Plastics, Gender and the Environment

Findings of a literature study on the lifecycle of plastics and its impacts on women and men, from production to litter

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Imprint

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We are grateful to the following editorial reviewers Trang Nguyen (UN), Olga Speranskaya (IPEN / Eco- Accord), Irene Dankelman (Radboud University Nijmegen, IRDANA Advise), Alexandra Caterbow (WECF)

Layout: Caroline Schoon, WECF
Photos by WECF, unless mentioned otherwise
Cover photos: WECF, Zeehondencentrum Pieterburen

Acknowledgements: This publication was financially supported by the European Union, Women2030 und Heinrich-Böll-Stiftung, Berlin.

ISBN 978-3-9813170-8-4

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Executive Summary

The main objectives of the small scale funding agreement and UNEP for the literature study "Gender and Plastics Management" are: to conduct research on the links between gender and plastics consumption and production, with focus on the impacts of the chemicals used in plastic production on human health, as well as the roles of women and men as agents of change in reducing the impacts of plastics on the environment (especially marine environment) and human health.

Results of this research will provide information to support the content development of the UNEA Study on Marine plastic debris and microplastics, and the GGEO (Chapter of State, Trends and Impacts) in sections related to sustainable consumption and production, gender and ocean protection, land management, and waste management.

Main findings from the literature study

Plastic production and consumption: The packaging industry uses about 40% of the global plastic production, and households use about 20% of the global plastics for consumer products. Studies found women buy basic consumer goods such as food, health items, clothing and household products more often than men. Men more often buy expensive goods like cars and electronic equipment. Studies showed also that two thirds of the global consumption of plastic material took place in the wealthiest regions: NAFTA, Western Europe and Japan. Thus, to some extend these facts could let us conclude that women in the wealthiest regions are important stakeholders to reducing plastics in basic consumer goods. However, the plastic consumption per person in less-wealthy regions is much lower than in wealthier countries, due to an inadequate collecting and processing infrastructure, the release of plastic litter into the environment can be much higher in the less wealthy region. It is forecasted that in the period 2015-2020 the global market for flexible plastics will grow annual by 3.4 %, with the annual growth rate in India and China expected to be between 9.4% and 6.9% respectively.

Plastics and hazardous chemicals: Studies, mainly from wealthy countries showed that both men and women can be at risk from hazardous chemicals during plastic production, usage and disposal. Very little research is available on the exposure of the work force to hazardous chemicals in the plastics industry in less-wealthy countries. Moreover, on a global level there is very scarce gender disaggregated literature to be found about the number of workers in the plastic industry, and their exposure to hazardous chemicals and resulting health effects during the several specific processes of plastic production and plastic waste management (i.e. recycling, incineration). Not only during production, but also in daily life, plastics, for example plastics from packaged food, PVC flooring, can release hazardous chemicals such as Endocrine Disrupting Chemicals (EDCs, affecting both men and women. In addition, EDCs are also identified in personal care and cosmetic products (PCCPs), of which women are the biggest users. In response to the finding that there is globally a considerable gap of knowledge about the health effects on men and women working in the plastic industry and plastic waste management, evidence on the health risks should be investigated and addressed particularly in less-wealthy countries beginning with implementing current health and safety legislation.

Management of waste: Taking a global perspective, the low income and lower-middle income countries dispose of far less amounts of municipal solid waste than the high and upper-middle income countries. Nevertheless globally landfilling of waste is still the most common practice. The EU collectively exports almost half of the plastics collected for recycling, at least 87% of which goes to China.

Although the household use of plastics in less wealthy countries is much lower than in wealthy countries, the less wealthy countries contribute to a large extend to plastic litter in waterways and Oceans due to the poor or lacking waste management. Globally 80% of the marine litter is land-based; five Asian countries contribute with more than half to the marine litter.

In addition, incineration is a part of plastics management and depending on the country these practices can be under controlled or uncontrolled conditions. Informal waste workers and pickers are important for collecting and recycling of waste in countries without formal waste management. More women earn livelihoods in the informal waste and recycling sectors than in similar formal occupations.

PET and PE is for waste pickers and recyclers the most valuable plastic and the most often recycled. However imported plastics or those collected from a landfill, may be too dirty for recycling. Men are more prone to collect high value recyclables than women.

Waste management, i.e. recycling behaviour, cannot be generally attributed to males or females, but there are gender roles, which may differ between cultures. As a consequence, exposure to health hazards may differ due to such gender roles. Key findings regarding the global practices on waste management are: international efforts should be made in particular to reduce the wealthy countries plastics waste disposal, targeting women as important stakeholders; infrastructure for adequate recycling practices should be communicated and established; formal and informal landfilling and incineration should be minimised, and the needs of men and women in the informal waste sector should be addressed.

Microplastics: The findings regarding the release of microplastics into the environment show the complexity of the causes and sources of microplastics. Investigated atmospheres, rivers, lakes and oceans are contaminated with different types of microplastics and from different land-based sources. The sources of the pollution depend on the location and the local/regional activities. To mention a few examples: the presence or absence of a plastic industry; population density and activities (released litter, washing machines, traffic); consumer habits on using PCCP and detergents with microplastics; level and type of solid waste management; and marine activities. Investigations showed that in Europe the fragmentation of plastic debris is the main source of microplastics, followed by tyre abrasion and pellet loss. Gender specific roles differ between cultures and activities. Evidence indicates that the uptake of plastic particles and associated chemicals through seafood consumption poses threats to human health. Evidence also indicates that micro plastics can be transported through the placenta to unborn foetuses. However, the amount and type of ingested plastic particles, and consequently the risks for human health upon consumption, depends on several factors and may vary between countries, species and populations of fish and seafood. To prevent future damage to human health and wildlife, intentionally added microplastics in PCCPs, such as in toothpaste, shampoos, baby care products or cleaning and maintenance products, needs to be prohibited as they are apparently easy to replace by harmless substances.

Environmental behaviour and gender roles: Research showed women tend to perceive various hazards as more risky in comparison to men and are less willing than men to impose health and environmental risks on others. However, waste management cannot generally be attributed to males or females, but there are gender roles, which may differ between cultures. Educational campaigns on all levels targeting decision-makers, men and women, and male and female consumers on, for example, the consequences of purchasing, reusing and disposing of plastic consumer goods, impacts and sources of microplastics in the environment and in food, microplastics in PCCP, and adequate plastic waste management need to take place.

Biodegradable plastics: based on the available evidence it can be concluded biodegradable plastics will not contribute to a reduction of marine litter.

Agents of change: men and women can act as agents of change in order to reduce plastics related to basic consumption and to increase the recycling rate of plastics. Nevertheless, awareness of the environmental problems related to plastics has to be raised globally among men, women and decision-makers. A reduction of plastic use in daily life requires a multi-sectorial approach. A regional or national ban on plastic bags and plastic one use disposable items is one step, moreover retailers and in particular consumers are important stakeholders for realizing a reduction of plastic consumption at household level. Alternatives to plastic goods have to be incentivised, promoted and produced. Globally, accessible and affordable infrastructures for the safe collection and recycling post-consumer plastics have to be in place.

The report

Section 1 "Understanding the overall dimensions of gender in plastic production and consumption" presents the dimension of production of plastic materials in different global regions and the demand and type of application of the most used plastics. Insight is given on the global annual consumption of plastics per capita and gender aspects of expenditures for consumer goods. This section ends with reflections on what could be done to reduce the consumption of consumer plastics.

Section 2 "Workforce and exposure in the plastic industry" describes problems faced by the workforce in the plastics industry and working with plastic and plastic containing products, and their exposure to chemicals used in plastic. Social and physical aspects of men and women which influence the workplace environment for both sexes, and also exposure to possible hazardous chemicals are highlighted. As far as was available, findings from literature on observed health impact on men and/or women in relation to chemicals associated with plastics was included. This section finishes with a discussion on programs or regulations to reduce exposure of hazardous chemical in the workplace.

Section 3 "Overview of hazardous chemicals in plastics and their impact on women´s and men´s health" gives examples of some specific chemicals (EDCs) in plastics and their impact on men´s and women´s health. Impacts in relation to plastic chemicals are presented in connection with male and female reproductive health, breast cancer and hypospadias.

Section 4 "Exposure to hazardous chemicals from some everyday products" describes some everyday plastic products that are globally used, such as PVC flooring or window frames, plastic toys and personal care and cosmetic products. Studies related to hazardous chemicals found in PVC flooring and toys and the associated health risks are presented. Furthermore, attention is given to the appearance of microplastic particles in PCCPs. The route of human exposure to microplastics from PCCP and related health risks are explained.

Section 5 "Gender and microplastics management" is dedicated to microplastics: what microplastics are and what are the sources in the environment (i.e. from oceans, rivers and lakes)? Examples of products are presented, where (primary) microplastics are added as an active ingredient, and examples of plastic products, which due to physical or composing processes release microplastics into the environment. Studies regarding the sources of microplastics in oceans and rivers are presented. Efforts are made to identify possible impact of men´s and women´s behaviour on the different sources of microplastics in the environment.

Section 6 "Marine environment: Exposure to (micro-) plastics and health aspects for aquatic organisms" focuses on the pathways of microplastics and the occurrence of microplastics in the marine environment and related health impacts on aquatic organisms. Studies showing the uptake of plastic particles and the transfer between trophic levels, along with the accumulation of plastic particles in animals are discussed. Gender aspects in relation with marine litter and the consumption of contaminated seafood are highlighted.

Section 7 "Plastic waste management" presents several aspects of (plastic) of waste management. General information is given about the globally different level of municipal solid waste generation, the level of plastic waste recovery and recycling rates. Aspects of informal waste collecting and recycling are considered and any studies with gender sensitive findings are included. In this section, studies of other common practices of waste management such as landfilling and dumping, controlled and uncontrolled incineration are presented.

Section 8 "Green consumerism, environmental awareness and behaviour" examines the association of gender with green consumerism, environmental awareness and behaviour. Studies on the influence of social determinants of consumers and the related plastic exposure are discussed as well gender roles and behaviour influencing the level of waste generation and management. A part of this section is dedicated to factors influencing pro-active behaviour and attitudes of men and women.

Section 9 "Wastewater" describes the occurrence of micro plastics in wastewater and the restrictions of wastewater treatment plants to retain microplastics. Besides microplastics from litter, washing machines and PCCP, this section highlights also the problematic issue for treatment plants of dealing with personal hygiene products like tampons or disposable napkins in the water.

Section 10 "Bio-plastics and classification of plastic waste" explains the differences between bio-degradable plastics and bio-plastics and its decomposition. This section also covers the classification of plastic waste.

Section 11 "Main findings from the Literature study and 12 "Recommendations" presents the main findings of this literature study and recommendations.

Section 13 "Women and men as agents of change" discusses the issue of women and men as agents of change in order to reduce the plastic consumption (and thus the production) and gives some examples of action that could be taken.

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Tables, figures and boxes

Abbreviations

ABS	Acrylonitrile butadiene styrene
AC	Acrylic
BDE	Bromodiphenyl ether
BPA	Bisphenol A
BADGE	Bisphenol A diglycidyl ether
CDC	Centers for Disease Control and Prevention
CE	Central Europe
CEO	Chief Executive Officer
CIS	Commonwealth of Independent States
COSHH	Control of Substances Hazardous to Health
CSO	Civil Society Organisation
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DEHP	Di-(2-ethylhexyl) Phthalate
DNA	Deoxyribonucleic acid
EEC	European Economic Community
EDC	Endocrine Disrupting Chemical
EfW	Energy from Waste
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agriculture Organization
Fs	Furans
HDPE	High density polypropylene
ILO	International Labour Organization
ISWA	International Solid Waste Association
LDPE	Low Density Polypropylene
MSW	Municipal Solid Waste
NAFTA	North American Free Trade Agreement
NGO	Non-Governmental Organisation
NP	Nonylphenol
OECD	Organisation for Economic Co-operation and Development
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyls
PCCD	Poly-Chlorinated dibenzo-dioxins
PCCP	Personal Care and Cosmetic Products
PCP	Personal Care Products
PE	Poly Ethylene
PES	Polyester
PET	Polyethylene terephthalate
PHA	Polycyclic aromatic hydrocarbon
PMMA	Polymethyl methacrylate
POP	Persistent Organic Pollutants
PP	Polypropylene
PS	Polystyrene
PUR	Polyurethane
PVC	Polyvinyl chloride
RAPEX	Rapid Exchange of Information System
RIC	Resin Identification Code
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
USA	United States of America
WE	Western Europe
WECF	Women Engage for a Common Future

Introduction – The nexus of gender and plastic

Gender differences define and shape the lives of men and women on many levels. In many cases it defines how we interact with our surroundings and in some cases where we work and how we live. Gender affects our health as biologically and socially defined roles affect and often dictate the work we do, where we live our lives and ultimately our health. Our gender roles do not exist in isolation but are defined in relation to one another and help define the power and hierarchy between the sexes.

Because of the ubiquitous nature of plastic, we are intrinsically linked with plastic in many ways due to our assigned gender roles, affecting us through usage, disposal, and through to how it is recycled, depending on cultural and social aspects, economic circumstances, and availability. Impacts on health can be compounded by the fact that there is a lack of studies, which consider gender, social status, and the specific living and working environments inhabited by women and men. General differences between males and females, independent of culture and geographic location, can be seen in relation to biological factors, like effects on the hormonal system, and on menstruation as well as pregnancy and breast-feeding.

70 Years since world war ll, plastic consumption has intensified. More and more studies and observations show that plastics can have a negative impact on all living organisms. Increasing numbers of studies and/or literature reviews on the exposure and toxicity of additives in plastics for humans; on the appearance of plastics in the environment; and on microplastics in body care products and in the Oceans, are published and reported in the media.

Although evidence on the interaction and association of chemicals in plastic debris in the environment (especially in soil, fresh water and the oceans) and their impacts on human health have been studied and fragmentally collected worldwide, there is little documented research and knowledge on the specific roles of women and men as agents of change in the management, production and usage of chemicals and plastics. Much can be learned from occupational studies showing correlations between plastics and ill health, compounded by the subsequent environmental exposures through contaminated air, food, soil and water. The lack of knowledge and information in this area does not imply that this issue does not exist or is not important, quite the contrary. One of our findings reveals that most studies on the interrelationship between gender, plastics and chemical management, including the different gender roles in the use and impact of plastics, plastic additives and plastic waste, are fragmented, and gender aspects are wholly considered.

This literature study intends to give insight into the gender-disaggregated aspects of impacts of plastics exposure to human health. Assessment will be considered throughout the entire life cycle, from production, up to their release into the environment or their management after usage, as well as the differentiated gender roles at each stage, and exploring the potential for men and women as agents of change in managing plastic-related waste. The implications of plastics and related hazardous substances in daily life for women, men and vulnerable groups, as well for aquatic (marine) life will be highlighted. Due to the existence of huge varieties of different types of plastics, this study mainly targets six types (PP, PE, PVC, PS, PET, PUR) of the most commonly used plastics and their life cycles. Gaps of knowledge on potential negative practices and environmental implications will be identified.

1. Understanding the overall dimensions in plastic production and consumption

Plastics have a large variety of properties including the fact that they are lightweight, resistance to breakage and chemicals, have electrical and thermal insulating capacity, are impermeable to water, light, and gases, all which contribute to making plastics the global all-purpose material particularly over the last decades.

When most of us think about plastics in relation to our daily lives, we think of plastic bags and packaging, which depending on how our waste is managed, are recycled, incinerated or disposed of in our environment.

In reality, dozens of types of plastics are on the market, each with its own purpose, its own properties and its own chemical formulation. Different types of plastics are required for example for toys, synthetic clothing, household items, coating's for furniture and doors, or construction materials for buildings or cars.

A listed summary of the production and consumption of plastics is given to help underscore understanding of the global management of plastics, their life cycle and potential gender disaggregated impacts on human health and the environment, and to formulate recommendations for policies on production, usage and disposal of plastics along with changes to consumer behaviour.

The world's plastic production increased by almost 20% from 250 million tonnes in 2009 up to 299 million tonnes in 2013, this includes plastics materials (thermoplastics and polyurethanes), other plastics (thermosets, adhesives, coatings and sealants) and PP-fibres (Plastics Europe 2015). As Table 1 shows, China is the biggest producer of plastic materials followed by Europe and the NAFTA countries.

Although global figures on the percentage usage of specific types of plastics are hard to get, information about the most common plastics and their usage in the European market and in the Indian sub-continent are published respectively by PlasticEurope (Plastics Europe 2015) and by Plastics On-Line. Polypropylene (PP), Polyethylene (PE) and Polyvinyl chloride (PVC) represent in both continents the main types of plastics and are used in many products, which can be found in most households and as packaging materials. Since women are still the main purchasers for their families they can have an impact on what products and related packaging they are going to buy, especially for food (Sayre, M. J. Silverstein 2009).

However, during transport to the consumer, fragile food and equipment may be protected by the producer or retailer with plastic packaging and this is not directly in the individual's sphere of influence

On a global level food and beverages packaging applications was the largest segment of the packaging industry with a demand of 55% of the entire plastic market.

Table 1: Worldwide production of plastic materials (thermoplastics and polyurethanes) in 2013

Does not include other plastics (thermosets, adhesives, coatings and sealants) nor PP-fibres.	
China	24,8%
Europe (WE +CE)	20,0%
NAFTA (Canada, USA, Mexico)	19,4%
Rest of Asia	16,4%
Middle East, Africa	7,3%
Latin America	4,8%
Japan	4,4%
CIS (Commonwealth of Independent States)	2,9%

Source: PlasticsEurope, 2015 (PEMRG) / Consultic

The demand for plastic packaging had a 35% share of the overall market with Asia Pacific dominating regionally due to a strong demand by India and China (Market Research Store 2016).

It is forecasted that during the period 2015-2020 the global market tonnage for flexible packaging will grow annually on average by 3.4%. The global growing rate for rigid plastics, amongst others PET bottles, was estimated on annually 4.4% until 2020 (Smithers Group 2015b).

The market for plastic packaging is in India and China the fastest growing market. For flexible plastic packaging the growing rate is estimated with annual 9.4% and 6.9%, respectively (Smithers Group 2015a).

The PlasticEurope report (2015) mentions that in Europe packaging applications are the largest application sector for the plastics industry and represents 39.6% of the total plastics demand.

Building and construction is the second largest application sector with 20.3% of the total European plastics demand. In Canada 33% of the plastics is used for construction. The Automotive industry in Europe is the third sector with a share of 8.5% of the total demand and 14% in Canada. Electrical and electronic applications represent 5.6% of the plastics demand.

Building and Wood Workers' International estimates that there are up to 180 million construction workers worldwide, with 75% in developing countries. Many of the workers are informal and women tend to make up less than 10% of the workers in each world region. There is a potential for exposure given the everincreasing amount of plastic used in or added to construction materials.

Table 2: The most commonly used plastics on the European market and the Indian subcontinent in percentages, with examples of usage

Some of the most common plastics	European Market*	Indian subconti-nent **	Examples of usage
Polypropylene (PP)	18.9%	30%	Crisp bags, food containers, bottle caps, drinking straws, yogurt containers, flowerpots, plastic pressure pipe systems, car fenders (bumpers).
Polyethylene low density and linear low density (PE-LD and PE-LLD)	17.5%	16%	Plastic bags, film for food packaging, cables sheaths, cosmetic and pharmaceutical tubes
PE – high density (HDPE)	12.1%	18%	Detergent jerricans, and bottles, fuel containers, buckets, milk jugs, toys, wastewater and drinking water tubes
Polyvinyl chloride (PVC)	10.4	21%	Window frames, floor tiles, wire and cable insulation, garden hoses, Plumbing pipes and guttering, shower curtains, window frames, flooring.
Polystyrene solid (PS)	7.1	3%	Food containers, plastic tableware, disposable cups, plates, cutlery, CD and cassette boxes.
Polystyrene expandable (PS-E)			Trays, plates, bowls and fish boxes, moulded sheets for building insulation and packing material (peanuts).
Polyethylene terephthalate (PET)	6.9	8%	Mineral water bottles, 2 litre soda bottles, other jars and bottles and food (microwavable) packaging, plastic film
Polyurethane (PUR)	7.4	Not listed	Cushioning foams, thermal insulation foams, surface coatings, printing rollers, pur-sponges.
Others	19.7	4%	Teflon coated pans, ABS-bricks, Polycarbonate fridge trays.

Source: Authors own table, adapted from:
** PlasticsEurope, 2014. Plastics – the Facts 2014*
*** http://www.plastics.gl/market/worlds-fastest-growing-regional-polymer-market/*

Agricultural applications have a 4.3% share of the overall production. Other application sectors such as appliances, household and consumer products, furniture and medical products comprise a total of 21.7% of the European plastics demand. This sector produces various products, which touch the nexus of gender and plastics in variety of ways. Nurses and medical professionals are exposed to substances in plastic via medical devices such as phthalate containing tubes, etc. Makers and vendors of furniture, shoes or toys are exposed to indoor air, which can contain high levels of toxic substances, which off-gas out of the plastic in these products.

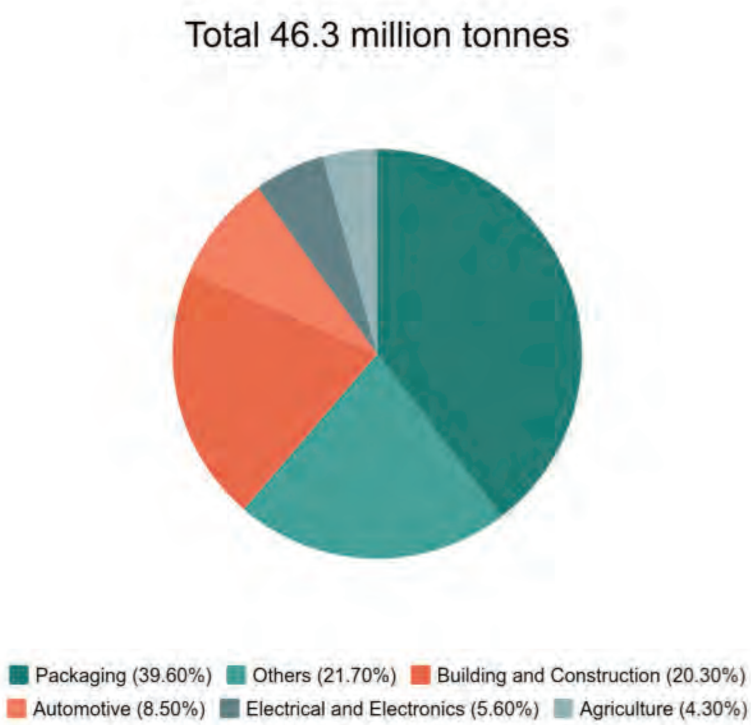
The majority of plastic packaging is made with one of six resins: polyethylene terephthalate (PET); high-density polyethylene (HDPE); polyvinyl chloride (PVC or vinyl); low-density polyethylene (LDPE); polypropylene (PP); or polystyrene (PS). In order to make it easier to identify the different types of polymers for recycling purposes in Europe, a Resin Identification Code (RIC) system was established, and assigns each of these resins a number from 1 to 6.

The coding system also includes a seventh code, identified as "other." Use of this code indicates that the product in question is made with a resin other than the six. Besides the 6 most common usedplastics (Table 2), which cover about 80% of the total plastic production, there are a large range of special purpose plastics.

A few examples are: *Melamine formaldehyde (MF) and Urea formaldehyde (UF)*. In the household, these two plastics can be used for covered Formica, in plates or toilet seats, MF for laminates (EngineersHandbook.com 2006). *Polymethyl methacrylate (PMMA)* (also known as Acrylic) is best-known as plexi-glass and for example, it is used for patios and in the automotive industry (Europe n.d.). Furthermore, it forms the basis of artistic and commercial acrylic paints.

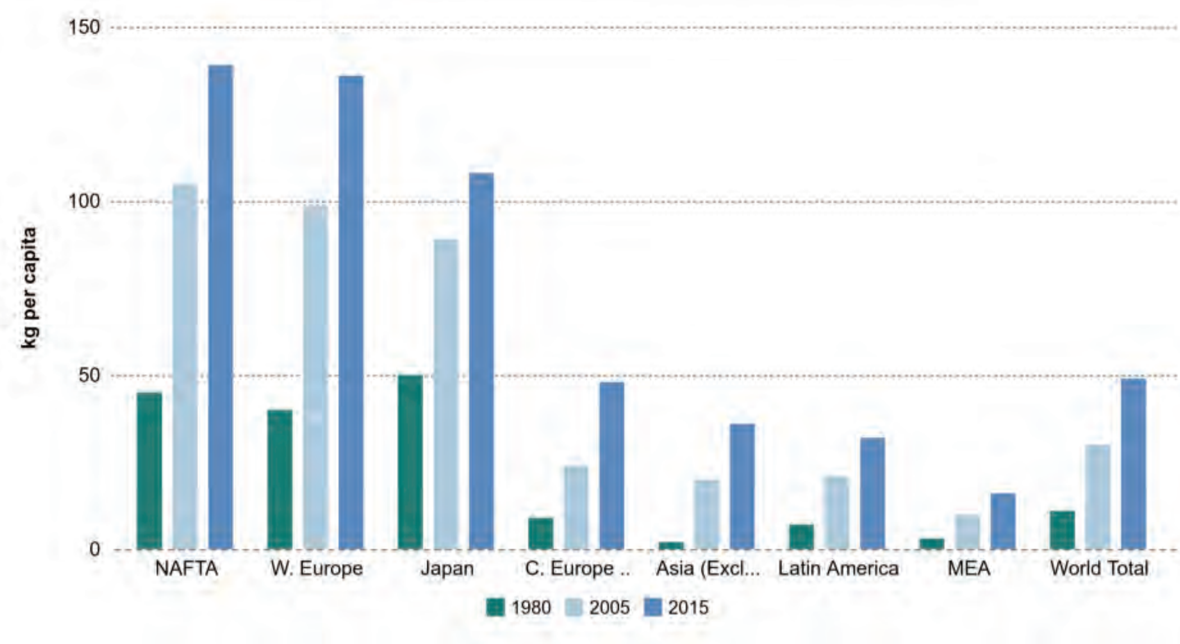
The statistical data presented in Figure 2 shows that people from the world's wealthiest regions have the highest consumption of plastic materials.

Figure 1: European plastic applications demand by different sectors in 2013



Source: PlasticsEurope, Plastics - the facts 2014/2015. "Others" including sectors such as household and consumer appliances, furniture, sport, and medical products.

Figure 2: Global consumption of plastic materials by region in kg per capita for 1980, 2005 and 2015



Source: http://www.statista.com/statistics/270312/consumption-of-plastic-materials-per-capita-since-1980/

From 2005 to 2015, the global plastic consumption increased by more than 50%, an annual grow of approximately 5% (Portal n.d.)It is expected that the global plastic demand will continue growing, from 233.75 million tons in 2013 to 334.83 million tons in 2020 (Grand View Research 2014).

In India, the demand for plastics while far behind countries like the US or China was estimated at 9.7 kg/capita consumption with an estimated demand of 16.5 million metric tonnes by 2016-2017. Currently, out of the 15,342 tons of plastic waste generated each day in India, 60% is collected and recycled while the remainder ends up in the environment.

From Figure 2, it can be concluded that in 2015 two thirds of the global consumption of plastic material per capita takes place in the wealthiest regions: NAFTA, Western Europe and Japan; in these most wealthiest regions a person consumed on average 3 to 4 times more plastic materials than a person in an Asian country (excluding Japan). However, researchers found that due to the mismanagement of plastic waste between 55% and 60% of the land-based plastics found in the Oceans, originates from five Asian countries where growth is very fast: China, Indonesia, the Philippines, Thailand and Vietnam (Conservation 2015) (see also chapter 6).

Gender aspects of plastic consumption expenditures

Consumption patterns of men and women are linked to consumption expenditures, which can be used to measure consumption patterns. But as Schultz and Stieß (2009), observed, consumption expenditures as collated by groups like Eurostat, are usually assigned to 'household behaviour', and are not disaggregated by sex (though there are exceptions in countries like Sweden or the UK). From Nordic European countries statistic, disparities were found between men and women on how they spend their financial resources on consumer goods. Men are more likely to buy expensive goods like homes, cars, electronic equipment; women more often buy basic consumer goods related to health, food, clothing and household articles (Schultz 2009).

Taking the global plastic demand into consideration about one fifth (21.7%) of the global demand is used for sectors such as household and consumer appliances, furniture, sport, and medical products (Figure 1).

Another approach to get insight into plastic consumption by men and women at a household level is to have a closer look at the packaging demand. Forty percent of the global plastic demand is used for packaging (Figure 1). It Is estimated that about half of the global packaging, by end market, is used for packaging food (pots, jars, flexible plastics) (Ernst et al. 2013). No studies were found on which part of food packages are applied to and/or bought by consumers or are used for or transporting food to and by the retailer.

As stated before, at household level it is more likely that women buy most of the food and other basic consumer goods; and this should be considered against the fact that, about 20% of the global plastic demand is at household level, and of that, two- thirds of this demand arises in NAFTA countries, Western Europe and Japan.

From these facts, one can conclude that women, at least in the wealthiest countries, could play an important role in reducing the application of plastic consumer goods in the household (Table 3).

Generally, the gender dimension of plastic production and consumption could be examined most obviously through: i) the analysis of the workforce in plastic-related industries, ii) the available data and cases of the role of men and women in plastic-consumption, (and thus, their respective roles in behaviour changing regarding choices, usage and disposal of plastic products), and iii) the workforce and participation of men and women in plastic-related waste management and waste-water treatment processes. It is important to emphasise that although gender dimensions could be observed qualitatively in the above mentioned aspect of plastic management, there is real data scarcity, irrespective of geospatial and socio-political context, to support a comprehensive analysis, given the fairly new attention to this.

Examples of reducing plastic consumption in daily life

So, the question is what can be done in order to reduce plastic consumption?

It is crucial to reduce packaging at source and raise awareness among consumers, especially in the wealthiest countries. Policy makers should be pressured to introduce and implement stricter regulation and possible taxes to reduce packaging.

In Australia, for example, One Million Women - is a campaign started because women make 85% of the household purchasing decisions and if one million women make better choices, it could lead to real change. The group produces information on how to work towards a zero waste kitchen and saying no to disposable plastic items such as cling wrap, plastic cutlery, cups etc. The aim is to live a low-carbon life and cut over 1 tonne of CO_2 pollution from daily life. A number of individuals have initiated plastic reduction campaigns on line using social media to raise awareness. Although the actions might be more locally based or individualistic, it inspires others when it is published on line through blogs, twitter, and Facebook feeds.

Retailers and industry play a huge part in reducing waste they generate during production and selling the final products. In the UK, the charity WRAP works with businesses, trade associations, local authorities and charities to move them towards a more sustainable and resource efficient economy. They run campaigns to reduce food and primary packaging waste from ending up as household waste and inform households and individuals on recycling and reducing consumption and waste.

Table 3: Selection of data on the application and consumption of plastics in household settings

Action related to plastics	Rates and quantities	Source
Annual consumption of plastic materials per capita (2015)	NAFTA, western Europe, Japan 108-139 kg Other global regions: 16-48 kg	Global Consumption of Plastic Materials by Region 1980 to 2015. Statista 2016
Women buy more often than men (Nordic countries)	Basic consumer goods: food, health, clothing and household articles	Gender aspects of sustainable consumption strategies and instruments. Institute for Social-Ecological Research (ISOE) 2009
European plastic demand	40% is used for packaging 20% is used for household and consumer appliances, furniture, sport, and medical products.	PlasticsEurope, Plastics - the facts 2014/2015
Application of packages	About 50% of the global packaging, by end market is used for packaging food (pots, jars, flexible plastics)	Unwrapping the Packaging Industry. Seven factors for success. EY 2013.

Source: Authors own table

Since the tax on plastic bags was introduced in England in 2015 there has been drop in usage from 7.64 billion bags in 2014 to only 640 million bags in 6mts after the ban was introduced. If this trend continues that would be a drop of 83% in terms of usage leading to a gain in revenue of £41.3m (Morelle 2016).

Besides national or regional regulations, NGOs and organisations play a crucial role in furthering waste minimisation. In 2005, the UK Women's Institute passed a resolution to protect natural resources. They planned a nationwide day of action returning packaging to supermarkets at the point of sale to raise awareness about over packaging. This type of campaigning originated from the Women's Environmental Network who ran a "Wrapping is a rip off" campaign in the 1990's.

In China, the 2008 State Council regulation banned the use of free plastic bags and the production, sale and use of ultra-thin plastic bags of 0.025 mm or less. This regulation resulted in a two third reduction in the use of use of bags in large supermarkets and malls.

As the ChinaDaily website reported in 2013, the regulation had less effect on the use of ultra-thin bags. Still six of the ten controlled supermarkets provided ultra-thin bags. Nevertheless, all supermarkets charged for the bags (XIAODONG 2013).

In Bengaluru, India, the government introduced a total ban of plastic bags, as well plastic cups, plates, flags or sheets used on dining tables in marriage halls, plastic sachets for chips and goods made with thermocol (similar to Styrofoam) and microbeads. After a month these plastics were still on the market, imported from outside the state, where a large number of plastic manufactories are located (Service. 2016).

France has banned the use of disposable cutlery, cups and plates under its Energy Transition for Green Growth bill which was passed in 2015 (French Ministry of Ecology 2015). By 2020 all items must be made of biodegradable materials.

These examples show that a reduction of plastic use in daily life requires a multi-sectorial approach. A regional or national ban on plastic bags and plastic one use disposable items is one step, moreover retailers and in particular consumers are important stakeholders for realizing a reduction of plastic consumption at household level.

Image 1: Girls with shopping bags in Dutch shopping street

2. Workforce and exposure in the plastic industry

Our gendered roles can determine the way which we use, dispose and work with plastics. Gender segregation of the labour force is widespread and leading to inequality in terms of pay, conditions and the kind of work done by men and women. In every sector, power dynamics are connected with our gender, our social standing and the roles we occupy and the rewards we reap in terms of pay, but are intrinsically connected to the impacts on our health. Women's historic role in child rearing and managing the household lead to many women taking part-time, unsecure and possibly hazardous work, while men's strength and masculinity means they may be assigned more powerful and managerial roles.

Increasing numbers of women have entered the workforce since 1940, especially into jobs traditionally not carried out by women. Yet health and safety has been slow to catch up with this new workforce, and specifically with work environments and practices that impact adversely on female bodies. Historically, research on health and safety in the workplace was not gender-specific and was extrapolated from male study groups to determine female exposures. (Schiebinger 2003). Many female dominated workplaces are considered 'safe' with little attention given to women's differing physiology (World Health Organisation 2006).

The European Plastics Industry stated in 2015 that direct employment was given to over 1.45 million people in Europe (Plastics Europe 2015). The figure shows, that the plastic industry is a considerable employer in Europe. Certainly, in other parts of the world, like China the plastic industry employs many men and women (Table 1). However, actual estimations on the number of employed people in the global plastic industry are not available or not accessible, or information about the proportion of men and women working in the plastics industry is often lacking. For this study Information on the numbers of women in the plastic industry was found for some countries.

The United States Department of Labor presents detailed yearly statistics on the labour force within the United States. It was estimated in 2015, that in total 372.000 people were employed in the plastic industry of which 30.7% were women (Labor 2015).

A working paper from the World Trade Organization (WTO) presents the total number of people and percentage of women employed in the plastics industry for Mauritius, Mexico, Peru, Philippines and Sri Lanka (ERSD 2003). The data for the plastic and rubber industry were partly jointly presented and partly separated (Table 4).

For the consistency of the presented data there is also information about employed people in the rubber industry for some countries listed in Table 4.

Table 4: Number of people and percentage of women employed in plastics and rubber industry

Country and year	Industry	Total people employed	Percentage of women	Sources
Mauritius (2000)	Plastics	1.390	31.3%	
	Rubber products	230	13.6%	WTO 2003
Mexico (2001)	Rubber and plastics	227.300	31.9%	WTO 2003
Peru (2001)	Rubber and plastics	19.400	18.6%	WTO 2003
Philippines (1997)	Rubber and plastics	42.893	27.7%	WTO 2003
Sri Lanka (2001)	Plastics	1.380	51.4%	
	Rubber products	14.260	32.7%	WTO 2003
United States (2015)	Plastics	372.000	30.7%	United States Department of Labor (2016)
	Rubber products (accept tires)	76.000	33.0%	

Source: Authors own table

This table shows that besides Sri Lanka, where the work force in the plastic and rubber industries is occupied by 51.4% women and in Peru by 18.6% women, the workforce in the other four presented countries is occupied by about one third women.

In India, the plastics market employs 3 million people in over 25,000 companies. In 2009, the domestic capacity for polymer production was 5.72m tonnes, whereas injection moulding was the main processing technology (see also chapter 2.3). Information on the proportion of women and men working in the plastic industry was not available. The largest consumption of plastic in India is in packaging which is 24% of overall consumption (Federation 2011).

As outlined before, plastics may contain chemicals with possible hazardous properties to which workers can be exposed during production. In chapters 4 and 5 we cite a few of the many studies revealing the health impact on workers, male or female during plastic production, many of the historic studies do not sex-disaggregate the data or focus specifically on women in the workplace.

2.1 Socially determined factors of the workforce

Socially determined factors such as family life, poverty, education and health govern the work women do and make it more likely they work in family businesses or in low-paid or part time positions. Much of this work is unregulated and women are less involved in the decision making around work practices and their environments. Hence, their health can be adversely affected by toxic exposures in the workplace, from products used on a daily basis and through food, air, soil and water.

The links may be more obvious in the less industrialised countries where women are more in touch with their environment through the growing of food and the gathering of fuel and water. But in spite of these links or maybe because of them, women are the ones most likely to be most concerned about environmental issues or impacts on health from exposures to toxins and therefore are more prepared to take action (Chapman 2012).

The jobs that women and men do, unfortunately, do not obey some 'natural law' where tasks are allocated to fit body size and social roles. If it were so, the gender division of labour would be good for women's and men´s health and exposures to hazardous plastics and chemicals might be minimised. Their gender does not keep women from being exposed to hazards, but it does condition the types of exposures they experience (World Health Organisation 2006).

There is also a "vertical" division of labour in many countries, where women occupy lower ranks than men. A gendered division of labour is found within the household as well as in paid employment; women and men do different tasks in the home (World Health Organisation 2006). This work is apportioned differently in different countries. This means women and men can be presented with different hazards or the same hazards in different forms while working. Women can experience 'double jeopardy' (Chavkin 1984) through toxic exposures in the workplace and home environment for example those working as cleaners. Indeed many of us face 'quadruple jeopardy' through our exposures in our home, workplace, air, soil and water (Andrew Watterson 2015).

Women tend to perceive various hazards as more risky in comparison to men (Finucane et al. 2010) and are less willing than men to impose health and environmental risks on others (Norgaard & York 2005). With only 13 of the world's 500 largest companies having a female chief executive officer (CEO) (UN 2010), instilling leadership potential in women and breaking the glass ceiling could lead to greater corporate social awareness and worker health protection.

2.2 Physiological differences between women and men and often incompatible labour protection policies

In relation to plastics handling, while there is some research on how different genders are exposed in more formal workplaces, there is a large and incompletely mapped informal 'workplace' which is unregulated, underresearched and unacknowledged. For example, informal waste pickers or those who work with plastics at home. This type of exposure is beyond the scope of most studies.

Women and men are exposed differently to hazards in the workplace due to biological gender differences such as body size, amount of adipose tissue, reproductive organs, hormones, heart function and other biological and physiological differences that can impact the effects and elimination of toxic chemicals and substances on the body (Messing et al. 2003).

Women's higher proportion of body fat provides a greater reservoir for bio-accumulating and lipophilic (fat-loving) chemicals (National Center for Environmental Health 2003), (EPA 2007). For example, the Centers for Disease Control and Prevention (CDC) reported that women, in comparison to men, had significantly higher levels of 10 of the 116 toxic chemicals they tested. Three of the 10 chemicals were phthalates – a group of chemicals found commonly in health and beauty products and plastics that are linked to birth defects (National Center for Environmental Health 2003).

Women's unique biology can create specific vulnerabilities at certain times in their lives including during puberty, menstruation, pregnancy, when nursing children and menopause all of which can be affected by workplace and environmental exposures. There is also potential for exposure to reproductive hazards before pregnancy and during the first trimester, which can affect the foetus leading to specific birth defects. Effects from exposures happen at much lower levels than those set at protecting the workers themselves (Julvez & Grandjean 2009). Women are also more likely to suffer disproportionally (60-80%) with Multiple Chemical Sensitivity (MCS) a condition which affects 2-6% of the population living in industrialised countries. MCS is an illness resulting from exposure to very low levels of certain toxic chemicals we come across in our daily lives including chemicals found in the workplace and in plastics and cosmetics (Nadeau 2014).

The problem with occupational studies on reproductive outcomes to exposures at work according to Grandjean (Julvez & Grandjean 2009) is that they do show ambiguous findings due to methodology and design problems, evidence of the consequences of industrial chemical exposure among pregnant workers is sparse despite the magnitude of this public health problem. It's also worth taking into consideration that maternal work, along with potential exposure may vary greatly from country to country (Shi & Chia 2001). The existence of international labour laws does not signify enforcement or implementation. Although other national, regional and voluntary codes of practice exist along with NGOs monitoring of workplace violations, according to the International Labour Organization figures there are more than 2.3 million deaths and 317 million accidents in workplaces each year.

In China, a hospital-based case–control study indicated that birth defects were significantly associated with maternal exposure to chemicals before and during the first trimester of pregnancy (Zhang et al. 1992).

Given that China is the biggest producer of plastic materials, the potential for exposure maybe considerable. This has implications for women working with developmental toxins before and in the first trimester of pregnancy.

Image 2: Women working in the plastics industry

These critical windows of vulnerability during early foetal development, puberty and pregnancy can have a distinctive biological effect, which may not become apparent until later in life with, for example, physical effects on genitalia being more apparent in baby boys. Thus, the nature of these effects is gendered.

In utero, exposure to phthalates in particular can cause adverse effects in the male reproductive system. Phthalates are used during plastics production and can leach from plastic products during usage and disposal. Studies have shown pre-birth exposure to phthalates can effect anogenital distance, foetal sex development, and anogenital index (anogenital distance relative to birth weight) in boys who experienced prenatal phthalate exposure. These studies are consistent with animal and other smaller sample studies. The data suggest that even at current low levels, environmental exposure to one phthalates, DEHP can adversely affect male genital development which can impact reproductive health later in life (Swan 2008), (Swan 2005).

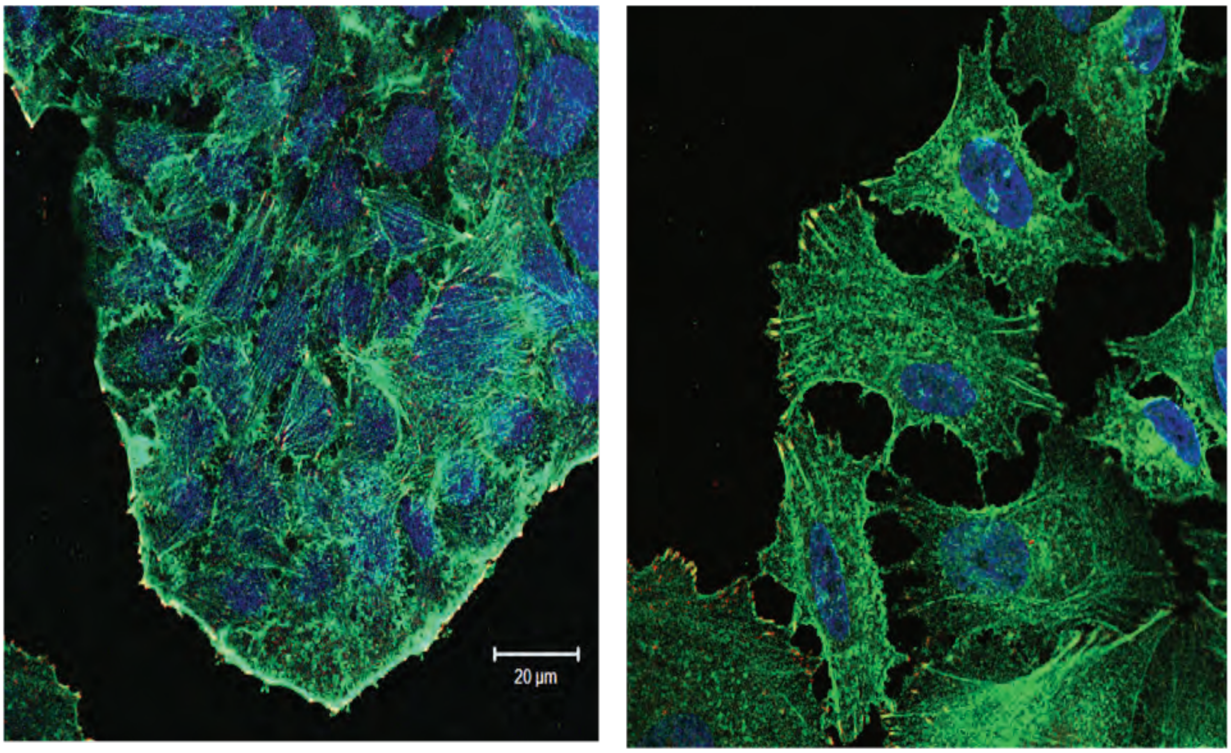
Most pregnant women are exposed to this ubiquitous chemical and mothers who had high concentrations of phthalates in their amniotic fluid reported shorter anogenital distances in their female offspring (Huang 2009).

In 2013, the Royal College of Obstetricians and Gynaecologists produced guidance for women in relation to chemical exposure during pregnancy urging them to take preventative action in relation to exposures. The report cited the links between exposure to environmental chemicals and adverse birth outcomes such as preterm birth, low birth weight, congenital disorders, obesity, impaired immune system development, adult disease, asthma, early puberty, cardiovascular effects, and cancer to name a few. The chemicals associated with plastic listed in the report were phthalates, Bisphenol A, and Polybrominated diphenyl ethers (PBDEs) (Bellingham & Sharpe 2013). However, the report did not consider workplace exposures in addition to those experienced at home or in the wider environment.

The workplace can be hazardous for a woman and her developing foetus. In some countries national laws protect pregnant women from having to work with hazardous chemicals and substances, or situations that put her at risk of injury during her pregnancy. The International Maternity Protection Convention, 2000 (No. 183 ILO) under health protection, article 3 states that: "Each Member shall, after consulting the representative organizations of employers and workers, adopt appropriate measures to ensure that pregnant or breastfeeding women are not obliged to perform work which has been determined by the competent authority to be prejudicial to the health of the mother or the child, or where an assessment has established a significant risk to the mother's health or that of her child" (Ilo 1952).

Around 70 countries have ratified at least one of the ILO conventions on maternity protection. And virtually every country in the world has some type of maternity protection legislation. Some go further

Image 3: Breast cancer cells under a microscope. On the left normal cells, on the right tumor cells induced by dioxin
© R. Barouki



than others. In Finland women can request a job transfer from the beginning of their pregnancies (Magnusson 2006). In the UK, there is a Pregnant Workers directive (92/85/EEC) which requires the employer to risk-assess the work of the pregnant worker, identify the risks and make sure "the work is of a kind which could involve risk, by reason of her condition, to the health and safety of a new or expectant mother, or that of her baby, from any processes or working conditions, or physical, biological or chemical agents".

In reality, it's very difficult to do this if the information is not available on the health impact to mother and foetus of certain chemicals used during chemical or plastics production such as endocrine disrupting chemicals (EDCs). According to the Trade Union Congress in the UK, most employers do not conduct risk assessments for new or expectant mothers (TUC 2005).

In Mexico, there are limits set for pregnant women's work handling, transporting or storing teratogenic or mutagenic substances (Ilo 2010). Yet in 49 countries, no protection exists relating to performing hazardous work while pregnant or breastfeeding. The laws can also work against women restricting their work options and contributing to gender based discrimination, for example in Columbia there is a blanket ban on women working in dangerous or unhealthy work or in mines. Of the 78 countries which have provisions forbidding hazardous work, 40 countries impose blanket bans on women working in jobs classified as dangerous for their reproductive health or general safety. This ignores the fact that men may also be harmed and there should be safe working conditions for all (Turner 2010).

2.3 Worker´s exposure to hazardous chemicals

The wide-ranging application of plastics means they are utilised in a huge range of industries. In Mauritius, Mexico, Philippines, and the US, women represent about 30% of those working in plastics production and manufacturing according to information from the Bureau of Labor Statistics and World Trade Organization, but the figure is probably far higher as illustrated in Table 4 since plastics are used in such a range of industries. As women occupy a disproportionate place in the low income bracket, they are more likely to take on unsafe employment and are employed in greater numbers in hazardous work environments. Worldwide figures on gender breakdown of workers are scarce.

Workers can be exposed to a toxic soup of chemicals found in most plastics industry environments. In manufacturing settings, plastic resin enters the workplace in the form of pellets, powders, granules, liquids or syrups. During the manual handling of the bulk product by opening, pouring, scooping, and subsequent stirring, mixing and grinding, sanding and buffering-dust, fumes and air contamination can lead to workers being exposed through a variety of methods.

Air monitoring tests do not show the true body burdens or measurement of the concentration of certain chemicals in the body. For example, in one test for acrylonitrile (an important monomer for the manufacture of useful plastics such as Polyacrylonitrile) the body burden for male workers from tested blood and urine was significantly higher than the air monitoring reading (Houthuijs et al. 1982). Other studies which measured levels of styrene (Brugnone 1993), brominated flame retardants (Thuresson et al. 2006) and phthalates (Hines 2009) had similar findings. In many studies of workers, the levels of toxic chemicals found in male workers were significantly higher than those found in the rest of the male population. Levels at which in laboratory animals produce breast and other tumours and adverse health effects (Keith 2014).

For manufacturing certain plastic objects, a resin is softened by heating and pressed in a form. Different processes, chemicals and additives are required for the production of different types of plastics so exposure to potentially hazardous chemicals is possible during different types of processes (DeMatteo 2011).

The most common processes are injection moulding, extrusion, blow moulding, calendaring and compression moulding (Figure 3). DeMatteo (2011) presents the potential exposure to hazardous substances for the different processes (Box 1). It is also easier to see the potential for exposure to hazardous chemicals and substances if we consider the diagram of an injection moulding or Calendering moulding machine below.

This simplified diagram of an injection moulding machine as used amongst others for manufacturing plastic beakers, caps for bottles or automotive parts and a diagram of calendaring moulding for producing high quality plastic films and sheets (mainly PVC) are presented in Figure 4. In particular the process of calendaring moulding (Figure 5) can be hazardous for the workers while they are exposed to large heated surfaces of plastics (DeMatteo 2011).

China is the largest toy producer and exporter in the world and Chinese workplaces where women predominate are the toy, electronics, shoe and garment-manufacturing sector.

In the toy manufacturing sector, toxic chemicals in the toys not only harm the children who will play with them but also the workers in the factories where they are manufactured.

A study looking at exploitation of toy factory workers found that in the two factories studied the vast majority of workers were women, although less than half the workers were listed on the employer's register.

One factory produced metal and plastic toys for large global companies who sell children's toys. The workers complained to the researchers about the air being filled with an irritating chemical odour, and health effects included sneezing, weeping eyes, skin peeling and dizziness. There was no protective equipment given to workers or information about the chemicals they were using. *"They operate machinery that produces the plastics for the toys. They breathe and touch the toxics, and almost never are they given protective gear or masks. In fact, most of the workers that we and our friends in China have interviewed would not know what protective gear looks like. They live and work in industrial slums that often resemble the images in Charles Dickens' novels, crowded, almost unbearably polluted, and with limited access to clean, safe water"* (Leung, Perry 2009).

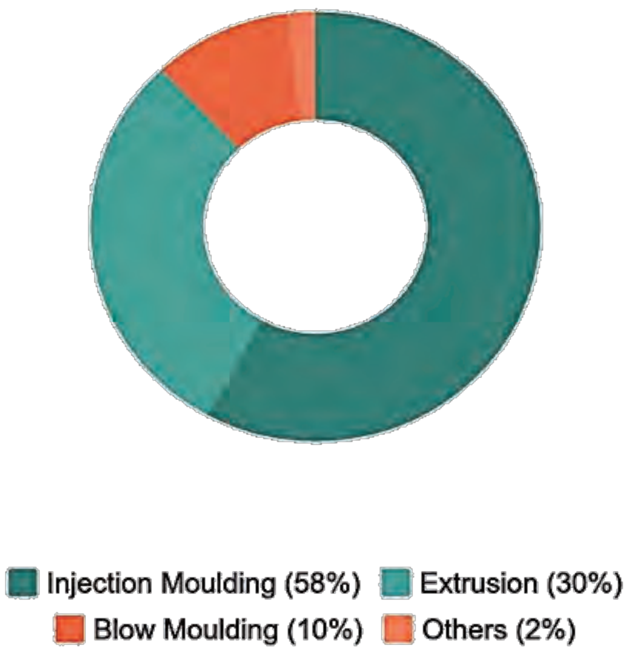
Wang et al. 2011 found in that a Chinese plastic recycling site with a history of over 20 years, various water samples from the exposed site were markedly higher than those at the reference site. Moreover, mean Di-(2-ethylhexyl) phthalate (DEHP) concentration in cultivated soil samples from the exposed site was 16 times higher than in the reference samples. The researchers also found in the urine of male workers significant elevated predictors for the damage of oxidative deoxyribonucleic acid, DNA, possible influencing the development of pulmonary, cardiovascular diseases and cancer (Wang et al. 2011).

In the US, a good example of action on toxics use reduction comes from the Toxics Use Reduction Institute in the University of Massachusetts, Lowell. The centre aims to develop TUR programs which help communities and companies to reduce toxins.

It is one of the implementing agencies for the Toxic Use Reduction Act adopted in 1989 in Massachusetts to reduce toxic chemicals by switching to safer alternatives for chemicals like phthalates used in the coatings of wires and cables, all under its greener plastics program. The act is designed to protect workers, public health and the environment while making Massachusetts businesses more competitive.

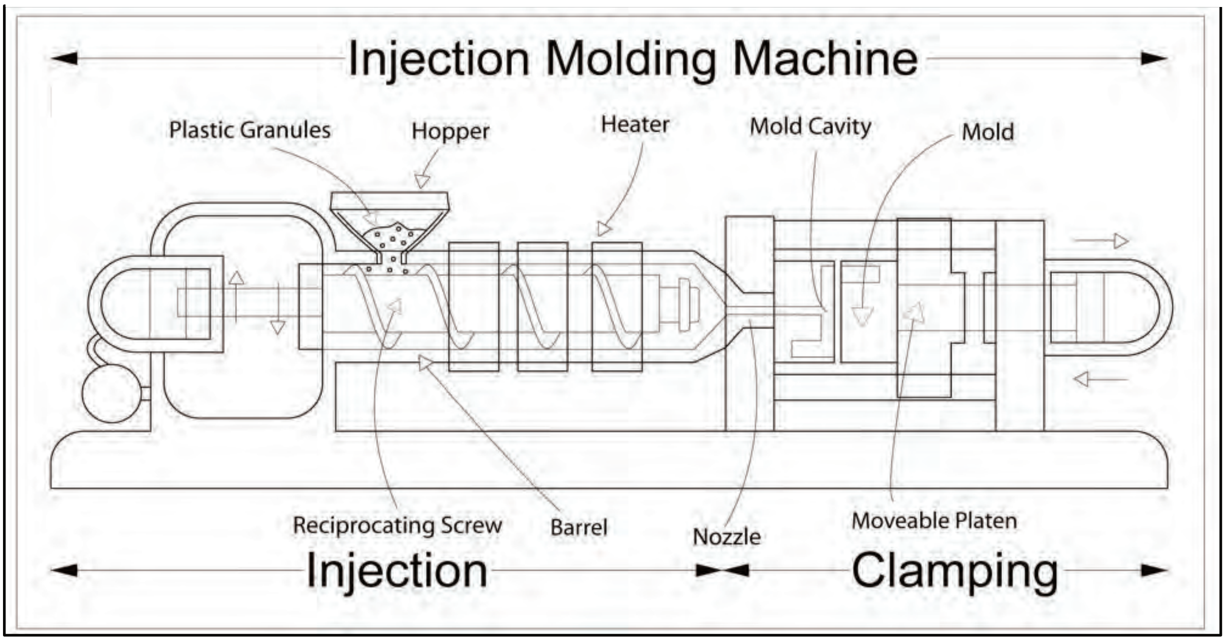
There are reporting requirements for business on their chemicals use, they present a plan focused on

Figure 3: Main processing techniques in India

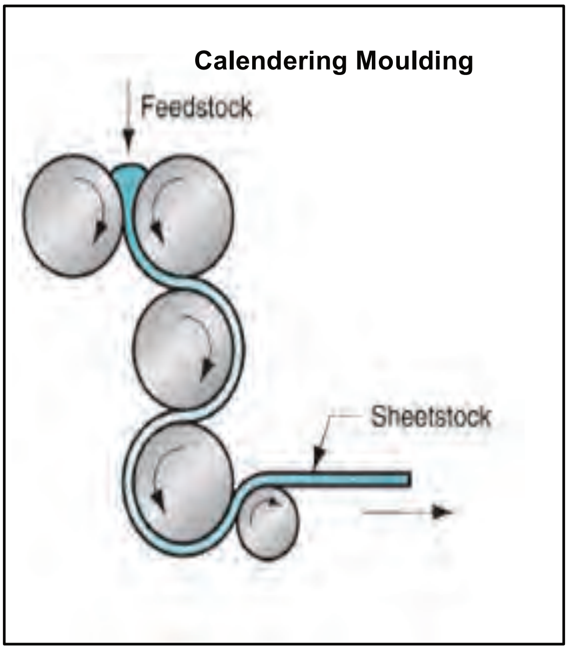


Source: Adapted by the authors from Federation 2011

Figure 4 and 5: Two Examples of plastic processes with different possible exposure to workers



Source: Brockey, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=21365163



Source: Mechanical Engineer´s World

reduction every 2 years and pay a fee which is used to support the work of the institutes.

Among other activities, the centre researches alternatives to toxic chemicals in plastics such as Bisphenol A and flame retardants, and alternatives.

To eliminate exposure of workers to hazardous chemicals and substances much more can be done by adhering to existing legislation provided by the ILO. More action is needed on preventing exposure at source to hazardous chemicals and substances through Control of Substances Hazardous to Health (COSHH) legislation (in the UK) and action from employers and industry. The legislation requires employers initially to carry out an assessment of the worker exposure based initially on preventing exposure for example using water based rather than solvent based products. If that cannot be accomplished the next step is to assess whether the hazardous substance can be substituted or can exposure be eliminated by changing the mechanics of the application, i.e. through using a brush rather than a spray. If this step cannot be achieved the next stage is to consider if there is a safer form of the substance to use, i.e. in a wax form rather than as a dust. The last option for control should be Personal Protection Equipment once all other options have been considered. Workers should be made aware of what they are working with and provided with adequate information in the form of safety data sheets so they can react to possible exposures. More information/research about possible exposure of hazardous chemicals during the different production and recycling processes should be available. Specific action needs to be taken on addressing new and emerging hazardous such as microplastics.

Box 1: Processes of plastic production and worker´s possible exposure

Most common plastic processes and worker´s possible exposure

Following are some examples of processes for the most common plastics and possible exposure to the workers: (DeMatteo 2011).

Resin Preparation-First step in the plastic production. The resin formulation and additives are adapted to the final desired product (e.g. PVC, PP, PT or others). If the process is manual and in batches, the probably exposure via direct contact or inhalation of possible hazardous substances (vapour, dusts, liquids) to the workers can be high.

Extrusion—Plastic pellets or granules are extruded to thin layers as used for plastic films and bags. Extrusion is done with hot plastics and in the open with venting and poses a high possibility of exposure to the workers.

Injection moulding—Plastic pellets or granules are injected in a mould. Injection moulding is used for producing butter tubs, yogurt containers, closures and fittings. This process is an enclosed thermal procedure, but the venting and melt degassing pose a medium possible exposure to the workers (Figure 4).

Blow moulding—Blow moulding is a process used to make, for example, carbonate soft drink bottles. The process of blow moulding is in conjunction with extrusion or injection moulding. The blow moulding (enclosed thermal) process as such, pose medium possible risks to the workers.

Calendering Moulding—Calendering mouldings to form sheets and coatings. Workers can be highly exposed to hazardous substances, due to the open thermal process used for large surfaces (Figure 4).

3. Overview of hazardous chemicals in plastics and their impact on women's and men's health

3.1 Plastics, EDCs and observed health effects

Male reproductive health

Sperm is very sensitive to damage from exposure to certain chemicals, radiation and vibrations. When the strength of evidence between exposure to endocrine disrupting chemicals (EDCs) and effects on male reproductive health is combined with case studies, effects observed in wildlife, and occupational and laboratory studies there is a strong biological plausibility of adverse association.

In the first study of its kind looking at ambient air levels of the phthalate DEHP in a PVC pellet plant in Taiwan, male workers exposed to the highest concentrations of DEHP in their personal air were found to have adverse effects on sperm mobility and integrity (Huang et al. 2011).

Men working in factories in four different regions in China where there was high exposure to BPA had deceased sperm concentration, count and motility compared with men who did not have detectable levels of BPA in their urine. Up to three times lower in terms of sperm concentration and four times lower in relation to sperm count. The factories were mainly epoxy resin manufacturers (Li et al. 2011).

A Nordic study calculated the costs of male reproductive disorders such as testicular cancer, infertility (low sperm count), hypospadias and cryptorchidism to Nordic countries and the EU through inaction on EDCs. The report estimated the fraction of incidences of male reproductive disorders assumed to be caused by EDCs. The percentages ranged from 2%-40% with the resulting costs ranging from €59 to €1,200 million (Olsson & Al 2014).

Breast Cancer

Numerous studies have linked breast cancer with exposure to EDCs either pre-birth, through occupational exposure or through exposure to chemicals in the wider environment.

A Canadian population-based case-control study found that women working in the plastics industry had a five-fold elevated risk for breast cancer and reproductive disorders (Brophy et al. 2012). In Canada, women hold a wide range of jobs in the plastics industry and the majority of automotive plastics manufacturing workers are women. This could be due to the fact that premenopausal women working in the plastics industry have much higher body burdens of hormone disrupting chemicals such as BPA, phthalates, vinyl chloride, styrene and acrylonitrile than the general population. These chemicals are all used in plastics production and like BPA and phthalates some can leach out of the products over time, further affecting women and children's health (DeMatteo et al. 2012). The Brophy study prompted the American Public Health Association to pass a resolution calling for action on occupational breast cancer. The resolution calls on the U.S. Surgeon General to declare the association between known classes of chemicals including EDCs and breast cancer while acknowledging that women working with these chemicals are particularly at risk (American Public Health Association 2014). For more information on BPA please see the Appendix 1.

Women's health, specifically breast cancer, was again linked to occupation in a review of the state of the evidence on breast cancer and occupation. The study cited 1,3 butadiene, acrylonitrile, benzene, BPA, flame retardants, phthalates, styrene, and vinyl chloride as chemicals of concerns in association with breast cancer for those women working in the plastics industry. But nurses, fire fighters, rubber and plastic products workers, food and beverage production workers, textile and clothing workers, and hairdressers also had elevated risk of breast cancer possible linked with plastic products, additives or ingredients they worked with on a daily basis (Engel & Rasanayagam 2015).

Women who work in textile factories and are exposed to synthetic fibres and petroleum products at work before their mid-30's seem to be most at risk of developing breast cancer later in life. Modern synthetic fibres are basically plastic resin treated with additives such as plasticizers, many of which are recognised mammary gland carcinogens and endocrine disrupting chemicals (Labrèche et al. 2010).

Research also points to pre-birth or early life exposures impacted on future breast cancer diagnosis. According to animal studies exposure to a mixture of common endocrine disrupting chemicals in the period shortly before or after birth may affect mammary gland formation. These mixtures of chemicals are close to what women are exposed to in the environment. They included plasticizers such as the phthalates DBP and DIEP, and Bisphenol A. There was no observed effects until adulthood (Mandrup et al. 2015).

Another source of BPA is the diet, when individuals switched from their normal diet for 3 days to eating only freshly sourced and unpackaged foods, the levels of BPA and certain phthalates detected in their urine decreased by 65% and 53% r*espectively* - until they resumed their normal diet after which their levels went back to those before their pre fresh food diet (Rudel et al. 2011).

Hypospadias

There has been considerable work done worldwide on the association between certain male genital malformations particularly hypospadias (is a birth defect of the urethra in the male where the urinary opening is not at the usual location on the head of the penis) and exposures to EDCs either singularly or in mixtures, including those EDCs used in plastics. These exposures can take place over a range of environments but a French cohort multi-institutional study found that parental professional, occupational and environmental exposures to mixtures of EDCs including phthalates and other toxic chemicals increased the risk of hypospadias in children. The jobs of both parents were considered around the time of fertilisation for the father and for one year before, the mother's jobs were detailed over three trimesters of the pregnancy. The father's most frequent jobs were as agricultural workers, laboratory technicians, cleaners and car mechanics exposing them to solvents, detergents and pesticides. The mother's most frequent jobs were cleaners, hairdressers, beauticians, and laboratory workers where there was potential exposure to multiple EDCs, in paints/ solvents/adhesives, detergents, cosmetics and industrial chemicals. In terms of environmental exposures, the researchers considered industrial areas, incinerators, and waste areas which were more frequent within a 3-km radius for mothers of hypospadiac boys (Kalfa et al. 2015).

Another register based case control study in Western Australia looked at occupational exposure to seven groups of EDCs including phthalates. Women exposed to phthalates were more likely to have an affected son compared with mild or isolated cases, the risks of moderate-severe hypospadias or multiple defects were increased up to two- and fivefold, respectively, with maternal exposure to most types of EDCs (Nassar 2010).

Box 2: The women firefighter's biomonitoring study on exposure to chemicals

A good example of workers taking action to examine the relationship between chemicals in plastics in health comes from the Women Firefighters Biomonitoring Collaborative Study, which is looking at occupational exposures to chemicals and carcinogens linked to breast cancer and those that are hormone disruptors. The study will compare levels in the large female workforce of firefighters with women working in other sectors of the city services.

Firefighters are exposed to a cocktail of chemicals such as flame retardants, dioxins, and the breakdown products of phthalates from burning plastic electronic products, furniture, building materials and dust in homes which catch fire.

The study uses a new technique called *Time of Flight* which tests for unpredicted exposures and checks for chemicals based on their molecular weight.

The project team includes the United Fire Service Women, the San Francisco Firefighter Cancer Prevention Foundation, Commonweal, the Silent Spring Institute and the Breast Cancer Fund. The study was implemented due to the high rates of breast cancer among the women fire fighters.

4. Exposure to hazardous chemicals from some everyday products

Plastic can be found in a wide range of products we come into contact with on a daily basis (Table 2). Consumers may not even be aware of the plastic content in products such as personal care or cosmetics, furnishings, building materials, or packing. In this section in particular, the exposure to possible hazardous substances from plastic toys and from PVC in flooring are highlighted. PVC is widely used for flooring and the fabrication of door and windows frames. Plastic toys are worldwide available in markets and shops and bought by women and men for children.

Children are particularly vulnerable to exposure to toxic chemicals and of significant concern because of a number of factors, including the fact that they have a higher metabolic rate and greater surface area to weight ratio than adults, their organ systems are immature and developing, and there is rapid growth of organs and tissues such as bone and brain. Children's exposure also differs from that of adults because children drink more fluids, eat more food, and breathe more air per kilogram of body weight. There is also a longer latency period in which to develop disease (Landrigan et al. 2004). Young children's frequent hand-to-mouth activity creates a pathway for toxic chemicals in toys, flooring and other products to enter the body.

Plastic toys

Not all the toys we buy for our children are safe. Toy manufacturers are not required to list the chemicals used in the toy production even if hazardous chemicals are present. Regulations for plastic toys are much laxer than for plastics that come into contact with food yet many toys can be placed in children's mouths. For example, the present EU limit for vinyl chloride in food packaging is 1mg/kg; one thousand times lower than the legal limit for the chemical industry. This has led to a proposal calling for toys specifically intended to be put into the mouth, such as teething rings, to follow the guidelines of the food directive (European Parliament 2008), (WECF 2008).

China is the world's largest exporter of toys with more than 86% of the world exports and the most common notification under RAPEX (the rapid alert EU system used to prevent the use of products posing a serious risk to health) in 2014 was for toys originating from China, and mostly due to chemical injury (European Commission 2014).

But new toys are not the only problem, soft plastic toys can contain hormone disrupting chemicals such as phthalates which leach from the product when washed or damaged through usage. Solid polymers degrade over time as they are exposed to light, heat, oxidizing agents, and handling. This is especially true for vintage toys or toys passed down the generations or given to charities.

One study tested a selection of vinyl and non-vinyl vintage toys compared with newly purchased toys. The vinyl toys consisted largely of Barbie and other dolls. The non-vinyl toys were made by a large well-known toy brand. Lead and cadmium was found in 67% of the vintage plastic toys frequently at concentrations exceeding current U.S. and European limits. Arsenic was detected at levels of concern in 16% of the samples (Miller & Harris 2015). Lead is particularly hazardous to children – there are no safe levels and even low amounts in a child's body have been linked to reduced intelligence. Cadmium is linked to renal damage and cancer and can build up in the placenta and may contribute to osteoporosis (Miller & Harris 2015).

Another study looked at the transference of Octa-BDE and Penta-BDE brominated flame-retardants used as plastic additives in electronics – and recycled into plastic used for children's toys in China. Both Octa-BDE and Penta-BDE are listed under the Stockholm Convention and should not be present in children's products or other consumer products due to their significant adverse effects on human health and the environment (Strakova & Joe DiGangi 2015).

There is currently no mandatory testing of toys-except in the US. Imported types of loombands (elastic bands for making bracelets) and charms were found to contain higher levels of phthalates despite EU restrictions on 6 phthalates to a maximum of 0.1% in toys, while other phthalates are restricted in items that can go in the mouths of children.

Image 4: Plastic toys often contain toxic substances

Out of the 16 packets tested, every single charm failed because they contained more than the legal limit of 0.1 per cent of phthalates – with two having levels of more than 50 per cent (The Independent Newspaper 2014).

PVC Flooring

PVC (or vinyl) flooring is one of the most popular types of flooring in the world due to its resilient nature. But PVC creates environmental hazards throughout its lifecycle, mostly because of its main constituent chlorine, which can lead to the creation of dioxin when it is manufactured, or burned in incinerators. Because PVC products are difficult to recycle they present a growing and costly waste problem.

PVC flooring also contains a number of additives in large quantities, some of which are also toxic. In particular, phthalates used as softeners (as discussed above) can leach out of PVC floors when they are washed or can be emitted into the air and attach to dust which can be inhaled or adhere to food and furnishings (Lowell Center for Sustainable Production 2011). Other hazardous additives used in PVC floors are chlorinated Paraffins and Tributyltin. All of these are listed internationally as chemicals for priority action for elimination.

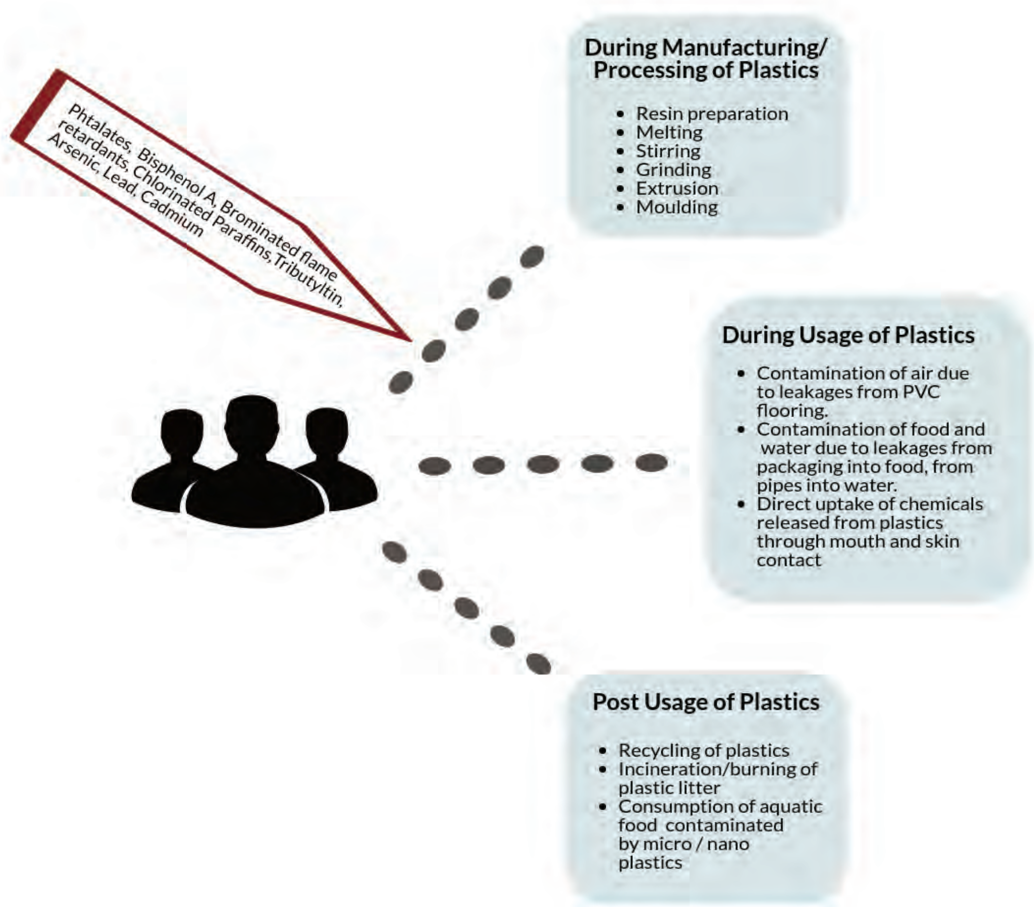
Women can come into contact with leachants from PVC flooring due to the fact that they still do most of the household cleaning (Thalif Deen 2009) and worldwide 83% of domestic workers are women (International Labor Organization 2011). There is evidence linking phthalates in PVC flooring to the development of asthma, so although PVC is undoubtedly the cheapest smooth flooring, it may not be the healthiest.

Plastic particles in personal care and cosmetic products

Microbeads is one term used to describe plastic particles added to Personal Care and Cosmetic Products (PCCP) but they are also called nanospheres, microspheres, plastic particulates and microplastics. These microbeads have been added to a wide range of personal care and cosmetic products for the last 50 years (see for more information chapter 5).

There is a potential for products to be contaminated by microplastics during manufacture from off shedding from workers clothes or skin. Microplastics have been found in German beer. Out of 24 different German beers that were tested, including both alcoholic and non-alcoholic, all were contaminated with microplastics. The research concluded that the possible cause of contamination was from materials used during the production process or from the clothes and skin of brewery workers. There may be the potential for contamination from this source into other consumer and food products (Liebezeit & Liebezeit 2014).

Figure 6: Examples of potential exposure of hazardous chemicals to men and women during the plastic life cycle



Source: Authors own figure

Box 3: Microplastics in personal care products and cosmetics

Women are still the biggest users of cosmetics and personal care products reportedly spending on average $15,000 on make up in their lifetime, contributing to the $382 Billion beauty industry where they form 85% of the consumer base (Ross Crooks 2013).

Microplastics, also often referred to as microbeads in the beauty industry, can be found in a variety of leave on and rinse-off formulations such as: conditioner, shower gel, lipstick, hair colouring, shaving cream, sunscreen, insect repellent, nail polish, bubble bath, anti-wrinkle creams, moisturizers, foundation, hair colour, hair spray, facial masks, eye shadow, and mascara.

Yet women are not the only ones at risk from exposure, as microplastics are also found in baby care products, shaving cream, deodorant, shampoo and shower gel, some products used by other members of the family.

The main route of exposure to microplastics is through the skin but we absorb them also through inhalation and ingestion. Studies of microbead toxicity and uptake by mammals indicate the fine particles can be transported through the gastrointestinal tract to the lymph and circulatory systems, through the placenta to unborn foetuses leading to a variety of biological responses negatively impacting on the health of human cells. When inhaled, studies have linked exposure to fine particulates with allergic reactions, such as asthma, cancer and heart disease (Leslie 2014).

5. Gender and microplastics management

5.1 Background

In recent decades a new type of a global environmental pollution of oceans, rivers and lakes by small sized debris of plastics, called microplastics, has been observed. These are largely unregulated, except by a few countries such as Canada and the recent USA bill to ban microbeads in cosmetics products starting in 2017 (US Congress 2015). Studies refer to microplastics as plastic particles smaller than 5 mm (Verschoor et al. 2014). Other studies mentioning the size of microplastic particles in literature are not uniformly standardised and fluctuate mostly between 0.001 mm and 5 mm and smaller (Bundesinstitut für Risikobewertung 2015).

Some of these particles are big enough to be visible to the human eye, they are generally solid and referred to as microbeads between 1 and 1000 µm while others are very tiny particles under 2.5 µm. Microspheres on the other hand can be hollow or porous and between 1-50 µm. They can be filled with an active ingredient which enhances the products adhesion or texture or acts like a porous sponge for releasing ingredients. Lastly there are nanospheres or nanocapsules ranging from 10-1000 nm.

Properties of microplastics are defined as being (Verschoor et al. 2014):

- Synthetic materials original from petrochemical sources
- Insoluble in water
- Non degradable
- Solid phase materials
- Smaller than 5 mm

A difference is made between “primary” microplastics, which are synthetic-based granules or beads produced and used with for a special purpose, for example as emulsifiers, film formers in personal cosmetics and care products, and so-called ”secondary” microplastics. Secondary microplastics are derived from plastic matter such as plastic bags, bottles or fibres (from clothes) due to physical and decomposing processes (Bundesinstitut für Risikobewertung 2015). Also paints and tyres can contribute to the release of microplastics into the environment. The rate of fragmentation and decomposing of large plastic items is dependent on several variables such as weathering (UV radiation) and the plastics formulation (Kershaw, P. J. & Leslie 2012).

The causes and sources of marine pollution with microplastics are highly dependent on location, the level of waste management, cultural habits, industrial and other human activities. Depending on the habits of men and women, they may or may not contribute to marine pollution with microplastics, or be exposed to microplastics. In this next section the application of microplastics and possible sources of microplastics in the environment will be highlighted.

5.2 Products that contain microplastics and the role of men and women in production consumption

Plastics have been added as ingredients in personal care and cosmetic products (PCCPs) for several decades with early patents dating from the 1960’s. Today they remain a hotbed of innovation in new PCCPs. Depending on the polymer type, composition, size and shape, the plastic ingredients have been included in formulations for a vast number of functions including: viscosity regulators, emulsifiers, film formers, pacifying agents, liquid absorbents binders, bulking agents, for an ‘optical blurring’ effect (e.g. of wrinkles), glitters, skin conditioning, exfoliants, abrasives, oral care such as tooth polishing, toothpaste, gellants in denture adhesives, for controlled time release of various active ingredients, sorptive phase (for delivery of fragrances, vitamins, oils, moisturizers, insect repellents, sun filters and a variety of other active ingredients), and prolonging shelf life by trapping degradable active ingredients in the porous particle matrix (UNEP 2015a).

Image 5: Nail polish for sale in the Netherlands

Sundt (2014) mentioned it was calculated that the consumption of microplastic particles in Europe in PCP would be on average 8 grams per capita per year, based on a total amount of applied microplastics in PCP of 790.000 tonnes in 2002. The consumption of microplastics in liquid soap and shower gel was estimated to be 100.000 tonnes. For Germany, it was calculated that the consumption of microplastics in cosmetics in cosmetic products could be 6.25 grams per capita per year (Sundt 2014).

The international Journal of Applied Science (2015) estimated an average use of microbeads in 2012 in the European Union plus Switzerland and Norway of 17.5 ± 10 mg/day/ capita. In 2012, the total amount of used microbeads in cosmetic products was 4360 tonnes. Furthermore it was calculated that microbeads originating from cosmetics contribute 0.1 -1.5% to the overall amount of plastic debris emitted to the North Sea (Gouin 2015). They are found mostly in liquid hand soap, face wash and shower gel.

5.3 Microplastics in the environment and its sources

Hidalgo-Ruz et al (2012) assessed the frequency of occurrence of different polymer types in 42 studies of microplastic debris sampled at sea or in marine sediments. The most frequent identified polymer types were polyethylene (PE) in 79% of the studies, polypropylene (PP) in 64%, polystyrene (PS) 40% and polyamide (PA) (nylon) in 17% of the studies.

Table 5: Examples of personal care products with functional microplastics

Product	Function	Reference
Wrinkle creams	Bulking, viscosity control	UNEP (2015)
Glitter in bubble bath or make-up	Viscosity control, aesthetic agent	UNEP (2015)
Body care products, colour cosmetics, skin care, sun care	Film formation, emulsion stabilising, skin conditioning	UNEP (2015)
Facial masks, sunscreen	Film formation	UNEP (2015)
Tooth paste, face and body wash	Exfoliating	Sundt (2014)
Shave foam, lipstick, mascara. sunscreen	Slip or bulking effect, or microspheres	Sundt (2014)

Source: Authors own table

Polyester (PES) and Acrylic (AC) were identified in 10% of the studies.Depending on the activities within a certain area, the sources of the secondary and primary microplastics can differ from river to river and from ocean to ocean.

Dris et al (2015) investigated the fall out of micro plastics in the atmosphere and estimated atmospheric fallout between 2 and 365 particles per day and m^2. The proportion of synthetic (petrochemical) fibres was 29%, whereas the fallout appeared higher in more urbanised settings (Dris et al. 2016).

In the Netherlands, Verschoor (2014) identified in her study of plastic debris, which consisted largely of packaging materials and disposable products, as the most important source of microplastics. Other secondary microplastic sources with a relatively high occurrence in the environment are: fibres and clothing, roadway run-off (including tire dust), dust from construction sites, agricultural plastic and input from abroad via the rivers Rhine, Meuse and Scheldt. In the same study, Verschoor called for the primary microplastics which are intentionally added to products for specific functions, to be given the highest priority for elimination in cosmetics, pigments and paints followed by polishing and cleaning agents, products which are mainly bought by women and for which the industry could easily find replacements for the microplastics with other harmless substances.

Toys are one of the items found in ocean plastic waste. A North Sea study by OSPAR (the cooperation between governments and the EU to protect the marine environment of the North-East Atlantic) looking at plastic debris in our oceans found plastic toys come 34 on the list of most found items. They can enter the ocean in a number of ways, through disposal, loss, dumped rubbish and also through marine accidents. For example, in 1992 a ship carrying containers with 29,000 plastic bathtub toys spilt its contents into the ocean. Scientists tracked where the toys washed up to study the oceans currents, ten months later they started to wash up on beaches. They anticipated that by the year 2000 a few of the toys will have been transported to many oceanic locations in the Northern Hemisphere (Ebbesmeyer & Ingraham 1994).

As shown in several studies, the occurrence of microplastics in the marine environment is not only due to the primary used and released microplastics, but also directly influenced by the beach and marine plastic litter. For example, a project on monitoring beach litter and possible sources of marine litter entering four Europeans seas: the Baltic Sea, North Sea, Mediterranean Sea and the Black Sea showed the composition and sources of the different types of debris/plastic waste are influenced by the presence of economic sectors and tourism, along with the behaviour of households (Arcadis 2012). The study was conducted in four sites, respectively Riga (Latvia), Ostende (Belgium), Barcelona (Spain) and Constanta (Romania), indicative for the four European Seas. The possible sources of the found litter areas are summarised in Table 6.

Table 6: Types of most frequently found plastic litter on European Beaches and the probable sources

Location	Percentage of plastics out of total collected coastal litter items	Probable identified source of total observed litter			
		Coastal / beach tourists	Household activities, including sanitary sources	Marine activities (shipping, fishing, port/marine industry	Other diverse sources
Baltic Sea -Riga	51% plastics, of which 70% packaging waste	25%	48%	12%	15%
North Sea-Ostende area	76% plastics (most frequently used and discarded consumer goods or production goods)	40%	10%	40%	10%
Mediterranean Sea-Barcelona	50% plastics (mainly packaging waste)	32%	40%	10%	18%
Black Sea - Constanta	65% plastics, of which 70% packaging waste	59%	28%	8%	4%

Source: Authors own table

Besides the release of microplastics into the environment due to plastic litter and intentionally added microplastics in consumer products, also the plastic industry may release microplastic resins into the river, which make their way towards the oceans. An example of this is the second biggest river in Europe and the main tributary of the Black Sea, the Danube. In a 2-year survey of plastic litter in the Danube, it was found in 2010 that industrial plastics (pellets, flakes, spherules) contributed with 86% of the drift density to the overall load of plastics in the Danube (Lechner & Ramler 2015). However in 2012, the drift density of other plastic litter dominated with 69% of the total load. The study was conducted in a free flowing stretch of the Austrian Danube between Vienna and Bratislava. In the Danube basin, there are dozens of plastic production sites and an unknown number of processing companies in Germany and Austria.

A study published by the German Federal Environment Agency estimated the fragmentation of plastic debris as the main source of secondary microplastics, followed by tyre abrasion and pellet loss. The contribution of synthetic fibres was estimated as the smallest source for secondary micro plastics in Europe and Germany (Table 7) (Umwelt Bundesamt 2015).

In the same study the quantities of primary microplastics used in Germany in different applications were estimated. The highest used quantity (yearly 100,000 tonnes) was found in technical applications of micronized synthetic waxes, for example used as additive controlling viscosity of floor or vehicle care, used in paints, inks or for food coating. However, little is known about the release of primary micro plastics from these types of application (Umwelt Bundesamt 2015). In cosmetic products the estimation of the yearly used primary microplastics was 500 tonnes (Table 8).

Although nowadays China is the main producer of plastics no studies were found on estimations of sources and used amounts of primary and secondary microplastics in China, neither in other important plastic producing countries such as India

Nevertheless it can be expected that as in Europe, in Asian countries the plastic industry is a considerably contributor to the release of secondary plastics (pellet loss) into the environment (Table 1).

Table 7: Overview of sources of and annual amounts of secondary micro plastics released in Germany and Europe

Source of secondary micro plastic	Germany*	Europe*
Fragmentation of plastic debris	Unknown	3,400,000 to 5,700,000
Tyre abrasion	60,000 to 111,000	375,000 to 693,750
Pellet loss	21,000 to 210,000	57,000 to 570,000
Shedding of synthetic fibres	80 to 400	500 to 2,500

All figures in tonnes per year

Source: (Umwelt Bundesamt 2015)

Table 8: Quantities of primary microplastics used in cosmetics and other applications

Applications of primary microplastics	Quantities of primary micro plastics used in tonnes in Germany
Cosmetic products	500
Detergents, cleaning and maintenance products in private households	No data available
Detergents, cleaning and maintenance products in trade and industry	<100
Blasting abrasives for deburring surfaces	<100
Applications in medicine	No data available
Micronized synthetic waxes in technical applications	100,000

Source: (Umwelt Bundesamt 2015)

Box 4: Policy action against microbeads and microplastics

A ban on microbeads, which are intentionally added to personal care products, has already been implemented in Illinois, USA in 2014 (Seltenrich 2015) and is being pursued in several other states such as California and New York. The "Microbead-Free Waters Act of 2015", a bill which would initiate the ban of production, introduction or delivery for introduction of plastic microbeads nationwide from July 2017, was passed by the US House of Representatives at the beginning of December 2015.

The Netherlands, Austria, Luxembourg, Belgium and Sweden have called for a European ban on microplastics (Council of the European Union 2014). Canada is the latest country to agree on a ban and has begun by classifying microbeads as toxic substances (Government of Canada 2015).

Public action and pressure on industry is also showing success in reducing the use of such microplastics, with a number of companies already pledging to stop using microbeads in their products (International Campaign Against Microbeads in Cosmetics 2015).

Policy action has proven very successful in plastic waste-related issues before. Plastic bag use, for example, has been decreased by policy action for the last 15 years globally on different levels (cities, states etc.) and with several approaches (bans, taxes, and public awareness campaigns). The actions emerged as a bottom-up trend in the global south and were later on followed in the global north. In some Asian countries, like Bangladesh, India or Taiwan, as well as in some African countries, plastic bags were completely or partly (depending on their thickness) banned since the 1990s to early 2000s. Yet not only the banning mechanisms, but also the implementation of taxes, as initiated in many industrialized countries, on the use of plastic bags has proved to be very successful. In Ireland for example, the introduction of a levy on plastic bags in 2002 reduced the use of plastic shopping bags by 90 to 95% (Clapp & Swanston 2009).

5.4 Can we manage microplastics in the environment – and what is the role for men/women as agent of change?

Sundt (2014) developed a conceptual model of mechanisms and different sources of microplastic pollution. Part of the model is presented below (Table 9) and gives an impression if and in where consumers regardless of gender could intervene in order to reduce microplastics in the environment.

The sources of microplastic pollution can be divided into intentionally added microplastics in consumer goods such as PCP and intentionally used microplastics in technical, industrial or medical applications. By-products of the product or processes are for example dust fibres from wear and tear of plastic products (synthetic clothes or plastic tables or plates) in household and agriculture (foil in greenhouses). Unintentional release of microplastics can occur via fires and illegal burning of plastic waste, often practiced in countries lacking a proper waste management.

Due to the complexity and the broad area of possible sources of microplastics or sources of secondary microplastics, and the lack of gender disaggregated data on handling the release of microplastics in the environment or health impacts on humans, only a few aspects on the role of men and women will be analysed in this study. In this chapter, we will not target the commerce and industry using microplastics in the area of technical and medical production and application or handling specific processes. The authors of this literature study highlighted in Table 9 in different colours those areas where men and/or women may act as an agent for change and where the processes may be beyond their direct influence.

The level of production of consumer goods is closely linked to consumer consumption patterns and subject to influencing the release of microplastics into the environment. The question can be posed which products contributing to environmental pollution with microplastics are predominantly bought, disposed of and/or recycled and by whom. Insight into consumption patterns, behaviour and practices of post-usage of plastics by both sexes could contribute to reduce microplastics in the environment. Speaking about the target group of "consumer", we mostly speak either about people having a household, about their basic need for food, clothes and housing, or about their behaviour and habits. As stated by Schultz (2009) women spend more of their financial resources on basic needs for the household such as food and clothing or articles for health, than men do. Expensive items such as homes, cars and electronic equipment are more often bought by men than women. From the intentionally added microplastics the most obvious one to mention is PCPs (personal consumer products) and where women may be the more important stakeholders to reduce the consumption of micro-plastic containing items.

Table 9: Primary microplastics and its main sources

Secondary microplastics and its sources						
A) Natural defragmentation of microplastic debris in the sea			B) Biological contribution to defragmenting microplastics		C) Remobilisation	
Macroplastic debris from illegal, unwanted or unregulated terrestrial waste handling (landfills. Littering public spaces)	Macroplastic debris from illegal, unwanted or unregulated maritime waste handling	Municipal effluent (Sewage system and storm water) wastewater from households including synthetic fibres and particles	Shredding by animals (grinding of plastics into microplastics in the gastric mill of abundant macro fauna)	Boring by animals (creation of microplastics by boring isopods)	Harbours (ship propellers, dredging contaminated sediment)	Construction sites (excavating plastic contaminated soil, Reuse of construction materials/ waste)

Source: Sundt (2014), modified by the author

Table 10: Secondary microplastics and its main sources

Primary microplastics and its main sources						
Microplastics intentionally created		B) Microplastics as an inherent by-product of product or process			C) Unintentional release	
Consumer products (personal care products)	Commercial or industrial use products containing microplastics: abrasive media in metal works and other processes; textile printing, oil-gas exploitation, medical applications	Microplastic dust emissions from industrial production (maintenance of plastic items, painted or plastic treated surfaces)	Dust fibers from wear and tear of plastic products, synthetic textiles during normal use, washing and drying synthetic textiles (household, indoor, city dust, agriculture)	Waste handling and recycling (shredding and fragmenting)	Transport (accidents)	Fires and illegal waste burning

Source: Sundt (2014), modified by the authors

Red: Products predominantly purchased by women
Green: Industrial use or emission of microplastics (no valuation of the gender dimension)
Orange: Most probably both male and female contribute to micro plastic pollution, unintended and/or by mismanagement of plastic waste
Transparent: May be considered as impact of the overall environmental (micro-) plastic pollution

6. Marine environment: Exposure to (micro-)plastics and health aspects for aquatic organisms

The main share of plastic litter is of terrestrial origin and introduced to the marine environment via rivers (Galgani et al. 2000; Araújo & Costa 2007; Barnes et al. 2009; Rech et al. 2014). Many plastic litter items found on beaches are clearly sewage and wastewater related, like personal care related waste and hospital waste (Williams et al. 2014; Araújo & Costa 2007). As shown in Table 6, litter from coastal and beach tourism, and litter from household activities are important sources of plastic pollution of the European Seas.

The type of waste management and the location of the litter influence highly leakages of land-based plastic waste into the Oceans. Globally more than 80% of the oceans plastic debris originate from land-based litter, and less than 20% from ocean-based sources such as fisheries (Conservation 2015). The researchers of McKinsey & Company and Ocean Conservancy estimated that more than 50% of the Ocean´s plastic debris is land-based originating from five Asian emerging and fast growing countries: China, Indonesia, the Philippines, Thailand and Vietnam (Conservation 2015).

Nevertheless, the problem of the marine debris is a global problem while the other 50% is originated from countries outside Asia.

The same report states that 75% of the land-based marine litter originates from uncollected waste; the other remaining part finds its pathway due to gaps in the management of the collection system itself for example, illegal dumping of the collected waste or leakages from the disposals. In the Philippines where 84% of the waste is collected, 74% of the plastic leakages originate from collected waste, because many dumpsites are adjacent to waterways; between 70% and 90% of the waste is dumped illegally by private hauler companies. In China where only 40% of the waste is collected, the major leakage point of plastic waste comes from uncollected waste from people living nearby a waterway.

The reasons why Asia and especially China are contributing so much to the plastic leakages into the Oceans is down to exploding populations, changing consumer habits, attitudes towards waste, inadequate waste collection and landfill management (Conservation 2015).

Image 6: Water polluted by plastic waste in Nigeria

In addition the researchers observed that 80% of the plastic waste has a low residual value (e.g. plastic shopping bags, foils) and is more prone not to be collected or to be wasted than high-value plastics such as polyethylene bottles.

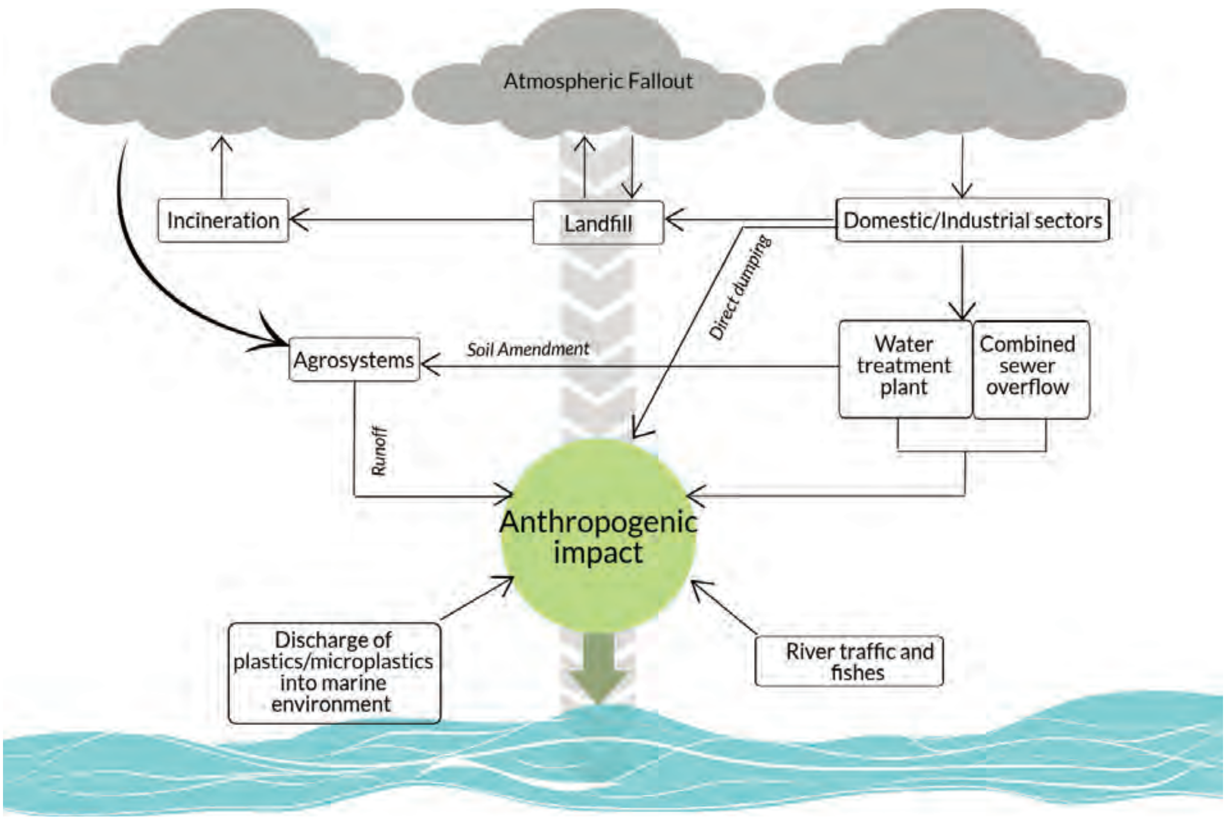
Furthermore, microplastics from households or industry enter aquatic systems via direct land-based runoff and from sewage treatment plants (Gallagher et al. 2015). Therefore, the minimisation of plastic waste (with regard to packaging, microbeads, synthetic clothing and disposable products, among others), and the effective management of such waste, especially with regard to wastewater treatment are crucial.

One particular waste issue which can constitute up to 4% of household waste (UK Figure) and take hundreds of years to decompose in a landfill site are disposable nappies (diapers). For just one baby nappies can constitute up to 50% of the waste from a household costing the tax payer £40 million in disposal charges (Edie.net 2002). In the US 467 diapers are sued very second which means 1,816 tons of diapers are used every day. Global figures are harder to estimate because large parts of the world don't use or can't afford disposable nappies, in some areas the market penetration is less than 2% (Richer Investment Diaper Consultancy 2014).

The modern disposable diaper (nappy) has a high absorbency capacity due to specific polymers. The pad of a disposable diaper consists of two essential elements, a hydrophilic (or superabsorbent) polymer and fibrous material such as wood pulp. A nonwoven sheet, made from plastic resins (nylon, polyester, polypropylene (PP) or polypropylene (PE)), keeps the adsorbent pad in place. As mentioned in Colon et al (Colon 2010) in 2006 the average baby diaper comprised of 36% superabsorbent polymer (SAP), 17% PP and 6% PS; SAP molecules have a long degradation period (in 100 days only 8% are composted). Under optimal composting conditions used baby nappies were compostable however the impact of the remaining component of SAP on soil was unknown.

A baby may use six to eight disposable nappies daily which have to be disposed of by the parents. In regions without a collecting system for waste, used nappies are disposed in the environment and may enter the waterways (see box below). The Women's Environmental Network in the UK began a Real Nappy Campaign in the early 1990's promoting, raising awareness and incentivising reusable nappy usage diverting from landfill the 90. WEN estimated parents could save up to £500/per year (Women's Environmental Network 2005).

Figure 7: Pathways and sources of microplastics within and from the terrestrial environment to fresh and marine waters. Source: Dris et al., 2015, adapted by authors



Box 5: Lack of safe management of disposable diapers threatens the environment in South Africa.

Many South African rivers and streams are threatened by the pollution of disposable diapers (nappies) while there is no adequate management of used nappies. At almost all bridges where rivers are being crossed, people are 'disposing' of used nappies. The plastic compounds in the disposable diapers hinder the natural decomposition; local rivers are blocked and polluted with plastics, chemicals (for example absorbent gel (sodium poly-acrylate) and zinc (used in skin protection creams in some nappies) and human excreta.

Members of the South African Water Caucus, a broad coalition of National Civil Society Organisations are taking action against these practices. Besides raising awareness of the issue particular with young mothers, the coalition appeals for the establishment of collection points where used nappies could be collected, re-cycled and re-used in ecologically responsible ways by the companies that produce, distribute and market them.

6.1 Occurrence and pathways of (micro-) plastics in the marine environment

The marine environment is a sink for immense quantities of plastic items and particles, floating on the sea surface, or accumulating on the seabed or coastal beaches. The principal variables, determining the amount of plastic entering the ocean are watershed outfalls and population density. Maritime activity, like fishing, is the main driver of ocean-based litter (Eriksen et al. 2014).

Floating and fragmentation of plastics

An estimated 5.25 trillion pieces of plastics and plastic particles are afloat in the world's oceans, being moved by winds and surface currents (Eriksen 2014). Their main accumulations are found in the five sub-tropical gyres (Law et al. 2010; Law et al. 2014; Eriksen et al. 2014; Goldstein et al. 2013). However, floating plastics are ubiquitous in the marine environment, and have even been found in the remote Antarctic environment. The abundances on the oceanic surface can reach up to hundreds of thousands of particles per km^2 (Galgani et al. 2015).

Eriksen et al. (2014) estimated that the Southern Hemisphere the Indian Ocean contains more particles and weight of plastics than the South Pacific and the South Atlantic together. As shown in Table 10 the North Pacific showed the highest count and weight of microplastics.

However, microplastics with a size of < 4.75 mm are much less abundant than predicted based on plastic fragmentation rates, which leads to the disquieting question: Where do these particles accumulate (Eriksen et al. 2014)?

Among the reasons for the seeming disappearance is the further fragmentation of microplastics into even smaller particles, as well as the ingestion by marine biota (Chapter 6.2, 6.3, 6.4). As a result of biofouling, microplastics sink to the ocean floors (Gregory 2009). Microplastics also intermingle with plant detritus or sand at coastal beaches (Barnes et al. 2009; Gregory 2009).

Although the expected and observed abundances of microplastics in the world´s ocean surfaces are high and extremely worrisome, they only represent 0.1% of the annual global plastic production (Eriksen et al. 2014) and can therefore be regarded as the very tip of the iceberg.

The model results for the count and weight of plastics floating in the world´s oceans (North Pacific, Indian Ocean, North Atlantic, Mediterranean Sea, and the South Pacific) are shown in Table 10 by Eriksen et al., 2014. The highest total count and weight of microplastics were found in North Pacific, followed by Indian Ocean. The Mediterranean Sea showed the lowest total count of microplastics and the South Atlantic the lowest weight of microplastics.

Beaches

Just as in the aqueous environment, the main share of beach litter usually stems from the nearest rivers (Araújo & Costa 2007; Rech et al. 2014). Climatic and oceanic conditions, particularly wind, near shore currents, wave motion and tidal dynamics (Browne et al. 2010; Carson et al. 2013; Doong et al. 2011) influence the movement of the incoming plastics and depositional patterns along the shoreline depend on its geomorphology and the distance to the nearest river mouth (Araújo & Costa 2007; Rech et al. 2014). In the case of 4 rivers along the Chilean coastline, plastic litter was mainly deposited on beaches to the north of the river mouths, following the prevailing equator ward low-level jet and declining abundances with distance to the river mouths were observed (Rech et al. 2014). Of course, the situation is different with regard to each beach and there are also cases in which garbage dumping due to leisure activities or ocean-based litter, from vessel traffic, fishing, or off-shore industries are the main sources of beach litter (Galgani et al. 2015). In fact, the top ten items collected during coastal cleanup campaigns as listed by The Ocean Conservancy (2014) related to leisure activities, like cigarette butts, plastic bags, beverage bottles, caps, straws, stirrers and beverage cans.

Seafloor and Deep-sea

An estimated 50% of marine plastic litter sinks to the seafloor, where it poses a threat to the structure of benthic communities (Gregory 2009; Engler 2012). Enclosed seas such as the Mediterranean or Black Sea may harbor some of the highest densities of marine litter on the seafloor, reaching more than 100,000 items km−2 (Galgani et al. 2000). Plastics are also found in bathyal (with a depth of 1000 to 4000 m) and abyssal (with a depth of 4000 to 6000 m) zones (Ramirez-Llodra et al. 2013). Depending on their flow-rate, as well as on the presence of bottom currents, rivers can contribute substantial shares of litter on the seafloor. An example is the non-tidal river Rhône, which has a deep bed and deposits the main share of litter 100 km offshore, while smaller rivers deposit litter nearer to their mouth region (Galgani et al. 2000). Litter deposition at large distances from the river mouth can also be due to high river run-off after storms and heavy rainfalls (Moore et al. 2002; Lattin et al. 2004). Where currents are weak, litter may also be deposited in estuaries or smaller rivers (Galgani et al. 2000). High abundances of seabed litter have been found especially in the Mediterranean Sea, probably as a result of the dense population along the coastline and the high frequency of shipping in the coastal water, in combination with a very low tidal flow. In coastal seas, litter abundances on the seafloor have been found to be generally higher. Bottom debris tends to accumulate in submarine canyons, which may act as channels for the deposition in the deep-sea environment, and continental shelves, rather than in the open ocean (Galgani et al. 2000; Lee et al. 2006; Pham et al. 2014; Galgani et al. 2015). The accumulation of plastics in the deep-sea environment raises special concern, as it is suggested, that degradation is even slower as a result of absence of light, and low oxygen concentrations and temperature (Galgani et al. 2015).

Table 11: The estimated total count and weight of microplastics in the world´s oceans

	Size Class	NP	NA	SP	SA	IO	MED	Total
Count	0.33-1.00 mm	68.8	32.4	17.6	10.6	45.5	8.5	183.0
	1.01-4.75 mm	116.0	53.2	26.9	16.7	74.9	14.6	302.0
	4.76-200 mm	13.2	7.3	4.4	2.4	9.2	1.6	38.1
	> 200 mm	0.3	0.2	0.1	0.05	0.2	0.04	0.9
	Total	199.0	93.0	49.1	29.7	130.0	24.7	525.0
Weight	0.33-1	21.0	10.4	6.5	3.7	14.6	14.1	70.4
	1.01-4.75 mm	100.0	42.1	16.9	11.7	60.1	53.8	285.0
	4.76-200 mm	109.0	42.5	17.8	12.4	64.6	57.6	306.0
	> 200 mm	734.0	467.0	169.0	100.0	452.0	106.0	2028.0
	Total	964.0	564.7	210.2	127.8	591.3	231.5	2689.4

NP = North Pacific, NA = North Atlantic, SP = South Pacific, SA = South Atlantic, IO = Indian Ocean, MED = Mediterranean Sea, Total = the global ocean. From: Eriksen et al., 2014

6.2 Uptake of plastic particles and transfer between trophic levels

Plastics, which were taken up upon ingestion or ventilation (Watts et al. 2014), have already been found in the digestive system/gastrointestinal system of a wide range of animals, from the very base of the food web (Setälä et al. 2014) to mammals (Eriksson & Burton 2003; Fossi et al. 2012; Besseling et al. 2015). Many of the affected species are consumed by humans directly or indirectly, as they are prey for species of human consumption (Engler 2012). Examples are several species of fish (Boerger et al. 2010; Foekema et al. 2013; Gassel et al. 2013), shellfish (eg. Mathalon & Hill 2014), and lobster (eg. Murray & Cowie 2011).

Anthropogenic debris has been found in about one quarter of samples of individual consumption fishes taken from markets in Indonesia and California, United States (Rochman 2015). In Indonesia in 55% and in California 67% of all sampled species anthropogenic debris were found. The same study identified different sources of the debris, reflecting the different waste management practices in the two regions. In Indonesia with a poor waste collection system the market fishes were mainly with plastic fragments contaminated. In the affected market fishes from California, with a higher plastic and textile use and a more advanced waste management policy, mainly synthetic fibres from textile were identified.

Plastics are ingested by a wide range of mesozooplankton species and transferred to the next trophic stage, the macrozooplankton (Setälä et al. 2014). This process has also been observed on higher trophic levels. It was shown that crabs took up microplastics by feeding on blue mussels. In the crabs, the particles migrated to the haemolymph and tissues (Farrell & Nelson 2013). Similarly, plastic particles found in the scat of fur seals were probably taken up through the consumption of lantern fish (Eriksson & Burton 2003). Upon the ingestion of fish, microplastic particles were also transferred to Norway lobsters (Nephrops norvegicus) (Murray & Cowie 2011). In two species of shellfish cultured for human consumption, 0.36 ± 0.07 (*Mytilus edulis* – Blue mussel) and 0.47 ± 0.16 (*Crassostrea gigas* – Pacific oyster) plastic particles per gram of wet weight were found. Based on this data, the calculated annual ingestion of microplastics by shellfish consumers is between 1800 and 11000 particles. In a Canada-based study, the amount of microplastics found in farmed blue mussels (aquaculture), was higher than in wild ones, Although this has to be further investigated, a reason may be that they are grown on polypropylene lines (Mathalon & Hill 2014). Given that the meat of several species of whales is consumed in some countries/regions (e.g. Alaska, Japan and Norway) it is important to mention that substantial amounts of plastics/associated toxics have been found in such species (Fossi et al. 2012; Besseling et al. 2015). Similarly, the uptake of nanoplastic particles and transport along a food chain was shown for aquatic organisms (eg. Cedervall et al. 2012). The health risks posed by such nano-sized plastic particles are discussed in the following section.

6.3 Plastic uptake and accumulation in animals

In addition to the impacts of plastic production and usage on human health, there is concern that plastic particles and/or any intrinsic or adhering toxic substance may be passed on to humans along the food chain, especially through the consumption of freshwater and marine biota, like fish and seafood. This concern is well founded, as plastics and the associated toxic chemicals can cause substantial damage in such biota, and plastic particles have evidenced potential to accumulate in animal tissues and can even be transmitted along trophic levels.

This problem is especially pronounced in the aquatic environment, as microplastic particles can take up and accumulate persistent organic pollutants (POPs), such as PCBs, DDT and Nonylphenol from the water, in an order of magnitude six times higher than the surrounding water (Wright et al. 2013). In PP pellets from the Japanese coast all three pollutants were detected, with varying concentrations between the sampling sites (PCBs (4 - 117 ng/g), DDE (0.16- 3.1 ng/g), and NP (0.13 - 16 µg/g)). The high accumulation potential suggests that plastic resin pellets serve as both a transport medium and a potential source of toxic chemicals in the marine environment (Mato et al. 2001).

In mussels, which are common seafood for human consumption, microspheres which the animals took up by feeding, did not only stay in the gut, but entered the circulatory system, where they could be found for more than 48 days after ingestion (Browne et al. 2008). In the same species, microplastic particles can accumulate in the digestive gland´s lysozymes, causing an inflammatory response and membrane destabilization (after 6h, increasing with time) (von Moos et al. 2012).

In a study of Japanese rice fish (*Oryzias latipes*) it was shown, that the uptake of virgin plastic pellets causes signs of stress, while the uptake of plastic pellets, which were exposed to marine water, results in the bioaccumulation of chemicals, and induces liver toxicity (Rochman, Hoh, et al. 2013). A consecutive study on the same species found that the ingestion of both virgin plastic pellets and marine plastic pellets (which had been incubated in marine water and consequently absorbed chemicals) altered gene expression in females, while the effect in male individuals was only observed after ingestion of marine plastic pellets. In one male individual, abnormal proliferation of germ cells could be observed (Rochman et al. 2014). Transfer of hazardous substances from plastic particles upon ingestion has also been observed in other species, like sediment-dwelling organisms, shearwaters, and fin whales (Teuten et al. 2009; Fossi et al. 2012; Tanaka et al. 2013). Such substances have a negative impact of reproduction and development, and induce genetic aberrations in several species of molluscs, crustaceans, insects, fish and amphibians (Oehlmann et al. 2009).

In female rats, Bisphenol A stimulated the reproductive system and exposure to high doses during pregnancy or lactation caused increased mortality rates, lower birth weight and delayed sexual maturity (Koch & Calafat 2009).

Upon ingestion by mammals (including humans), plastic particles can translocate from the gut to the lymphatic system (Hussain et al. 2001; Carr et al. 2012; Van Cauwenberghe & Janssen 2014). It is suggested, that such plastic particles may carry luminal molecules into muscular tissues, thereby enhancing gut infectivity or immune stimulation emanating from the adhered molecules (Powell et al. 2010; Van Cauwenberghe & Janssen 2014).

Recent studies also show the threats posed by nanoplastics to planktonic biota, like growth inhibition and reduction of Chlorophyll, a content in green algae (*Scenedesmus obliquus*) as well as alterations to reproduction, reduced body size and higher rate of malformation in neonates of *Daphina magna* (Besseling et al. 2014).

6.4 Seafood and gender aspects

Although the presence of toxic chemicals in the marine environment released from plastics and micro and/or nanoplastics in human food and their health effects have not been thoroughly investigated yet, the ability of nanoplastics to pass cellular membranes, and even the placenta, should raise concern, especially with regard to exposure of females during pregnancy (Bouwmeester et al. 2015; Wick et al. 2010).

Gender differences can occur with respect to preferences in seafood and fish, as well as

Image 7: Seal trapped by fishing gear in the Netherlands © Zeehondencentrum Pieterburen

consumption frequencies, which could cause differing exposure to plastics. In a Portugal-based study males showed a higher preference for wild and smoked fish and a lower acceptance of frozen fish than women.

Hake, pink, cusk, eel and redfish are more frequently consumed by females, while cephalopods and sardine are more frequently consumed by males. In a Spain-based study, females were more likely to consume horse mackerel, octopus, and hake, than males.

However, both studies showed that such food preferences are strongly dependent on the geographic region within a country (Cardoso et al. 2013). A study from Italy confirms that both gender and location influence consumption patterns, with females, especially from coastal areas, tending to prefer fresh fish and males, especially from inland areas, mainly consuming processed fish products (Cosmina et al. 2012).

A lower frequency of consumption of wild-caught fish in females is consistent with a study from South Carolina, USA (Burger 2000). Another USA-based study however found a very weak but consistent relation of gender and consumption preferences, with females being more likely to prefer wild fish and seafood to aquaculture products (Hall & Amberg 2013). An investigation conducted in China found out that males were more informed about green seafood labels, which is suggested to be a result of their higher attention to government food policies (Xu et al. 2012).

For a detailed analysis of the gender-related effects of endocrine disrupting chemicals see chapter 3.

6.5 Fishing related marine litter and gender

Inhabitants of coastal communities are directly concerned by coastal and marine litter. Gender differences can be observed with regard to the kind of exposure to litter as well as the different types of litter production. In small-scale fisheries, there is a distinction with regard to catch types (shells/fish) and fishing areas (near-shore/off-shore) found in studies from several countries, especially in the Asian and Pacific region (Kleiber et al. 2014). Commercial fishing is clearly a male-dominated activity (FAO 2015).

In many communities, females concentrate on shell and smaller fish, while males are more involved in the catching of fish off-shore. Consequently, off-shore habitats, like reef edges or pelagic zones, are described as typically used by male fishers, while near-shore habitats, like mangroves, estuaries and the intertidal zone are typically used only by female or by both male and female fishers (Kleiber et al. 2014).

The role of male and female fishers in causing marine litter pollution differs between the genders. Marine plastic pollution due to lost or discarded fishing gear is a major problem (eg. Pham et al. 2013). It is more related to male fishers, as the activity of shell gleaming does not involve any fishing gear. This kind of pollution has a substantial impact on the marine ecosystem, not only because of the effects of plastic, but also because lost fishing nets can function as so-called ghost-nets, entangling marine biota and thereby causing death or degradation (Gregory 2009). For the females, involved in shellfish gleaming, beach litter is an important problem, as it harms the shellfish and can therefore cause them economic losses (Newman et al. 2015). These gender differences however, vary between cultures and geographic regions.

In an Australia-based study on commercial fisheries, Kilpatrick et al. (2015) found that female family members served as channels of communication with fishers, promoting physical and mental health issues. Therefore even if they are not practically involved in fishing activities, women have influence on decision making related to fisheries. This could be important for management of fishing-related waste.

7. Plastic waste management

7.1 Municipal solid waste generation

Municipal Solid Waste (MSW) tends to be generated in much higher quantities in wealthier regions of the world because of the high proportion of urban populations adopting high-consumption lifestyles. Societies use more and more packaging and plastic materials producing approximately 1.2 kg/person/day solid waste (2013) that is expected to increase to 1.42 by 2025. The most industrialized countries of OECD (34 nations) today generate ~ 50% of world's waste, whereas populous China produces 70% of solid waste in the SE Asian region (Valavanidis & Vlachogianni 2015).

However, with a growing population and economy, as well an urbanisation the demand on safe and disposal products grows especially in developing countries. For example in 1975 the average consumption of plastics per capita was in Vietnam only 1 kg per person, 40 kg in 2012 and 55 kg was predicted for 2015 (Federation 2010). As Table 11 shows, much of the global MSW is dumped by upper-middle and lower-middle income countries, posing in particular a threat to environmental pollution.Globally, an estimated 1.3 billion tonnes of solid waste is collected yearly and will increase to an expected 2.2 billion tonnes by 2025 (UNEP 2013).

Also the estimation on the type of disposal of MSW in the regions with different levels of income shows that high income countries produce the most waste and after incineration and recycling, landfilling is the most common treatment of MSW (The World Bank 2012). In comparison with the high and upper-middle income countries, the low income and lower-middle income countries dispose of far less amounts of MSW. Nevertheless in all regions landfilling is the most common treatment of MSW.

Table 12: Overview global Municipal Solid Waste disposal by income (million tonnes)

High Income		**Upper – Middle income**	
Dumps	0.05	Dumps	44
Landfills	250	Landfills	80
Compost	66	Compost	1.3
Recycled	129	Recycled	1.9
Incineration	122	Incineration	0.18
Other	21	Other	8.4
Low Income		**Lower-Middle income**	
Dumps	0.47	Dumps	27*
Landfills	2.2	Landfills	6.1
Compost	0.05	Compost	1.2
Recycled	0.02	Recycled	2.9
Incineration	0.05	Incineration	0.12
Other	0.97	Other	18

Source: http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf; adapted by authors.
**Including China*

Image 8: Informal waste dumping place in rural Romania

The International Solid Waste Association (ISWA Task Force 2014) reports the composition of solid waste, which follows global patterns due to globalisation of the consumerism culture and global trade effects.

For example, the plastics content of municipal solid waste is globally often 10-15% by weight, even in cities which don't use much plastic; moreover, the quantities of waste electronic equipment are increasing rapidly. E-waste is mainly shipped to less-wealthy countries, for example to Africa where it causes severe health and environmental problems.

Jambeck (2015) cited population size and the quality of waste management systems as largely determining which countries contribute the greatest mass of uncaptured waste available to become plastic marine debris. Without waste management infrastructure improvements, the cumulative quantity of plastic waste available to enter the ocean from land is predicted to increase by a factor of two and up to five times by 2025, depending on the mass of the mismanaged waste (Jambeck 2015). Jambeck defined mismanaged waste as material that is either littered or inadequately disposed. Inadequately disposed waste is not formally managed and includes disposal in dumps or open, uncontrolled landfills, where it is not fully contained. Furthermore it was said, mismanaged waste could eventually enter the ocean via inland waters.

Although local governments have little power to regulate the quantity, heterogeneity, and material composition of the products consumed and discarded by the citizens, they mostly decide on which waste management technologies and strategies to implement.

The current global waste dilemma also evidences an industry failure, with manufacturers primarily determining the material composition of their products and packaging; therefore making them complicit with the waste problem (Gutberlet 2015). Gutberlet mentions, most citizens are also failing to minimize their waste generation, to reorient their consumption habits and lifestyles, and to initiate/participate in public discussions on waste and the social, economic, and ecological implications of its waterways, wastewater outflows, and transport by wind or tides

The wealthier and most advanced countries with respect to waste management such as Denmark or Germany have mostly a formal communal waste management strategy in place. Other less wealthy countries may lack the financial means and required infrastructure for a formal waste management, and often have to deal with the accumulating plastic wastes in their country. However, wealthier countries usually produce more communal waste than developing countries, due to their higher consumption.

7.2 Plastic recovery rates

According to PlasticsEurope (2012) in the EU-27, plus Norway and Switzerland, 25.1 million tonnes of post-consumer plastic waste ended up in the waste upstream. 26% of the plastic waste was recovered through recycling and 36% by energy recovery processes, while 38% still went to landfill. However, much of the European plastic waste is not recycled in the European countries. Plastic waste flows from Western countries with established recycling collection systems mainly to China, which dominates the international market, receiving around 56% by weight of global imports. The EU collectively exports almost half of the plastics collected for recycling, at least 87% of which goes to China (ISWA Task Force 2014).

The USA produces yearly about 33.6 million tons plastic waste, of which 6.6% is recycled and 7.7% is combusted for energy recovery (Cho 2012). The recycling rate of PET bottles and jars was 31.3% in 2013 and of HDPE white translucent bottles 28.2% (EPA 2013). The rest ends up in landfills.

The study done by the Ocean Conservation in the five focus countries China, Indonesia, the Philippines, Thailand and Vietnam, estimated almost 60% of the plastic waste is not collected. The report observed in the Philippines that the collection rate of low-value plastics was almost zero and for high value polyethylene bottles nearly 90% (Conservation 2015).

ISWA mentions that plastic scrap imports in China are rapidly increasing, as are domestic plastics (recycling and energy from waste).

The poor quality of domestic recyclates necessitates quality imports for capital-intensive better quality manufacturing, while the inferior imports and domestic recycled plastics end up at either low-tech, uncontrolled plants and maybe also EfW plants. While the Chinese Government is actively working to increase the quality of imported plastics and reduce the number of unregulated facilities (Operation Green Fence an initiative by the Chinese Government designed to more fully inspect incoming secondary commodities, including scrap, with a goal of prohibiting the import of unwashed and contaminated material entering China), the environmental benefits from plastic exports to China are questionable given the dominance of uncontrolled reprocessing or manufacturing with lower environmental standards as for example in Europe (ISWA Task Force 2014)

PET can be recovered and repeatedly recycled by thoroughly washing and remelting it for use in new PET products, or by chemically breaking down the PET into its constituent raw materials, which are then purified and converted into new PET. In case PET is unsuitable for recycling because it is too dirty or contaminated to be properly cleaned, it can be used as an energy source. This is called "thermal recycling" (Association 2015).

The same study mentions that PET may be used for manufacturing new products in many industrial areas such as packaging for detergents, cosmetics, high-quality carpets, foils, car spare parts, pillow fillings for allergic people and fabrics. Its variety of applications in many industries therefore makes PET attractive.

Box 6: A study on recycling in Thailand

A study in Thailand (Menikpura et al. 2013), conducted in the municipality Nonthaburi (Thailand) covering an area of 39 km^2 and hosting a population of 0.27 million estimated a municipal waste generation of 370 tonnes at 0.8 kg per capita per day. The waste consisted of 14.4% plastic waste. The researchers stated, despite a considerable recycling rate for steel (40%) and paper (23%), only 3.3% of the plastics were recycled, due to the low market value of plastics such as polypropylene (PP) and low density polyethylene (LDPE). The rest was landfilled.

The major focus of this study was to identify the effects of the recycling activities on the sustainability of the existing waste management. A set of relevant indicators has been used to evaluate the ultimate damages/ effects related to environmental, economic and social aspects of waste management methods, including valorisation, such as “Damage to ecosystems”, “damage to abiotic resources” and “Life cycle cost”.

Furthermore “damage to human health” and “income based community well-being” were considered as the most relevant indicators for social sustainability assessment. The results obtained showed that recycling contributes substantially to improving overall social, economic and environmental sustainability of the waste management system.

Image 9: Formal waste collection system in the Netherlands

About three-fourths of reclaimed PET is used to make these products. Much of the remainder is extruded into sheet for thermo-forming, stretch blow moulded into non-food containers, or compounded for moulding applications (Industry 2015).

However, also in wealthy countries like the US the recycling rate of postconsumer plastics such as PET and HDPE bottles is very limited at only 30%. (Coalition 2011).

According to the Sustainable Packaging Coalition lack of infrastructure is identified as an important barrier for consumers to collect plastics. Moreover lacking the possibility to sort collected plastics and the fluctuation of the prices for virgin and recycled resins makes it less attractive for the companies to include post-consumer plastics in their production programs

7.3 Collecting and recycling practices

Formal - Informal waste recycling

In certain countries the management of solid waste and recycling is carried out by informal recyclers or waste pickers. The informal recyclers collect waste from homes, streets, commercial and industrial establishments and the final disposal sites. They contribute to the wider waste management system often providing this service free of charge to municipalities, central government or residents. Some 20 million people around the world depend for their livelihood on informal recycling from municipal solid wastes. The main driver is poverty, working conditions are often very unsafe and unhygienic, and child labour is commonplace (ISWA Task Force 2014). Although waste pickers contribute significant to waste collection and recycling, their social status is in general low and in all cultures traditionally they have a bad reputation instead of being viewed as environmental champions and waste reducing agents. (Gunsilius 2010; Dias 2015).

It was reported that 50 per cent of US plastic scraps were shipped to China, and much of that material was recycled in a primitive way (The Christian Science Monitor 2013). Laizhou, a county-level city in Yantai Prefecture, Shandong Province, had a lot of small family-owned workshops undertaking plastic scrap recycling. These small entrepreneurs wash, melt, extrude, and chop polyethylene into pellets that could be remelted and turned back into film. Safety equipment is unknown, and pollution controls are weak. The water and chemicals used to cleanse the plastic run directly into local rivers (Rucevska et al. 2015).

According to Gunsilius (2010), the informal valorisers and service providers have unpleasant and dangerous working conditions. On average, 71% of all informal sector households where someone works in the informal sector fully depend on the income of that person.

There is potential for double jeopardy where women and other workers are not only exposed to toxics from the direct work they are doing but also as a result of working or living close to where manufacturing or some cases reprocessing is carried out. In India where plastic recycling is done in informal settings with poor health and safety conditions many women are employed to sort and strip the plastic, sitting on the ground and working with their bare hands. Copper wires are stripped of their PVC coatings and this work is mainly carried out by women, children and elderly people. The machinery which grind's, moulds or otherwise reshapes the plastic is often operated in open areas exposing the women and other workers to dust and fumes from the heated plastics (Toxics Link 2016).

A study about gender aspects in the informal waste economy in Nigeria concluded that gender inequality is an ingrained phenomenon in the waste-recycling economy in Nigerian cities. Women play very little part in decision-making and ownerships of the more profitable sectors of the economy, namely the scrap dealers or middlemen (Nzeadibe & Adama 2015).

Research (Gutberlet 2013) in the metropolitan of Sao Paulo (Brasil) found that the recyclers in the informal waste sector suffered from economic and social exclusion. Many of the informal recyclers were women. From the organised and formal recycling cooperatives, more than half of the participants were women, who carry out the same tasks in the waste management as men (Gutberlet 2013). It was stated that these cooperatives create opportunities for education and social development of the recyclers.

More women earn livelihoods in the informal waste and valorisation sectors than in similar formal occupations.

However, women tend to be concentrated in lower-earning activities such as waste picking, their average income is lower. Even when they do the same kind of work, for example, itinerant waste buying, they tend to earn less and are also paid lower rates for materials by junk shops. This tendency for women to earn less than men was borne out by a collaborative project in Latin America between networks of waste pickers studying the gender perspective on recycling which found that there was a clear gender division when it came to who was allowed to recycle the waste with the highest value or occupy positions of authority. Women often lose out because of their limited time and energy due to responsibility for the household and childrearing (Brito 2015).

Over the last 5 years in South Africa the annual compounded growth of plastic recycling was 5.5%, with a strong grow in the recycling of PET, PE-LD/LLD and PS (Monya Vermaak 2016). According to Plastics I SA the biggest challenge was the lack of consistency of the incoming stream of recyclables: Waste pickers collected a large quantity of the recyclables from landfills which were contaminated and therefore of very poor quality. Due to impurities up to 40% of the collected plastics had to be rejected. This clearly highlights the need for an effective separation at the source. Furthermore there are difficulties to recycle plastics, such as mixed materials or multi-layer packaging films. The same report states that recyclers have to face a general downturn in the economy and the social impacts of greater costs for electricity and water shortages.

However, studies on gender roles of waste-pickers reveal that the ratio of women to men waste pickers differs from country to country as well as the kind of work to be done which is influenced by the gender roles (Schenck 2012).

Box 7: Identified needs for improving the plastic recycling in South Africa (Source: Plastics I SA 2016)

Political will Decision makers and legislators have to be informed and be aware of the challenges of recycling.

Stakeholder commitment More products need to be designed with their recyclability in mind; extend Producers Responsibility Organisations.

Quality of Recyclables Waste pickers, collectors and recyclers should communicate their requirements; sorting practices should better be managed.

Energy and water efficiency Recyclers have to optimise the resource efficiency. For the same tonnage recyclers use three to four times more electricity than converters.

Public awareness and education – The public needs to be educated to separate at source and to insist on recyclable packaging, cleaning out residual contents etc.

Alternate technologies not all material can be recycled, therefore the plastic industry should find some technology partners to tailor make mechanical alternative recycling methods.

For example, in India the work of the waste picker is mainly done by men, in Dakha city mainly by women.

The same study mentioned that informal landfill waste pickers are exposed to injuries and or health risks caused by broken glass, inhalation of dust, chemicals, hospital and medical waste although there is no gender disaggregated data for this. It would be important particularly in countries where currently no formal communal waste collection and recycling systems exist, to integrate the informal waste pickers in any future waste management plans and to raise general awareness about the important role waste pickers play and could play in public society. As shown in Belo Horizonte, Brazil and in Pune, India, one of the steps to be undertaken is to integrate waste pickers, for example into cooperatives, associations or micro-enterprises, taking the gender equity into account (Brito 2015) (Tangri 2012).

Box 8: Case Study: The pollution caused by informal sector recycling in China.

Hebei province in China formally known as the site of the summer residence of the Qing-dynasty emperors now has a very different notoriety, it is known as North China's plastic waste capital. Pre-2011 it was home to around ten thousand informal businesses which processed millions of tons of plastic waste each year. The Wenan area of Hebei was notorious for having polluting industries but the final straw that led to the crackdown on this informal sector came in 2011 when the Xiaobai River became so toxic it wiped out thousands of acreage of crops.

Although the local economy took a huge blow the devastating health and environmental impacts of dealing with this toxic waste pushed the government to close down the unregulated polluting businesses in the locality sending them instead to set up covertly in other areas. Thousands of small washing and shredding shops were closed leaving only a few factories which moulded items like hoses or buckets.

In 2010 it was estimated that between 1.3 and 2.5 million tons of waste and recycled plastic was traded or produced in Wenan. There was somewhere between 10,000 to 20,000 processers, traders and shops employing between 10,000 and 20,000 local and migrant labourers.

Indications of the impacts on health surfaced when it was noticed that large numbers of Wenan residents suffered from enlarged livers (which is a condition related to improper plastic processing), pulmonary conditions, thrombosis and very high blood pressure. These cases were report by the town doctor. In fact it was said that none of the town's young men were making it into the military due to their enlarged livers.

Reports of contaminated plastics originating from Wenan highlighted the fact that unsterilized recycled plastic pellets contained medical waste, and plastic food bags and take –out food containers coming from Wenan all contained toxic chemicals. Even up to a month before the shutdown a journalist reported that tons of medical waste was still being badly processed in Wenan.

Unfortunately for those working in the informal recycling and processing waste sector in Wenan the authorities did not follow the good example set by the waste pickers co-operatives set up in Brazil or Columbia. Instead of provided a regulated business park with proper waste handling and water processing facilities they destroyed the businesses for the problems they had no hope of solving.

Last year the Chinese government targeted plastic processing businesses nationally banning all small-scale shops under 30,000 ton capacity and ordering businesses to move to new regulated industrial parks. But with falling plastic prices and the price of crude oil, manufacturers are choosing cheaper imported virgin material over recycled plastics. In China much of its domestic waste could be re-diverted to incinerators unless state funded recycling companies capture the market. Sadly recycling businesses that relocated to the Guiyu's state new managed industrial parks look to be just as polluting as the informal shops. The only hope is that the race to the bottom means the newly emerging waste sector act in an environmentally responsible manner. But the legacy remains from China's plastic and e-waste recycling, and other dirty industries. Over a third of China's surface water is unsuitable for human contact.

In the Hebei area, a pond is situated in the vicinity of a plastic waste recycling factory district. Due to pollution from the factories, the pond's water has changed into a strange pink colour. Although the local government has financed and supervises the construction of a waste water treatment facility, the local plastic factories still discharge all their waste water directly in the environment. Over the last ten years, the groundwater in this area is so polluted that is it undrinkable, and the local population has no choice but to buy their own drinking water, which has become yet another financial burden on low-income families (Goldstein 2016).

7.4 Landfills and dumping; controlled and uncontrolled

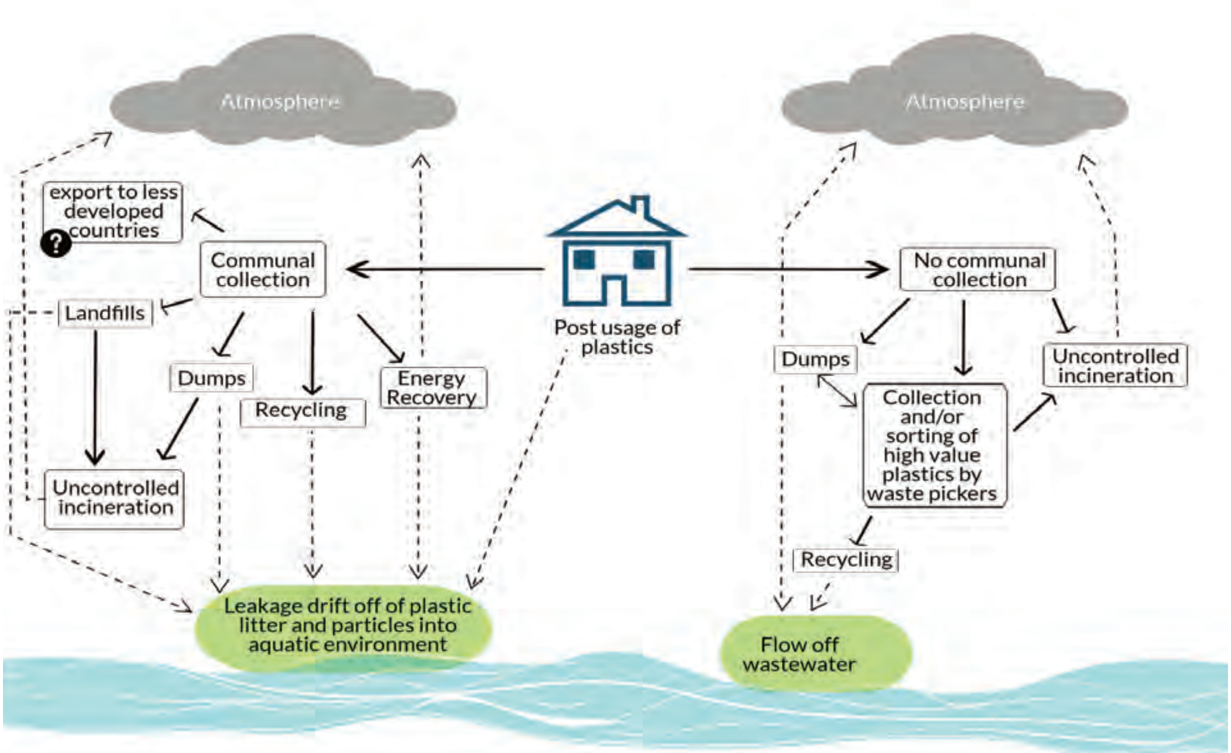
Litter dumping, both on a small fly-tipping (illegal dumping of waste) and a large scale (illegal and legal landfills) contribute substantial amounts of litter to the coastal and marine environment. This can be due to direct littering in the sea, from vessel traffic, or on beaches, as well as terrestrial littering in urban or rural sites, with subsequent transport to rivers and the ocean. There are differences due to gender, regarding environmental awareness, waste generation, separation and recycling, illegal littering and waste reduction activities (as described in the following paragraphs).

Landfills

Legal landfills, if not under the control of technical professionals and management, can, like an illegal landfill, both pose threats to humans and the natural environment. These problems are defined as contamination of ground and surface water, emission of bulk and trace gases in an uncontrolled manner and the creation of nuisance, affecting the surrounding area (Golder Europe EEIG 2005). Such landfills are a common problem around the world and are in many cases situated directly along riversides or beaches (Williams & Simmons 1999; Jordá-Borrell et al. 2014; Rech et al. 2015), which enhances the transport of waste to the ocean and coastal beaches. However, heavy storms and rainfalls can also transport waste, especially light-weight items like plastics, from remote areas to the nearest waterways, from where it gets into rivers and oceans (Barnes et al. 2009).

Therefore, efforts for waste minimization are crucial (Afroz et al. 2011). Such efforts can be the separation, reuse and recycling of litter, strict laws that aim for the reduction of waste, and conscious shopping, e.g. with respect to food packaging. In the "Report on implementation of the landfill directive in the 15 member states of the European Union" (Golder Europe EEIG 2005), ten member states reported to have no illegal landfills at all (Austria, Belgium-Flemish, Denmark, Finland, Luxembourg, Netherlands, UK) while six other member states reported a significant number of illegal landfills (Belgium-Walloon, France, Greece, Ireland, Italy, Portugal) (Golder Europe EEIG 2005). However, the comparability of this data is limited, as the classification of a waste-polluted site as "landfill" or "fly-tipping" site (which were not reported in the respective report) may differ between the countries.

Figure 8: Global practices pathways of post used plastic consumer products and its environmental risks



The main waste types on the illegal landfills in EU member states were construction/demolition material, bulky items. A major reason for the existence of such illegal landfills in these states is "fragmented/inadequate administrative responsibility". Other reasons are the costs and effort (long distance) of using a legal waste collection facility (Golder Europe EEIG 2005)

Public opinion polls conducted in countries from several regions around the world show that the main reason for illegal dumping activities is the lack of controlled/legal and affordable waste collection services (Babayemi & Dauda 2009; Jordá-Borrell et al. 2014). Generally the lack or ineffectiveness of municipal waste management as well as a lack of environmental awareness are basic causes for the common existence of illegal landfills (Golder Europe EEIG 2005; Babayemi & Dauda 2009; Adebo & Ajewole 2012; Jordá-Borrell et al. 2014).

Illegal landfills often contain construction or demolition material, as well as bulky household waste or furniture (Williams & Simmons 1999; Golder Europe EEIG 2005; Jordá-Borrell et al. 2014). In a study from Bulgaria, the prohibition of dumping specific litter items, like construction waste, in the containers for waste collection, was named as another reason for illegal litter deposition (Bentvelsen 2005). Interestingly, in a UK based study, illegal litter deposition sites were found in areas where the deposited items could have been given to waste collection free of charge, which leads to the question if the responsible people were aware of this service (Williams & Simmons 1999).

Littering / dumping on a small scale

Apart from the disposal of litter in landfills, there is the problem of fly-tipping, which is generally seen a in public places, like streets or parks and in nature and is often related to leisure activities (Williams & Simmons 1999; Carson et al. 2013; Rech et al. 2015). Again, one reason for this behaviour is the lack of legal and controlled garbage disposal options, like garbage cans (Al-Khatib et al. 2009), but the frequency of littering is related to gender (as detailed in the following section), age, and socio-economic situation of a person. In the past, the usage and consequent dumping of plastic bags, which were among the most commonly dumped plastic waste items, was immediately and significantly reduced by introducing levies on their use (Newman et al. 2015). This shows how policies can be used as a tool for waste reduction

7.5 Incineration: controlled and uncontrolled

People burn plastics for various reasons – either because there are limited energy sources; it is easier than hauling it to the local disposal site; to avoid paying for a regular service or if no municipal waste service exists; or quite simply, it's an easy way to get rid of the plastic waste. Indoor plastic burning is often practiced in low-income areas where citizens use their own stoves for cooking and heating, and expensive wood is saved, with concomitant reduction in garbage; however, this

Image 10: Uncontrolled burning of plastics in Kyrgyzstan

scenario imposes disproportionately health impacts to women and small children in their care, due to their greater involvement in cooking.

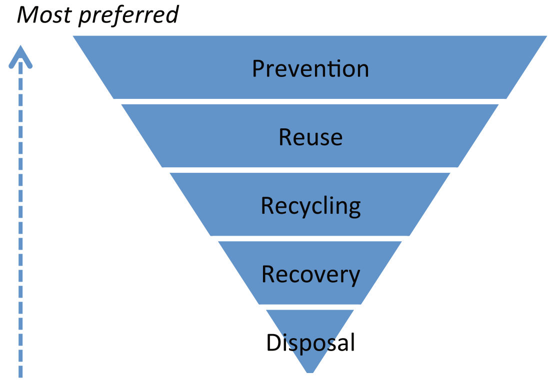
In many low-income countries, a large percentage of waste cannot be properly managed and recycled. To get rid of the waste one of the methods is open burning of municipal dumpsites or burning the content of collecting bins. Interestingly, studies from Nigeria and Ghana also found gender differences with respect to the employment of illegal waste deposition techniques. While men were more frequently involved in open dumping on land or in waterways, as well as in the burying of waste, women were more often involved in waste burning (Aaniamenga Bowan et al. 2014; Babayemi & Dauda 2009). This means that males and females are not equally affected by waste-related health risks, with females being more exposed to the toxic gases, which result from the burning of waste.

Plastics containing chlorine compounds (for example PVC) are potential chlorine source of PCCD/Fs (dioxins and furans), a group of persistent organic compounds (POPs). See chapter 3 for health risks. On open burning waste sites these plastics are evidentially a potential source for PCCD (Shih et al. 2015). The study conducted by (Shih et al. 2015) estimated that due to the open burning at dumpsites in Kenya, the risk of all cancers increased considerable.

8. Green consumerism, environmental awareness and behaviour

With the introduction of the so-called waste hierarchy a political instrument was developed for taking action regarding a waste management strategy, indicating the most preferable action to reduce and to manage the waste (UNEP 2013) (Figure 19). According to UNEP (2011) waste management policies are often a reaction on actions on local level; national governments may have a strategic interest, following already established local practices and solutions. Hence for developing a strategy for a sound (plastic) waste management it is vital to be aware of the local practices, needs, behaviour, roles of men and women.

Figure 9: Waste management hierarchy (UNEP, 2013)



8.1 Social determinants and plastic exposure

Social determinants can influence health depending on where people live and work. Various societal factors such as exposures to toxicants, occupational hazards, maternal habits, psychosocial factors, socioeconomic status, racial disparity, chronic stress, and infection may impact health. They can also impact the health of future generations. Pregnancy repercussions include spontaneous abortion, preterm birth, alterations in the development of the foetus, and long-term health of offspring. Although much is known about individual pregnancy outcomes, little is known about the associations between such outcomes and societal factors (Weck et al. 2008).

There is also a connection between what pro-environmental action and concerns women have, and what they do about it in relation to work and home life, and their travel. Some 12,872 Australian women aged over 20 years were questioned about environmental issues at work, and at home. Although 76% agreed they often take environmental action at work and were concerned about environmental problems, this increased with age, educational level and income of the female questioned. There was also a correlation between hours of work and pro-environmental action at home, with part timers doing better at recycling and reducing waste. In this Australian study, the behaviour of others at work strongly influenced 81% of the women for example when their managers encouraged environmental action. This worked even better when managers and co-workers made a green stance and it also transferred to more pro-environmental action at home (Chapman 2012).

The study found the barriers for women to incorporate more pro-environmental actions into their daily lives were commuting, inability to work from home and demands of home and family responsibilities. Greater financial incentives, availability of green technology and having more time were seen as facilitators to environmental action at home and work. Waste reduction initiatives in the workplaces would help considerably in cutting the amount of plastic waste generated, disposed of and recycled.

Packaging plays an important role in most consumers' daily life. For example, products are wrapped in foils, articles and produce are pre-packed in boxes or other types of containers, large-sized and breakable products are packed in foams and foils, and shopping items are transported in plastic bags. To some degree consumers can decide how they like to transport their purchases. But sale packaging is not always avoidable and for the industry an important factor for selling their products.

Image 11: Children in Romania participating in a waste collection activity

Korhonen et al. (2015) studied the relationships between the Millennials (aged between 18-30 years) and their perception of packaging. This young generation representing four geographical regions: Europe, Latin America, USA and Asia, became excited about products with new packaging and they also openly admitted that packaging persuades them to buy products, but Europeans experienced less value from the experiential properties and aesthetics of packaging and had more critical views on the environmental aspects of the packaging materials. Unfortunately, in this study, gender related perceptions and views were not explored.

8.2 Gender roles in waste generation and management

Gender is frequently found to influence several factors of waste generation and management. However, in the course of the present literature review, no studies investigating these relations over a broad cultural and geographical range could be found. The information available from single studies, which are presented in the following paragraphs, shows that gender roles differ between cultures and socio-economic realities and seem to be closely related to the roles and activities of men and women in domestic households.

Clear gender-related differences were identified with respect to waste generation in a study conducted in Poland, with the principal influencing factors being the number of unemployed women in a region, as well as the male: female ratio. It is suggested that the increased garbage generation rates related to women not employed in the formal workforce are due to their role as care-takers of children or other family members at their home (Talalaj & Walery 2015). Waste management, as a household-related activity, is also frequently seen as a typical female task. This was shown, for example, in two studies from Ghana and Dhaka city, Bangladesh, in which the collection, placement and management of solid waste were clearly attributed to females (Aaniamenga Bowan et al. 2014; Afroz et al. 2011). However, the survey conducted in the Wa Municipality of Ghana showed that this distinction due to gender was only observed in the lower and middle income residential areas of the Wa Municipality in Ghana, but not in the higher income areas, which indicates the influence of socio-economic realities on gender roles (Aaniamenga Bowan et al. 2014).

In some studies from different parts of the world, females were found to be more committed to waste-related issues. In two Nigeria-based studies for example, knowledge about waste management regulations and waste collection services was more pronounced in female survey participants than in male ones and they were more frequently willing to pay for waste removal services, although socio-economic factors influence the results (Adebo & Ajewole 2012; Babayemi & Dauda 2009). In a study conducted in Palestine, females admitted to littering less frequently than males, which may in part be due to the local customs, where littering by females is seen more negatively than when done by males (Al-Khatib et al. 2009).

In further studies from Nigeria, Iran and the USA, females have been found to be more engaged in source separation of waste and recycling. It was suggested that this may be related to a higher responsibility of women for domestic households and it was consequently proposed to consider females as the main target groups for training programs (Babaei et al. 2015; Meneses 2005). A study conducted in China presented the finding that highly educated, more urbanised, young and female people showed the most positive environmental behaviour, including sorting waste and recycling bags. Income did not influence the behaviour (Chen et al. 2011).

An Australian survey found that of the 7399 workers who were interviewed on their recycling and waste disposal behaviour: 81.4% of the men and 85.6% of the women said they sort waste for recycling; 38% of the men and 46% of the women use green or recyclable bags. Positive recycling behaviour and awareness was shown to be more present among women than among men. Those workers with university degrees were more likely to recycle, use reusable bags, and reduce energy usage than those with lower levels of educational attainment. But the reverse was true when it came to food waste recycling. it is questionable if these found differences are significant for the final plastic waste load originating from households, either collected by men or by women (Chapman & Walton 2012).

However, in other studies, for example from Malaysia, the USA, Portugal, Spain and Turkey no significant relationship between recycling behaviour and gender or other waste-related issues was found (e.g. Saphores et al. 2012; Mutang & Haron 2012; Bernad-Beltrán et al. 2014; Ugulu 2015). For example, a study on environmental behaviour among health-care staff in a German hospital showed that gender and age have minor and inconsistent impact on their personal recycling behaviour at work and at home (Vogt & Nunes 2014). The results of the self-reporting did not identify more environmental awareness and behaviour at home among women than among men. But, men often bought more refillable packages and less lavish packing than women. It must therefore be concluded, that there is a gender dimension to the generation and management of solid waste, but it is strongly intertwined with socio-economic and cultural factors. Concordantly, Aaniamenga Bowan et al. (2014) emphasize that the solid waste problem is complex and not limited to any gender, age or income group.

8.3 Factors influencing pro-environmental behavior and attitudes

Research has shown that women in the United Kingdom (Devon) are more environmentally aware and active than men and the majority of green consumers tend to be female (Gilg et al. 2005). A study looking at young people's consumer behaviour in South Africa found that women are more likely to buy green products and be more conscious of the environment (Anvar 2014). In general, women lobby for bans on unsustainable products, more recycling and energy conservation and better labelling of the social and environmental impacts of products and production (Caiazza & Barrett 2003). Overall, research in OECD countries found that in comparison to men's more resource intense and unsustainable lifestyles and consumption patterns (regardless of whether they are rich or poor), women have a lighter environmental footprint than men (OECD 2008).

However, as suggested before, gender is not the only influencing factor with respect to solid waste management and pro-environmental attitudes. Another influencing factor is age, with environmental awareness and the use of waste collection services being highest in the group aged thirty or more years in a study by Babayemi and Dauda (2009). The awareness of waste management regulations was also related to the educational level, but the use of waste collection services and "other" waste disposal, like burning or burying, was not. Consistently, the unavailability of waste collection services in the street or area of residence was the most common reason for not using them. Less common reasons were the ineffectiveness or cost of such services (Babayemi & Dauda 2009).

Further influencing factors are education and income. Although, generally-speaking a higher level of education enhances environmental awareness, a higher income, which may be related to a higher level of consumerism, can lead to an increased generation of waste (Afroz et al. 2011; Odufuwa et al. 2012; Eastman et al. 2013). Of course, it needs to be considered, that there are also gender differences in both education and income (Hausmann & Tyson 2010). A literature review on recycling behaviour (Schultz et al. 1995) resulted in the finding that the relationship between gender and recycling behaviour is not significant. It was stated that recycling at household level is a general household behaviour. However a positive relation was found between income and recycling behaviour. The findings for the relationship between age and recycling were contradictory.

The availability of information is also crucial for solid waste management. Most participants of a survey in Bangladesh, who stated to have knowledge about solid waste minimization, specified that this knowledge came from newspapers, television, and radio. The potential of this media in environmental education, especially in cultures or regions where the use of the internet is not ubiquitous, should be recognized and used (Afroz et al. 2011).

Table 13: Overview of influencing on factors on green consumerism, environmental behaviour and attitudes abstracted from chapter 7.3 and 8.

Influencing factors on green consumerism, environmental behaviour and attitudes			
Factor	Positive	Neutral	Negative
Gender	Female in United Kingdom (Gilg et al. 2005); Female in South Africa (Anvar 2015); Female (Calazza & Barrett 2003); Female in Nigeria (Adebo & Ajeole 2012), (Babayemi & Dauda 2009); Female in Nigeria, Iran, USA (Babaei et al. 2015, Meneses 2005) Female in Australia (Chapman 2012) Female in China (Chen et al. 2011) Male in Palestina (Al-Khatib et al 2009).	Gender (Schultz et al. 1995); Gender in Malaysia, USA, Portugal, Spain, Turkey (Saphores et al. 2012, Mutang & Haron 2012, Bernad-Betrán et al. 2014, Ugulu 2015); Gender in Germany (Vogt & Nunes 2014); Gender slightly in Australia (Chapman & Walton 2012).	Lack of waste collection services, Nigeria (Babayemi & Dauda 2008).
Age	Higher age, Nigeria (Babayemi & Dauda 2008); Young, China (Chen et al. 2011).	Contradictory (Afroz et al. 2011, Odufuwa et al. 2012, Eastman et al. 2013).	
Education and income	Higher education, Nigeria (Babayemi & Dauda 2008); Higher education, China (Chen et al. 2013); Higher education and income (Afroz et al. 2011, Odufuwa et al. 2012, Eastman et al. 2013). Higher income (Schultz et al. 1995); Higher education in Australia (Chapman & Walton 2012).	Income, China (Chen et al. 2011).	
Incentive	Tax on plastic consumer bags, UK, China (The guardian – science and environment – Rebecca Morelle 30/7/16; (Xiaodong 2013)		Low value of recyclables *(Plastics I SA 2016)*

Source: authors own table

9. Wastewater

9.1 Microplastics in wastewater

Household-generated microplastics often stem from cosmetics, like skin cleansers and other personal care products, cleaning products, medicinal products (Gouin et al. 2015; Fendall & Sewell 2009) and especially washing machines, which introduce big amounts of plastic fibres (> 1900 particles per wash of a single synthetic garment) into wastewaters (Browne et al. 2011; Browne 2015). Microplastics like preproduction pellets are emitted to the sewage systems from industrial production plants. Apart from the effects of chemical substances, which are added during the production process, as well as those taken up from the aqueous environment, plastics in wastewater pose the risk of harbouring new and/or pathogenic bacterial communities and introducing them to freshwaters and the marine environment (Tagg et al. 2015). However, possible effects on human health and possible gender dimensions remain to be investigated.

Standard sewage plants cannot completely retain microplastics. A rather small plant in Sweden with a microplastic retention rate of 99%, still released 1770 microplastic particles per hour (about 15.5million particles per year) into the sea (Magnusson et al. 2014).

Apart from direct effluents of wastewater treatment plants, sewage overflow during storm water events and runoff from sewage-based fertilizers on agricultural or public lands are pathways for microplastics (Faure et al. 2012; Eriksen et al. 2013).

In Germany twelve investigated sewage plants release annually 93 million to 8.2 billion microplastic particles and fibres into rivers, the largest share being plastic fibres. A final filtration system in one of the investigated plants reduced the amount of emitted microplastics by 97% (Mintenig et al. 2014).

In effluents of wastewater treatment plants in the Netherlands, concentrations from 9 to 91 microplastic particles/L (mean about 52 particles/L) were found (Velzen 2013).

Image 12: Waste water management in Germany

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The incomplete retention of microplastics by wastewater treatment plants in other industrialized countries are pointed out in several studies (Hastings & Potts 2013; Martin & Eizhvertina 2014; Dris et al. 2015; Gallagher et al. 2015).

In many regions of the world however, it is a common practise to discharge sewage without any previous treatment, which leads to the pollution by sewage of around 50% of all fresh and marine waters. Obviously, not only human faeces, but also plastics enter the waters this way (Baum et al. 2013

.

9.2 Personal hygiene and wastewater: gender aspects

Although it is reported that improvement of wastewater treatment plants has led to a general decline in sewage-related debris on beaches of the UK (Williams et al. 2014). The 2014 Beachwatch report reveals that the number of wet wipes on UK beaches has risen by around 50% over the past year, and these were the most common sewage-related litter item as people increasingly use them instead of toilet paper, in baby changing, to remove make-up and to apply fake tan (Marine Conservation Society 2014). This is problematic, as such wipes are more persistent than toilet paper and some even contain plastic (Marine Conservation Society 2015). Other important litter items in waste water are menstrual hygiene products and personal hygiene-related products, like tampons, disposable napkins, applicators, and cotton buds. These items clog sewage systems and enhance the filling up of latrines, thereby causing problems. While tampons, which mostly consist of cotton and rayon, are somewhat biodegradable, the other products listed above contain plastics, which persist in the environment for a long time and can be transported to rivers and, subsequently, to the ocean (Kjellén et al. 2011). In several UK-based studies it was shown that a large number of menstrual hygiene products can be found in the riverine environment, probably coming from combined-sewer-outfalls (Williams & Simmons 1997; Williams & Simmons 1999). While personal hygiene related products can be used independently of gender, menstrual-hygiene related items are clearly related to females and this presents a gender-related difference and a starting point for improvements in waste water and sanitation management.

Literature shows that in many settings menstruation is a taboo subject, and facilities where females can change, wash and dry (in case of reusable cloth) or dispose of (in case of one-use items) used sanitary napkins or tampons in private, is often missing (Kjellén et al. 2011; Adams et al. 2009). This poses great difficulties to females and even leads to them missing days at school or abandoning school when puberty is reached, thereby causing unequal learning and working opportunities for male and female students and professionals (Adams et al. 2009).

Although professional solid waste management is mostly operated by men, females are often responsible for the disposal of menstruation-related waste in cultures or locations where menstruation and related topics is seen as a taboo (Mjoli-Mncube 1998). If and where possible, taboos might be addressed by educating male stakeholders and workers in solid waste management about menstruation-related waste. Common options for the disposal of menstruation-related items are bins or incinerators (Kjellén et al. 2011; Lynch 1996). As discussed in previous chapters of this report, both incineration and land filling pose threats to humans and the environment and neither of them is an ideal solution to the problem, which highlights the importance of more sustainable items for menstruation hygiene management, such as washable cloth, menstruation cups, or natural sponges.

However, the inappropriate disposal of sanitary items is not only a problem with respect to menstrual hygiene-related waste or taboos. The above mentioned studies from the UK show that the flushing of sanitary solid waste is a global problem and is not limited to female consumers. Independently of gender, many sanitary items, like wet wipes are often thought to be flushable and not only the lack of other options for disposal, but also convenience was shown to be a reason for the flushing of litter items in a study conducted in New Zealand (Lynch 1996). Educational campaigns on the disposal of single-use items have proven to be successful in the minimization of flushed items before (Kjellén et al. 2011).

10. Bio-plastics and classification of plastic waste

10.1 Bio degradable and bio-based plastics

The term 'bio degradable' polymers and biopolymers or bio plastics raises certain positive expectations on the decomposition to the consumer. The European Bioplastics explains that bio-plastics can include a whole range of materials, which are bio-based, biodegradable or both. Furthermore, it is stated that bio-based means that the material or product is (partly) derived from biomass (plants). The European Bioplastics mentions, depending on the application different types of bioplastics are processed in these products: biodegradable polymers such as starch-based plastics or PHA, and biobased, non-biodegradable commodity plastics such as biobased PE and PET (Bioplastics 2015). Within this study no Literature from researchers on potential hazardous additives or compounds in or released from biodegradable and bio-based plastics during production, usage and post-usage was found.

Examples of common bio-based plastics are cellophane derivate from cellulose (e.g. wood, cotton hemp), rayon derivate from e.g. wood pulp or Chitosan made of chiton (UNEP 2015b).

The term "biodegradable" can be used if a material fulfils certain national or regional standards of decomposing making use of an industrial composting system. The level of established decomposing rate does not apply to household composting heaps neither to marine environment (UNEP 2015b).

Studies on the biodegradability showed that not all bio-polymers are compostable under household conditions, or even at standardized conditions. Scientific trials carried out by (Broglio et al. 2012), indicated that only thin (few micron) plastic films mainly deployed in agriculture, are successfully compostable and biodegradable. Ice cream spoons (0.8 mm) made of a corn-based biopolymer, or a shopping bag (40 um) in additive HDPE did not pass the test successfully.

Other researchers (Vaverková & Adamcová 2015), investigated the biodegradability of different bioplastic materials (sponge cloth) in a controlled composting environment. The main conclusion was that the effectiveness of the degradation strongly depends on the composting conditions and on the chemical nature of the materials.

One of the expected properties of biodegradable plastics is that a composting process should degrade the material. However in a marine environment the conditions are quite different to a land-based composting system, and a rapid degradation is unlikely to occur (UNEP 2015b). In addition it is likely that there would be leakages of biodegradable plastics into waterways, similar to the overall leakages of plastics, depending on the regional use of biodegradable plastics. Based on the available evidence it can be concluded biodegradable plastics will not contribute to a reduction of the marine litter (UNEP 2015b). Consumers are faced with the choice of buying bio plastics or biodegradable plastic packaging, plates or cutlery where the expectation of buying environmental friendly product cannot be met.

10.2 Classification of plastic waste

Plastic waste is generally classified as harmless solid waste, which means that its release into the environment is legal up to a relatively high level (Rochman, Browne, et al. 2013; Lechner et al. 2014; Lechner & Ramler 2015; Zbyszewski et al. 2014). Leading researchers in the field of plastic pollution suggest to classify plastic waste as hazardous in order to be able to strictly regulate the emission of such waste to the environment and to enhance investigation on alternative and safer materials. An example of stricter regulation of plastic waste emissions is the Californian "Nurdles Law", under which the release of preproduction microplastics (which are used for the production of larger plastic items) is currently illegal (Doughty & Eriksen 2015). While this law refers to unintentional losses of microplastics by industry, intentional plastic release as in the case of the usage of many personal care products remains completely legal and uncontrolled. For public and possible policy actions on banning the use of microplastics in such products (see chapter 13).

In addition to policy actions, the employment of filters for washing machines, as well as the identification of concrete sources of pollution (place, person or company) are promising approaches to mitigate pollution by microplastics (Browne 2015).

11. Main findings from the literature review

11.1 Plastic production and demand

- Globally China is the biggest producer of plastics, followed by Europe.
- In 2013, the global production of plastics was almost 300 million tonnes, plastic production increases annually by 5%.
- At a global level food and beverages packaging applications constituted the largest segment of the packaging industry with a demand of 55% of the entire plastics market.
- Building and construction is the second largest application sector comprising 20.3% of the total European plastic demand; appliances, household and consumer products, furniture and medical products use almost 20%.
- The market for plastic packaging in India and China is the fastest growing market. For flexible plastic packaging the annual growth rate is estimated to be 9.4% and 6.9%, respectively.

11.2 Plastic usage and gender

- The 6 most commonly used plastics “the big six” are PP, PE, PS, PVC, PET, PUR, and cover about 80% of the total plastic production.
- A considerable part of the so-called “big six” plastics are used by consumers in daily life and for packaging of goods.
- About half of the global packaging, by end market, is used for packaging food (e.g., pots, jars, flexible plastics) resulting in 20% of the total produced plastics.
- In 2015, two thirds of the global consumption of plastic material took place in the wealthiest regions: NAFTA, Western Europe and Japan. Annual consumption per capita in NAFTA, Western Europe, and Japan ranged from 108 to139 kg; in other global regions this rate was from 16 to 48 kg; in India the demand for plastics was estimated to be 9.7 kg /capita consumption.
- Men are more likely to buy expensive goods like homes, cars, electronic equipment; women more often buy basic consumer goods such as food items, health items, clothing and household articles.
- In 2012, the European Union plus Switzerland and Norway used a total amount of 4360 tonnes of microbeads in cosmetic products, the average use of microbeads per capita was estimated at 17.5±10 mg/day.
- At household level it is more likely that women buy most of the food and other basic consumer goods and this could play an important role in reducing the use of plastic consumer goods in the household.
- Reduction of plastic use in daily life requires a multi-sectorial approach.
- Tax on plastic bags proved to be an efficient measure to reduce plastic shopping bags. For example since the tax was introduced in England in 2014 there has been a drop in usage from 7.64 billion bags to only 640 million bags 6 months after the ban.

11.3 Workplace and Health effects

- Actual estimations on the number of employed people in the global plastic industry are not available or not accessible, or information about the proportion of men and women working in the plastics industry is often lacking.
- As far as gender-disaggregated data on the workforce in the plastic industry is available, the assumption is that about 30% of the workforce are women.
- Depending on the applied processes in plastic production, workers are exposed to a greater or lesser extent to potentially hazardous chemicals; for example open thermal processes with large surfaces may pose a higher health risk to workers.

Women

- Women's unique biology can create specific vulnerabilities at certain times in their lives including during puberty, menstruation, pregnancy, nursing children and menopause.
- Women have been excluded from occupational health studies despite their unique biology creating specific vulnerabilities to workplace exposures especially when working with plastics and in the plastics industry.
- A Canadian study found that women working in the plastics industry had a five-fold elevated risk for breast cancer and reproductive disorders. The study linking breast cancer and occupation prompted the American Public Health Association to pass a resolution calling for action on occupational breast cancer.
- Women occupationally exposed to seven groups of EDCs including phthalates were more likely to have a son affected by health problems, with the risk of moderate-severe hypospadias or multiple defects increased up to two and fivefold respectively, with maternal exposure to most types of EDCs.
- There is potential for women to be exposed at work to reproductive hazards before pregnancy and during the first trimester leading to specific birth defects. Effects from exposure happen at much lower levels than the supposedly safe levels set for daily exposures of workers in the workplace.
- Socially determined factors such as family life, poverty, education and health govern the work women do and make it more likely that they work in family businesses, low paid or part time positions with little or no protection from hazardous chemicals.
- Research reflects that pre-birth or early life exposures to certain EDCs impacts on future breast cancer diagnosis.

Men

- A French multi-institutional cohort study found that parental professional, occupational and environmental exposures to mixtures of EDCs including phthalates and other toxic chemicals increased the risk of hypospadias in male offspring.
- Sperm mobility and integrity is affected by air borne exposure to DEHP in PVC pellet plants. Air monitoring tests do not show the true measurement of the concentration of certain chemicals in the body (body burden); this makes body burdens harder to determine and regulate.
- In many studies, the levels of toxic chemicals such as phthalates, BPA and styrene found in male workers for example working in a PVC pellet or epoxy resin plant, are significantly higher than those found in the rest of the population – these are levels in which laboratory animals produce breast tumours and other adverse health effects.
- In most plastics industry environments, workers can be exposed to a toxic soup of chemicals.
- A Nordic study calculated costs of male reproductive disorders such as testicular cancer, infertility (low sperm count) hypospadias and cryptorchidism to Nordic countries and the EU through inaction on EDCs could be up to €1,200 million per year.

11.4 Endocrine disruptors released from plastics

- Bisphenol A (BPA) used widely in plastic is ubiquitous in the environment and also in the human body. It can leach from products it's been added to. Humans are exposed through inhalation, skin contact and ingestion.
- *BPAs and phthalates can leach from plastic packaging into food: after 3 days switching from a "normal" diet* to a diet with only freshly sourced and unpacked food the levels of BPA and certain phthalates detected in consumer´s urine reduced by 65% and 53% r*espectively.*
- BPA has been classed as a reproductive toxicant 1b yet remains in use in many products- pregnant women and infants are exposed to in the home and workplace.
- Water systems cannot filter out BPA from drinking or bathing water.
- BPA and other endocrine disruptors interfere with male sperm in terms of motility, sperm count and concentration thus hampering conception.
- BPA substitutes have also been found to cause measurable effects on brain development and behaviour specifically up to the second trimester of pregnancy. Researchers have advised pregnant women to avoid BPA and also BPA substitutes which they found equally affect neurodevelopment.
- Many phthalates, also contained in plastics, are known endocrine disruptors and their substitutes have also been found to cause health effects.
- Personal care and cosmetic products can contain high volumes of phthalates (used to carry fragrance) which can enter the body

through the skin and are detected in urine; women are the biggest users of PCCPs.
- Phthalates have been linked with early puberty in both males and females.
- Polybrominated diphenyl ethers (PBDEs) added to plastics as flame retardants are found in human secretions such as blood and breast milk.
- High levels of PBDEs have been found in fish, sea food and marine mammals as well as in dairy products and even vegetables.
- Levels of PBDEs in breast milk have been equated with how much fish a woman eats.
- Plasticizers and other additives can leach out of PVC flooring through wear and tear and washing.
- EDCs such as phthalates are found in soft plastic toys, or brominated flame retardants used as plastic additives in electronics – and recycled into plastic used for children's toys in China; China makes 86% of the world's exports of toys.

11.5 Microplastics and microbeads in the environment

- Microplastics are released into the natural environment from the use of consumer products to which they have intentionally been added such as personal care and cosmetic products, cleaning products, pigments and paints (primary microplastics).
- Microbeads originating from cosmetics contribute 0.1 -1.5% to the overall amount of plastic debris emitted to the North Sea.
- Microplastics can be released when plastic products crumble from general wear and tear or due to UV radiation, as well as during the industrial production process or during washing synthetic textiles (secondary microplastics).
- Microplastics are found in the atmosphere; the fallout appeared to be higher in more urbanised settings than in rural settings.
- Microplastics enter the aqueous environments constantly from untreated sewage and wastewater treatment plants, which cannot filter the small particles. Standard sewage plants cannot completely retain microplastics.
- The pollution of water bodies with different types of microplastics, primary and/or secondary microplastics, depends in particular on the following aspects:
  - Presence or absence of plastic industry (pellets, fragments);
  - Population density and activities (traffic/tyres and brakes, released litter, fibres from washing machines);
  - Consumer habits – using PCCP and detergents with microplastics (micro beads);
  - Presence or absence of sewerage system, leading the wastewater into a water body (microbeads from PCCP, detergents, micro fibres from clothing, flow-off from roads);
  - The level and type of solid waste management, including plastics (films, fragments);
  - Presence or absence of tourist industry (beach);
  - Marine activities (fishing, shipping).
- In Europe the main sources of secondary microplastics are fragmentation of plastic debris, followed by tyre abrasion and pellet loss; the contribution of synthetic fibres was estimated as being the smallest source for secondary micro plastics.
- Plastic waste is handled as harmless solid waste by legislation, which means that it can be legally released in considerable high quantities. Policies for the reduction of microplastic use (bans) are only now emerging.
- The industry could easily find replacements for the microplastics with other harmless substances in cosmetics, pigments and paints, polishing and cleaning agents; products which are mainly bought by women. However, the global ban of microplastics in consumer goods is a minimal contribution to the elimination of microplastics in the environment.
- Microplastics induce several health problems in mammals and can be transported through the gastrointestinal tract to the lymph and circulatory systems.
- Microplastics can pass through the placenta to the unborn foetus.

11.6 Marine Environment and Seafood

- Globally more than 80% of the oceans plastic debris originates from land-based litter, 20% from fishing activities; between 55% and 60% of the land-based plastics found in the oceans originate from five Asian emerging and fast growing countries. China, Indonesia, the Philippines, Thailand and Vietnam.
- The highest total count and weight of microplastics were found in the North Pacific, followed by the Indian Ocean. The

Mediterranean Sea showed the lowest total count of microplastics and the South Atlantic the lowest weight of microplastics.

- An estimated 50% of marine plastic litter sinks to the seafloor, where it poses a threat to the structure of benthic communities. The accumulation of plastics in the deep-sea environment raises special concerns, as it is suggested that degradation is even slower as a result of the absence of light, and low oxygen concentrations and temperature.
- The high accumulation potentially suggests that plastic resin pellets serve as both a transport medium and a potential source of toxic chemicals in the marine environment.
- Management of plastics influences the appearance of anthropogenic debris in fish: In Indonesia in 55% of the sampled species of fish for consumption mainly plastic particles were identified; in California 67% of the sampled species of fish for consumption mainly fibres from textiles were detected.
- Evidence indicates that the uptake of plastic particles and associated chemicals through seafood consumption poses a threat to human health.
- The amount and type of ingested plastic particles, and consequently the risks for human health upon consumption, depends on several factors and may vary between species and populations of fish and seafood.
- There is a gender dimension to fish and seafood preferences and consumption frequencies, which is strongly influenced by the consumers' geographic location and may lead to differences in exposure to plastics and toxic chemicals between male and female consumers.

11.7 Management of plastic waste

- In comparison with the high and upper-middle income countries, the low and lower-middle income countries dispose of far less amounts of Municipal Solid Waste (MSW). However, due to the mismanagement of plastic waste, between 55-60% of the land-based waste found in the oceans originates from 5 Asian low income and lower-middle income countries.
- Globally, in all regions landfilling is the most common treatment of MSW.
- In Asia 80% of the plastic waste has a low residual value (e.g. plastic shopping bags, foils) and is more prone to non-collection or to be wasted than high-value plastics such as polyethylene bottles.
- Without waste management infrastructure improvements, the cumulative quantity of plastic waste available to enter the ocean from land is predicted to increase by a factor of two, and up to five times by 2025, depending on the mass of the mismanaged waste.
- Informal waste workers are important for collecting and recycling of waste in countries without formal waste management. However, informal waste workers are often on the lowest rung of the social ladder.
- Many families where someone works in the informal waste sector depend fully on that income.
- More women earn livelihoods in the informal waste and recycling sectors than in similar formal occupations. As a consequence babies and children often accompany their mothers in the informal waste sector and are exposed to unsafe and unhygienic environments.
- Forming waste pickers cooperatives creates opportunities for education and social development.
- More than half of the global collected plastic waste is exported to China where the environmental conditions are questionable given the dominance of uncontrolled reprocessing and manufacturing.
- Depending on the country, incineration of plastics is part of the global plastic waste treatment: either in wealthy countries by controlled processes such as energy recovery or by uncontrolled processes such as open burning of landfills or backyard burning in remote areas, and by indoor burning for heating and cooking purposes.
- In particular during indoor and backyard burning, which is mostly practiced by women, women and other household members are exposed to health risks.
- Formal waste management, including controlled large-scale incineration of plastic waste for energy recovery is male domain.
- A common reason for the deposition of waste in illegal landfills is the lack of well-organized and affordable waste collection services, especially for bulky and non-household items.
- Recyclables from landfills are often contaminated and therefore of very poor quality, and are rejected by plastic recycling companies.
- Fly tipping is often also related to missing opportunities for legal waste deposition at the site of waste generation (e.g. during leisure

activities), like waste baskets. The frequency of fly-tipping however, is also related to gender, age and socio-economic factors.

- The lack of possibilities to sort collected plastics and the fluctuation of the prices for virgin and recycled resins makes it less attractive for recyclers to include post-consumer plastics in their programs.
- Waste management cannot be generally attributed to males or females, but there are gender roles, which may differ between cultures. As a consequence, exposure to health hazards may differ due to such gender roles.

11.8 Environmental Awareness and Behaviour

- In general women are more likely to take affirmative environmental action if time and family responsibilities allow. However, some studies identified no significant relationship between environmental behaviour and gender.
- Influencing factors are education and income. Although, generally speaking a higher level of education enhances environmental awareness, a higher income which may be related to increased consumerism, can lead to an increased generation of waste.
- Women tend to perceive various hazards as more risky in comparison to men and are less willing than men to impose health and environmental risks on others.
- Pro-environment action at the work place is most likely if the co-workers and management are involved.
- Many litter items in wastewater are gender-related, like condoms or menstrual hygiene products. The lack of facilities for change, cleaning and disposal of such items does not only cause their inappropriate disposal and consequent threats to the sewage system and natural environment, but also means social and professional disadvantages for menstruating females, especially when living in cultures in which menstruation is a taboo.
- The type of packaging of products and awareness of the environmental aspects plays an important role for the buying behaviour of consumers.
- Currently biodegradable and bio-plastics don´t fulfil expectations with regard to degradation and/or composting properties; biodegradable plastics are not produced from renewable sources.
- Bio-based plastics and bio plastics may be a mix of renewable sources; however, the potential for degrading or composting may be, in particular in marine environment, equal to the common fuel-based plastics.

12. Recommendations

12.1 Research gaps

The points outlined below are only a few of the many points that should be considered:

- Gender specific research on the impact of plastics on human health and our environment, production, usage and post-usage management. In particular on:
  - Environmental pollution and exposure of men and women to hazardous substances during all stages of production, formal and informal plastic recycling and incineration practices in different global settings;
  - Developing short-life (degradable and/or compostable) plastics and on the release of possible hazardous substances and chemicals;
- The passage of chemicals through breast milk and the placenta should be tested in relation to all environmental and occupational chemicals.
- Bio-monitoring of exposed male and female workers in plastic production and recycling processes.
- Levels of plastic contamination need to be investigated and compared between the most consumed fish and seafood species, as well as between populations from different habitats and from different origins (wild caught / aquaculture).
- The consequential exposure levels for men and women to microplastics and associated hazardous chemicals needs to be investigated as a basis for a reliable gender-related risk assessment.

12.2 Recommendations, addressing four stakeholder groups

A) Consumers and households

- Educational campaigns are needed to inform consumers about the hazards of plastic to human health and the environment, posed by the products they use.
- Women can play an important role as the main controllers of household spending and as informed consumers to demand zero or minimal plastics or alternative packaging for consumer goods.
- Information campaigns are needed for men and women addressing the possible presence of microplastics in PCCP and cleaning products.
- On community level, gender sensitive action plans should be developed and implemented to reduce and recycle plastics that do not contain POPs.
- Efforts should be made on the elimination of PVC and other hazardous chemicals in consumer products.
- Full disclosure on substances used in construction and building material, e.g. relining of water pipes with plastic, should be available to tenants and householders.
- Full disclosure on substances in consumer products is needed to give consumers the right to know and the ability to make informed consumer choices to avoid buying wasteful plastics in the first place.

B) Healthcare and educational institutes

- Encourage hospitals to sign up to the Healthier Hospitals Initiative (HHI) which advocates less waste and safer chemicals and a roll out of this initiative in other countries to implement a completely new approach to improving environmental health and sustainability in the health care sector.
- Education campaigns in schools, and childcare institutions for staff and pupils on the problems associated with plastics usage and how to reduce it.
- Encourage schools and in particular childcare institutions to avoid plastic materials and unhealthy toys.

C) Workplace/industries

- An acknowledgement of the association between known classes of chemicals and breast cancer, and other diseases caused by environmental factors, and the fact that women working with these chemicals are particularly at risk.

- Action points should emphasize precautionary and prevention policies and the importance of identifying the workplace and other environmental hazards that contribute to breast cancer, infertility and development defects.
- Public and corporate procurement should incorporate green chemistry, toxics use reduction and informed substitution principles in their purchasing practices.
- Enhancement and enforcement of existing international and national health and safety legislation, to reach the highest level of protection for human health and the environment.
- Risk assessment of workplace exposure to hazardous chemicals, such as carcinogenic, mutagenic, reprotoxic (CMR's) substances and EDCs from plastics manufacturing and plastic additives need to take the developing foetus into account. Consideration should be given to the fact that sometimes there are no safe levels of exposure.
- Redesigning of plastics production processes which expose workers unnecessarily with a move towards automation, local exhaust systems, confinement, and wet methods to reduce dust or air borne particles.
- Safe substitution of hazardous chemicals.
- Existing legislation to protect workers from hazardous chemicals especially in relation to plastic and waste management should be fully implemented.

D) Communities / decision-maker

Education and waste management

- Public education by industry and government to raise awareness about waste plastic and its correct disposal is crucially needed.
- Waste deposition and management services, for household waste as well as for bulky and non-household items, must be improved and residents must be informed about these services in their areas/neighbourhood.
- Uncontrolled landfills, waste dumping and incineration of plastics, as well as informal waste management should have the highest priority in relation to addressing environmental pollution and associated health risks.
- All stakeholders should be actively involved in the planning of a formal waste management and minimisation strategy, taking social, gender and economical aspects in consideration.
- The biological necessities of females in relation to menstruation should be addressed in public environments, especially schools and the workplace. Facilities for the changing, cleaning and the appropriate disposal of menstrual hygiene related items are crucial.

Marine environment

- National, regional and local waste minimisations plans should be developed by key stakeholders and key user groups to tackle prevention of marine litter at source.
- Increased action on the establishment of more effective filters, especially for wastewater plants, but also for domestic items like washing machines.
- Initiatives and actions should be developed and implemented for plastic (and cigarette butts) collection during marine activities and for the (coastal) tourism industry.

Packaging and disposable products

- Plastic waste should be classified as "hazardous" waste, in order to implement stricter policies on the release of such waste into the natural environment and to encourage the development of alternative materials.
- A tax should be introduced on one-use disposable plastic products such as plastic cutlery, disposable cups, plastic water bottles and plastic bags.
- A policy framework is needed on the prevention and management of plastic packaging material (short and long term).
- Efforts should be made to minimize plastic used in the packaging industry; finding safe alternatives for plastic and/or reducing the packaging on products must be a first step.
- Product design in relation to plastic waste minimisation needs to be addressed by industry.
- Use the existing EU framework on Ecodesign to improve efficiency, through requirements on reparability, durability and recyclability.
- Economic instruments are helping (e.g., green taxes, incentives, Pay-as-you-throw) to reduce waste. Clear rules are needed for extended producer responsibility.

12.3 Legislation and policies (national and international)

- Introduce a phase-out and safe substitution of all hazardous substances that cause concern for human health and development, and the environment.
- Introduce regulations that require all ingredients in a product, including phthalates, BPA or microplastics, to be clearly listed on the label.
- Global ban on microplastics and microbeads in personal care and cosmetic products, and cleaning products, and other major sources of exposure.
- A global treaty on plastics which would address production, use and disposal, set taxes for polluters and single use products, consider banning certain hazardous products or dictate consideration of waste minimisation at the design stage.
- Take into consideration how any stand-alone treaty might relate to the relevant parts of the Sustainable Development Goals which address marine pollution, sustainable consumption and production, and health of humans and the environment.
- All regulations on water need to include specific targets and a phase out plan for EDC's and microplastics in marine environment and the water supply.
- Phase out and substitute all hazardous chemicals in consumer products, especially in children´s products, and ensure global implementation.
- International and national targets and action plans should be developed globally to reduce the plastic litter in the environment.
- International and national policies should increase their efforts to ban unnecessary packaging and plastic bags, and the use of intended microplastics in consumer articles.
- The export of plastic waste/recycling products from wealthy to less wealthy countries should be banned.
- Experienced countries should support less-experienced countries to reduce and manage their plastic waste.
- Separation at source to access waste easier should be implemented not only for the waste pickers to access waste but also to prevent unnecessary waste flowing to the landfill sites.
- Separation at source must be encouraged through awareness-raising with households in residential areas of the importance of sorting waste this could be accompanied with incentives by local municipalities.

Labelling

- Clear labelling of personal care, cosmetics, cleaning products and paints containing microplastics including a time-line on decomposition.
- Clear labelling of all ingredients in consumer products including transparency about ingredients and procedures throughout the supply chain.
- Labelling of products containing PBDEs or other potential EDCs.
- Introduce an 'ocean friendly' labelling system which set out tougher standards for plastic itself, if plastics were designed to be 'ocean friendly' then this could reduce the land based plastic litter into the oceans. Waste minimisation needs to take the lead over recycling.

13. Women and men as agents of change

Women and men – in their respective social roles - are affected by hazardous chemicals and contribute to environmental problems, related to production, consumption and post-consumer management of plastics.

The main responsibilities for regulation should lie with government, industry and legislators yet if it were not for consumers demanding cheaper, lighter and more convenient products, we may not have such a problem with plastic waste as we currently do. There are different responsibilities: for the safety of workers in the plastic industry; for putting safe plastics in circulation; for consumption of plastics and management of post-usage of plastic materials, all of which require different measures and approaches with the involvement of different groups of stakeholders.

The most immediately affected group are workers, who come into first contact with the raw materials and production process for plastic. Many workers are exposed on a daily or hourly basis and throughout the lifecycle of the plastic whether this exposure occurs during manufacture of plastic products through moulding, cutting or melting processes, or the use of plastic products in their work, such as hairdressers, and PCCPs or during its disposal in incinerators, landfills or processing, burning and recycling plants.

Consumers are secondary stakeholders - women and men in households – who create demand through their buying behaviour and have the potential to affect their environment. However, this is dependent on the fact that they are well informed about, for example, possible hazardous additives in PCCP, the potential hazards of microplastics, plastic fibres (fleece) and hazardous chemicals in plastic products they use in daily life.

CSOs play a vital role in raising awareness about the problems of plastics and microplastics in the environment and their potential health hazards, alongside scientific institutions.

Reduction of the use and increasing the recycling rate of plastics is a global task and those countries with a poor record on the collection of plastic may be supported by experienced countries and share their approaches and measures. It should also follow that those countries with a disposable culture and a throw-and-forget approach using increasing amounts of plastic need to be supported to move away from their wasteful love of plastics by countries where resources are more valued. There could be organisational and technical support for raising awareness and establishing formal collection and recycling infrastructures, and waste minimisation strategies where gender differences in the perception of the problem could bring unique perspectives and solutions.

Synthetic textiles and plastics used in households, purchased by women and men, are just a part of the whole plastic usage. In many parts of the world, food, breakable equipment and tools are pre-packed especially small-sized articles such as screws or nails and the packaging in practice is difficult to avoid. In many countries cheap clothing on sale i.e. fast fashion consists entirely or partly of synthetic fibres and which theoretical could be avoided. However alternatives such as hemp, bamboo, wool or cotton are for many consumers often too expensive or not available. Plastic bags for shopping or packaging vegetables or fruits could be avoided, but apparently the strategy of reduction plastic waste has to be supported by national ordinances or laws. In several countries promising initiatives have been undertaken:

Box 9: Campaigns against microbeads

A good example is the International campaign against microbeads in Cosmetics “Beat the Microbead”. Also, local community based actions such as Clean UP Georgia where the environment is affected by plastic litter.

Yet, increased financial support is needed to intensify CSO’s and scientific institution´s activities and engagement.

Box 10: Promising initiatives in Rwanda, the U.S., India, Bhutan, Bangladesh, Ladahk, the Netherlands and the U.K.

The Rwandian female Minister for Environment, Rose Mukankomeje, pushed the ban on plastic bags aimed at cleaning cities and protecting rivers and lakes. The law, passed in 2008, prohibits all manufacturing, use and importation of all poly-propylene bags in Rwanda, and was put in place by means of a nation-wide awareness raising campaign through mass media. To avoid plastic imports by tourists, Rwanda´s women were engaged to make cotton bags which were provided to tourists (Minani 2014). The campaign is presented by Rose Mukankomeje in a TEDx talk (Mukankomeje 2010).

Another good example is the female Dutch Minister of the Environment, Wilma Mansveld, who passed a law to ban the provision of free plastic carry bags by the retailer to the consumer from 1 January 2016.

As the first state of the US, Hawaii introduced a ban on plastic grocery bags that are 2.25 mils thick and has handles for reusable, although with several exemptions. However, retailers adapted the law by handing out slightly thicker bags (Herreria 2015).

Initiatives are set up for a “life without plastics” offering practical advice on how to avoid plastics at home:

Think Beyond Plastics is a global initiative which supports disruptive innovation in the field of conventional plastics including materials, manufacturing and product design. An innovative project in India called Amrutdhara set up water stations to cut down on the use of plastic bottles. Other projects supported include those promoting sustainable cutlery and take away food packaging, and innovative ideas around safer plastic additives.

Some examples are:

- One Dutch man was so upset by the rubbish in the river on his way to work he used to leave earlier each day so he could stop and pick up a bag full. He publicised his work on Facebook encouraging others to do the same and so 100 metres of the river bank was cleaned up.
- Local campaigns on banning plastic bags can expand and inspire others to take action for example Plastic Free Himalaya. The campaign follows the lead of similar projects in Bhutan, Bangladesh and Ladakh and calls on governments and the tourist industry to ban single use polyethylene plastic bags and plastic water bottles. The initial campaign in Ladakh was organised by the Women’s Alliance and successfully achieved a ban on plastic bags in the region.
- Anecdotal evidence gathered in a unique way by a woman who paddled the 400 miles of English waterways in 22 days found over 2,500 different pieces of plastic waste during the course of her journey, mostly footballs and toys but also other plastic items. She was motivated to take the journey after seeing the amount of plastic debris in the Paddington Basin while paddling near her London home. She raised awareness about the issue through documenting the waste on Instagram and her website blog. She noticed more waste plastic in city areas than rural. Her journey raised money for WaterAid and WaterTrek.

One of the keys to successful recycling practices is providing households and public facilities (schools, health care etc.) with the possibility to separate and collect their waste; and provision for picking up or disposal of plastics should be in place. For communities and cities with informal waste sector, the Regional Initiative for Inclusive Recycling (IRR) produced a guide on “Gender and Recycling, Tools for Project Design and for Implementation. This gender guide has been prepared by female staff from the CSO “WASTE”, and is a tool that: *supports the opening of spaces for the participation of women in the processes that affect their development; fosters attitudes whereby this participation is valued; and is geared towards actions that improve women’s living conditions*. (Rudin 2013)

The banning of plastic bags and microplastics in PCCP are extremely good starting points and may raise awareness among retailers and consumers about the environmental pollution caused by plastics, nevertheless plastic bags and PCCP are only a part of the whole plastic problem.

There have been calls for a global treaty on plastics. Although many UN declarations and initiatives highlight the need to address plastic and microplastic pollution in our oceans and waterways including the UN Sustainable Development Goals, they have done little to solve the problem. The treaty could be a stand-alone agreement addressing the production, use and disposal of plastics or could be drawn from existing treaties targeted at dealing with plastic waste from, for example, the Basel, Rotterdam and Stockholm conventions. A stand-alone treaty would be more effective than a marine treaty because it could outline how to deal with harmful plastics throughout their life cycle including banning the most hazardous ones. Given that plastics end up in the ocean they don't start there, the root cause of the problem needs to be addressed.

Tougher standards are needed for plastic itself, if plastics were designed to be 'ocean friendly' then this could reduce the land based plastic litter into the oceans. Waste minimisation needs to take the lead over recycling with initial action on minimising waste at the design stage such as getting rid of separate straws in juice cartons. Products should be labelled to allow tracking showing where they were manufactured and sold which could enable targeted regulation for the highest polluters. Biodegradable plastics should only be labelled as such if they degrade completely without any adverse environmental or health effects from decomposition.

Any new agreement would need to incorporate enforceable marine litter standards alongside strong monitoring, reporting and enforcement legislation with adequate penalties including taxes on the most common type of marine litter such as cigarette butts, polystyrene foam, and single use plastic bags (Gold 2013).

Plastics could also be tackled under SAICM as a so called emerging issue akin to nanoparticles it would need to include land and marine based approaches. But whichever type of agreement is chosen it should include a detailed plan of how to deal with plastics throughout their lifecycle, effective collection and recycling systems, producer responsibility, create conditions for a more circular economy, and adequate provisions to deal with existing plastics waste. Funding could be sourced through the huge savings estimated to be around $120 through recycling plastic packaging which is normally thrown away. In addition to these points there needs to be financial support from the international community for low-income countries to manage their waste and in the absence of sustainable alternatives to produce toxic free plastics (Simon 2016).

Image 13: Flip-flop left behind

Annex 1

Hazardous chemicals found in the most common plastics

Bisphenol A

BPA is a chemical building block that is used primarily to make polycarbonate, a hard clear plastic which is found in many consumer products, it is also used to make epoxy resins which constitute 30% of the total BPA usage. It is one of the world's most widely-manufactured chemicals found in almost every human on the planet as well as in the environment. (Vandenberg 2010) Over 2.2 million tonnes of BPA are produced each year and it has been used in a vast array of consumer goods for over 50 years (Reuters 2010).

Because of Bisphenol A's corrosion protection ability, thermal stability and mechanical strength, it is found in everything from the lining of tin cans to dental fillings, drinking water containers, wine vat linings, plastic toys, resin based paints, floorings, computers, medical equipment and thermal papers (receipts), construction materials and in the protective coating for automotive and marine uses (Department of Health and Human Services & Centers for Disease Control and Prevention 2009).

But unfortunately BPA can leach from products. BPA and its derivatives have been detected in humans, wildlife, and in our environment, also contaminating municipal and industrial effluents (WHO/IPCS/EDC/UNEP 2004). Significant amounts of BPA (0.01 ppm to 50 ppm) has been reported in the ocean leading to widespread global contamination of sea sand and sea water from BPA due to hard plastic rubbish dumped in the ocean and from epoxy resin used to seal the hulls of ships (Saido, K. Sato 2010).

BPA is an endocrine disrupting chemical (EDC) and oestrogenic which means it can have very specific health effects on women. The EU has classified BPA as a reproductive toxicant 1b. It has been found to cross the placenta and so the foetus can be constantly exposed at vulnerable windows of human development and through breastfeeding (Engel et al. 2006), (Bailin et al. 2008). Exposure to even low levels of BPA at specific times in the womb, or during development, can contribute to breast and prostate cancer, endometriosis, heart disease, obesity, diabetes, fertility problems, birth defects, altered immune system function, and effects on brain development, behaviour and reproduction (Balakrishnan et al. 2010).

Adverse effects from BPA have been shown in marine mammals even at low doses and well below the supposedly 'safe' levels set for human exposure, levels of exposure which many humans experience daily (vom Saal et al. 2007), (Vandenberg 2010).

BPA substitutes have also been found to cause measurable effects on brain development and behaviour specifically up to the second trimester of pregnancy. Researchers have advised pregnant women to avoid BPA and also BPA substitutes which they found equally affect neurodevelopment (Kinch et al. 2015).

There has been much debate as to whether endocrine disruptors like BPA are safe to use or not. The conflict centres on whether extremely low doses of BPA can affect humans or not. "*The biologists say BPA, like other hormones, seems to have effects at low doses that don't occur at high doses. That doesn't happen with the other chemicals that toxicologists are accustomed to"* (E. Grossman 2013), (Vandenberg et al. 2012). An award winning article explored the issue of vested interests in relation to the slowing down of legislation to regulate endocrine disrupting chemicals like BPA and concluded that journals and editors who signed an editorial criticising the EU on plans to regulate EDCs had links to industry which included receiving research funding, or serving as advisers or consultants to industry (Horel 2013).

Till receipts

BPA is used to treat thermal paper to make it easy to see printed information such as printed on receipts. But it can be absorbed through the skin via contact with paper products containing BPA and contact with, or ingestion of, water and foods that were manufactured or packaging in BPA-based plastics. (Liao & Kannan 2011), (Schreder 2010). Residues from hands can also be ingested (EPA 2010).

Handling till receipts containing BPA results in the chemical being absorbed into our blood stream and ironically using hand sanitizers results in higher quantities being absorbed (Hormann et al. 2014). Substitution is not the answer as BPA substitutes such as Bisphenol S or F may also have hormone disrupting properties (Rochester & Bolden 2014).

In 2014, the French government proposed to ban the use of BPA as it posed significant risk to workers, the targeted population for the restriction proposal was pregnant women in terms of potential risk to the foetus (due to their exposure as workers and consumers) to BPA contained in the thermal paper they might handle. Working as a cashier is a female dominated job for example in France with 89% of cashiers assessed to be female, the government calculated that the number of foetuses exposed in utero would be around 32,000 (ANSES 2014). The subsequent health costs and effects were deemed too high a price to pay. The EU Chemicals Agency agreed with the report that there was a risk to workers but not to consumers and will consider a ban later in 2015 (European Chemicals Agency 2015).

Lining of drinking water pipes

Consumers can be exposed to BPA in fresh drinking water from pipes leading into their own homes. BPA is used in the relining of drinking water pipes; it is also used to reline sewage pipes. Relining consists of recoating the inside of the water pipe rather than replacing the entire pipe. This is done with epoxy resin containing BPA or Bisphenol A Diglycidyl Ether (BADGE), which can leach BPA (Beronius A 2011).

The Swedish Chemicals Agency, instructed by the Swedish government, took water samples from apartments with relined water pipes and found BPA in concentrations were between 0.01 and 1 microgram of BPA per litre of water. Higher levels were found in hot water. Sweden is now considering whether to ban the relining of pipes with BPA or BADGE having withdrawn its intention to call for an EU wide ban (KEMI 2013).

The contamination of water by BPA has implications for fresh water ways and our oceans. The general opinion is that BPA is easily biodegradable by treating sewage. But research has shown that *"neither basic wastewater treatment not basic drinking water treatment will eliminate the oestrogens, androgens, or detergent breakdown products from water, due to the chemical stability of the structures"* (Falconer 2006).They are carried over into the general aquatic environment. After ground passage, they can eventually be found in drinking water (Kuch & Ballschmiter 2001). Research has mainly focused on leaching from landfills and BPA entering our water systems through effluent. There is little if any monitoring of the effects from relining of pipes and BPA contaminated water from storage.

It's worth remembering that BPA is not the only EDC found in drinking water, multiple contaminants and mixtures are turning up in our water supplies. There is no regulatory standard or measurement for these contaminants even though they are known to have effects even at trace amounts (Solomon 2010).

Epoxy linings already in place have the potential to affect water quality for decades, given their longevity (in the order of 30 years or more (Jackson et al. 2007). Research shows high migration of BPA with the deterioration of resins over time (Larroque 1989). There is also potential for absorption through BPA contaminated bathing water.

Phthalates

Phthalates are used in a wide range of applications, the higher molecular weight ones such as DEHP (Di (2-ethylhexyl) phthalate) are primarily used as plasticizers in the manufacture of flexible vinyl plastics which in turn are used in consumer products, flooring and wall coverings, food content applications and in medical devices. The lower molecular weight members of the phthalate family such as DEP (*Diethyl Phthalate)* and DBP (Dibutyl *Phthalate)* are used as solvents in personal care products, perfumes, lotions and cosmetics, varnishes and coatings and in some pharmaceuticals used to provide timed releases of medicines. They are known endocrine disruptors.

Two sources of the phthalates found in infants are personal care products and household dust. A study investigated the association between phthalate concentration in an infant's urine and the application by the mother of personal care products such as baby lotion, baby shampoo and baby powder to the infant's skin. In one 24 hour period, 9 different phthalates were measured in 162 infant's urine. The findings were strongest in younger infants under 8 months who maybe particularly vulnerable to developmental and reproductive toxicity (Sathyanarayana 2008). It was unclear in this study as to the phthalate content of specific products because personal care product manufacturers are not required to list phthalates on the labels.

Phthalates are linked with early puberty and exposure at key times known as 'critical windows of vulnerability', "*can have a very distinctly biological, developmental, and thus gendered nature*" (Scott 2015). They also affect the thyroid gland (Velez 2015) and in a US survey, exposure to EDCs in utero were found to lower the age at which the onset of puberty occurred in off spring, as well as the age at which breast buds developed in girls (Velez 2015). Boys are also entering puberty earlier, a longitudinal study indicated that high exposure to Dibutyl Phthalate isomers (DBP) was associated with earlier age of puberty for boys (Mouritsen et al. 2013).

A well-known study carried out between 1994 and 1998 on Puerto Rican girls aged six months to eight years provides strong evidence for the association between exposure to phthalates and early puberty. The researchers analyzed forty-one blood samples from girls diagnosed with early-onset puberty and compared them with thirty-five control samples. High levels of phthalates – on average, 450 parts per billion – were found in 68% of the case samples, compared with an average level of only 70 parts per billion in the control group (Colon 2000).

Although certain phthalates have been substituted due to concerns for health, phthalates are still used widely in food wrapping and packaging. DEHP was banned in Europe in 2004, but it's still allowed in the United States. Over the past decade, however, manufacturers voluntarily began to replace DEHP with DINP and DIDP (Leonardo Trasande 2015). But the replacement phthalates Diisononyl Phthalate (DINP) and Diisodecyl Phthalate (DIDP) have been linked to high blood pressure, insulin resistance (a precursor to type 2 Diabetes) and other metabolic disorders in children and teens. A study measured levels of the two phthalates in urine of children and found a correlation between every 10-fold increase in the levels of the two chemicals and the children's blood pressure. The researchers also found a link between the two chemicals and insulin resistance (Leonardo Trasande 2015).

Polybrominated Diphenyl Ethers

PBDEs are added to plastic materials and polymers such as high impact polystyrene, polyurethane foam, wire and cable insulation to decrease the likelihood and intensity of fire, they can be found in electronic circuit boards, vehicles, furniture, carpets, building materials etc. and can constitute up to 30% of the final product and polymers. There are 3 major types, penta-, octa- and deca- PBDEs. Penta is mainly added to polyurethane foam for furniture cushions; Octa is used in plastic casings for computers, TVs, automotive parts and electronics; Deca is added to high impact plastics for electronic equipment, as well as to plastic toys and furniture.

They decompose at high temperatures and liberate the bromine atoms, which are affective at stopping the basic chemical reaction that drives oxygen dependent fires. They do not bind chemically with the plastic so leach out continuously. High levels have been found in fish, shell fish, marine mammals, meat and dairy products and even in vegetables from Canada to Japan (Bocio et al. 2003), (Hale et al. 2003).

They have been associated with adverse effects on the liver, thyroid, linked to developmental and reproductive toxicity and developmental neurotoxicity, there is also a suggestion they are linked to cancer (Costa & Giordano 2007). Concentrations found in human blood, umbilical cords, and breast milk have been increasing over time, highlighting a definite and very specific gender connection between plastics and women (Meironyté D, Norén K 1999), (Hooper & She 2003) .

The highest levels of PBDEs in foods have been found in Japan where the levels in women's breast milk were equated to the amount of fish in their diet (Ohta S 2002). Eating seafood and traditional seafood diets also contributed to high levels of PBDEs in breast milk tested from mothers in the Faroe Islands where the population's traditional seafood diet includes pilot whale blubber, sea birds and their eggs. Elevated levels of PBDEs ranging from 4.7 to 13 ng/g fat were detected (Fängström et al. 2005). Levels were found to increase over the years.

Diet and house dust appear to be the major sources of PBDE exposure in the general population, but occupational exposure can also occur. Certain occupations such as those working in electronic dismantling plants or as computer technicians have been found to have higher levels of PBDEs in their blood (Jakobsson et al. 2002), (Sjödin A 1999). As plastics containing PBDE break down with age they release the PBDEs – this is true for polyurethane foam, which becomes brittle and breaks into crumbs particularly when exposed to sunlight. This foam dust can get into air, soil and water and into the human body (Hale et al. 2002).

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