Toxics Link
for a toxics-free world

TOXIC THREADS

Assessing Nonylphenol Contamination in Indian Textiles & the Environment

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 toxic pollution, provide cleaner alternatives, and bring together groups and people affected by this problem. 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 for India and the rest of the world." Toxics Link has unique expertise in areas of hazardous, medical, and municipal wastes, international waste trade, and the emerging issues of pesticides, Persistent Organic Pollutants (POPs), hazardous heavy metal contamination, etc. from the environment and public health point of view. We have successfully implemented various best practices and have brought in policy changes in the aforementioned areas apart from creating awareness among several stakeholder groups.

About Environmental Defense Fund

A global non-profit, Environmental Defense Fund (www.edf.org) collaborates with governments, NGOs, research and academic institutions, corporates and others to support and advance India's vision of shared, sustainable prosperity. We combine scientific and economic foundations, a broad network of partnerships and a pragmatic approach in support of India's ambitions.

Acknowledgment:

We thank Mr Ravi Agarwal, Director, Toxics Link and Mr Satish Sinha, Associate, Director, Toxics Link, for their continuous guidance and support.

We would also like to thank our collaborating partners Mr Mahesh Pandya, Paryavaran Mitra; Mr Mahesh Sharma, Gramin Vikas evam Paryavaran Sanstha and Dr Kanchan Kumari, Pr. Scientist CSIR-NEERI, Kolkata Zonal Centre, helping us in the collection of samples.

Supervised by:

Mr Piyush Mohapatra, Senior Programme Coordinator, Toxics Link, email: **piyush@toxicslink.org**

Dr Maria Doa, Senior Director, Chemicals Policy, Environmental Defence Fund, email: **mdoa@edf.org**

Research and Compilation by:

Dr Deepak Marathe, Sr. Programme Officer, Toxics Link

Ms Alka Dubey, Programme Coordinator, Toxics Link

Ms Vidhi Mathur, Sr. Programme Officer, Toxics Link

Toxics Link
for a toxics-free world

CELEBRATING 25 YEARS 1998-2023

Environmental Defense Fund

Collaborating partner

H-2, Jangpura Extension
New Delhi - 110014, India
www.toxicslink.org

TOXIC THREADS

Assessing Nonylphenol Contamination in Indian Textiles & the Environment

Abbreviations

APs	Alkylphenols
APEOs	Alkylphenol Ethoxylates
BIS	Bureau of Indian Standards
BSMI	The Bureau of Standards, Metrology and Inspection
CHCC	Chemicals of High Concern to Children
CSPA	Children's Safe Products Act
ECHA	European Chemicals Agency
EDC	Endocrine Disrupting Chemical
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EU	European Union
K-REACH	Korean Act on Registration and Evaluation of Chemical Substances
NABL	National Accreditation Board for Testing and Calibration Laboratories
NP	Nonylphenol
NPE	Nonylphenol Ethoxylates
PPA	Pollution Prevention Act
REACH	Registration, Evaluation, Authorisation, and Restriction of Chemicals (European Union Regulation)
SDG	Sustainable Development Goal
SNUR	Significant New Use Rule (Issued by the U.S. Environmental Protection Agency to regulate certain chemicals)
UK	United Kingdom
UNEP	United Nations Environment Programme

Table of Contents

List of Figures

List of Table

Executive Summary

Nonylphenol (NP) is an industrial chemical belonging to the alkylphenol group, primarily used in the production of surfactants. It is a byproduct of the degradation of Nonylphenol Ethoxylates (NPEs) and is a concern due to its potential health and environmental impacts.

This report is an effort towards presenting information on nonyphenols, its usage in textiles and presence in environmental matrices. NPEs are widely used as surfactants and detergents in textile manufacturing and can remain as residues in finished products. During washing, they are released into the environment, where they degrade into Nonylphenols (NP), known for their toxicity, persistence, bioaccumulation, and endocrine-disrupting properties.

The study aimed to assess the presence of NP in textile products available in the Indian market, investigate NP contamination in river water, sediment, and effluent samples from major textile hubs in India, and evaluate the potential environmental and human health risks associated with NP and NPE exposure.

A total of 40 branded and local textile products were collected from retail shops and online platforms across 10 major textile hubs in India. Surface water, sediment, and effluent samples were collected from upstream and downstream locations of rivers flowing through major textile hubs. The samples were analysed in a NABL-accredited laboratory to determine NP concentrations in textiles and NP levels in environmental matrices.

The findings reveal that NP was detected in 15 out of 40 textile products (37%)

NPE concentrations in contaminated textiles ranged from 8.7 to 957 mg/kg, with 13 out of 15 products exceeding the European Union (EU) regulatory limit of 100 mg/kg. The highest NPE concentration (957 mg/kg) was found in female hosiery innerwear. Additionally, 10 out of 15 contaminated products were innerwear (both men's and women's), with NPE levels ranging from 22.2 to 957 mg/kg. 60% of baby and children's products tested positive for NPEs, with concentrations between 8.7 and 764 mg/kg. Furthermore, 13 out of 15 contaminated products were manufactured in India, while the origin of two items was unknown.

The environmental contamination assessment showed that NP was detected in surface water

The highest NP concentration in surface water was recorded in Cooum River (70 µg/L)

collected from five major rivers near textile hubs: Cooum River (Chennai), Adyar River (Chennai), Buddha Nullah (Ludhiana, Punjab), Bandi River (Rajasthan), and Sabarmati River (Ahmedabad). The highest NP concentration in surface water was recorded in the Cooum River (70 µg/L), followed by the Adyar River (60 µg/L) and the Bandi River (40 µg/L). The Sabarmati River recorded 7.9 µg/L NP in surface water, with sediment samples showing 360 µg/kg NP and 810 µg/kg NP mixed isomers. Buddha Nullah exhibited the highest NP contamination in sediments, with NP at 460 µg/kg and NP mixed isomers at 1190 µg/kg. Effluent samples from textile industries contained NP at 10.1 µg/L. The presence of NP in downstream locations, absent in upstream points, strongly suggests point-source pollution from textile industries.

The study underscores significant NP contamination in Indian textiles and water bodies near textile hubs. High NP levels in consumer textile products, especially innerwear and children's clothing, raise concerns about prolonged human exposure. The findings indicate that industrial discharge is a primary source of NP pollution in major rivers, posing risks to aquatic ecosystems and human health.

While several countries have taken proactive measures, India is still far behind in addressing the issue of NP and NPE. The European Union, Japan, China, The United States, and the Republic of Korea have recognised the risks associated with these chemicals and

implemented regulations to restrict their use in various products, including textiles. Furthermore, The United Nations Environment Programme (UNEP) has designated NP as a chemical of global concern.

The European Union, Japan, China, the United States, and the Republic of Korea have recognised the risks associated with these chemicals

This Toxic Link report aims to highlight the concerns with regard to nonylphenol and its ethoxylates usage in India.. NP's persistence, bioaccumulation, and toxicity pose significant risks to the environment, marine ecosystems, and the food chain. Additionally, consumers, particularly children, may be exposed through skin contact and ingestion. In order to address these risks, India may take decisive action to align with global efforts in restricting NP use. Strengthening regulations and promoting safer alternatives in textile manufacturing and consumer products are essential in safeguarding human health, preserving the environment, and ensuring sustainable market practices.

1. Introduction

Nonylphenol (NP) is an industrial chemical belonging to the alkylphenol group, primarily used in the production of surfactants. It is a byproduct of the degradation of Nonylphenol Ethoxylates (NPEs) and is a concern due to its potential health and environmental impacts.

1.1 Nonylphenol and Its Ethoxylates

Nonylphenol (NP)* is a high-volume industrial chemical. It is considered as workhouse surfactant due to its amphipathic properties, which allows for the compound to be used in diverse industrial applications. 4-Nonylphenol, the most commonly used isomer, makes 90% of commercial production of Nonylphenol (Raju et al., 2018).

Nonylphenol is used as a base chemical in the manufacture of various industrial compounds, including Nonylphenol ethoxylates, tris(nonylphenol) phosphite, Nonoxynol, and Nonylphenol-formaldehyde condensation resins. These derivatives play a critical role across multiple industries as detergents, wetting agents, dispersants, defoamers, de-

The term 'Nonylphenol' used in this document refer to both nonylphenol and nonylphenol ethoxylates where the discussion is specific to nonylphenol ethoxylates.

inkers, and antistatic agents. Among the many applications, NPEs are most extensively used in the textile industry as a cleaning agent. Additionally, NPEs also help protect polymers and rubbers due to their antioxidant properties (Toxics Link, 2024; Lani, 2010) **(Figure 1)**.

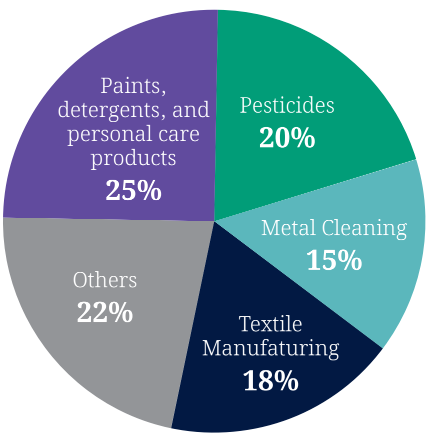
Figure 1: Application of Nonylphenol

(Source: (Loyo-Rosales et al., 2004), (OEcotextiles, 2024), (IMAP, 2016), (Hatipoglu et al., 2024))

1.2 Consumption of Nonylphenol in India

There are multiple usage of NP amongst different sectors in India. In 2020, the country's NP production stood at around 95,000 tonnes, with a projected annual growth rate of 6.50% CAGR through 2030 (Chemanalyst, 2024). The annual consumption of NP in the country ranges from 40,000 to 44,000 tonnes, with significant usage in sectors such as pesticides (20%), metal cleaning (15%), textile manufacturing (18%), and paints, detergents, and personal care products (25%). However, actual consumption data remains limited, which poses challenges for precise market forecasting and effective regulatory planning (CSE, 2008) **(Figure 2)**.

Figure 2. Consumption of Nonylphenol in different sectors in India (%)



1.3 Toxicity of Nonylphenols

Several research studies have established NP as an endocrine-disrupting chemical (EDC) that adversely affects the hormonal systems of various organisms (Malmir et al., 2020; Ahmadpanah et al., 2019; Cao et al., 2019; Saravanan et al., 2019). NP has been detected across multiple trophic levels, including plankton, fish, birds, mammals, and benthic invertebrates (Casatta et al., 2016; Diehl et al., 2012). Studies also indicate that NP can negatively impact the reproductive, immune, and central nervous systems in fish, rodents, birds, and humans. Due to its lipophilic nature, NP can bioaccumulate in living organisms (Ademollo et al., 2008; Keith et al., 2001).

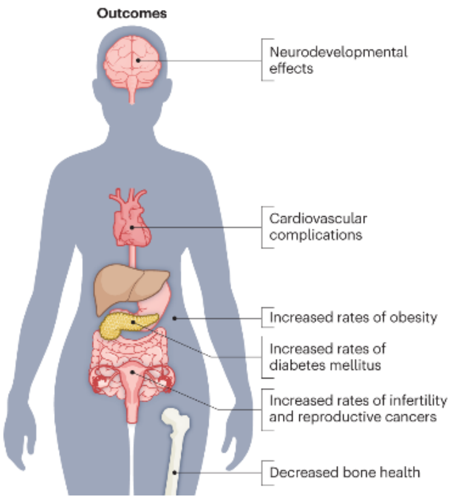
Furthermore, contamination has been identified in various biological and environmental matrices, such as food (Lee et al., 2023), drinking water (Xu et al., 2022), human adipose tissue (Sengul and Cevdet, 2017), urine (Ringbeck et al., 2021), maternal blood plasma, and amniotic fluid (Shekhar et al., 2017). The presence of NP has also been confirmed in human blood serum and breast milk (Azzouz et al., 2016), raising concerns about its potential transfer from mother to foetus. This concern is further supported by the detection of NP in uterine tissue and early-stage embryos in pregnant women (Chen et al., 2016).

1.4 Potential impacts on Human Health

Nonylphenol poses significant human health risks, particularly to children, due to its endocrine-disrupting properties. Studies have shown that NP exposure over multiple generations can lead to slight but statistically significant changes in reproductive development, including alterations in the oestrous cycle length, timing of vaginal opening, ovarian weight, and sperm/spermatid count in laboratory animals at doses of 30-100 mg/kg/day (European Union, 2002; Chapin, 1999).

Human exposure to NP and NPE occurs through multiple pathways, including ingestion of contaminated food and water, inhalation of polluted air, and contact with household dust. Additional exposure risks arise from NP migration from plastic packaging into food and beverages, as well as the use of textiles, detergents, and personal care products containing NP.

Figure 3: Health Impact of NP



In humans, it mimics oestrogen, leading to reproductive and developmental issues. Based on multiple studies, the chemical was found to be persistent and bio-accumulative in nature. NP may be accumulated in fish with a bioconcentration factor of 1300 (Ferreira-Leach and Hill, 2001).

Limited data is available on children's exposure to NP; however, a biomonitoring study in Italy has detected its presence in human breast milk, with a maximum recorded exposure of 3.9 µg/kg/day. (Ademollo et al., 2008) **(Figure 3).** It has been associated with developmental abnormalities in embryos and children. Research by Lepretti et al., (2015) further suggests that NP may interfere with intestinal homeostasis function in humans.

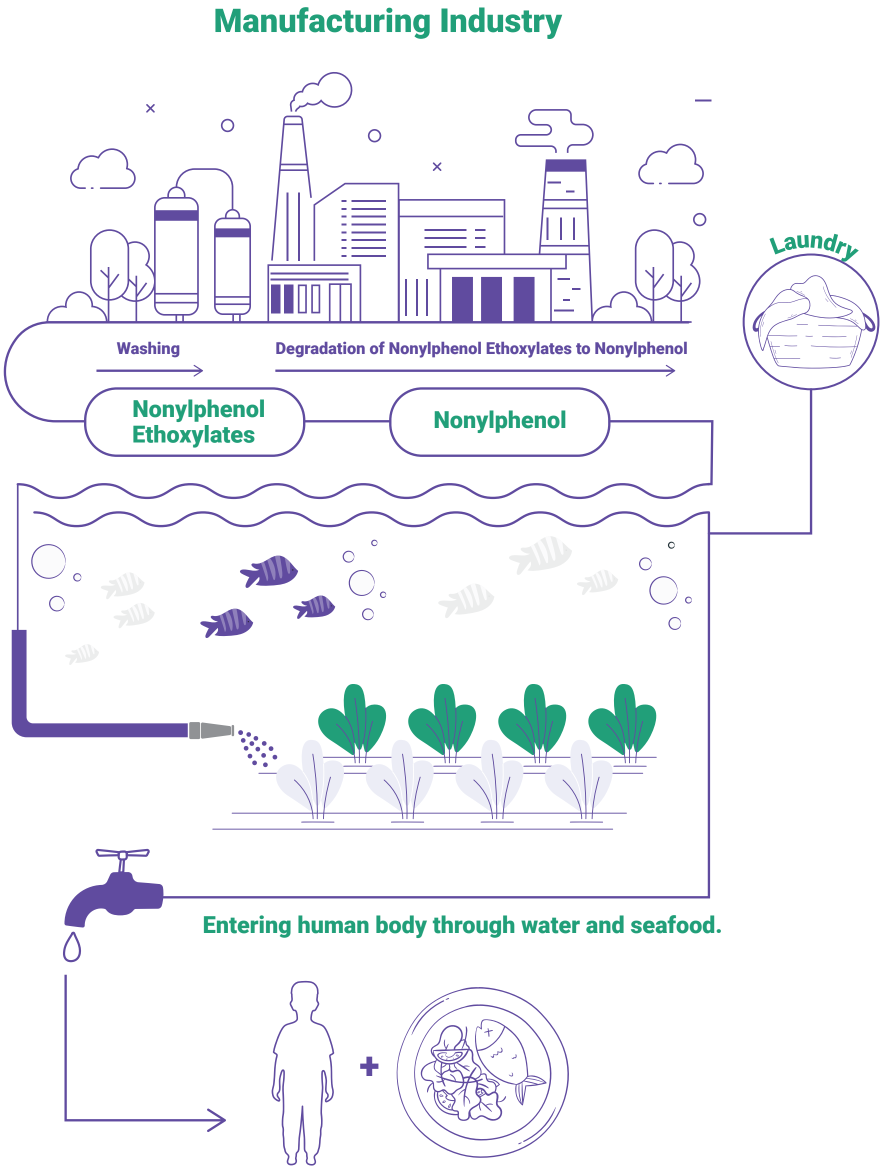
Recent studies have also linked NP exposure to carcinogenic outcomes, including prostate cancer in men (Forte et al., 2016; Kim et al., 2016) and breast cancer in women (Ko et al., 2019; Wen et al., 2020).

In response to these concerns, the European Union has imposed stringent regulations on NP and NPEs. Consequently, these compounds have been largely replaced with alternative surfactants, such as alcohol ethoxylates, in regions including Europe, Canada, and Japan. Similarly, considering their negative impact, in 1976, the UK government signed a voluntary agreement for the restriction of the usage of NP in domestic and industrial detergents (Groshart et al., 2001). The chemical was later restricted for use by several countries in various products (Raecker et al., 2011). Later, the United Nations Environment Programme (UNEP) identified NP as a chemical of global concern (UNEP, 2003).

1.5 Fate & Behaviour of Nonylphenol and its ethoxylates in Environment

NPEs can breakdown to NP which is persistent in the environment. NP and NPEs are often found in water, soil, and sediments near industrial sites. **(Figure 4)**.

Figure 4: Fate of NP in the Environment



This study primarily focused on understanding the presence and levels of NP (NP and NPE) contamination in detergents, textiles, and environmental samples, including soil, water, and sediment, to evaluate their potential environmental and human health risks. This report presents the findings based on the tests conducted and gives necessary recommendations for action planning.

2. Nonylphenol and Challenges in textile

2.1 Nonylphenol in Detergents

Nonylphenol ethoxylates have long been used as cost-effective surfactants in detergents due to their strong cleaning properties, however, once released into the environment they degrade into nonylphenol (Blankenship and Coady, 2005). Numerous studies confirm the prevalence of NPEs in detergents worldwide. For instance, NPs were reported in 41% of 90 tested household detergents in Taiwan, with concentrations ranging from 0.2% to 21wt% (Cheng and Ding, 2002). The recent work by Bernal-Jácome L.A. et al., (2024) reported NPs in 30 detergent samples in Mexico and emphasized upon the potential health risks from NPs during storage. Similarly, a study by Toxics Link (2019) found NP levels between 0.82 and 11.92 wt% in 12 detergent samples sold in the Indian market. These findings underscore the common use of NPs in household detergents and possible environmental risks associated with the detergent.

2.2 Nonylphenol in Textiles

NPEs are widely used as surfactants in the textile industry due to their amphiphilic properties, enabling efficient processing and finishing of fabrics (Brigden et al., 2012). However, these NPEs break down into nonylphenol, which has been detected in textiles across global markets (USEPA, 2024). For example, a Greenpeace study analyzed garments from 29 countries, including India, and found NP in 89 out of 141 items tested, with concentrations ranging from 1 ppm to 45,000 ppm (de Araujo et al., 2018). The UK Environment Agency identified NP in 28 out of 100 cotton clothing samples from non-EU countries, with concentrations ranging from 3.3 ppm to 1759 ppm, underscoring the potential health risks associated with NP residues in textiles (UK gov, 2013). In India, Toxics Link has detected NP in 11 out of 23 samples, ranging from 18 to 11,160 ppm (Toxics Link, 2023). These findings emphasize the global prevalence of NP contamination in textile-related products and the pressing need for more comprehensive research and regulation, particularly in India, to mitigate health risks.

Figure 5: Fate of Nonylphenol ethoxylates in the textile industry

3. Rationale of the Study

Nonylphenol is widely recognized as a hazardous chemical due to its endocrine-disrupting properties and adverse impacts on aquatic ecosystems and human health. Despite global efforts and regulatory measures to control their use, in India, the chemical is not regulated, and there are very few scientific studies available in the Indian context to understand the chemical's challenges

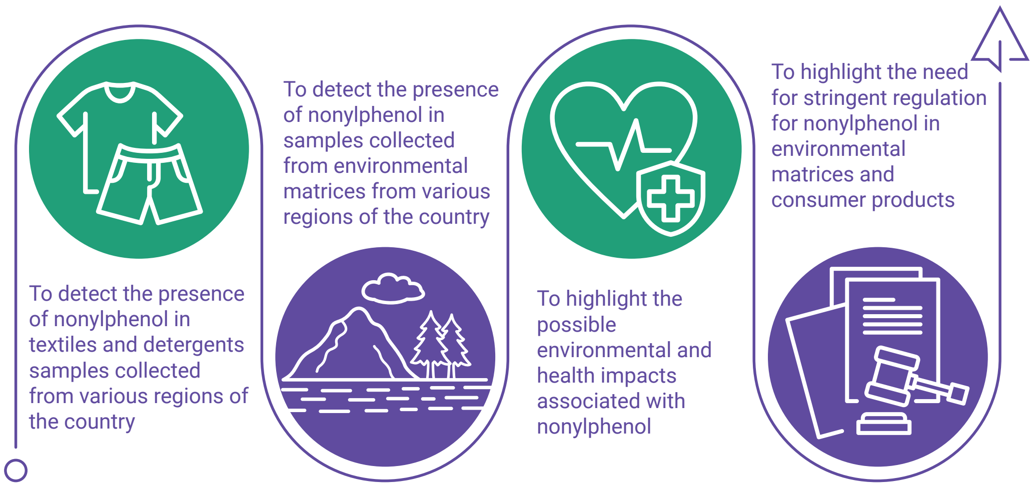
In 2019, Toxics Link conducted a comprehensive assessment revealing alarming levels of NP in detergents (0.82–11.92 wt%) and river water samples (9.2–41.3 mg/L) (Toxics Link, 2019). The highest concentration of NP was detected in the Bandi River in Pali, Rajasthan, a major textile hub, suggesting possible high usage of NP in the textile-related sectors.

Furthermore, research studies by Toxics Link found significant concentrations of NP in garments from local and high-end brands, ranging from 18–11,160 mg/kg in 44% of tested textile products. This particularly concerns women and children, whose exposure to such chemicals poses a heightened health risk (Toxics Link, 2023).

Despite the pervasiveness of the issue, there is a lack of research and no specific standards for NP in environmental matrices and consumer products in India (except cosmetics and personal care products).

These findings are alarming, as access to clean water is essential for human health and development. Safe drinking water is the cornerstone of the United Nations Sustainable Development Goal (SDG) 6, which aim to ensure universal and equitable access to safe and affordable drinking water for all by 2030. However, over half of India's population still lack access to safe drinking water, resulting in approximately 200,000 deaths each year. Additionally, the economic impact of waterborne diseases caused by chemical contamination is estimated at $600 million, underscoring the pressing need to regulate this chemical with robust monitoring systems in place upstream and downstream.

Objective



4. Research Methodology

4.1 Sample Collection

The present study investigates the correlation between the presence of NP in textiles & detergents and its release into environmental matrices during textile production, processing, and washing. To achieve this, we conducted a mapping of textile industries and selected textile hubs located near rivers for further study.

4.1.1 Textiles:

A total of 40 (local and branded) textile samples were collected from textile retailer shops and online platforms from 10 major textile hubs of India. Both branded and local samples were collected from different locations. The samples were then sent to the laboratory for analysis of NP **(Table 1) (Figure 6).**

Figure 6: Sampling locations of Textile samples

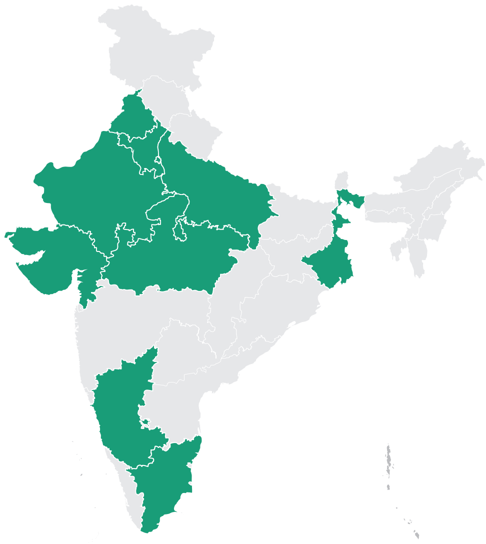


Table 1: Sampling details of Textile

Sample ID	Branded	Mode of Purchase	Cost per piece (INR) (Rs)	Fabric	Type of Material	Sampling location
TL-NP/TX-01	Local	Offline	60	Cotton	Innerwear (Kids)	Kanpur, UP
TL-NP/TX-02	Local	Offline	60	Cotton	Vest (Kids)	
TL-NP/TX-03	Brand	Offline	75	Cotton	Innerwear (Kids Girl)	
TL-NP/TX-04	Brand	Offline	250	Jeans	Jeans (Kids)	
TL-NP/TX-05	Local	Offline	120	Cotton	Innerwear (Men)	
TL-NP/TX-06	Brand	Offline	100	Cotton	Vest (Men)	
TL-NP/TX-07	Brand	Offline	459	Jeans	Jeans (Men)	
TL-NP/TX-08	Local	Offline	100	Cotton	Innerwear (Women)	
TL-NP/TX-09	Brand	Online	497	100% Cotton	Innerwear vest (Kids)	Noida, UP
TL-NP/TX-10	Brand	Online	545	Cotton	Innerwear vest (Kids)	New Delhi
TL-NP/TX-11	Brand	Online	583	Cotton	Innerwear vest (Kids)	Panipat, Haryana
TL-NP/TX-12	Brand	Offline	80	Cotton	Innerwear vest (Kids)	Tiruppur, Tamil Nadu

Sample ID	Branded	Mode of Purchase	Cost per piece (INR) (Rs)	Fabric	Type of Material	Sampling location
TL-NP/TX-13	Brand	Offline	100	Cotton	T-Shirt (Kid Girl)	Ahmedabad, Gujarat
TL-NP/TX-14	Brand	Offline	60	Cotton	Innerwear (Kid Girl)	
TL-NP/TX-15	Local	Offline	40	Hosiery	Top (Kid girl)	
TL-NP/TX-16	Brand	Offline	250	Jeans	Jeans (Kid)	
TL-NP/TX-17	Brand	Offline	250	Hosiery	T-Shirt (Boy)	
TL-NP/TX-18	Brand	Online	438	Cotton	Vest (Men)	Surat, Gujarat
TL-NP/TX-19	Brand	Online	399	Cotton	Vest (Men)	Bengaluru, Karnataka
TL-NP/TX-20	Brand	Online	239	Cotton	Vest (Women)	Tiruppur, Tamil Nadu
TL-NP/TX-21	Brand	Online	296	Hosiery	Vest (Boy)	
TL-NP/TX-22	Brand	Online	419	Unknown	Innerwear (Boy)	
TL-NP/TX-23	Brand	Online	395	Cotton	Vest (Girl)	
TL-NP/TX-24	Brand	Online	449	Cotton	Innerwear (Boy)	
TL-NP/TX-25	Brand	Online	228	Supercombed Cotton	T-Shirt (Kid)	
TL-NP/TX-26	Brand	Offline	550	Unknown	Jeans (Boy)	Indore, Madhya Pradesh
TL-NP/TX-27	Local	Offline	200	Hosiery	Vest (Boy)	
TL-NP/TX-28	Brand	Offline	200	Unknown	Innerwear (Men)	
TL-NP/TX-29	Brand	Offline	150	Cotton	Vest (Kid)	New Delhi
TL-NP/TX-30	Brand	Offline	60	Cotton	Innerwear/Pant (Kid)	Indore, Madhya Pradesh
TL-NP/TX-31	Brand	Offline	250	Hosiery	Pant (Boy)	Ahmedabad, Gujarat
TL-NP/TX-32	Brand	Offline	300	Unknown	T-Shirt (Kid)	Indore, Madhya Pradesh
TL-NP/TX-33	Brand	Offline	499	Unknown	T-shirt (Girl)	Kolkata, West Bengal
TL-NP/TX-34	Brand	Offline	709	Unknown	Jeans (Kid)	
TL-NP/TX-35	Brand	Offline	100	Hosiery	Vest (Men)	New Delhi
TL-NP/TX-36	Brand	Offline	100	Cotton	Innerwear (Men)	
TL-NP/TX-37	Brand	Offline	350	Cotton	T-Shirt (Kid)	
TL-NP/TX-38	Brand	Offline	100	Cotton	Innerwear (Men)	
TL-NP/TX-39	Brand	Offline	100	Cotton	Vest (Men)	
TL-NP/TX-40	Brand	Offline	120	Cotton	Innerwear (Kids)	

4.1.2 Detergents

A total of 25 different detergent samples covering both liquid and powder formulations (local and branded) available in retail outlets and online stores, were selected for sampling. The samples were collected from different regions of India to ensure geographical diversity and represent different manufacturing practices. The samples were sent to a NABL-accredited laboratory for analysis. **(Table 2).**

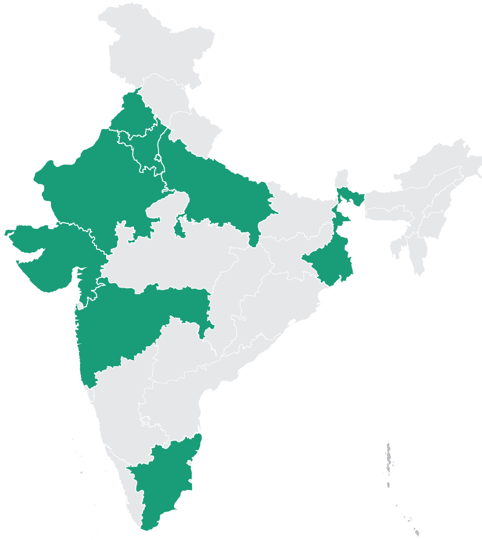
Table 2: Sampling details of Detergents

Sample ID	Type	Mode of Purchase	Brand/Local	Location of Manufacturing Unit
TL-NP/DT-01	Powder	Offline	Brand	Kanpur, U.P.
TL-NP/DT-02	Powder	Offline	Local	Kanpur, U.P.
TL-NP/DT-03	Powder	Offline	Brand	Kanpur, U.P.
TL-NP/DT-04	Powder	Offline	Brand	Kanpur, U.P.
TL-NP/DT-05	Liquid	Online	Brand	Hyderabad, Telangana
TL-NP/DT-06	Liquid	Online	Brand	Chennai, Tamil Nadu
TL-NP/DT-07	Liquid	Online	Brand	Sirmore, H.P.
TL-NP/DT-08	Liquid	Online	Brand	Naroli, Dadra and Nagar Haveli
TL-NP/DT-09	Powder	Online	Brand	Thane, Maharashtra
TL-NP/DT-10	Powder	Online	Brand	Kolkata, West Bengal
TL-NP/DT-11	Powder	Online	Brand	Ghaziabad, U.P.
TL-NP/DT-12	Powder	Online	Brand	Nashik, Maharashtra
TL-NP/DT-13	Powder	Online	Brand	Raipur, Chhattisgarh
TL-NP/DT-14	Powder	Online	Brand	Chhitorgarh, Rajasthan
TL-NP/DT-15	Powder	Online	Brand	New Delhi
TL-NP/DT-16	Powder	Online	Brand	Puducherry
TL-NP/DT-17	Liquid	Offline	Brand	Poland
TL-NP/DT-18	Powder	Offline	Brand	Mumbai, Maharashtra
TL-NP/DT-19	Liquid	Offline	Local	New Delhi
TL-NP/DT-20	Liquid	Offline	Local	New Delhi
TL-NP/DT-21	Powder	Offline	Brand	New Delhi
TL-NP/DT-22	Powder	Offline	Local	New Delhi
TL-NP/DT-23	Powder	Offline	Local	New Delhi
TL-NP/DT-24	Powder	Offline	Brand	New Delhi

4.1.3 Environmental Samples

Sampling was carried out at both upstream and downstream locations of rivers passing through major textile hubs to evaluate the impact of anthropogenic activities on NP contamination. The sites were selected based on visual assessments and available industrial information at the time of collection. Few samples were also collected from the point of confluence of textile effluent/sewage and the rivers **(Figure 7).**

Figure 7: Sampling locations of Environmental matrices



Water

Thirty-three water samples were collected from different rivers and effluent discharge points in different cities of India. These sites were selected based on locations of textile industrial hubs that have reported discharge of treated industrial effluents to the water bodies. Surface water was sampled using pre-cleaned amber-coloured glass bottles. Samples were stored at 4°C and sent to laboratory for further analysis **(Table 3).**

Table 3: Nonylphenol in water

Sr. No.	Sample code	River/ Drain	Location	Latitude/Longitude	Type of sample
1	TL-NP/EN-02	Noyyal River, Tamil Nadu	Upstream	11° 6’32.56”N 77°17’39.83”E	Water
2	TL-NP/EN-04	Noyyal River, Tamil Nadu	Downstream	11° 6’41.30”N 77°22’16.59”E	Water
3	TL-NP/EN-03	Cooum River, Chennai, Tamil Nadu	Upstream	13° 4’18.12”N 80°13’46.34”E	Water
4	TL-NP/EN-06	Cooum River, Chennai, Tamil Nadu	Downstream	13° 4’33.57”N 80°16’58.54”E	Water
5	TL-NP/EN-08	Adyar River, Chennai, Tamil Nadu	Upstream	12°59’50.91”N 80° 8’30.79”E	Water
6	TL-NP/EN-05	Adyar River, Chennai, Tamil Nadu	Downstream	13° 0’54.00”N 80°15’32.50”E	Water

Sr. No.	Sample code	River/ Drain	Location	Latitude/Longitude	Type of sample
7	TL-NP/EN-09	Ganga River, Kanpur, U.P.	Upstream	26°28’10.79”N 80°22’16.56”E	Water
8	TL-NP/EN-10	Ganga River, Kanpur, U.P.	Downstream	26°24’29.55”N 80°26’44.40”E	Water
9	TL-NP/EN-13	Jajmau, Kanpur, U.P.	Effluent	26°24’14.51”N 80°26’1.95”E	Effluent Water
10	TL-NP/EN-14	Yamuna River, New Delhi	Upstream	28°44’16.45”N 77°13’48.04”E	Water
11	TL-NP/EN-15	Yamuna River, New Delhi	Downstream	28°35’34.94”N 77°16’21.16”E	Water
12	TL-NP/EN-17	Drain, Panipat, Haryana	Upstream	29°26’57.67”N 76°56’57.73”E	Water
13	TL-NP/EN-18	Drain, Panipat, Haryana	Downstream	29°25’32.37”N 77°2’17.53”E	Water
14	TL-NP/EN-20	Thane Creek, Mumbai, Maharashtra		19° 3’26.37”N 72°57’40.38”E	Water
15	TL-NP/EN-22	Uppanar River, Tamil Nadu	Downstream	11°25’50.63”N 79°46’50.41”E	Water
16	TL-NP/EN-24	Hindon River, Ghaziabad, U.P.	Downstream	28°40’32.13”N 77°24’21.44”E	Water
17	TL-NP/EN-25	Buddha Nullah, Ludhiana, Punjab	Upstream	30°55’28.95”N 75°55’33.90”E	Water
18	TL-NP/EN-26	Buddha Nullah, Ludhiana, Punjab	Downstream	30°55’8.42”N 75°53’55.15”E	Water
19	TL-NP/EN-27	Kothari River, Bhilwara Rajasthan	Upstream	25°25’34.20”N 74°36’14.97”E	
20	TL-NP/EN-52	Kothari River, Bhilwara Rajasthan	Midstream	25°25’46.51”N 74°36’55.83”E	Water
21	TL-NP/EN-28	Kothari River, Bhilwara Rajasthan	Downstream	25°25’40.79”N 74°37’21.78”E	
22	TL-NP/EN-31	Ankodia Canal, Vadodara, Gujarat	Upstream	22°20’52.90”N 73° 9’36.61”E	Water
23	TL-NP/EN-32	Ankodia Canal, Vadodara, Gujarat	Downstream	22°20’13.79”N 73° 7’38.23”E	Water
24	TL-NP/EN-34	Hooghly River, Kolkata, West Bengal	Upstream	22°35’11.95”N 88°20’57.73”E	
25	TL-NP/EN-35	Hooghly River, Kolkata, West Bengal	Downstream	22°33’35.42”N 88°19’59.60”E	
26	TL-NP/EN-37	Tapi River, Surat, Gujarat	Upstream	21°14’47.29”N 72°54’26.25”E	Water

Sr. No.	Sample code	River/ Drain	Location	Latitude/Longitude	Type of sample
27	TL-NP/EN-39	Tapi River, Surat, Gujarat	Downstream	21°13'59.8"N 72°53'32.5"E	Water
28	TL-NP/EN-42	Sabarmati River, Ahmedabad, Gujarat	Upstream	22°59'41.44"N 72°33'52.46"E	Water
29	TL-NP/EN-41	Sabarmati River, Ahmedabad, Gujarat	Downstream	22°58'45.56"N 72°32'29.10"E	Water
30	TL-NP/EN-40	Sabarmati River, Ahmedabad, Gujarat	Downstream	22°58'51.58"N 72°32'35.67"E	Effluent Water 1
31	TL-NP/EN-43	Sabarmati River, Ahmedabad, Gujarat	Downstream	22°58'53.62"N 72°32'39.22"E	Effluent Water 2
32	TL-NP/EN-45	Bandi River, Pali Rajasthan	Upstream	25°46'8.26"N 73°21'21.63"E	Water
33	TL-NP/EN-46	Bandi River, Pali Rajasthan	Downstream	25°46'56.73"N 73°14'55.70"E	Water

Sediment

A total of 16 sediment samples were taken from riverbeds downstream of textile industrial hubs. A stainless-steel trowel was used for sampling. The samples were stored in amber-coloured glass bottles, sealed to prevent oxidation, and stored at 4°C and then sent to laboratory for analysis **(Table 4)**.

Soil

Two soil samples were collected from agricultural fields of Vadodara, Gujarat and Jajmau, Kanpur. The sampling sites were selected due to the indiscriminate use of treated effluent from common effluent treatment plants for irrigation purposes. A stainless-steel trowel was used to collect samples at a depth of 0–15 cm from different locations and then mixed to get representative samples. The samples were then stored in an amber-coloured glass bottle and maintained at approximately 4°C during transport to the laboratory for analysis **(Table 4).**

Table 4: Nonylphenol in Soil and Sediments

Sr. No.	Sample code	River/Drain	Location	Latitude/Longitude	Type of sample
1	TL-NP/EN-01	Noyyal River, Tamil Nadu	Downstream	11° 6’41.30”N 77°22’16.59”E	Sediment
2	TL-NP/EN-11	Ganga River, Kanpur, U.P.	Downstream	26°24’29.55”N 80°26’44.40”E	Sediment
3	TL-NP/EN-16	Yamuna River, New Delhi	Downstream	28°35’34.94”N 77°16’21.16”E	Sediment
4	TL-NP/EN-19	Drain, Panipat, Haryana	Downstream	29°25’32.37”N 77°2’17.53”E	Sediment
5	TL-NP/EN-21	Thane Creek, Mumbai, Maharashtra		19°3’26.37”N 72°57’40.38”E	Sediment
6	TL-NP/EN-23	Vellar River, Tamil Nadu	Downstream	11°30’18.20”N 79°46’26.99”E	Sediment
7	TL-NP/EN-47	Bandi River, Pali, Rajasthan	Upstream	25°46’8.26”N 73°21’21.63”E	Sediment
8	TL-NP/EN-30	Bandi River, Pali, Rajasthan	Downstream	25°46’56.73”N 73°14’55.70”E	Sediment
9	TL-NP/EN-36	Buddha Nullah, Ludhiana, Punjab	Downstream	30°55’8.42”N 75°53’55.15”E	Sediment
10	TL-NP/EN-38	Tapi River, Surat, Gujarat	Downstream	21°13’59.8”N 72°53’32.5”E	Sediment
11	TL-NP/EN-44	Sabarmati River, Ahmedabad, Gujarat	Downstream	22°58’53.62”N 72°32’39.22”E	Sediment
12	TL-NP/EN-48	Kothari River, Bhilwara, Rajasthan	Upstream	25°25’34.20”N 74°36’14.97”E	Sediment
13	TL-NP/EN-49	Kothari River, Bhilwara, Rajasthan	Midstream	25°25’46.51”N 74°36’55.83”E	Sediment
14	TL-NP/EN-29	Kothari River, Bhilwara, Rajasthan	Downstream	25°25’40.79”N 74°37’21.78”E	Sediment
15	TL-NP/EN-50	Hindon River, Ghaziabad, U.P.	Downstream	28°40’32.13”N 77°24’21.44”E	Sediment
16	TL-NP/EN-51	Hooghly River, Kolkata, West Bengal	Downstream	22°33’35.42”N 88°19’59.60”E	Sediment
17	TL-NP/EN-12	Jajmau, Kanpur, U.P.	Downstream	26°24’14.11”N 80°26’2.23”E	Soil
18	TL-NP/EN-33	Vadodara, Gujarat	Downstream	22°20’12.28”N 73°7’42.59”E	Soil

4.2 Analytical Techniques

The samples were sent to certified laboratories M/s NimkrTek India Pvt. Ltd., Mumbai and M/s SGS India Pvt., Ltd. Chennai for testing of NPs and NPEs. The samples were tested by using standard ISO protocol given below:

Sr. No.	Product/Environmental matrices	Analytical method	Detection Limit
1	Textiles	HPLC-MS performed analysis with reference to **ISO 18254-1:2016**.	1 mg/kg
2	Detergents	HPLC-MS performed analysis with reference to **ISO 21084:2019** and **ISO 18254-1:2016.**	5 mg/kg
3	Water	HPLC-MS performed analysis with reference to **ISO 21084:2019.**	5 µg/L
4	Sediment	HPLC-MS performed analysis with reference to **ISO 21084:2019** and **18254-1:2016**.	0.2 mg/kg
5	Soil	HPLC-MS performed analysis with reference to **ISO 21084:2019** and **18254-1:2016**.	0.2 mg/kg

5. Result and discussion

The analysis revealed variations in NP concentrations across samples. The concentrations were expressed in weight per cent (wt%) due to the solid nature of the textile samples and the heterogeneous distribution of NP within them.

5.1 Presence of nonylphenol in textile samples

The analysis revealed variations in NP concentrations across the samples. The concentrations were expressed in weight per cent (wt%) due to the solid nature of the textile samples and the heterogeneous distribution of NP within them. This highlights that sampling from different areas of these samples could yield varying NP concentrations, necessitating wt% as the standard measure **(Figure 8 and Table 5)**.

Table 5: NPE in the textile samples collected across Indian markets

Sr. No.	Sample code	Material	Manufactured	Mode of Purchase	Nonylphenol as NPE (%)	Nonylphenol as NPE (mg/kg)	Cost per piece (INR) (Rs)
01	TL-NP/TX-01	Cotton	Kanpur, U.P.	Offline	BDL	BDL	60
02	TL-NP/TX-02	Cotton	Kanpur, U.P.	Offline	BDL	BDL	60
03	TL-NP/TX-03	Cotton	Kanpur, U.P.	Offline	0.0119	119	75
04	TL-NP/TX-04	Jeans	Kanpur, U.P.	Offline	BDL	BDL	250
05	TL-NP/TX-05	Cotton	Kanpur, U.P.	Offline	0.0788	788	120
06	TL-NP/TX-06	Cotton	Kanpur, U.P.	Offline	BDL	BDL	100
07	TL-NP/TX-07	Jeans	Kanpur, U.P.	Offline	0.0254	254	459
08	TL-NP/TX-08	Cotton	Kanpur, U.P.	Offline	0.0957	957	100
09	TL-NP/TX-09	100% Cotton	Noida, U.P.	Online	BDL	BDL	497
10	TL-NP/TX-10	Cotton	New Delhi	Online	BDL	BDL	545
11	TL-NP/TX-11	Cotton	Panipat, Haryana	Online	BDL	BDL	583
12	TL-NP/TX-12	Cotton	Tiruppur, TN	Offline	0.0514	514	80
13	TL-NP/TX-13	Cotton	Ahmedabad, Gujarat	Offline	BDL	BDL	100
14	TL-NP/TX-14	Cotton	Kolkata, WB	Offline	0.0129	129	60
15	TL-NP/TX-15	Hosiery	Ahmedabad, Gujarat	Offline	BDL	BDL	40
16	TL-NP/TX-16	Jeans	Ahmedabad, Gujarat	Offline	0.00087	8.7	250
17	TL-NP/TX-17	Hosiery	Tiruppur, TN	Offline	0.0187	187	250
18	TL-NP/TX-18	Cotton	Surat, Gujarat	Online	BDL	BDL	438
19	TL-NP/TX-19	Cotton	Bengaluru, KA	Online	BDL	BDL	399
20	TL-NP/TX-20	Cotton	Tiruppur, TN	Online	BDL	BDL	239
21	TL-NP/TX-21	Hosiery	Tiruppur, TN	Online	0.0406	406	296
22	TL-NP/TX-22	Cotton	Tiruppur, TN	Online	BDL	BDL	419
23	TL-NP/TX-23	Cotton	Tiruppur, TN	Online	BDL	BDL	395
24	TL-NP/TX-24	Cotton	Tiruppur, TN	Online	BDL	BDL	449
25	TL-NP/TX-25	Super Combed Cotton	Tiruppur, TN	Online	BDL	BDL	228
26	TL-NP/TX-26	Cotton	-	Offline	0.0764	764	550

Sr. No.	Sample code	Material	Manufactured	Mode of Purchase	Nonylphenol as NPE (%)	Nonylphenol as NPE (mg/kg)	Cost per piece (INR) (Rs)
27	TL-NP/TX-27	Hosiery	-	Offline	0.0140	140	200
28	TL-NP/TX-28	Cotton	Indore, MP	Offline	BDL	BDL	200
29	TL-NP/TX-29	Cotton	Delhi	Offline	BDL	BDL	150
30	TL-NP/TX-30	Cotton	Indore, MP	Offline	BDL	BDL	60
31	TL-NP/TX-31	Hosiery	Tiruppur, TN	Offline	0.0306	306	250
32	TL-NP/TX-32	Cotton	Indore, MP	Offline	BDL	BDL	300
33	TL-NP/TX-33	Cotton	Kolkata, WB	Offline	BDL	BDL	499
34	TL-NP/TX-34	Cotton	Kolkata, WB	Offline	BDL	BDL	709
35	TL-NP/TX-35	Hosiery	Kolkata, WB	Offline	0.0275	275	100
36	TL-NP/TX-36	Cotton	Kolkata, WB	Offline	0.0560	560	100
37	TL-NP/TX-37	Cotton	New Delhi	Offline	BDL	BDL	350
38	TL-NP/TX-38	Cotton	New Delhi	Offline	BDL	BDL	100
39	TL-NP/TX-39	Cotton	New Delhi	Offline	BDL	BDL	100
40	TL-NP/TX-40	Cotton	New Delhi	Offline	0.00222	22.2	120

**BDL: Below Detection Limit*

Figure 8: Nonylphenol in Textile

The major findings of the study are as follows:

- Out of 40 textile products examined, NP was detected in 15 out of 40 textile products (About 35%).
- NP concentration ranged from 8.7 to 957 mg/kg in these 15 products.
- NP in 13 out of 15 products were above the present EU limit (<100 mg/kg). The remaining 2 products having NP below the EU limit were kid jeans and underwear.
- 8 out of 15 products were manufactured from cotton whereas 5 products were made from hosiery and the fabric of the other two items was not mentioned on the product.
- 13 out of 15 products were manufactured in India, while the place of manufacturing of the remaining two items (kids jeans and mens vest) was not known.
- Female innerwear made with hosiery had the highest NP concentration (957 mg/kg).
- 10 out of 15 samples were innerwear products (men & women) wherein NP concentration was found in the range of 22.2 to 957 mg/kg.
- 60% (9 out of 15) of baby and children's products had NP (8.7-764 mg/kg).

Results show that NP in 13 out of 15 tested textile products at levels exceeding the EU's permissible limit of <100 mg/kg (ECHA, 2015), indicating concerns about Nonylphenol's presence in these products. Incidentally, the chemical was detected in textile products across all the cities like Kanpur, Tiruppur, Ahmedabad, Kolkata, and New Delhi from where samples were being collected. In this study, 8 out of 15 products examined were manufactured from cotton, whereas 5 products were made from hosiery. This was also observed in previous research reports where NPE was detected in several cotton products, including those imported from India (Yixiu Wu, 2015; UK gov, 2013; Greenpeace International, 2012). The study also attempted to assess whether there was any correlation between the cost of the samples and the presence of NP; however, no such link was established.

Countries like Japan and the U.S. have also restricted NP and its ethoxylates in textile processing (USEPA, 2004). The high NP levels in our study emphasize the urgent need for regulatory intervention and industry-wide adoption of safer alternatives in India. One of the possible reasons for the detection of NP in cotton products may be due to the use of these non-ionic surfactants in washing and scouring of cotton.

Nonylphenol as NPE is are used in the textile manufacturing processes for the following functions:

- Washing and scouring of raw wool and cotton
- Fibre lubrication
- Dye levelling
- Surface active agent for cleaning and rinsing textiles
- Auxiliary agent in bleaching step
- Wetting agent for textiles
- Emulsifier for oils, fibres

Nevertheless, successive studies revealed the presence of NP exclusively in products from domestic (Indian) brands, while international brands showed no traces of NP. Thus the finding highlights a lack of effort by domestic textile brands to phase out or minimize the use of NP, which can be attributed to the absence of regulatory restrictions in India. In contrast, Indian manufacturers supplying textile products to international brands have demonstrated awareness of the consequences of NP usage and appear to comply with stricter standards. This suggests that Indian manufacturers possess the capability to produce NP-free products but are not transitioning to sustainable alternatives due to the regulatory vacuum in the country.

It is worth noting, however, that the residue levels in finished products cannot be considered definitive evidence of NP usage during production. The levels depend on several factors, such as the number and efficiency of wash cycles during the finishing process.

5.2 Presence of nonylphenol in Environmental matrices

The presence of NP in environmental matrices can be linked to its industrial applications, particularly the use of NP-based surfactants in industrial detergents and its role as an intermediate in textile processing. The detection of NP in textile products indicates its widespread use in textile manufacturing. However, there is limited data on NP levels in surface water compared to other environmental compartments in India. This study establishes a connection between NP usage in industrial surfactants, detergent discharge, and its occurrence in surface water, sediments, and soil across various sampling locations, as detailed in **Tables 6 and 7.** The spatial distribution of NP concentrations in surface water and sediment samples from major textile hubs during the post-monsoon period is illustrated in **Figure 9.**

Table 6: Nonylphenol in water

Sr. No.	Sample code	River	Location	Type of sample	NPE (µg/L)
1	TL-NP/EN-02	Noyyal River, Tamil Nadu	Upstream	Water	BDL
2	TL-NP/EN-04	Noyyal River, Tamil Nadu	Downstream	Water	BDL
3	TL-NP/EN-03	Cooum River, Chennai, Tamil Nadu	Upstream	Water	BDL
4	TL-NP/EN-06	Cooum River, Chennai, Tamil Nadu	Downstream	Water	70
5	TL-NP/EN-08	Adyar River, Chennai, Tamil Nadu	Upstream	Water	BDL
6	TL-NP/EN-05	Adyar River, Chennai, Tamil Nadu	Downstream	Water	60
7	TL-NP/EN-09	Ganga River, Kanpur, U.P.	Upstream	Water	BDL
8	TL-NP/EN-10	Ganga River, Kanpur, U.P.	Downstream	Water	BDL
9	TL-NP/EN-13	Jajmau, Kanpur, U.P.		Effluent	BDL
10	TL-NP/EN-14	Yamuna River, New Delhi	Upstream	Water	BDL

Sr. No.	Sample code	River	Location	Type of sample	NPE (µg/L)
11	TL-NP/EN-15	Yamuna River, New Delhi	Downstream	Water	BDL
12	TL-NP/EN-17	Drain, Panipat, Haryana	Upstream	Water	BDL
13	TL-NP/EN-18	Drain, Panipat, Haryana	Downstream	Water	BDL
14	TL-NP/EN-20	Thane Creek, Mumbai, Maharashtra		Water	BDL
15	TL-NP/EN-22	Uppanar River, Tamil Nadu	Downstream	Water	BDL
16	TL-NP/EN-24	Hindon River, Ghaziabad, U.P.	Downstream	Water	BDL
17	TL-NP/EN-25	Buddha Nullah, Ludhiana, Punjab	Upstream	Water	BDL
18	TL-NP/EN-26	Buddha Nullah, Ludhiana, Punjab	Downstream	Water	BDL
19	TL-NP/EN-27	Kothari River, Bhilwara Rajasthan	Upstream	Water	BDL
20	TL-NP/EN-52	Kothari River, Bhilwara Rajasthan	Midstream	Water	BDL
21	TL-NP/EN-28	Kothari River, Bhilwara Rajasthan	Downstream	Water	BDL
22	TL-NP/EN-31	Ankodia Canal, Vadodara, Gujarat	Upstream	Water	BDL
23	TL-NP/EN-32	Ankodia Canal, Vadodara, Gujarat	Downstream	Water	BDL
24	TL-NP/EN-34	Hooghly River, Kolkata, West Bengal	Upstream	Water	BDL
25	TL-NP/EN-35	Hooghly River, Kolkata, West Bengal	Downstream	Water	BDL
26	TL-NP/EN-37	Tapi River, Surat, Gujarat	Upstream	Water	BDL
27	TL-NP/EN-39	Tapi River, Surat, Gujarat	Downstream	Water	BDL
28	TL-NP/EN-42	Sabarmati, Ahmedabad, Gujarat	Upstream	Water	BDL
29	TL-NP/EN-41	Sabarmati, Ahmedabad, Gujarat	Downstream,	Water	7.9
30	TL-NP/EN-40	Sabarmati, Ahmedabad, Gujarat	Downstream	Effluent Water 1	10.1
31	TL-NP/EN-43	Sabarmati, Ahmedabad, Gujarat	Downstream	Effluent Water 2	BDL
32	TL-NP/EN-45	Bandi, Pali, Rajasthan	Upstream	Water	BDL
33	TL-NP/EN-46	Bandi, Pali, Rajasthan	Downstream	Water	40

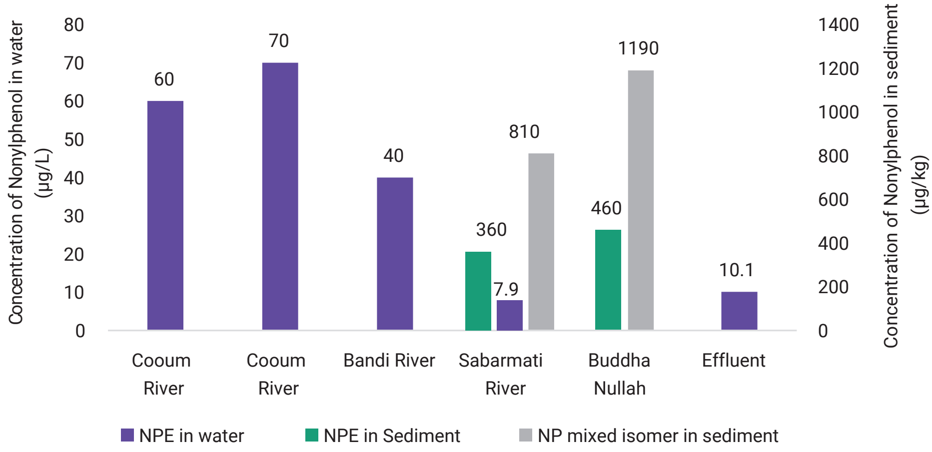
**BDL : Below Detection Limit*

Table 7: Nonylphenol in Soil and Sediments

Sr. No.	Sample code	River	Location	Type of sample	Nonylphenol as NPE (µg/ kg)	NP mixed isomers (µg/ kg)
1	TL-NP/EN-01	Noyyal River, Tamil Nadu	Downstream	Sediment	BDL	BDL
2	TL-NP/EN-11	Ganga River, Kanpur, U.P.	Downstream	Sediment	BDL	BDL
3	TL-NP/EN-16	Yamuna river, New Delhi	Downstream	Sediment	BDL	BDL
4	TL-NP/EN-19	Drain, Panipat, Haryana	Downstream	Sediment	BDL	BDL
5	TL-NP/EN-21	Thane Creek, Mumbai, Maharashtra		Sediment	BDL	BDL
6	TL-NP/EN-23	Vellar River, Tamil Nadu	Downstream	Sediment	BDL	BDL
7	TL-NP/EN-47	Bandi, Pali, Rajasthan	Upstream	Sediment	BDL	BDL
8	TL-NP/EN-30	Bandi, Pali, Rajasthan	Downstream	Sediment	BDL	BDL
9	TL-NP/EN-36	Buddha Nullah, Ludhiana, Punjab	Downstream	Sediment	460	1190
10	TL-NP/EN-38	Tapi River, Surat, Gujarat	Downstream	Sediment	BDL	BDL
11	TL-NP/EN-44	Sabarmati, Ahmedabad, Gujarat	Downstream	Sediment	360	810
12	TL-NP/EN-48	Kothari River, Bhilwara, Rajasthan	Upstream	Sediment	BDL	BDL
13	TL-NP/EN-49	Kothari River, Bhilwara, Rajasthan	Midstream	Sediment	BDL	BDL
14	TL-NP/EN-29	Kothari River, Bhilwara, Rajasthan	Downstream	Sediment	BDL	BDL
15	TL-NP/EN-50	Hindon River, Ghaziabad, U.P.	Downstream	Sediment	ND	BDL
16	TL-NP/EN-51	Hooghly River, Kolkata, West Bengal	Downstream	Sediment	ND	BDL
17	TL-NP/EN-12	Jajmau, Kanpur, U.P.	Downstream	Soil	ND	BDL
18	TL-NP/EN-33	Vadodara, Gujarat	Downstream	Soil	ND	BDL

**BDL : Below Detection Limit*

Figure 9: Nonylphenol in Environmental matrices



- The study revealed significant Nonylphenol (NP) contamination in various rivers across major textile hubs in India.
- NP was detected in surface water from the Cooum River (Chennai), Adyar River (Chennai), Buddha Nullah (Ludhiana, Punjab), Bandi River (Rajasthan), and Sabarmati River (Ahmedabad).
- The highest NP concentration in surface water was detected in the Cooum River at 70 µg/L, followed by the Adyar River at 60 µg/L and the Bandi River at 40 µg/L.
- In the Sabarmati River, NP levels were recorded at 7.9 µg/L in surface water, while sediment samples showed 360 µg/L of NP and 810 µg/L of NP mixed isomers.
- Buddha Nullah exhibited the highest contamination in sediments, with NP reaching 460 µg/L and NP mixed isomers at 1190 µg/L.
- Effluent samples from textile industries also showed NP contamination at 10.1 µg/L. The presence of NP in downstream locations and its absence in upstream points strongly suggests point-source pollution from industrial activities, particularly textile manufacturing.
- The significantly higher NP concentration at the downstream point of the Sabarmati River is likely due to effluent discharge from nearby textile units.

The findings of our study reveal significant Nonylphenol contamination in major Indian rivers associated with textile hubs. The highest NP concentration in downstream of surface water was observed in the Cooum River (70 µg/L), followed by the Adyar River (60 µg/L) and the Bandi River (40 µg/L). In the Sabarmati River, surface water NP levels were 7.9 µg/L, while sediment samples showed concerning levels of 360 µg/kg for NP and 810 µg/kg for NP mixed isomers. Buddha Nullah exhibited the highest NP contamination in sediments, with NP at 460 µg/kg and NP mixed isomers at 1190 µg/L.

The detected NP concentrations in Indian surface waters significantly exceed international water quality standards. For example, the Canadian Council of Ministers of the Environment (CCME) has set a freshwater quality guideline for NP at just 1.0 µg/L to protect aquatic life (Canadian Water Quality Guidelines for the Protection of Aquatic Life, 2002), while the U.S. Environmental Protection Agency (EPA) has also established strict ambient water quality criteria for NP to safeguard aquatic organisms (US EPA, 2005). Similarly, sediment contamination in the Sabarmati River (360 µg/kg) and Buddha Nullah (460 µg/kg) surpasses the CCME's interim sediment quality guideline of 1.4 mg/kg (1400 µg/kg) dry weight. These elevated NP levels in Indian rivers indicate a significant ecological risk, emphasizing the need for stringent regulatory standards to control industrial discharges and prevent further environmental degradation (Pavan et al., 2024; He et al., 2020; Ho and Watanabe, 2017; Toxics Link, 2019; Mahalakshmi et al., 2020; Roy Choudhury, 2014; Soares et al., 2008).

In order to check the source of NP in the environment, we conducted the testing of NP in detergents. Previous studies by Toxics Link highlighted the presence of NP in domestic detergents, identifying them as a major source of NP contamination in textiles and the environment. In the present study, 24 detergent samples, including one duplicate, were collected and analyzed for NP content. However, the results revealed that NP concentrations in all samples were below the detection limit **(Table 8)**. The absence of NP in these detergent samples (both local and branded) suggests that NP may be phased out or may no longer be used in domestic detergents. However, it is possible that NP may still be in use in industrial-grade detergents or surfactants, which were not included in this study due to their limited availability in the market and their direct procurement by industries from detergent or chemical manufacturers. Given that industrial processes, particularly in the textile and leather sectors, extensively use NP-based surfactants, it is crucial to investigate the role of industrial effluents in environmental NP contamination. Furthermore, NP could also originate from other sources, such as pesticides, plastics, or untreated municipal wastewater, necessitating a more comprehensive source apportionment study to identify and mitigate NP pollution in the environment.

Table 8: Results of NP in the domestic detergents

Sample Id	Brand/Local	Type	Mode of Purchase	Manufactured in	Nonylphenol as NPE (mg/kg)	Cost (INR) (Rs.)
TL-NP/DT-01	Brand	Powder	Offline	Kanpur, U.P.	BDL	345
TL-NP/DT-02	Local	Powder	Offline	Kanpur, U.P.	BDL	200
TL-NP/DT-03	Brand	Powder	Offline	Kanpur, U.P.	BDL	250
TL-NP/DT-04	Brand	Powder	Offline	Kanpur, U.P.	BDL	160
TL-NP/DT-05	Brand	Liquid	Online	Hyderabad, Telangana	BDL	287
TL-NP/DT-06	Brand	Liquid	Online	Chennai, Tamil Nadu	BDL	279
TL-NP/DT-07	Brand	Liquid	Online	Himachal Pradesh	BDL	279
TL-NP/DT-08	Brand	Liquid	Online	Gujarat	BDL	333
TL-NP/DT-09	Brand	Powder	Online	Thane, Maharashtra	BDL	223
TL-NP/DT-10	Brand	Powder	Online	Assam	BDL	224
TL-NP/DT-11	Brand	Powder	Online	Ghaziabad, U.P.	BDL	299
TL-NP/DT-12	Brand	Powder	Online	Nashik, Maharashtra	BDL	454
TL-NP/DT-13	Brand	Powder	Online	Raipur, Chhattisgarh	BDL	278
TL-NP/DT-14	Brand	Powder	Online	Chittorgarh, Rajasthan	BDL	179
TL-NP/DT-15	Brand	Powder	Online	New Delhi	BDL	228
TL-NP/DT-16	Brand	Powder	Online	Kirumambakkam, Puducherry	BDL	240
TL-NP/DT-17	International brand	Liquid	Offline	Mazowieckie, Poland	BDL	446
TL-NP/DT-18	Brand	Powder	Offline	Mumbai, Maharashtra	BDL	64
TL-NP/DT-19	Local	Liquid	Offline	New Delhi	BDL	200
TL-NP/DT-20	Local	Liquid	Offline	New Delhi	BDL	200
TL-NP/DT-21	Brand	Powder	Offline	Hapur, U.P.	BDL	256
TL-NP/DT-22	Local	Powder	Offline	New Delhi	BDL	150
TL-NP/DT-23	Local	Powder	Offline	New Delhi	BDL	150
TL-NP/DT-24	Brand	Powder	Offline	Hapur, U.P.	BDL	199

**BDL: Below Detection Limit*

6. Limitation of the study

- The sample size was insufficient to establish broader trends or achieve statistical significance.
- Seasonal variations, particularly the post-monsoon effect, significantly influence contamination levels, as monsoon rains dilute, transport, and redistribute pollutants, impacting result interpretation.
- Analytical constraints exist, including detection limits that restrict the identification of lower concentrations of Nonylphenol.
- Identifying the exact sources of contamination was challenging, as multiple pollution sources, including industrial effluents, household wastewater, and agricultural runoff, contribute to NP presence in the environment.
- The absence of comprehensive industrial discharge data limits the ability to trace contamination back to its sources with certainty.
- Industrial samples from inside the premises were not collected due to restrictions on access and permission constraints, limiting the direct assessment of contamination at source.
- The study does not assess the long-term ecological and human health impacts of Nonylphenol exposure in Indian conditions.

These limitations highlight the need for more extensive research, larger datasets, and continuous monitoring to comprehensively understand the extent and impact of Nonylphenol contamination in India.

7. Conclusions and recommendations

The Bureau of Indian Standards (BIS) and the Central Pollution Control Board (CPCB) have identified Nonylphenol (NP) as a toxic chemical and a substance of concern due to its hazardous nature (BIS, 2022; CPCB, 2016). There is an established science that NP is an endocrine disruptor with potential carcinogenic effects, posing significant environmental and human health risks.

This study detected notable levels of NP in textiles, water, and sediment, particularly in industrial regions such as the Cooum River (Chennai), Adyar River (Chennai), Bandi River (Rajasthan), Buddha Nullah (Punjab), and Sabarmati River (Ahmedabad). The contamination of these ecosystems raises concerns about NP's potential infiltration into drinking water supplies, increasing public health risks.

Although NP was not detected in detergents in this study, it is known to be used in industrial surfactants, which could contribute to environmental contamination. Research from other countries has shown that NP-based surfactants, commonly used in industrial processes and detergents, are major sources of pollution, leading to bans in several jurisdictions, including the European Union.

The continued use of NP-based surfactants in India highlights the need for further investigation and potential regulatory action. A significant issue is the discrepancy in business practices, since international companies that have banned NP from regulated markets continue to allow its usage in goods marketed and sold in India. This underlines the need for strict regulatory measures to restrict NP in supply chains and exposes the flaws in voluntary promises by industry. The absence of regulatory limits on NP in environmental matrices and the lack of national bans on its use in textiles highlight a critical policy gap that urgently needs to be addressed.

Furthermore, the absence of stringent measures in India creates a potential discrepancy in trade practices. With other countries implementing regulations and restrictions, Indian textile products containing toxic chemicals may face barriers or trade limitations in the global market. This could hinder the competitiveness of the Indian textile industry and affect its reputation in terms of sustainability and responsible manufacturing practices. It is essential for India to recognize the concerns associated with these chemicals and prioritize their regulations and restrictions in various sectors, especially textiles. By aligning with international efforts and adopting strict measures, India can safeguard its population, promote sustainable manufacturing practices, and ensure compliance with global standards for chemical management.

RECOMMENDATIONS

7.1 Textiles sector

- National policies may be developed to gradually phase out NP in textiles, aligning with international trade and environmental standards.
- Textile manufacturers can be encouraged to adopt green chemistry principles and shift to safer alternatives.
- Certification schemes and labeling for NP-free textiles may be introduced to improve market transparency.
- Monitoring of industrial effluents can be enhanced to ensure compliance with NP discharge limits.
- Research on bio-based or biodegradable surfactants can be promoted for textile processing.
- Training programmes for workers and manufacturers can be conducted to increase awareness of NP risks and alternatives.
- Public awareness campaigns may be launched to educate consumers on the benefits of NP-free textiles.
- More research studies needs to be conducted to elucidate the impact of NP on the ecosystem.
- To prepare a comprehensive plan to restrict or phase out toxic chemicals such as NP wherever possible.

7.2 Detergents sector

- National regulations can gradually eliminate NP from detergent formulations.
- Research on safer, biodegradable surfactants may be encouraged to facilitate the transition away from NP.
- Small and medium-scale detergent manufacturers can be supported with financial and technical assistance for adopting NP-free alternatives.
- Mandatory labeling of detergents may be introduced to ensure transparency on chemical ingredients.
- Consumer awareness initiatives may be developed to promote the use of NP-free detergents.
- Monitoring and compliance checks for detergent manufacturing units can be strengthened.
- Collaboration between government, industry, and researchers may help accelerate the adoption of eco-friendly alternatives.
- Phase out NP, used as surfactants, with suitable alternatives available in the market.

7.3 Environmental Matrices

- Regulatory frameworks can be strengthened to monitor and control NP contamination in water bodies, soil, and sediments.
- Effluent discharge standards may be revised to include stricter limits for NP and related chemicals.
- Advanced wastewater treatment technologies may be promoted to improve the removal efficiency of NP from industrial and municipal wastewater.
- Public and community participation may be encouraged in environmental monitoring and awareness programmes.
- Data sharing and collaboration between research institutions, government agencies, and industries can be strengthened to track NP pollution trends.

8. Appendices

8.1 Regulatory Context and Environmental Impact

Multiple countries have taken necessary steps to regulate and restrict Nonylphenols, their isomers and NP-based chemicals (such as NPEs, TNPP, etc.) due to their harmful impact on human health and the environment. Some have voluntarily phased out the production and consumption of NPs. For instance, when NP as a suspected EDC became a social concern in Japan in the 1990s, consumers refused products containing the chemical. Therefore, the Japan Vinyl Goods Manufacturers Association changed the composition of PVC stretch films in 2002; since then, NP has not been detected in Japanese stretch films. However, overall restrictions have been largely sector-specific.

8.1.1 Regulations on products

Rotterdam Convention: In 2019, the Interim Chemical Review Committee (ICRC) and Chemical Review Committee (CRC) had found NP and NPEs meeting all the criteria of Annex II under pesticide categories. However, as of 2023, it was not accepted under Annex III (IISD Reporting Service, 2019).

India: In India regulation on NP is placed only in cosmetics. IS 4707 (Part 2):2009 by the Bureau of Indian Standards (BIS) prohibits use of Nonylphenol in cosmetics.

Global

European Union

- **Textile**: In 2016, the **European Union** (EU) published a revised regulation under Annex XVII to Regulation (EC) No 1907/2006 to restrict NPEs in textile products in concentrations to 0.01% by weight of that textile article or of each part of the textile article. This entry came into force on 3rd February, 2021 and applies to textiles that can reasonably be expected to be washed in water during their life cycle (ECHA, 2021).
- **Cleaning detergent**: REACH Annex XVII, Entry 46, 2005 restricts the use of NP and NPE in concentrations equal to or higher than 0.1% in products for industrial and institutional cleaning and domestic cleaning. EU countries such as Norway, Sweden, Belgium, Netherlands, etc. have banned the use of NPEs in household detergents since the 1990s.

Denmark: In January 2005, Denmark banned the use of NP and NPEs in the manufacturing of all consumer products including textiles, leather, pesticides, paints, lacquer, etc (Denmark, 2005).

United States of America

- In 2018, the US EPA added NPEs to the list of toxic chemicals, subject to reporting under section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) and section 6607 of the Pollution Prevention Act (PPA) (EPA, 2022).
- The US Environmental Protection Agency (EPA) has come up with a significant new use rule (SNUR) for 15 nonylphenols and nonylphenol ethoxylates. The NPEs with the CAS Nos. 7311-27-5, 9016-45-9, 26027-38-3, 37205-87-1 and 51938-25-1 are in

the list. 'Persons subject to these SNURs would be required to notify EPA at least 90 days before they manufacture (including import) or process any of these 15 chemical substances for a significant new use. The required notification would provide EPA with the opportunity to evaluate the new uses and protect against unreasonable risks, if any, from potential new exposures to NPs and NPEs, before that activity occurs.

- Some states have come up with regulations to monitor NPs in textile products. For example:
  - **Oregon**'s 73 high-priority chemicals of concern for children's health, as required by the Toxic-Free Kids Act passed in 2015 include specific alkylphenols (4-NP and its isomer mixtures; 4-tert-octylphenol). According to this Act, the manufacturers must provide biennial notice to Oregon Health Authority of children's products sold in Oregon that are covered by this Act and contain such chemicals in the final product at or above the practical quantification limit.
  - **Washington**'s Children's Safe Products Act (CSPA) requires manufacturers to report each year if their children products contain chemicals of high concern to children (CHCC). Alkylphenols re part of the CHCC list. However, none of the alkylphenol is restricted at present (Department of Ecology State of Washington, 2024).

Canada

- Canada conducted a Priority Substance Risk Assessment in 2001, after which NP and NPEs were listed as toxic under **Schedule 1 of section 64 of the Canadian Environmental Protection Act 1999** (the Toxic Substances List). The use of NPEs has been phased down in Canada since 2004, with most users of nonylphenols required to prepare and implement pollution prevention plans. Since then, companies and their chemical suppliers have voluntarily phased out NPEs from processing many products such as textiles, personal care products, paper and pulp, pesticides, etc. (Canada, 2022).

Asia

China

- China issued a new national standard GB/T 39498-2020 Guidelines for the use and control of key chemical substances in consumer products. The new standard came into effect in June 2021 and includes NPs & NPEs and other alkylphenols & alkylphenol alkylthoxylates (APs & APEOs).
- On December 30, 2022, the Chinese Ministry of Ecology and Environment released a list of new pollutants for priority management (2023). It came into force on March 1, 2023. This list includes NPs classified as an environmental endocrine disruptor of very high concern. For this pollutant, the proposed management measures are usage prohibitions to strengthen the source control (China, 2023).

Taiwan

- **Textile**: The Bureau of Standards, Metrology and Inspection (BSMI) (2018) has revised safety requirement for textile and apparel products, CNS 15290:2018– Safety of Textiles (General Requirements) that restricted the NPE and NP in textiles less than 1,000 mg/kg (0.1%) (China, 2022).

- **Detergents**: The Taiwan Environmental Protection Administration (EPA) has banned the use of NP and NPE in the manufacturing of domestic detergents since January 1, 2008 in accordance with the Toxic and Concerned Chemical Substances Control Act

South Korea

- **Detergent**s: The Korean Act on Registration and Evaluation, etc. of Chemical Substances (also known as K-REACH) in 2016 has restricted NP and NPE in household products including detergents not more than 0.1% for products or components within (CIRS Group, 2016).

8.1.2 Environmental Standards

Country	Established standards
Sector	**Textile**
European Union	√
US*	
China	
South Korea	
Japan	
Taiwan	√
India	

* The US has regulations on limiting the use of NPs & NPEs but does not have standards for the same

References

- Ademollo, N., Ferrara, F., Delise, M., Fabietti, F., Funari, E., 2008. Nonylphenol and octylphenol in human breast milk. Environ Int 34, 984–987. https://doi.org/10.1016/j.envint.2008.03.001
- Ahmadpanah, K., Soltani, M., Rajabi Islami, H., Shamsaie, M., 2019. Effects of nonylphenol on hematological parameters and immune responses in immature rainbow trout (Oncorhynchus mykiss). Mar Freshw Behav Physiol 52, 151–165. https://doi.org/10.1080/10236244.2019.1661779
- Azzouz, A., Rascón, A.J., Ballesteros, E., 2016. Simultaneous determination of parabens, alkylphenols, phenylphenols, bisphenol A and triclosan in human urine, blood and breast milk by continuous solid-phase extraction and gas chromatography–mass spectrometry. J Pharm Biomed Anal 119, 16–26. https://doi.org/10.1016/j.jpba.2015.11.024
- Bernal-Jácome L.A., Izar-Landeta, J.M, Flores-Ramírez, R. et al., 2024. Nonylphenol ethoxylate degradation in detergents during shelf time, a new exposure pathway, and a perspective on their substitution. Environ Sci Pollut Res . https://doi.org/https://doi.org/10.1007/s11356-024-33260-7
- Blankenship, A.L., Coady, K., 2005. Nonylphenol, in: Encyclopedia of Toxicology. Elsevier, pp. 260–263. https://doi.org/10.1016/B0-12-369400-0/00698-0
- Brigden, K., Santillo, D., Johnston, P., 2012. Nonylphenol ethoxylates (NPEs) in textile products, and their release through laundering. https://www.greenpeace.org/static/planet4-international-stateless-develop/2012/03/806ceff8-dirty_laundry_product_testing_technical_report_01-2012.pdf
- Canada, 2022. Performance measurement evaluation for risk management of nonylphenol and its ethoxylates, eco-component. https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/evaluation-risk-management-nonylphenol-ethoxylates.html
- Canadian Water Quality Guidelines for the Protection of Aquatic Life, 2002. NONYLPHENOL AND ITS ETHOXYLATES. https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/evaluation-risk-management-nonylphenol-ethoxylates.html
- Cao, X., Wang, X., Chen, H., Li, H., Tariq, M., Wang, C., Zhou, Y., Liu, Y., 2019. Neurotoxicity of nonylphenol exposure on Caenorhabditis elegans induced by reactive oxidative species and disturbance synthesis of serotonin. Environmental Pollution 244, 947–957. https://doi.org/10.1016/j.envpol.2018.09.140
- Careghini, A., Mastorgio, A.F., Saponaro, S., Sezenna, E., 2015. Bisphenol A, nonylphenols, benzophenones, and benzotriazoles in soils, groundwater, surface water, sediments, and food: a review. Environmental Science and Pollution Research 22, 5711–5741. https://doi.org/10.1007/s11356-014-3974-5
- Casatta, N., Stefani, F., Pozzoni, F., Guzzella, L., Marziali, L., Mascolo, G., Viganò, L., 2016. Endocrine-disrupting chemicals in coastal lagoons of the Po River delta: sediment contamination, bioaccumulation and effects on Manila clams. Environmental Science and Pollution Research 23, 10477–10493. https://doi.org/10.1007/s11356-015-5656-3
- Central Pollution Control Board (CPCB), 2016, PHENOLS & PHENOLIC COMPOUNDS. https://cpcb.nic.in/uploads/News_Letter_Phenols_Phenolic_Compounds_2017.pdf
- Chapin, R., 1999. The effects of 4-nonylphenol in rats: a multigeneration reproduction study. Toxicological Sciences 52, 80–91. https://doi.org/10.1093/toxsci/52.1.80
- Chemanalyst, 2024. Nonylphenol Ethoxylates Market Analysis: Industry Market SIze, Plant Capacity, Production, Operating Efficiency, Demand & Supply, End-User Industries, Sales Channel, Regional Demand, Company Share, Manufacturning Process 2015-2032 Decode the Future of Nonylphenol Ethoxylates [WWW

Document]. URL https://www.chemanalyst.com/industry-report/nonylphenol-ethoxylates-market-2927#:~:text=The%20global%20Nonylphenol%20Ethoxylates%20market,the%20forecast%20period%20until%202032 (accessed 8.6.24).

- Chen, M., Fan, Z., Zhao, F., Gao, F., Mu, D., Zhou, Y., Shen, H., Hu, J., 2016. Occurrence and Maternal Transfer of Chlorinated Bisphenol A and Nonylphenol in Pregnant Women and Their Matching Embryos. Environ Sci Technol 50, 970–977. https://doi.org/10.1021/acs.est.5b04130

- Cheng, C.-Y., Ding, W.-H., 2002. Determination of nonylphenol polyethoxylates in household detergents by high-performance liquid chromatography, Journal of Chromatography A. https://doi.org/10.1016/S0021-9673(02)00959-7

- China, 2023. China issues 2023 List of Key Controlled New Pollutants. https://enviliance.com/regions/east-asia/cn/report_8936

- China, 2022. For Your Health, Say No to Nonylphenol Detergents. https://www.cha.gov.tw/cp-193-5691-5cc96-2.html

- CIRS Group, 2016. South Korea restricts NP and NPE under K-REACH. https://www.cirs-ck.com/en/south-korea-restricts-np-and-npe-under-k-reach

- Correia, V.M., Stephenson, T., Judd, S.J., 1994. Characterisation of textile wastewaters - a review. Environ Technol 15, 917–929. https://doi.org/10.1080/09593339409385500

- CSE, (Centre for Science and Environment), 2008. Authorities clueless Carcinogen NP in a large number of products in India. [WWW Document]. URL http://indiaenvironmentportal.org.in/content/32665/authorities-clueless-carcinogen-np-in-a-large-number-of-products-in-india/ (accessed 11.12.24).

- de Araujo, F., Bauerfeldt, G., Cid, Y., 2018. Determination of 4-Nonylphenol in Surface Waters of the Guandu River Basin by High Performance Liquid Chromatography with Ultraviolet Detection. J Braz Chem Soc. https://doi.org/10.21577/0103-5053.20180079

- De Ruiter, H., Holterman, H.J., Kempenaar, C., Mol, H.G.J., De Vlieger, J.J., Van De Zande, J.C., 2003. Influence of adjuvants and formulations on the emission of pesticides to the atmosphere A literature study for the Dutch Research Programme Pesticides and the Environment (DWK-359) theme C-2. https://edepot.wur.nl/38200

- Denmark, 2005. Possible Control of EU Priority Substances in Danish Waters 9 Assessment of nonylphenol. https://www2.mst.dk/Udgiv/publications/2007/978-87-7052-566-4/html/kap09_eng.htm

- Department of ecology State of Washington, 2024. Chemicals of high concern to children (CHCC) [WWW Document]. URL https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Childrens-Safe-Products-Act-Reporting/Chemicals-of-high-concern-to-children (accessed 9.5.24).

- Diehl, J., Johnson, S.E., Xia, K., West, A., Tomanek, L., 2012. The distribution of 4-nonylphenol in marine organisms of North American Pacific Coast estuaries. Chemosphere 87, 490–497. https://doi.org/10.1016/j.chemosphere.2011.12.040

- ECHA, 2015. Substance Evaluation Conclusion document SUBSTANCE EVALUATION CONCLUSION as required by REACH Article 48 and EVALUATION REPORT for Nonylphenol, branched, ethoxylated United Kingdom. https://echa.europa.eu/documents/10162/7ab0382c-48e7-88fa-9dca-5defbe0b7bb2

- Ejlertsson, J., Nilsson, M.-L., Kylin, H., Bergman, Å., Karlson, L., Öquist, M., Svensson, B.H., 1999. Anaerobic Degradation of Nonylphenol Mono- and Diethoxylates in Digestor Sludge, Landfilled Municipal Solid Waste, and Landfilled Sludge. Environ Sci Technol 33, 301–306. https://doi.org/10.1021/es980669u

- EPA, 2022. Addition of Certain Chemicals; Community Right-to-Know Toxic Chemical Release Reporting. https://www.govinfo.gov/content/pkg/FR-2022-11-30/pdf/2022-25946.pdf

- European Union, 2016. Nonylphenol and Nonylphenol Ethoxylates: EU REACH Annex XVII: NP and NPEs Restriction. https://www.chemsafetypro.com/Topics/Restriction/REACH_annex_XVII_Nonylphenol_and_Nonylphenol_Ethoxylates.html

- European Union, 2002. European Union Risk Assessment Report 4-nonylphenol (branched) and nonylphenol 2 nd Priority List 4-nonylphenol (branched) and nonylphenol European Union

Risk Assessment Report. https://echa.europa.eu/documents/10162/43080e23-3646-4ddf-836b-a248bd4225c6

- Ferreira-Leach, A.M.R., Hill, E.M., 2001. Bioconcentration and distribution of 4-tert-octylphenol residues in tissues of the rainbow trout (Oncorhynchus mykiss). Mar Environ Res 51, 75–89. https://doi.org/10.1016/S0141-1136(00)00256-7
- Forte, M., Di Lorenzo, M., Carrizzo, A., Valiante, S., Vecchione, C., Laforgia, V., De Falco, M., 2016. Nonylphenol effects on human prostate non tumorigenic cells. Toxicology 357–358, 21–32. https://doi.org/10.1016/j.tox.2016.05.024
- Greenpeace International, 2012. Toxic Threads: The Big Fashion Stitch-Up. https://www.greenpeace.org/international/publication/6889/toxic-threads-the-big-fashion-stitch-up/
- Groshart, Okkerman, Wassenberg, 2001. Chemical study on alkylphenols. https://edepot.wur.nl/174304
- Hatipoglu, F., Girgin, D.C., Uludag, D., Pinar, E.U., 2024. Comparative study of styrenated-phenol and nonylphenol as accelerators in solvent-free epoxy primers. Int J Adhes Adhes 132, 103674. https://doi.org/10.1016/j.ijadhadh.2024.103674
- Ho, H., Watanabe, T., 2017. Distribution and Removal of Nonylphenol Ethoxylates and Nonylphenol from Textile Wastewater—A Comparison of a Cotton and a Synthetic Fiber Factory in Vietnam. Water (Basel) 9, 386. https://doi.org/10.3390/w9060386
- IISD Reporting service, 2019. Earth Negotiations Bulletin A Reporting Service for Environment and Development Negotiations. https://enb.iisd.org/events/15th-meeting-chemical-review-committee-crc-15-rotterdam-convention-prior-informed-consent
- IMAP, 2016. Nonylphenols: Environment tier II assessment Preface. https://www.industrialchemicals.gov.au/sites/default/files/Nonylphenols_%20Environment%20tier%20II%20assessment.pdf
- Karakaş, C., 2014. SUBSTANCE FLOW ANALYSIS OF NONYLPHENOL AND NONYLPHENOL ETHOXYLATES IN TURKEY A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES OF MIDDLE EAST TECHNICAL UNIVERSITY.
- Keith, T.L., Snyder, S.A., Naylor, C.G., Staples, C.A., Summer, C., Kannan, K., Giesy, J.P., 2001. Identification and Quantitation of Nonylphenol Ethoxylates and Nonylphenol in Fish Tissues from Michigan. Environ Sci Technol 35, 10–13. https://doi.org/10.1021/es001315h
- Kim, S.-H., Nam, K.-H., Hwang, K.-A., Choi, K.-C., 2016. Influence of hexabromocyclododecane and 4-nonylphenol on the regulation of cell growth, apoptosis and migration in prostatic cancer cells. Toxicology in Vitro 32, 240–247. https://doi.org/10.1016/j.tiv.2016.01.008
- Kishor, R., Purchase, D., Saratale, G.D., Ferreira, L.F.R., Bilal, M., Iqbal, H.M.N., Bharagava, R.N., 2021. Environment friendly degradation and detoxification of Congo red dye and textile industry wastewater by a newly isolated Bacillus cohnni (RKS9). Environ Technol Innov 22, 101425. https://doi.org/10.1016/j.eti.2021.101425
- Klemenčič, A.K., Balabanič, D., 2011. Presence of phthalates, bisphenol A, and Nonylphenol in paper mill wastewaters in Slovenia and efficiency of aerobic and combined aerobic-anaerobic biological wastewater TR presence of phthalates, bisphenol A, and nonylphenol in paper mill wastewaters in Slovenia and efficiency of aerobic and combined aerobic-anaerobic biological wastewater treatment plants for their removal. https://www.researchgate.net/profile/Aleksandra-Krivograd-Klemencic/publication/260877332_PRESENCE_OF_PHTHALATES_BISPHENOL_A_AND_NONYLPHENOL_IN_PAPER_MILL_WASTEWATERS_IN_SLOVENIA_AND_EFFICIENCY_OF_AEROBIC_AND_COMBINED_AEROBIC-ANAEROBIC_BIOLOGICAL_WASTEWATER_TREATMENT_PLANTS_FOR_THEIR_REMOV/links/0deec5329547ee2da7000000/PRESENCE-OF-PHTHALATES-BISPHENOL-A-AND-NONYLPHENOL-IN-PAPER-MILL-WASTEWATERS-IN-SLOVENIA-AND-EFFICIENCY-OF-AEROBIC-AND-COMBINED-AEROBIC-ANAEROBIC-BIOLOGICAL-WASTEWATER-TREATMENT-PLANTS-FOR-THEIR-REM.pdf
- Ko, D.S., Lee, D.R., Song, H., Kim, J.-H., Lim, C.K., 2019. Octylphenol and nonylphenol affect decidualization of human endometrial stromal

cells. Reproductive Toxicology 89, 13–20. https://doi.org/10.1016/j.reprotox.2019.06.003

- Lani, A., 2010. BASIS STATEMENT FOR CHAPTER 883, DESIGNATION OF THE CHEMICAL CLASS NONYLPHENOL AND NONYLPHENOL ETHOXYLATES AS A PRIORITY CHEMICAL AND SAFER CHEMICALS PROGRAM SUPPORT DOCUMENT FOR THE DESIGNATION AS A PRIORITY CHEMICAL OF Nonylphenol and Nonylphenol Ethoxylates. https://www.maine.gov/dep/safechem/childrens-products/rules/chapter883supplementalbasisstatement.pdf
- Lara-Moreno, A., Aguilar-Romero, I., Rubio-Bellido, M., Madrid, F., Villaverde, J., Santos, J.L., Alonso, E., Morillo, E., 2022. Novel nonylphenol-degrading bacterial strains isolated from sewage sludge: Application in bioremediation of sludge. Science of The Total Environment 847, 157647. https://doi.org/10.1016/j.scitotenv.2022.157647
- Lee, S.M., Cheong, D., Kim, M., Kim, Y.-S., 2023. Analysis of Endocrine Disrupting Nonylphenols in Foods by Gas Chromatography-Mass Spectrometry. Foods 12, 269. https://doi.org/10.3390/foods12020269
- Lepretti, M., Paolella, G., Giordano, D., Marabotti, A., Gay, F., Capaldo, A., Esposito, C., Caputo, I., 2015. 4-Nonylphenol reduces cell viability and induces apoptosis and ER-stress in a human epithelial intestinal cell line. Toxicology in Vitro 29, 1436–1444. https://doi.org/10.1016/j.tiv.2015.04.022
- Loyo-Rosales, J.E., Rosales-Rivera, G.C., Lynch, A.M., Rice, C.P., Torrents, A., 2004. Migration of Nonylphenol from Plastic Containers to Water and a Milk Surrogate. J Agric Food Chem 52, 2016–2020. https://doi.org/10.1021/jf0345696
- M. M. Nijkamp, L.M.J.E.D. and J.J.A.M., 2014. Hazardous Substances in Textile Products. Bilthoven .
- Mahalakshmi, R., Pugazhendhi, A., Brindhadevi, K., Ramesh, N., 2020. Analysis of Alkylphenol ethoxylates (APEOs) from tannery sediments using LC–MS and their environmental risks. Process Biochemistry 97, 37–42. https://doi.org/10.1016/j.procbio.2020.06.015
- Malmir, M., Faraji, T., Ghafarizadeh, A.A., Khodabandelo, H., 2020. Effect of nonylphenol on spermatogenesis: A systematic review. Andrologia 52. https://doi.org/10.1111/and.13748
- Manzano, M.A., Perales, J.A., Sales, D., Quiroga, J.M., 1999. The effect of temperature on the biodegradation of a nonylphenol polyethoxylate in river water. Water Res 33, 2593–2600. https://doi.org/10.1016/S0043-1354(98)00480-1
- Mao, Z., Zheng, X.-F., Zhang, Y.-Q., Tao, X.-X., Li, Y., Wang, W., 2012. Occurrence and Biodegradation of Nonylphenol in the Environment. Int J Mol Sci 13, 491–505. https://doi.org/10.3390/ijms13010491
- Metcalfe, C.D., Bayen, S., Desrosiers, M., Muñoz, G., Sauvé, S., Yargeau, V., 2022. An introduction to the sources, fate, occurrence and effects of endocrine disrupting chemicals released into the environment. Environ Res 207, 112658. https://doi.org/10.1016/j.envres.2021.112658
- OEcotextiles, 2024. APEOs and NPEOs in textiles [WWW Document]. URL https://oecotextiles.blog/tag/nonylphenol-ethoxylates/ (accessed 8.6.24).
- Pavan, M., Samant, L., Mahajan, S., Kaur, M., 2024a. Role of Chemicals in Textile Processing and Its Alternatives. pp. 55–72. https://doi.org/10.1007/978-981-99-9856-2_5
- Priac, A., Morin-Crini, N., Druart, C., Gavoille, S., Bradu, C., Lagarrigue, C., Torri, G., Winterton, P., Crini, G., 2017. Alkylphenol and alkylphenol polyethoxylates in water and wastewater: A review of options for their elimination. Arabian Journal of Chemistry 10, S3749–S3773. https://doi.org/10.1016/j.arabjc.2014.05.011
- Pubchem, 2024. 4-Nonylphenol [WWW Document]. URL https://pubchem.ncbi.nlm.nih.gov/compound/4-Nonylphenol (accessed 10.4.24).
- Raecker, T., Thiele, B., Boehme, R.M., Guenther, K., 2011. Endocrine disrupting nonyl- and octylphenol in infant food in Germany: Considerable daily intake of nonylphenol for babies. Chemosphere 82, 1533–1540. https://doi.org/10.1016/j.chemosphere.2010.11.065
- Raju, S., Sivamurugan, M., Gunasagaran, K., Subramani, T., Natesan, M., 2018. Preliminary studies on the occurrence of nonylphenol in the marine environments, Chennai—a case study. The Journal of Basic and Applied Zoology 79, 52. https://doi.org/10.1186/s41936-018-0063-1

- Ringbeck, B., Belov, V.N., Schmidtkunz, C., Küpper, K., Gries, W., Weiss, T., Brüning, T., Hayen, H., Bury, D., Leng, G., Koch, H.M., 2021. Human Metabolism and Urinary Excretion Kinetics of Nonylphenol in Three Volunteers after a Single Oral Dose. Chem Res Toxicol 34, 2392–2403. https://doi.org/10.1021/acs.chemrestox.1c00301

- Roy Choudhury, A.K., 2014. Environmental Impacts of the Textile Industry and Its Assessment Through Life Cycle Assessment. pp. 1–39. https://doi.org/10.1007/978-981-287-110-7_1

- Saha, S., Narayanan, N., Singh, N., Gupta, S., 2022. Occurrence of endocrine disrupting chemicals (EDCs) in river water, ground water and agricultural soils of India. International Journal of Environmental Science and Technology 19, 11459–11474. https://doi.org/10.1007/s13762-021-03858-2

- Saravanan, M., Nam, S.-E., Eom, H.-J., Lee, D.-H., Rhee, J.-S., 2019. Long-term exposure to waterborne nonylphenol alters reproductive physiological parameters in economically important marine fish. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology 216, 10–18. https://doi.org/10.1016/j.cbpc.2018.11.009

- Selvaraj, K.K., Shanmugam, G., Sampath, S., Joakim Larsson, D.G., Ramaswamy, B.R., 2014. GC–MS determination of bisphenol A and alkylphenol ethoxylates in river water from India and their ecotoxicological risk assessment. Ecotoxicol Environ Saf 99, 13–20. https://doi.org/10.1016/j.ecoenv.2013.09.006

- Sengul, S., Cevdet, U., 2017. Nonylphenol in Human Breast Milk in Relation to Sociodemographic Variables, Diet, Obstetrics Histories and Lifestyle Habits in a Turkish Population. Iran J Public Health. PMCID: PMC5439038

- Shekhar, S., Sood, S., Showkat, S., Lite, C., Chandrasekhar, A., Vairamani, M., Barathi, S., Santosh, W., 2017. Detection of phenolic endocrine disrupting chemicals (EDCs) from maternal blood plasma and amniotic fluid in Indian population. Gen Comp Endocrinol 241, 100–107. https://doi.org/10.1016/j.ygcen.2016.05.025

- Soares, A., Guieysse, B., Jefferson, B., Cartmell, E., Lester, J.N., 2008a. Nonylphenol in the environment: A critical review on occurrence, fate, toxicity and treatment in wastewaters. Environ Int 34, 1033–1049. https://doi.org/10.1016/j.envint.2008.01.004

- The Bureau of Indian Standards (BIS), 4-NONYLPHENOL — SPECIFICATION, Doc No.: PCD 09(18967) WC April 2022, https://resource.chemlinked.com.cn/chemical/articles/file/is-4-nonylphenol-1.pdf

- Toxics Link, 2024. Nonylphenol – An Endocrine Disrupting Chemical. https://toxicslink.org/publications/reports/nonylphenol-an-endocrine-disrupting-chemical

- Toxics Link, 2023. Stitched with chemicals: Understanding Nonylphenol presence n Textile Products. https://toxicslink.org/wp-content/uploads/2023/08/Nonyphenol%20Textile%20Report%202023.pdf

- Toxics Link, 2022. Toxic Chemical "Nonylphenol" A Barrier to Safe Drinking Water. https://toxicslink.org/publications/reports/toxic-chemical-nonylphenol-a-barrier-to-safe-drinking-water

- Toxics Link, 2019. Dirty Trail Detergent to Water bodies. New Delhi. https://toxicslink.org/publications/reports/nonylphenoldirty-trail-detergent-to-water-bodies

- UK gov, 2013. Nonylphenol ethoxylates (NPE) in imported textiles. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1026176/Nonylphenol_ethoxylates_in_imported_textiles_-_withdrawn.pdf

- US EPA, 2005. Aquatic life ambient water quality criteria—nonylphenol [WWW Document]. URL https://nepis.epa.gov/Exe/ZyNET.exe/P1004WZW.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2000+Thru+2005&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C00thru05%5CTxt%5C00000021%5CP1004WZW.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Re-

sults%20page&MaximumPages=1&ZyEntry=1&-SeekPage=x&ZyPURL (accessed 8.8.24).

- USEPA, 2024. Fact Sheet: Nonylphenols and Nonylphenol Ethoxylates. https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/fact-sheet-nonylphenols-and-nonylphenol-ethoxylates

- USEPA, 2004. List of Inert Pesticide Ingredients List 4B - Other ingredients for which EPA has sufficient information to reasonably conclude that the current use pattern in pesticide products will not adversely affect public health or the environment. - By Chemical Name. US EPA Inert (other) Pesticide Ingredients - List 4B by Chemical Name

- Wen, H.-J., Chang, T.-C., Ding, W.-H., Tsai, S.-F., Hsiung, C.A., Wang, S.-L., 2020. Exposure to endocrine disruptor alkylphenols and the occurrence of endometrial cancer. Environmental Pollution 267, 115475. https://doi.org/10.1016/j.envpol.2020.115475

- Xu, C., Ling, H., Fan, C., Xiang, L., Zhang, S., Li, W., Yi, C., 2022. Higher levels of nonylphenol were found in human urine and drinking water from rural areas as compared to metropolitan regions of Wuhan, China. Environmental Science and Pollution Research 29, 66950–66959. https://doi.org/10.1007/s11356-022-20513-6

- Yixiu Wu, 2015. You did it! Toxic chemical banned in EU textile imports. You did it! Toxic chemical banned in EU textile imports - Greenpeace International

- Zhong, M., Yin, P., Zhao, L., 2017. Nonylphenol and octylphenol in riverine waters and surface sediments of the Pearl River Estuaries, South China: occurrence, ecological and human health risks. Water Supply 17, 1070–1079. https://doi.org/10.2166/ws.2017.002

Toxics Link
for a toxics-free world

H-2, Jangpura Extension
New Delhi - 110014, India
T: +91-(0)11-49931863

https://www.instagram.com/toxics_link/
https://www.facebook.com/toxicslink
https://twitter.com/toxicslink
https://www.youtube.com/toxicslink
www.toxicslink.org