blood Serum of Residents	Czech Republic	Ceske Budejovice: <240–340 ng/g lw Ostrava: <240–1530 ng/g lw	(Parizkova, et.al., 2023)

iv. Occurrence of CPs in Environmental matrices

Year	Country	Matrix	CP Type	Concentration	Findings Summary	Reference
Air						
2022	China	Air	SCCPs	SCCPs: Gas phase: 81.7–988 ng/m^{3}Particulate phase 7.40–454 ng/ m^3	Air samples from emission zones contain SCCPs.	(Zhang et.al., 2022)
Soil						
2023	China (Shanghai)	Soil (0–45 cm)	SCCPs, MCCPs	SCCPs: 52.6–977.1 ng/g dw; MCCPs: 417–10,712 ng/g dw	Higher near industrial zones, vertical migration observed	Xu et al. (2023)

Year	Country	Matrix	CP Type	Concentration	Findings Summary	Reference
2023	Tanzania	Soil Organic matter	SCCPs, MCCPs	SCCPs: 400-21300 ng/g; MCCPs: 65000 ng/g	The source of SCCPs and MCCPs was the electronic waste	(Haarr, et.al., 2023)
2014	China (Urban)	Soil	SCCPs, MCCPs	SCCPs: ND–615 ng/g,MCCPs: 1.95–188 ng/g	Urban background and hotspots assessed	(Wang et.al., 2014)
2016	China (E-waste area)	Soil	SCCPs, MCCPs	SCCPs: 1800 to 240,000 ng/g dw, MCCPs: 170 to 890 μg/g, dw	Soil near the e-waste site	(Zeng, et.al., 2016)
2022	China	Soil	SCCPs	SCCPs: 30.4–554,161ng/g	Soils near industrial regions (especially emission zones) showed significant SCCP accumulation.	(Zhang et.al., 2022)
Water						
2024	Pakistan (River Ravi)	River water	SCCPs, MCCPs	SCCPs: <LOD–19 ng/L; MCCPs: 25–55 ng/L	First report from River Ravi	Shabbir et al. (2024). Sci. Total Environ.
2022	China	Water	SCCPs	SCCPs: 27.0–4700 ng/g	Water samples from emission zones showed extremely high SCCPs.	(Zhang et.al., 2022)
2009	Germany	Wastewater	SCCPs	Up to 4.8 μg/L	Wastewater effluent as a source	(Stockholm Convention on POPs, 2009)
2018	Spain	Wastewater	SCCPs	<0.13μg/L	SCCPs were detected in 54% of the effluent from a metropolitan area sample	(Rubirola, et.al., 2018)
Sediment						
2023	China (East/Yellow Sea)	Marine sediment	SCCPs, MCCPs	SCCPs: 0.703–13.4 ng/g; MCCPs: 0.094–4.19 ng/g	Offshore contamination	(Li, et.al., 2023)

Year	Country	Matrix	CP Type	Concentration	Findings Summary	Reference
2022	China	Sediment	SCCPs	SCCPs: 32.5–350,000 ng/g	Sediment samples from emission zones showed extremely high SCCPs.	(Zhang et.al., 2022)
2018	China (Pearl River Delta)	Sediment	SCCPs, MCCPs	SCCPs: 320–6,600 ng/g MCCPs: 880–38,000 ng/g	Industrial hotspots	(Pan, et.al, 2018)
2024	Pakistan (River Ravi)	Sediment	SCCPs, MCCPs	SCCPs: <LOD–170 ng/g; MCCPs: <LOD-100 ng/g	Low–moderate contamination	(Tahir, et.al., 2024)
2022	China (Lake core)	Sediment core	MCCPs	Up to 3,200 ng/g	Sediment records show historic increase	(Nipen, et.al., 2022)
2020	Spain (Barcelona coast)	Marine sediment	SCCPs	210–1,170 ng/g	Coastal contamination from urban activity	(Huang, et.al., 2020)
Biological						
2015	China	Duck (e-waste area)	SCCPs, MCCPs	Up to 20,000 ng/g lipid	Very high bioaccumulation	(Luo, et.al., 2015)
2016	Arctic	Seal blubber	SCCPs	Up to 120 ng/g lipid	Arctic bioaccumulation	(Sun, et.al., 2016)
2021	Canada/ USA	Fish (Great Lakes)	SCCPs, MCCPs	Up to 4,500 ng/g lipid	Increasing MCCPs over time	(Tomasko, et.al., 2021)
2005	Global (Review)	Marine fish/ seabirds	SCCPs	Fish: up to 15 µg/g lipid	Trophic magnification	(Braune,et. al., 2005)

v. Releases of CPs from Production, Use, and Disposal

Product/Use Category	CP Type(s)	Production Losses	End-Use Losses	Main Release Routes	References
CP Production	SCCPs, MCCPs, LCCPs	0.3% to wastewater (Europe); <0.1% (USA)	Not applicable	Wastewater, air, landfilling	European Chemicals Agency (2008); US EPA (2009)
Metalworking Fluids	SCCPs, MCCPs, LCCPs	1–2% from blending/ formulatingw	10%; 18.5% (oil-based); 31.6% (water-based fluids)	Spills, washoff, volatilisation	OECD (2000); European Chemicals Agency (2008); US EPA (2009)

Product/Use Category	CP Type(s)	Production Losses	End-Use Losses	Main Release Routes	References
PVC & Plastics Production	MCCPs, LCCPs	0.3–1.5% from processing methods	0.05%/yr (air/wastewater); 0.1–0.2% (open calendering)	Spray, volatilisation, wastewater	European Chemicals Agency (2008); US EPA (2009); Environment Canada & Health Canada (2008)
Rubber Production & Use	SCCPs, MCCPs, LCCPs	SCCPs: 1–10%; MCCPs/LCCPs: ~15%	0.05–0.1% to air/year; <0.01% to washoff	Volatilisation, abrasion	US EPA (2009); European Commission (2005)
Textiles & Polymeric Materials	SCCPs, LCCPs	Not specified	0.05% over product lifetime	Washoff of coatings, abrasive losses	US EPA (2009); Environment Canada & Health Canada (2008)
Paints & Sealants	MCCPs, LCCPs	0.1% to air; 0.3% to wastewater	0.4%/year to air (7-year life); 0.15%/year to wastewater	Volatilisation, washoff, abrasion	European Chemicals Agency (2008); US EPA (2009)
Plastics Recycling	All CP types	Unknown	Unknown	Dust release during chopping/grinding	European Chemicals Agency (2008); Environment Canada & Health Canada (2008)
Sewage Biosolids (Land Application)	All CP types	Unknown	Unknown	Runoff, leaching from biosolids	European Chemicals Agency (2008); Environment Canada & Health Canada (2008)
Landfilling	All CP types	Unknown	Unknown	Leaching	European Chemicals Agency (2008); Environment Canada & Health Canada (2008)
Incineration	All CP types	Unknown	Unknown	PCDD/F formation during incineration	European Chemicals Agency (2008); Environment Canada & Health Canada (2008

Notes:

a) Emission factors apply to annual consumption figures of CPs in the respective products.

b) Leaching from rubber/polymers is thought to be significantly lower than from paints, sealants, and adhesives. No specific percentage was provided in the source.

vi. Environmentally Relevant Physical Properties of SCCP Congeners and Mixtures of Isomers

SCCP Congener	% Cl	Vapor Pressure (Pa)	Henry's Law Constant (Pa·m³/mol)	Water Solubility (mg/L)	log Kw	log Ka	References
$C_{10}H_{18}Cl_4$	50	0.028	17.7	328, 630, 2,370	5.93	8.2	Drouillard, et.al., 1998a; Drouillard, 1988b; Sijm and Sinnige 1995; BUA, 1992)
$C_{10}H_{17}Cl_5$	56	0.0040–0.0054	2.62–4.92	449–692	–	8.9–9.0	(Drouillard, et.al., 1998a; Drouillard, 1988b; Sijm and Sinnige 1995)
$C_{10}H_{16}Cl_6$	61	0.0011–0.0022	–	–	–	–	(Drouillard, et.al., 1998a)
$C_{10}H_{13}Cl_9$	71	0.00024	–	400	5.64	–	(Sijm and Sinnige 1995)
$C_{11}H_{20}Cl_4$	48	0.01	6.32	575	5.93	8.5	(Drouillard, et.al., 1998a; Drouillard, 1988b)
$C_{11}H_{19}Cl_5$	54	0.001–0.002	0.68–1.46	546–962	6.20–6.40	9.6–9.8	(Drouillard, et.al., 1998a; Drouillard, 1988b)
$C_{11}H_{18}Cl_6$	58	0.00024–0.0005	–	–	6.40	–	(Drouillard, et.al., 1998a; Sijm and Sinnige 1995)
$C_{12}H_{20}Cl_6$	56	–	–	–	6.61	–	(Sijm and Sinnige 1995)
$C_{12}H_{19}Cl_7$	59	–	–	–	7.00	–	(Sijm and Sinnige 1995)
$C_{12}H_{18}Cl_8$	63	–	–	–	7.00	–	
$C_{12}H_{16}Cl_{10}$	67	–	–	–	6.6	–	
$C_{13}H_{23}Cl_5$	49	0.00032	–	78	6.14	9.4	
$C_{13}H_{22}Cl_6$	53	–	–	–	6.77–7.00	–	
$C_{13}H_{21}Cl_7$	58	–	–	–	7.14	–	
$C_{13}H_{16}Cl_{12}$	70	2.8×10^{-7}	–	6.4	7.207	–	(BUA, 1992)
C_{10}–C_{13} (49% Cl)	49	–	–	–	4.39–6.93	–	(Renberg, et.al., 1980)
C_{10}–C_{13} (63% Cl)	63	–	–	–	5.47–7.30	–	
C_{10}–C_{13} (70% Cl)	70	–	–	–	5.68–8.69	–	
C_{10}–C_{13} (71% Cl)	71	–	–	–	5.37–8.69	–	

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