Report Cigarette Filters

Cigarette Filters and Extended Producer Responsibility

September and October 2021

GoClean foundation

ZwerfAfval Kompas

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Cigarette filters are the most commonly found litter item worldwide. Throughout the Netherlands, around 9.5b cigarettes were sold in the year 2020, and it is estimated that 2/3 of cigarette filters end up on the streets as litter each year (World Health Organization, 2017). This could even be a conservative estimate, as certain studies have put this number as high as 75 or even 90%.

Most cigarette filters contain chemicals and are made of cellulose acetate (plastic), which causes them to be non-degradable. They are therefore a source of bulk plastic as well as microplastic pollution. Given that it has been estimated that 300 million kilos of microplastics enter our ecosystems per year, we argue that cigarette filters and specifically the microplastics that they contain constitute a major environmental problem. Furthermore, cigarette filters are largely superfluous, as they do nothing to limit the health effects of cigarette smoke, but were instead introduced by cigarette manufacturers to give the impression that harmful substances would be filtered away and that their product therefore was not damaging to smokers. This is untrue and, as we discuss below, cigarette filters serve very little purpose.

Anecdotally, it is not uncommon to see smokers discard their cigarette filters in an irresponsible way, despite the presence of an ashtray nearby. Because of the sheer preponderance of cigarette filters and the disturbing circumstances of plastic and chemical pollution that they cause, we decided to start a more in-depth study into the pollution rate of filters in the Netherlands.

In the first instance, there is clearly an issue with the correct disposal of cigarette filters by smokers. More than three quarters of smokers see cigarette filters as litter and know that filters are not biodegradable. However, 74% of these people discard the cigarette filters on the ground anyway. This implies that it will be hard to change the behaviour of smokers with more educational campaigns about the consequences or different kinds of ashtrays. The influence of these campaigns on smokers who do not see cigarette filters as litter is debatable. Only educating smokers about the fact that cigarette filters contain plastic could be useful, perhaps because only 45% of smokers know that there is plastic in them.

However, smoking is mostly a social activity. This means that changing social norms within society has the highest effect on the proper discarding of cigarette filters. One option in order to achieve this is to influence social norms by increasing the number of role models to portray and implement the social norm of properly disposing of cigarette filters. This role model method should also be used to change the belief that cigarette filters make smoking safer in order to remove the cigarette filter from cigarettes again.

Cigarette filters are hugely damaging to the environment. Not only do the chemicals that leach out of them not simply disappear, they also do not biodegrade. Furthermore, researchers have shown that cigarette butt leachate and nicotine are poisonous to microbes, plants, fish, and mammals. Cigarette filters are found to be a significant source from where metals enter the natural environment, and they also have an adverse influence on the growth of plants. After being exposed to cigarette filters for three weeks, grass and clover showed a large reduction in the growth of new leaves and the germination process was less successful.

In order to raise awareness about the plastic pollution of the environment through littered cigarette filters, a number of cleanup actions were held over a two year period. First, a one day action in Amsterdam to Clean the Butt in 2019 was carried out, during which 35 people collected 50,000 filters in 2 hours. This led to the Plastic PeukMeuk (Plastic Butt Smut) action day in 2020 during which 142,000 cigarette filters were picked up from the streets in several cities of the Netherlands by over 150 participants using the motto #nofilterplease. In 2021 over half a million cigarette filters were collected by hundreds of participants (along with tens of thousands interested bystanders) during the one day action Plastic Peukmeuk 2021, which took place in 88 cities throughout the Netherlands to focus attention on the enormous and underappreciated plastic pollution problem, in order to appeal to the government to start an investigation into the abolishment of the plastic cigarette filter.[1] This (Plastic Butt Smut) campaign ran from 10 June 2021 to 10 July 2021, during which time cigarette filters were picked up and registered in the Litterati app by many volunteers throughout the Netherlands. The volunteers went out on one or more days during this period of one month and registered and picked up cigarette filters in locations of their own choice throughout the Netherlands. Finally, a more formal monitoring process was carried out between September-October 2021,

[1] For more information, visit the website https://plasticpeukencollectief.nl/plastic-peukmeuk-2021

which was designed to measure the accumulation of cigarette filters in a set number of locations over time.

In the above final monitoring action, eight different types of locations were examined and many cigarette filters were found during the six weekly measurements. This was also the case for the two types of control locations. This confirmed the omnipresence of cigarette filters throughout the Netherlands and demonstrates how widespread this pollution issue is. Given the high numbers of cigarette filters in the first measurement and the decrease to a stable pollution level of 26 cigarette filters per 100 m² per week in the following five measurements, it can be argued that the government does not properly clean the cigarette filters. In order to prevent serious pollution by these filters, it is necessary to clean the filters at last on a weekly basis.

We also provide an estimate of what the cleanup costs might look like when cigarette filters are cleaned manually. Our data indicate that 21,181 full time employees would be needed to keep the Netherlands clean of the cigarette filters that are littered each year . This amounts to approximately € 0.11 per filter on soft surfaces and € 0.06 per filter on hard surfaces. The higher cost for soft surfaces is driven by the fact that it's easier to manually clean filters from hard surfaces. For hard surfaces machine clearing is a good way to go, but the costs of the expensive equipment and other costs like fuel and maintenance should not be overlooked. For soft surfaces manually clearing cigarette filters seems to be the only option. Machines don't work on soil and mechanical cleaning on soft surfaces disturbs the natural environment. Furthermore, these costs only refer to wage costs and do not factor in fixed capital costs relating, for example, to machinery, or those relating to environmental degradation when growing tobacco, in addition to the perhaps immeasurable cost associated with more general harm to the natural world caused by the filters themselves.

Our conclusions are as stark as they are straightforward. Cigarette filters cause tremendous harm to the natural world. The Ministry of Infrastructure and Water Management recently ordered a study to establish the steps needed to achieve a 70% reduction of filters that end up in nature by 2026. In view of the results of our research, we argue that this reduction can only be achieved if the filter is removed from the cigarette. Clearly more needs to be done to address the damage that cigarette filters are currently doing, as well as to prevent further harm through social and behavioural intervention. The costs of doing so might be large, but it is imperative that justice be done.

Executive summary Dutch

Wereldwijd zijn sigarettenfilters het meeste gevonden soort zwerfafval. In 2020 werden in Nederland ongeveer 9,5 miljard sigaretten verkocht. Geschat wordt dat 2/3 van deze sigarettenfilters elk jaar als zwerfafval op straat belandt (Wereldgezondheidsorganisatie, 2017). Die schatting zou zelfs aan de lage kant kunnen zijn, omdat andere onderzoeken dat aandeel hebben vastgesteld op 75 of zelfs 90%. De meeste sigarettenfilters bevatten chemicaliën en celluloseacetaat (plastic), waardoor ze niet afbreekbaar zijn. Daarmee vormen ze een bron van grote plastic vervuiling, ook als microplastic. Aangezien er naar schatting 300 miljoen kilo van dat microplastic jaarlijks in ons ecosysteem belandt, zijn sigarettenfilters en met name de microplastics die ze bevatten, een groot milieuprobleem.

Sigarettenfilters zijn grotendeels overbodig. Het filter draagt niets bij aan het beperken van de effecten op de gezondheid van het roken van sigaretten. Sigarettenfabrikanten introduceerden de filters om de indruk te wekken dat het filter de schadelijke stoffen uit de tabak zou tegenhouden en dat roken dus niet schadelijk zou zijn voor rokers. Dit blijkt niet waar te zijn. Een sigarettenfilter lijkt dus eigenlijk geen echte functie te hebben.

Vaak zien we dat rokers hun sigarettenfilters op straat of in de natuur weggooien, ook als er dichtbij een asbak aanwezig is. Vanwege het enorme aantal sigarettenfilters in het milieu en de daardoor verontrustende vervuiling die ze veroorzaken, hebben we besloten een diepgaander onderzoek te doen naar de vervuilingsgraad van sigarettenfilters in Nederland.

In eerste instantie is er duidelijk een probleem met het correct weggooien van sigarettenfilters door rokers. Meer dan driekwart van de rokers vindt dat een sigarettenfilter afval is en weet dat deze niet afbreekbaar is. Toch gooit 74% van hen de sigarettenfilters op de grond. Dit geeft aan dat het moeilijk zal zijn dit gedrag van rokers te veranderen door middel van meer bewustheid campagnes en meer of andersoortige asbakken. De invloed van die campagnes op rokers die sigarettenfilters niet als afval beschouwen is discutabel. Alleen het voorlichten van rokers over het feit dat er plastic zit in sigarettenfilters, is van nut gebleken, misschien omdat maar 45% van de rokers weet dat er plastic in zit.

Omdat roken vooral een sociale activiteit is, zal het veranderen van de sociale norm binnen deze groep het meeste effect hebben op het op de juiste manier weggooien van

sigarettenfilters. Om deze sociale normen te beïnvloeden stellen we voor om het aantal rolmodellen binnen deze groep te vergroten. Deze rolmodellen moeten de juiste sociale norm uitstralen en laten zien op welke wijze sigarettenfilters weggegooid moeten worden. Tenslotte zou deze methode met rolmodellen ook gebruikt moeten worden om rokers voor te lichten, dat het gebruiken van een filter het roken niet veiliger maakt. Daarna is de volgende stap om de filter van de sigaret te verwijderen.

Sigarettenfilters brengen het milieu enorm veel schade toe. De chemicaliën die uit sigarettenfilters lekken verdwijnen niet en de filters zelf breken niet af. Daarnaast hebben onderzoekers aangetoond dat nicotine en andere stoffen die uit de filters lekken giftig zijn voor microben, planten, vissen en zoogdieren.

Sigarettenfilters vormen een belangrijke bron van waaruit metalen in het milieu belanden. Ook hebben ze een nadelige invloed op de groei van planten. Na een blootstelling aan sigarettenfilters gedurende drie weken bleek er een grote vermindering in de groei van nieuwe bladeren bij gras en klaver. Het ontkiemingsproces was ook minder succesvol.

De afgelopen paar jaar is er een aantal schoonmaakacties georganiseerd om mensen er meer bewust van te maken dat sigarettenfilters een grote bron van plastic vervuiling zijn in het milieu. Allereerst was er in 2019 een actiedag in Amsterdam onder het motto Clean the Butt. Hierbij raapten 35 personen in 2 uur tijd 50.000 filters op. Dit leidde in 2020 tot de actiedag Plastic PeukMeuk, waarbij meer dan 150 deelnemers onder het motto #nofilterplease 142.000 sigarettenfilters opraapten van de straten van diverse steden in Nederland. In 2021 raapten honderden deelnemers meer dan een half miljoen sigarettenfilters op. Hiermee werden tienduizenden geïnteresseerde passanten bereikt. Deze actiedag heette Plastic Peukmeuk 2021, en werd in 88 steden door heel Nederland georganiseerd om aandacht te vragen voor dit enorme en ondergewaardeerde probleem van plastic vervuiling. Het doel was om een beroep te doen op de regering om een onderzoek te starten naar de afschaffing van de plastic sigarettenfilter[2]. De actie liep van 10 juni tot en met 10 juli 2021. Door heel Nederland raapten veel vrijwilligers sigarettenfilters op en legden deze vast middels de Litterati-app. De vrijwilligers trokken in die periode een of meerdere dagen erop uit om op door henzelf gekozen locaties door heel Nederland sigarettenfilters te registreren en op te rapen. Dat leidde tot de opzet en uitvoering van een formeler monitoringsproces, dat in september en oktober 2021

[2] Voor meer informatie, bezoek de website https://plasticpeukencollectief.nl/plastic-peukmeuk-2021

werd uitgevoerd. Het doel was om gedurende een bepaalde tijd op een vast aantal locatiesoorten te meten hoeveel sigarettenfilters daar werden aangetroffen.

In bovengenoemde monitoring werden 8 verschillende typen locaties onderzocht en gedurende de 6 wekelijkse metingen werden er vele sigarettenfilters aangetroffen. Dat was ook het geval bij de 2 typen controlelocaties. Deze monitoring bevestigt dat sigarettenfilters in het Nederlandse milieu overal vertegenwoordigd zijn en toont aan hoe wijdverspreid dit probleem van vervuiling is.

In aanmerking genomen dat het aantal sigarettenfilters tijdens de eerste meting erg hoog was en tijdens de 5 daarop volgende metingen afnam naar een stabiel vervuilingsniveau van 26 sigarettenfilters per 100 m² per week, kan er gesteld worden dat de overheid de sigarettenfilters niet goed opruimt. Om ernstige vervuiling door die sigarettenfilters te voorkomen is het nodig dat ze minimaal een keer per week opgeruimd worden.

We geven ook een inschatting van de omvang van de kosten van het handmatig opruimen van sigarettenfilters. Uit onze gegevens blijkt dat er elk jaar 21.181 full time medewerkers ingezet zouden moeten worden om de filters uit het Nederlandse milieu te halen. Dit komt neer op ongeveer € 0,11 per filter aangetroffen op een zachte ondergrond en € 0,06 per filter op harde oppervlakken. De hogere kosten voor reiniging op een zachte ondergrond komen voort uit het feit dat het eenvoudiger is om handmatig sigarettenfilters op te ruimen op een harde ondergrond. Op harde oppervlakken kan machinaal reinigen een goede aanpak zijn, maar de kosten van deze dure apparaten en bijkomende kosten zoals brandstof en onderhoud moeten ook in aanmerking genomen worden. Op zachte ondergrond lijkt handmatig opruimen van sigarettenfilters de enige mogelijkheid. Machines werken niet op een zachte ondergrond en mechanische reiniging zou ook de natuurlijke omgeving verstoren. De hierboven genoemde kosten dekken overigens alleen de loonkosten en houden nog geen rekening met vaste kosten van bijvoorbeeld het machinepark of de aantasting van het milieu door het verbouwen van tabak. Daarnaast zijn er de wellicht onmeetbare kosten die verband houden met de meer algemene schade aan de natuurlijke wereld die door de filters zelf veroorzaakt worden.

We kunnen concluderen dat sigarettenfilters een enorme schade aan de natuur veroorzaken. Het ministerie van Infrastructuur en Waterstaat heeft recent laten weten een onderzoek uit te laten voeren om er achter te komen welke stappen er nodig zijn om tot een reductie van 70% minder sigarettenfilters in de natuur te komen. Op basis van de uitkomsten van ons onderzoek

concluderen wij dat deze reductie alleen bereikt kan worden als de filter van de sigaret verwijderd wordt. Het is duidelijk dat er meer gedaan moet worden om de schade aan te pakken die de sigarettenfilters op dit moment aanrichten. Ook zijn sociale en gedragsmatige maatregelen nodig om verdere schade te voorkomen. De kosten hiervan kunnen hoog zijn, maar het is absoluut noodzakelijk dat gerechtigheid geschiedt.

Foreword by Dr. Thomas E. Novotny

This comprehensive document first presents a thorough review of the rapidly accumulating research on the environmental toxicity of cigarette butt waste, extending from microscopic organisms to invertebrates, to fish, to birds, to plants, and possibly even to humans through the food chain. There are trillions of filters discarded into the environment every year; these filters don't readily degrade; they contain and leach out toxic chemicals such as nicotine, carcinogens, and metals; they require public resources to clean them up; and they are the result of a product that, when used as directed, has a good chance of killing the consumer.

Moreover, the cigarette filter, as a plastic, toxin-infused waste product, is described here as to what it really is: a fraudulently marketed tool to reassure smokers they are doing something to protect themselves from the risks of smoking. Instead, they are exposing themselves to all the same toxins and carcinogens as in unfiltered cigarettes, and they even experience higher risks of certain types of lung cancer because of the filter. They are discouraged from quitting by the implication that the filter is doing something to reduce risks, and it encourages kids to start smoking because the filter makes it easier to smoke. The filter is a source for microplastics that we can measure in the runoff from urban environments, and it is the single most picked up item of trash on beaches and other natural environments around the world. Therefore, it makes no sense to continue to sell filtered cigarettes based on what we know about the composition and fraudulence of the filter. If we want to reduce the plastic waste produced by the almost six trillion commercial cigarettes sold each year, almost all of which are filtered, we should ban the sale of filtered cigarettes. More research is needed as to the human health effects of cigarette butt waste, but what we do know should justify immediate action to reduce this unnecessary waste stream.

Research is also presented here to help understand the social and behavioural determinants of inappropriate cigarette butt discarding. These determinants are difficult to change, and they stem from widespread misconceptions about the filter and about cigarette filters as a toxic waste item. As smoking restrictions moved smokers from indoor environments to outdoor environments, smokers were more likely simply to dump that small piece of trash produced after smoking somewhere onto streets and sidewalks, into drains, into flowerpots, or into waste receptacles. It is ubiquitous and seems to be the last acceptable form of littering.

The team has taken on the task of estimating the economic costs of cigarette butt cleanup, and their findings describe the labor costs inherent to these cleanups. This is likely to be an underestimate of the total environmental costs of butt waste, as there are secondary costs related to environmental degradation and the public nuisance of cigarette butt waste that could be included in these estimates. These results should alert policy makers to the negative economic externalities of smoking and support upstream policies, such as banning the sale of filtered cigarettes, to reduce the burden of butt waste cleanup on communities, voluntary groups, and taxpayers.

The research presented here also describes sophisticated monitoring of tobacco product waste using geolocation and repeat assessments of impacted areas to demonstrate the continuous and widespread nature of the butt waste problem. Surveillance of environmental contamination with cigarette filters is an important step in demonstrating the problem, calling attention to it among those who may engage in policy interventions, and measuring the impacts of these interventions.

This document is a great reference for those concerned with protecting the environment from toxic, plastic waste products and reducing the devastating impacts of the ongoing tobacco epidemic. Using environmental policy to change what tobacco products are sold and discarded, estimating the economic burden of cleaning up these products, measuring the environmental burden of cigarette butt waste, and denormalizing tobacco use overall through environmental activism can have enormous effects on human health and environmental sustainability. It is time to act on both fronts.

Introduction

Cigarette filters are the most commonly found litter item worldwide. Throughout the Netherlands, around 9.5bn cigarettes were sold in the year 2020, and it is estimated that 2/3 of cigarette filters end up on the streets as litter each year (World Health Organization, 2017). This could even be a conservative estimate, as certain studies have put this number as high as 75 or even 90%. Anecdotally, it is not uncommon to see smokers discard their cigarette filters in an irresponsible way, despite the presence of an ashtray nearby. Because of the sheer preponderance of cigarette filters and the disturbing circumstances of plastic and chemical pollution that they cause, we decided to start a more in-depth study into the pollution rate of filters in the Netherlands.

By way of an example, consider first the issue of plastic pollution. Almost all cigarette filters are made of cellulose acetate, which causes them to be non-degradable. They are therefore a source of bulk plastic as well as microplastic pollution. Given that it has been estimated that 300 million kilos of microplastics enter our ecosystems per year, it can be concluded that cigarette filters and specifically the microplastics that they contain are a contributor to this problem. This is particularly of concern in aquatic ecosystems, where they tend to accumulate (Belzagui et al., 2021).

In addition to the issue of plastic pollution, chemicals leach out of the tobacco waste products into the environment. Because of the widespread consumption of tobacco products, nicotine and tobacco byproducts such as cotinine end up in many solid-waste landfills or dumps. In fresh samples of landfill leachate (liquid that drains out before any storage or processing), cotinine was among the most frequently detected chemicals. Cotinine has also been detected in groundwater contaminated with landfill leachate and in reclaimed water used to irrigate. (World Health Organization, 2017) These chemicals are a serious threat to living organisms and ecosystem health when discarded in the environment, as they are toxic to microbes, insects, fish and mammals (Bonanomi et al., 2015).

The incorrect disposal of cigarette filters is therefore a matter of high importance. Cigarette filters constitute a large proportion of waste in the Netherlands, and they may impact ecosystems as microplastics as well as chemical toxins. With this report, we hope to shed light on a number of practical insights regarding the level of cigarette butt pollution throughout the

Netherlands, such as areas that are particularly affected by tobacco product waste. Furthermore, we aim to provide guidance on the effort required to clean up cigarette butt pollution, as well as a quantitative estimate of the responsibility that cigarette manufacturers have for this pollution problem.

This report consists of four sections. The first gives insights into the behavioural and environmental aspects of tobacco product waste. The second outlines our data and methods used for the analyses. The third provides an estimate of cleanup costs for cigarette filters, while the fourth and final section provides some policy implications of this report.

The behavioural aspect: why do smokers litter their cigarette butts?

Starting from the early nineteen hundreds, filters were attached to commercial cigarettes.[3] Cigarette filters are mistakenly thought of as a protective health device (Novotny et al., 2009). However, cigarette filters are rather a marketing tool to sell cigarettes as 'safer'. With machine measurements, the yield of nicotine and tar from a burning cigarette was shown to be reduced. However, in practice it is not proven that the nicotine and tar are also reduced when a person, instead of a machine, smokes the cigarette. Another disadvantage of the filter is that it can sustain smoking (Novotny et al., 2009). When people start experimenting with smoking they experience less irritation with filtered cigarettes. Cigarette filters may also discourage people from quitting, because they believe the filtered cigarette is less dangerous for their health. This would mean that throughout the population the smoking-attributable disease burden has not been reduced by the introduction of cigarette filters.

Besides these behavioural problems related to filters, there is also a huge environmental problem. The cigarette filters used nowadays are mostly made of a type of non-biodegradable plastic called cellulose acetate (Currie & Stack, 2021). In 2019, worldwide 5.5 trillion cigarettes were produced. Approximately 80% of these cigarettes may have been discarded into the environment after smoking (Torkashvand & Farzadkia, 2019). In other studies, 65% of smokers reported that they discarded their cigarette filters improperly (Rath et al., 2012). The smoking ritual involves cigarette filters thrown on the ground or out of a car window instead of into an ashtray. When plastic filters are thrown into the environment, this may then present a risk for humans and wildlife, on land and in the sea. If we do not want to create more damage to our planet, we have to limit the amount of tobacco product waste that is discarded into the environment. In this paper we look at the behavioural aspect of why people improperly dispose of their cigarette filters. After this, we consider several options to influence the behaviour of smokers who improperly discard cigarette filters.

[3] For timeline of introducing and using cigarette filters see: https://tobaccocontrol.bmj.com/content/11/suppl_1/i51/T1

Littering behaviour of smokers

The behaviour of smokers regarding cigarette butt littering can be predicted by three variables: personal factors, social factors and structural factors (Dehdari, 2022).

Personal factors

First, for the personal factors it is important to look at the knowledge and beliefs people have about cigarette filters. In 2012, 79% of the adult US smokers knew that cigarettes are not biodegradable (Rath et al., 2012). In 2021, 89% of US youth surveyed knew that cigarette filters are not biodegradable and are harmful to the environment (Epperson et al., 2021). However, only 43.1% of the respondents knew that cigarette filters contain plastic.

It is noteworthy that while 86% of smokers believed cigarette filters are litter, 74% reported disposing them on the ground at least once in their life. When a smoker does not see cigarette filters as litter, they are 3.5 times more likely to litter their cigarette filters sometime in their life and 4 times more likely to have littered them in the past month (Rath et al., 2012). However, a study from 2022 found somewhat different results. In 2022, 45% of the smokers that had a negative opinion about throwing cigarette filters on the ground did it themselves (Dehdari, 2022). It seems that being aware or not about the negative environmental consequences of cigarette butt littering does not make a significant difference in the actual littering. Not feeling responsible for the proper disposal of the cigarette butt is an important personal characteristic related to the littering of cigarette filters.

Most smokers saw the littering of cigarette filters as a habit instead of a conscious decision (Dehdari, 2022). Discarding the cigarette filters on the ground is a behaviour that smokers are unconscious of and mostly ignore (Castaldi et al., 2021). It is unconscious, because the act of smoking is done with limited concentration and a lack of attention. This goes together with the assumption that cigarette butt littering can be considered as acceptable, since it is such a normative behaviour.

Many smokers believe incorrectly that filters make cigarettes safer when compared to cigarettes without filters (Epperson et al., 2021); 48% of the youthful respondents in this study think that filters make it easier to smoke cigarettes, while 29% believe that filters make cigarettes less harmful to smoke and 43% feel that cigarettes without filters are less attractive to smoke.

In an innovative observational study from New Zealand, more cigarette filters were observed to be littered in the evening (86%) than during lunchtimes (68%) (Patel et al., 2013). When cigarette filters were extinguished with the hand, only 5% was discarded on the ground. When the cigarette butt was not extinguished with the hand (stepped on) 94% was littered; 74% of the observed smokers did not extinguish their cigarette butt.

In self-reported surveys, it is more likely that male smokers have littered their cigarette filters in the past month when compared to female smokers (Rath et al., 2012). Also, the small size of the butt can influence improper disposal because it can be seen as having less impact or being totally insignificant to the environment (Dehdari, 2022).

Structural factors

Second, for structural factors we can look at characteristics of the environment where cigarettes are smoked. Overall, 42% of the smokers discard their cigarette butt on the ground because they have problems finding a proper place or bin to discard their cigarette butt (Castaldi et al., 2021). It is also found that when the density of ashtrays is higher and when the ashtrays are closer to the location of the smoker, there will be less cigarette filters discarded on the ground. This suggests that smokers' individual effort to find a bin is a critical factor in the willingness to dispose of cigarette filters properly.

If we look at urban areas where there is a high population density, we see a high amount of cigarette filters on roads and pavements (Araújo & Costa, 2019). These public spaces are most affected around commercial areas. This may be related to the density of selling points located in these areas. In commercial areas, mostly the consumption and sale areas are more likely affected by butt waste. This shows a strong correlation between cigarette butt litter, consumption by locals, and product availability. This was also found by Marah and Novotny (2011). They concluded that the waste of cigarette filters is therefore not equally distributed in urban environments.

Another study suggested further evidence for butt waste concentration related to places of consumption (Valiente et al., 2020). They concluded that hospitality venues had the highest concentration of cigarette filters with 76%. The second highest concentration is found near public transportation stops with 65%. Also, playgrounds had a high concentration with 53%. Entrances to educational venues are also noteworthy with 39%. Cigarette filters were also

found near the entrance of supermarkets (8%), near benches (6%) and in lower concentrations at other public pathways such as squares, streets and parks.

Also, in central districts there is a higher concentration of cigarette filters than in peripheral ones (Valiente et al., 2020). This may be due to the fact that central districts have more of the high consumption concentration venues. In the peripheral districts, where most land use is for residence and industry, the highest concentration of filters was found around squares and large streets where most leisure services were located. Overall, 73% of the outdoor residential public spaces in Madrid contained littered cigarette filters. This outcome was similar to a study done in Scotland, which found that 75% of the streets in cities in Scotland contained cigarette butt litter. High concentration places such as hospitality venues are associated with cigarette consumption and sales. Other high concentration places, such as public transportation stops and educational venues, may demonstrate high concentrations of butt due to indoor smoking restrictions.

In Tehran, Iran, it was found that parks were most severely impacted by cigarette filters and that the areas around administrative offices were least polluted (Torkashvand et al., 2021).

Social factors

Third, social factors are the way people are perceived by others and how they feel they are seen. People believed that the littering of cigarette filters was an accepted norm which is part of the culture of smokers (Dehdari, 2022). They also had role models, such as friends, family and celebrities, who contributed to the acceptance of this norm. If young people or children see the littering of cigarette filters it will become more likely for them to do the same when they start smoking. This also applies to smokers in general. When they see other smokers dispose of their cigarette filters on the ground, they are more likely to do the same. Seeing the act makes it into a normal act. It is also found that there is less role modelling for the proper disposal of cigarette filters. For younger smokers the littering of cigarette filters can also be a game, especially when they smoke together with their friends.

Influencing the littering behaviour of smokers

Personal, structural and social factors were used to predict the littering behaviour of smokers. These three factors can also be used as targets for influencing the behaviour of smokers.

Personal factors

First, personal beliefs and knowledge can be targeted by campaigns. To make campaigns against the littering of cigarette filters effective, it should be emphasized that there is toxic waste in cigarette filters and that it is not just litter. It is harmful to people and the environment when cigarette filters are improperly disposed of (Rath et al., 2012). These attitudes and awareness about the environment and the habits of smokers should influence the improper discarding of cigarette filters (Dehdari, 2022). However, anti-littering campaigns that are carried out thus far have not yet changed the littering of cigarette filters (Araújo & Costa, 2019). Therefore, there is insufficient proof for the effectiveness of behaviour change campaigns.

Anti-littering campaigns can help improve the littering behaviour of people (Currie & Stack, 2021), especially focusing on the fact that cigarette filters contain plastic. However, only 45% of the surveyed smokers and nonsmokers are aware of this fact. When these educational campaigns are used together with cleanup campaigns which make local people aware of the ways they can help prevent the littering of cigarette filters, the anti-littering campaigns become more effective (Currie & Stack, 2021).

The government of South Korea tries to specifically target people on holiday by using flyers with the text “Are you going on holiday? Leave your cigarettes at home” (Araújo & Costa, 2019). Another example of a campaign is from the Canadian *Pacific Whale Foundation* and is called *Keep Your Filters Off the Beach*. This campaign distributed free individual butt containers and incentivized smokers to be responsible with their cigarette filters. However, the effectiveness of these campaigns is not proven.

Another measure that has been considered is to eliminate cigarette filters (Araújo & Costa, 2019). It would make sense to stop using cigarette filters according to environmental concerns. However, cigarette filters are a marketing tool used by the industry to deceive people into thinking they reduce health risks from smoking. While this is the common belief among smokers, this attribution is simply a fraud. Because filters make it easier to smoke and do not

protect the health of smokers, there are no health reasons to keep selling cigarette filters; instead, there are significant environmental reasons to stop the sales of filtered cigarettes.

Morgan et al. (2022) assessed the impact on the littering behaviour of smokers of anti-littering messages on cigarette packs. When compared to chemical toxicity messages, anti-littering messages resulted in more intentions to dispose of cigarette filters properly in the future. They also increased awareness of cigarette filters as the most collected litter item and the proper ways of disposing of them. Lastly, the anti-littering messages resulted in less littering from car windows when compared to messaging about chemical toxicity. However, it did not result in complete proper disposal of cigarette filters. The benefit of anti-littering messages on cigarette packs instead of in media campaigns is that it targets specifically smokers (Morgan et al., 2022). Effective messages can contribute to more support for policies that are aimed at reducing the littering of cigarette filters. They can also change social norms around smoking and individual butt discarding behaviour.

When smokers used cigarettes labelled with messages about chemical toxicity, 52% knew that cigarette filters are the most picked up form of litter and 48% knew that cigarette filters are not biodegradable (Morgan et al., 2022). When smokers used cigarettes from a pack with anti-littering messages on it, 66% knew that cigarette filters are the most common sort of litter, and 68% knew that cigarette filters are not biodegradable. Smokers also saw anti-littering messages as more effective to discourage littering of cigarette filters than when the chemical messages were used. The largest effect of the anti-littering messages was seen with thoughts about the correct disposal of cigarette filters. This effect is associated with a higher intention to dispose of cigarette filters correctly.

Structural factors

Second, structural factors can be changed by altering the smoking environment. One important environmental factor that determines littering behaviour are ashtrays. Making portable ashtrays available may be effective in reducing the littering of cigarette filters (Castaldi et al., 2021). When these ashtrays are combined with encouraging messages to dispose of cigarettes properly there is no difference in effect. The effort cost of disposing cigarette filters properly may have the highest effect on reducing butt littering.

Research has also been done with a ballot bin project (Kataržytė et al., 2020). A ballot bin is a normal ashtray with a voting system. The bin has two ashtrays, and by dropping the cigarette butt in one of them the participant can answer the question that is displayed. The questions related to daily life issues are interesting, not necessarily related to smoking. This project examined the change in ratio between cigarette filters dropped in the bin and on the ground next to the bin. Using the ballot bin increases awareness, but was not efficient in reducing the amount of cigarette filters littered. Another conclusion made is that the number of visitors can be used to predict the number of filters littered. The higher the number of people the higher the number of cigarette filters littered.

Another option is to put a ban on smoking in public areas (Araújo & Costa, 2019). Such a ban results in a significant reduction of smoking and therefore also a significant reduction of cigarette butt litter. This measure is often countered by politicians with the claim that banning smoking in these places would be a violation of individual rights. Compliance with the smoking ban is highly related to the resources available to enforce these bans. Resistance can also come from the smokers themselves, because they do not want to feel isolated during smoking. To enforce this measure there have to be fines on smoking in the specific public spaces. These fines are effective despite the ongoing criticism of it being a violation of individual rights of smokers. However, for smoking bans to be lasting and effective they have to be accepted and understood by the whole society. This would require educational campaigns which are based on scientific facts.

Taxes and fees can also be used to reduce the littering of cigarette filters (Araújo & Costa, 2019). The littering of cigarette filters can be seen as a negative externality because of the public cleaning costs and the costs of environmental damage. These costs can be a general tax to all citizens of a city or a specific tax on cigarettes, which increases the price of cigarettes. When cigarettes become more expensive, the sales of cigarettes and therefore the littering of cigarette filters will also be reduced.

Social factors

Third, changing social norms can also be used to reduce the littering of cigarette filters (Castaldi et al., 2021). Smokers care about how they are judged by others and what other people are doing regarding smoking. Social norms can be divided into two types. Descriptive

norms are about “what most others do” and injunctive norms are about “what is socially accepted within a culture”. In a clean environment, people discard fewer cigarette filters than in a littered environment. Setting a good example by picking up cigarette filters from the ground or throwing them in a proper disposal place reduces littering effectively. It is shown that messages advocating injunctive norms reduces litter more effectively than messages activating descriptive norms.

Social norms can be created by visible results of antisocial behaviour (Sagebiel et al., 2020). This also happens when cigarette filters are dropped on the ground. Other people will see this and accept this behaviour as the social norm, which results in dropping their cigarette filters as well. This leads to the conclusion that extra cleaning effort can result in reduced littering. However, the additional cleaning costs will probably not be proportional to the effect it has on the littering of cigarette filters.

To control the littering of cigarette filters through social norms three sources of control are described (Pascual et al., 2014). The first is conformity, which is addressed by placing a sign saying most people throw the cigarette butt in the ashtray above the ashtray. The second is compliance without pressure, which means ‘but you are free to …’. This was addressed by placing a sign saying that people are free to throw the cigarette butt in the ashtray. The third source of control is obedience to authority. This is addressed by the setting, namely in a shopping mall without any official authority and in a Préfecture, a French administration office, which is a place of authority.

When none of the above sources of control were used, around 15% of the cigarette filters were observed to be littered (Pascual et al., 2014). The conformity message showed the best result, decreasing littered cigarette filters to 6%. The compliance message gave no substantial result. When the authority and non-authority setting are compared, the authority setting showed significantly better results with a decrease to 11% instead of an increase to 16% in the non-authority setting. However, the best results were obtained by combining the conformity message with the other sources of control. When the conformity message was combined with an authority setting, the littering rate decreased to 5%. For the compliance message, littering decreased to 9.5%, and for the non-authority setting to 12%. To conclude, it was easier to get a lower rate of littering cigarette filters at the entrance of a Préfecture than at the entrance of a

shopping mall. Combining both settings with a conformity message the littering rate also dropped. Using only a compliance message had no significant effect.

Government policy can have a huge impact on the social norms in a society. However, on its own policy is not effective to reduce the littering of cigarette filters (Currie & Stack, 2021). Currie and Stack (2021) show that a policy which attempts to change social norms is only effective when it is implemented together with awareness about the policy and sustained law enforcement. This also poses a problem to the effectiveness of policy. For laws to be effective there has to be regular enforcement. When resources are limited, enforcement can become a problem.

There are also a few limiting factors to the effectiveness of policies (Axelsson & Van Sebille, 2017). The first is the lack of economic concerns and political engagement. The second and largest is the lack of social engagement and motivation. Cities all over the world agree on this point. They also agree on the fact that for policy on cigarette butt littering to be effective it needs assistance from higher governments. In areas of direct control the public engagement and knowledge is high. Most of the cities used in the research have little legal backing for their policies. For most cities, the aesthetic of the city was the main motivation for implementing policy.

Lastly, it is important to mention that the strong traders and tobacco manufacturers lobby is often the cause of failure to implement measures effectively (Araújo & Costa, 2019). It should be noted that anti-littering campaigns that the tobacco industry carried out have not yet changed the littering of cigarette filters.

Conclusion

More than three quarters of smokers see cigarette filters as litter and know that the filters are not biodegradable. However, 74% of these people discard cigarette filters on the ground anyway. This means it would be hard to change the behaviour of smokers with more effective educational campaigns about the consequences. The influence of these campaigns on smokers who do not see cigarette filters as litter is debatable. Therefore, using campaigns to influence individual behaviour change does not merit investment. However, one option for an educational campaign would be about the fact that cigarette filters contain plastic. It seems that only 45% of the people know this and it could be an important fact to increase the willingness to dispose of the cigarette butt properly.

It has been found that ‘laziness’ and the effort costs needed make it more likely for smokers to litter their cigarette filters. Solutions that target this problem are creating a higher density of ashtrays or providing portable ashtrays. However, these solutions do not result in significant change in the behaviour of smokers. Providing more or different ashtrays is therefore not a solution.

Instead of changing the personal or structural factors, it may be more helpful to change the social norm because smoking is mostly a social activity instead of an individual one. This can be effectively done by creating more role models for proper disposal of cigarette filters and by decreasing the influence of role models that litter their cigarette filters. Role models represent the injunctive norms by portraying what is socially acceptable. Proper role models can be created by combining several measures.

First, already established role models with influence, for example on social media, can be partners with the government for a campaign portraying the desired social norms for cigarette butt littering. Second, policies must be implemented by the government to discourage the littering of cigarette filters. Such policy will only be effective when it is sustained by law and enforcement. The role model campaign can also help to establish awareness for the policy. When littering is discouraged by the policy, smokers will more likely properly dispose of their cigarette filters, which automatically creates proper role models within social groups. Last, the environment of smokers should not display the results of behaviour opposing the desired social norm. This can increase anti-social behaviour. In the case of cigarette filters, this means that places with a lot of cigarette filters on the ground have to be cleaned by the cities or citizens. Intolerance for anti-social behaviour has a huge influence on proper role modelling which can make it worth the cost and effort of cleaning.

Role models within society could also be used for another purpose. It is widely believed that cigarette filters make smoking safer. However, this belief is proven to be false. For environmental reasons it would be best to remove the cigarette filters from cigarettes. Role models can be used to change the belief in the safety of smoking by using filters. The changing of this belief will also be helpful for health reasons. It is proven that the use of cigarette filters sustains smoking, because it results in a safer feeling when smoking and in less irritation. This decreases the urgency for smokers to quit. When cigarette filters would no longer be used, the urgency to quit may increase, and less people would smoke. Therefore, the main goal of

socially targeted campaigns should be to remove the filters from cigarettes. However, it is best if this is combined with campaigns to change the improper disposal behaviour. When filters are still used they should be properly disposed. Also, when cigarette filters are no longer used, the remains of the cigarette should still be disposed properly because of the toxic compounds the cigarette itself contains, which can also influence the environment in a negative way.

To conclude, there are several options targeting individual smokers explored, such as awareness campaigns and more or different ashtrays, which are not effective. Only, educating people on the fact that cigarette filters contain plastic could be helpful. However, smoking is mostly a social activity. This means that changing the social norms within a society has the highest effect on the proper discarding of cigarette filters. One option to influence these social norms is by increasing the proper role models within society to portray and implement the social norm of properly discarding cigarette filters. These role model methods should also be used to change the belief that cigarette filters make smoking safer in order to remove the cigarette filter from cigarettes again.

Discussion

There is variability among research reports regarding data on cigarette butt litter. This can be explained by the difference in year and place the studies are conducted. Every year and at every place a different amount of cigarettes is smoked, the knowledge and beliefs about cigarette filters can differ, and the amount of littering the cigarette filters can be different. However, most studies come to the same conclusion, as represented in this paper.

Before campaigns targeting social norms are designed another literature review should be conducted. This could cover the disinformation the tobacco industry has spread in order to sustain smoking. When this disinformation is made clear and correct, academically sound, information can be made available, interventions are more likely to be implemented. In practice it is shown that people are sensitive to information based on academic research, and that can change personal and social behaviour. When the campaign can show the correct information, with the proper academic base, it will become an even stronger tool in changing social norms.

Cigarette butts and the environment

Although cigarette filters constitute up to 40% of coastal litter, their impact on the environment has typically been of limited scientific interest, and research in this area has not been especially prolific (Oliva et al., 2021). An example that bucks this trend, however, is the 2009 article "Cigarettes filters and the Case for an Environmental Policy on Hazardous Cigarette Waste" by Thomas E. Novotny et al., which has become an important source for subsequent studies. General background information is given, followed by a series of studies that show that the cellulose acetate filter material pollutes the environment, making cigarette filters a plastic litter problem. In addition, they make the case that cigarette butt litter is a form of chemical waste and has a deadly effect on many different forms of life, from microorganisms to animals and plants. Furthermore, it also covers solutions to this problem that have been proposed by the tobacco industry ('clean up your mess' and 'stop smoking, start vaping') as well as those from independent scientists (Extended Producer Responsibility, elimination of single use filters, elimination of cigarette production).

General background information

As was highlighted in the introduction, two out of three cigarettes are not disposed of correctly and end up as litter. With a global annual consumption of about 6.25 trillion cigarettes, that amounts to 4.17 trillion cigarette filters littered every year worldwide. However, this is likely to be a conservative estimate. In a study published two years after the WHO source above, it was estimated that, per year, 6 trillion cigarettes are consumed and 4.5 trillion cigarettes are discarded, which equals 75% of all smoked cigarettes (Araújo & Costa, 2019). Two years after that, global consumption was estimated to be 5.5 trillion cigarettes, with 4.95 trillion cigarette filters thrown away and ending up in the environment (Araújo & Costa, 2021), which brings the percentage to as high as 90% of all smoked cigarettes. Researchers believe that cigarette butt waste material could reach 1.2 million tons and increase by 50% by 2025 (Torkashvand et al., 2020) .

The cigarette filter itself was developed in the 1950s to address growing fears that lung cancer was associated with smoking (Harris, 2011). However, what started as a sincere effort to lessen health issues caused by smoking eventually morphed into a way to sell more cigarettes and convince consumers that their interests were aligned with those of cigarette manufacturers. This is to say that filters became a marketing trick, as they did little to protect the health of

smokers; rather, they were used solely to increase the perception that smoking could be made to be less harmful. In order to achieve lower tar measurements, filters were designed to have holes in them. Clean air could then be mixed with smoked air and therefore the machine measurements on tar were lower than they would in fact be in real consumption conditions, where the fingers of the smoker cover these holes and smokers inhale more deeply in order to absorb sufficient nicotine (Song et al., 2017). Furthermore, the filter changes how tobacco combusts, adding further poisonous substances to the smoke. Holes in the filters are also responsible for the growing number of lung adenocarcinomas among people who smoke, and they make it harder for many smokers to try to stop smoking, as the incorrect conviction that cigarette filters protect their health persists (Novotny et al., 2009). Since the 1960's cigarettes with filters became the standard, with up to 99% of cigarettes sold having the filter attached. Almost all of these filters are made of cellulose acetate, a plastic product.

Plastic

At a material level, filters are small straight bars containing approximately 12,000 fibres, pieces of which can become detached during both the production process as well as when the cigarette is smoked (Novotny et al., 2009). Microfibres from these filters are a significant origin of micro-plastics and degrade slowly. A two-year-long combined lab and field study showed that a littered cigarette butt lost only about 38% of its mass during decomposition (Bonanomi et al., 2015). A subsequent field study that lasted a total of five years into the decomposition of littered cigarette filters showed a process of three phases: in the first 30 days the cigarette filters lost about 15% of their mass; the following 2 years the decomposition rate progressed very slowly; during the last stage the outcome depended on the presence of nitrogen and the composition of the microbiome (Bonanomi et al. 2020). However long this process might take, cigarette filters are made of cellulose acetate, which make the filters non-degradable. Littered cigarette filters cause huge amounts of plastic and microplastic pollution, which concentrates in the marine environment.

Cigarette filters made from biodegradable material do not compare favourably with those made from plastic; at best, the results are mixed. One study found that, when disposed of directly into the soil, for example as a result of littering, there is no difference after 6 months in terms of the rate of decomposition (Joly & Coulis, 2018). On the other hand, when put in a composting bin for 6 months, the unsmoked biodegradable filter decomposed faster than plastic filters. However, the decomposition rate of the biodegradable filter from a smoked cigarette was much

slower than from the unsmoked one. Biodegradable cigarette filters have been found with worse results than plastic filters, likely because they contained more metal components and in higher concentrations than the plastic filter (Koroleva et al., 2021). Almost all cigarettes sold worldwide contain the plastic filter which is not biodegradable (Novotny & Slaughter, 2014).

As at least two out of three smoked cigarettes are thrown on the ground every year, this means that around 300 million kilograms of microfibres per year are released by smoked cigarette filters (Belzagui et al., 2021). These filters decompose slowly, and the substances inside the filter percolate into the ground and increase stressors to the ecosystem. As we will show below, cigarette filters contain poisons, nicotine, and agents, all of which are the main cancer-causing chemicals that can be found in tobacco products.

Chemical waste in the environment

Aside from plastic pollution, cigarette butt littering also harms the environment in other ways. The chemicals that leach out of cigarette filters do not simply disappear, nor do they biodegrade. Their impact is also not lessened by flowing into our canals, rivers, and oceans. In fact, the Dutch water authorities claim that the water filters, which clean the water coming out of the sewer system, are only able to prevent whole cigarette filters. When a cigarette filter falls apart into smaller pieces of plastic and microplastics the water filters are not able to prevent them from entering the water system. Because the water filters do not capture these plastics, a lot of microplastics are discharged into the Dutch surface waters.

Healton et al. (2011) reported on how the over 4,000 chemicals used in the production of a cigarette affect the environment, both from the smoking process itself, as well as through cigarette butt littering. Controlled research using test fish showed that even filters which had not been smoked and did not contain tobacco already were lethal; when the filters were smoked, lethality increased, and when there was remnant tobacco on a smoked filter, the lethality was maximized. Even unsmoked filters, without tobacco attached, had measurable lethality in this standardised toxicity study. (Slaughter et al., 2011).

Researchers have shown that cigarette butt leachate and nicotine are poisonous to microbes, plants, organisms in standing or flowing water, bivalves such as mussels, plankton (consisting of small animals and the immature stages of larger animals), fish, and mammals. Cigarette filters are found to be an important source for metals in the environment (Farzadkia et al., 2022). There were concentrations of lead, cadmium, chromium, zinc, copper, and nickel found in the

leachates of smoked cigarettes. Nevertheless important knowledge gaps remain related to the impacts by tobacco product waste on human health and ecosystems (Beutel et al., 2021).

Danger to life

The environmental impact of littered cigarette filters, particularly for aquatic organisms, is significant (Dobaradaran et al., 2021). As the cigarette filters remain in the water for an extended period of time, and are likely to travel a large distance before sinking to the bottom of the body of water where they end up, various organisms living in the water will absorb the toxic chemicals from the cigarette filter. Through laboratory tests, it was found that cigarette filters remain in the water between 3 to 20 days before they reach the sediment.

In two general studies on the effect of cigarette butt littering, Lima et al. (2021) show that a small quantity of filters was able to influence the reproduction of copepods (Lima et al., 2021). Baran et al. (2020) also demonstrate that natural cell reproduction in microorganisms can be hindered by a couple of dozen pieces of cigarette filters in water. Cigarette butt leachates also appear to have an influence on how fish develop: low concentrations of smoked filters cause an increase in their heart rate, an acceleration of their development, and a change in behaviour. High concentrations slowed the heart rate down, caused a slower development, and caused many fish to die (Lee & Lee, 2015). Another study on the effects of littered cigarette filters on animals was carried out on snails (Booth at al., 2015). Snails were exposed to different concentrations of leachate. As a result, all of the snails died after eight days at a concentration of five cigarette filters per litre in which they soaked for two hours. A third study (Montalvão et al., 2019) also demonstrates the adverse effects of cigarette butt litter on aquatic life. Here, mussels were shown to incorporate heavy metals from the leachates of cigarette filters. Furthermore, their behaviour also changed (Montalvão et al., 2019). Finally, water fleas were exposed to cigarette butt leachates for 48 hours. The chemicals released from the filters were deadly to the flea in a concentration of one butt per eight litres of water (Register, 2000).

Plants absorbing chemicals

Cigarette filters also have an adverse influence on the growth of plants (Green et al., 2019). After being exposed to cigarette filters for three weeks, grass and clover showed reduction in the growth of new leaves and reduced germination. It was concluded from this study that littered cigarette filters can cause a reduction in the growth of plants and change the photosynthesis process.

Field experiments on nicotine from cigarette butt litter showed that just one cigarette butt per square meter in the soil causes herbs and spice plants to absorb nicotine, which enters the soil from the discarded cigarette filter (Selmar et al., 2018).

Solutions

Cigarette filters are ubiquitous litter items. They may cause serious damage to the environment, and the costs of cleaning them up are immense (Hoek et al, 2020). According to the tobacco industry, smokers are the root of this problem, and it claims that a change in their behaviour is where the solution lies. From the point of view of an extended producer responsibility, however, tobacco companies should be held accountable for the total cost of tobacco production, from cradle to grave.

The World Health Organization describes the environmental impact of the tobacco industry in detail (Zafeiridou et al, 2018). In their words, its negative influence is not limited to peoples' health, but it also causes damage to the environment across the life cycle of the product. They also claim that it cannot coexist with the global development goals; instead, the production and consumption of cigarettes should end in order to reach the Sustainable Development Goals (SDGs) (including goals 12, 13, 14, and 15). They promote Extended Producer Responsibility (EPR) regulations to make the tobacco industry accountable for post-consumer cigarette waste. Part of the solution could be the elimination of single-use filters, elimination of unnecessary packaging, and "polluter pays" levies on the profits of the tobacco industry. These could be used to fund programs to restore the environment, to make people aware of the bad influence of tobacco products on the environment, and to reduce the mortality rate worldwide caused by tobacco use.

Cigarette filters, cigarette packages, and cellophane cigarette pack wrappers are also common litter items picked up during cleanups. EPR would make tobacco producers accountable for removing all tobacco product waste, from collecting it to safely disposing of it (Curtis et al., 2017). As so often, the tobacco industry blatantly protects its earnings even though people's lives are endangered by their products (Truth Initiative, z.d.). Now a next generation is threatened with addiction to nicotine through the rise of e-cigarettes and other new products, which are framed by the tobacco companies as their contribution to the solution by ending the use of combustible cigarettes.

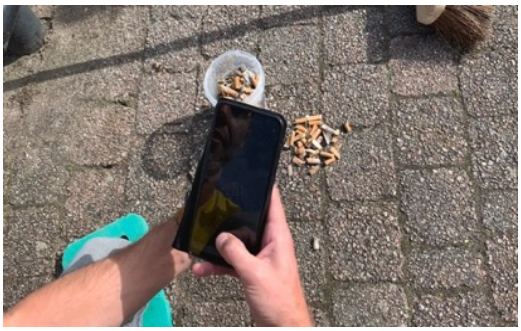
The cigarette butt litter problem is a threat to the social acceptability of smoking, and the response of the tobacco industry was to support “solutions” that did not harm their revenues. They pointed to smokers as the wrongdoers and supported environmental groups in their efforts to clean up cigarette filters (Smith & McDaniel, 2011). But the tobacco industry has not succeeded in lessening the impact of cigarette litter. Those in favour of tobacco control should work together with environmental groups and come up with policy options in which the industry is held responsible for cigarette waste. Furthermore, more research needs to be done to see how far the problem reaches. Measures based on science should be taken against this epidemic of littered cigarette filters. It is not necessary to have this litter, and it can be prevented, particularly given the fact filters, found on almost all commercial cigarettes, do not lessen the effects of smoking on health and are now known to be a source of microplastic pollution (Healton et al., 2011).

Cigarette butts collection throughout the Netherlands

In order to raise awareness about the plastic pollution of the environment through littered cigarette filters, a one day action in Amsterdam to Clean the Butt in 2019 was carried out, during which 35 people collected 50,000 filters in 2 hours. This led to the Plastic PeukMeuk (Plastic Butt Smut) action day in 2020 during which 142,000 cigarette filters were picked up from the streets in several cities of the Netherlands by over 150 participants using the motto #nofilterplease. In 2021 over half a million cigarette filters were collected by hundreds of participants (along with tens of thousands interested bystanders) during the one day action Plastic Peukmeuk 2021, which took place in 88 cities throughout the Netherlands to focus attention on the enormous and underappreciated plastic pollution problem in order to appeal to the government to start an investigation into the abolishment of the plastic cigarette filter.[4] The Plastic Peukmeuk (*Plastic Butt Smut)* Campaign was started from 10 June 2021 to 10 July 2021. Cigarette filters were picked up and registered in the Litterati app by many volunteers throughout the Netherlands. The volunteers went out on one or more days during this period of one month and registered and picked up cigarette filters on locations of their own choice throughout the Netherlands. This chapter briefly describes the main facts of this campaign.

Methodology

Litterati is a Registration Application for smartphones. In this app all the cigarette filters that has been picked up are captured with a photo, which is tagged with GPS coordinates and registration labels. All registered litter items can be found on a map that provides a good picture of what has been found in which locations.



Litterati App

The photos are provided with registration labels (so called Tags), which form a valuable contribution to the analysis of the litter. De labels are added according to the COMB method.

[4] For more information, visit the website https://plasticpeukencollectief.nl/plastic-peukmeuk-2021

COMB stands for Category, Object, Material and Brand. This method simplifies data analysis on composition, quantity, target groups, and origin of the litter items.

The cigarette filter has the following labels: *Smoking*, *Cigarette butt*, *Cellulose Acetate*.

The ZwerfAfvalKompas (*Litter Compass)* is an online impact platform that has been developed to enable the tagging of the pictures that have been registered in the Litterati app, and making the data consistent.

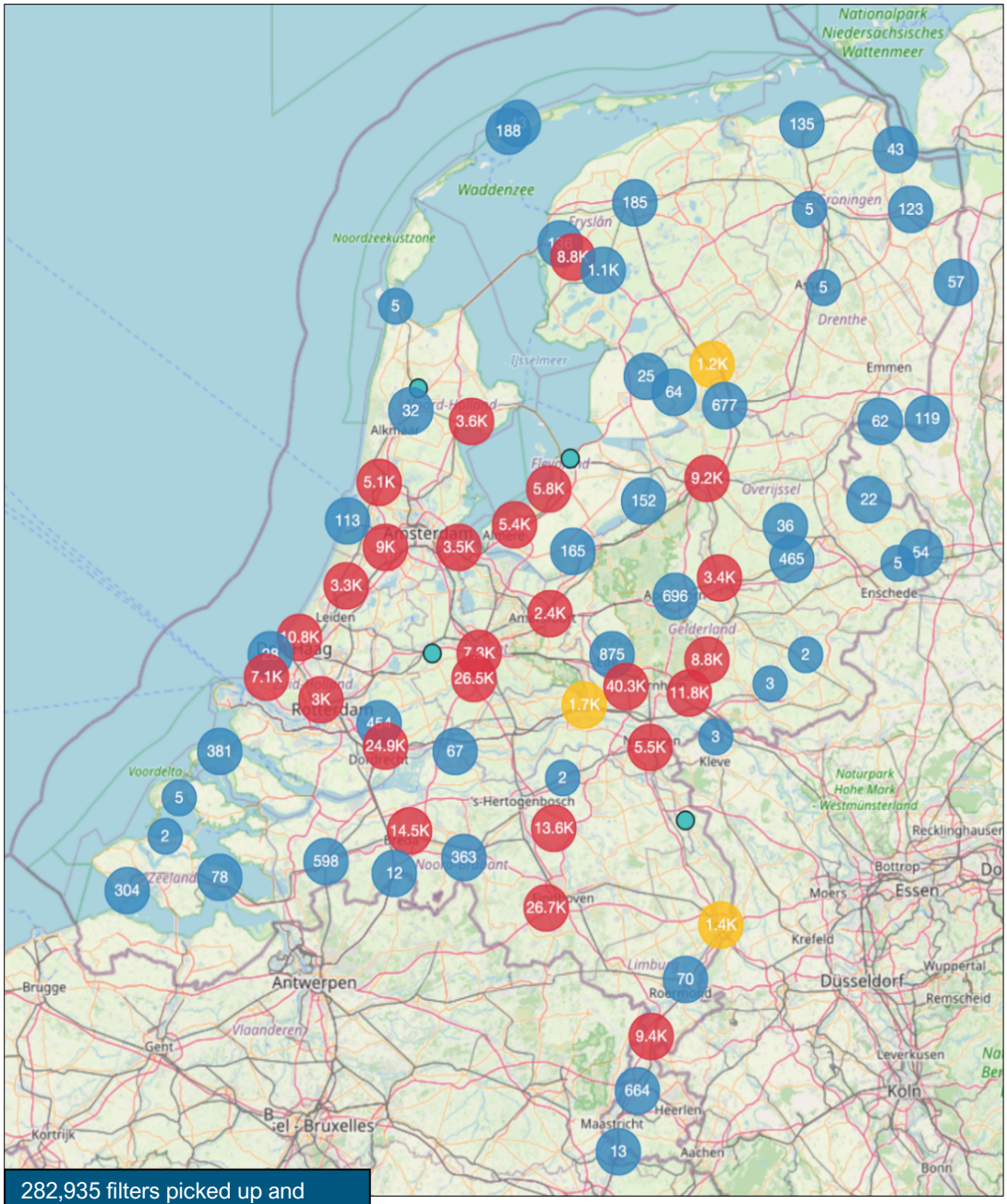
Through the analysis tools in the Compass insights are gained and a translation is made to detailed and complete factual information. The data overviews in this report have been obtained from the ZwerfAfvalKompas (*Litter Compass)*.

Our data search was limited to the start date 10 June 2021 and end date (included) 10 July 2021. We narrowed our search further by only taking into consideration all photos which had the Object tag “cigarette butt”. In the ZwerfAfvalKompas the resulting quantities can be projected onto the map of the Netherlands based on the GPS coordinates of where the photo was made. We can zoom in on certain days and locations to investigate hotspot areas.

Overview map of the Netherlands: registered filters from 10-06-2021 to 10-07-2021

The overview map of the Netherlands provides a global insight in the locations and numbers of filters that have been picked up and registered.

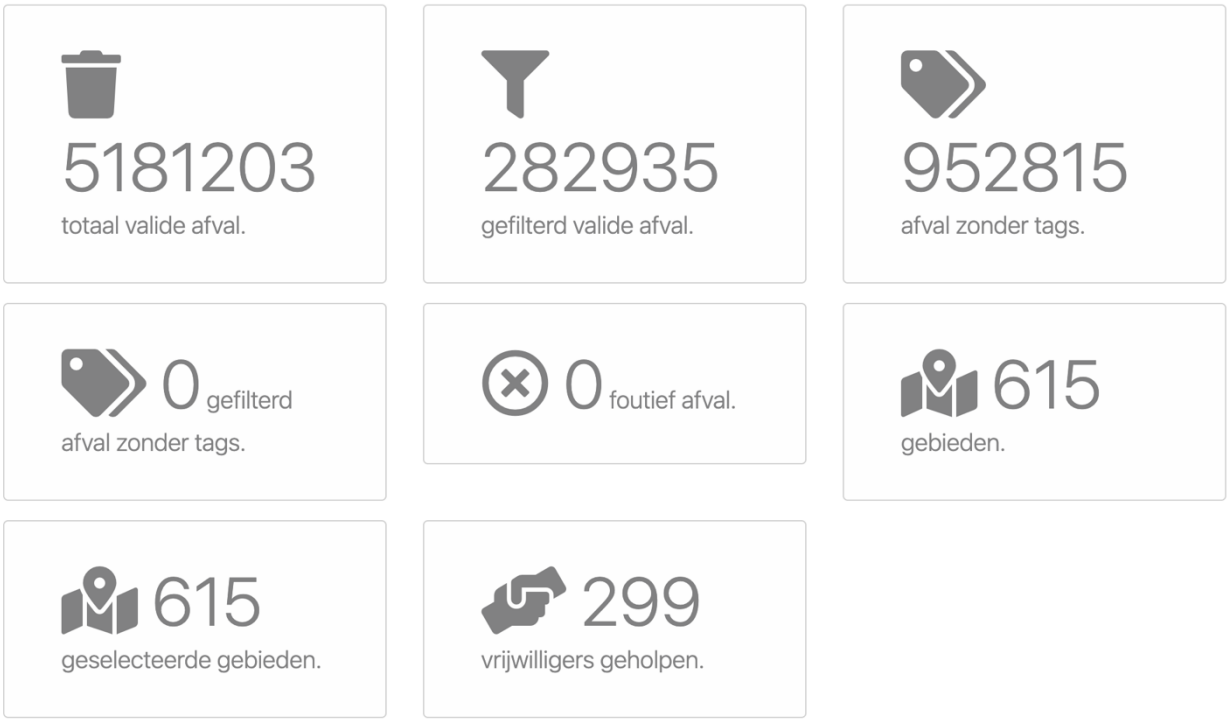
The different colours give an indication of the quantities that have been found. Blue indicates tens, yellow hundreds and red thousands.



282,935 filters picked up and registered in the Netherlands

Statistical representation

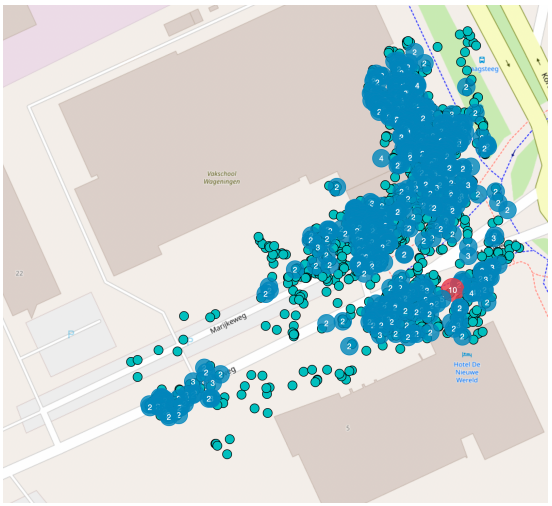
This statistical representation has been derived from the *Litter Compass*.
With the date filter set to *10-06-2021 to 10-07-2021* and the object filter set to *cigarette butt*, it is shown that 282,935 filters have been picked up and registered by 299 different volunteers. All cigarette filters have been tagged with the labels *cigarette butt* and *cellulose acetate*.

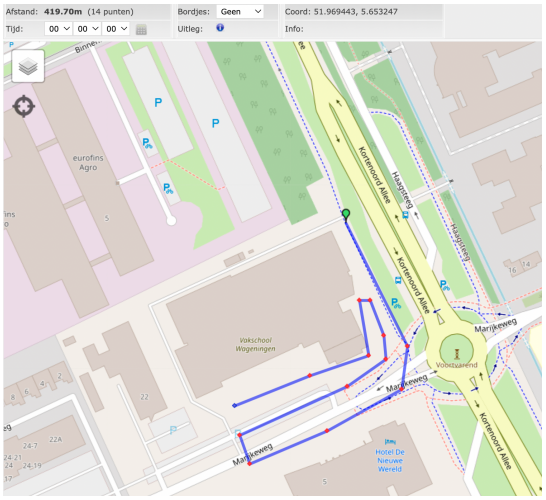


Hot spot locations

The images below provide a picture of measurements of 4 different hot spot locations within 4 different municipalities on the 10th of July 2021. These images are a small sample from the large number of hot spot locations in The Netherlands on that day. They provide a rough picture of the density of cigarette butt litter. Every green dot is a cigarette butt. The blue and red dots are tens and hundreds of cigarette filters.

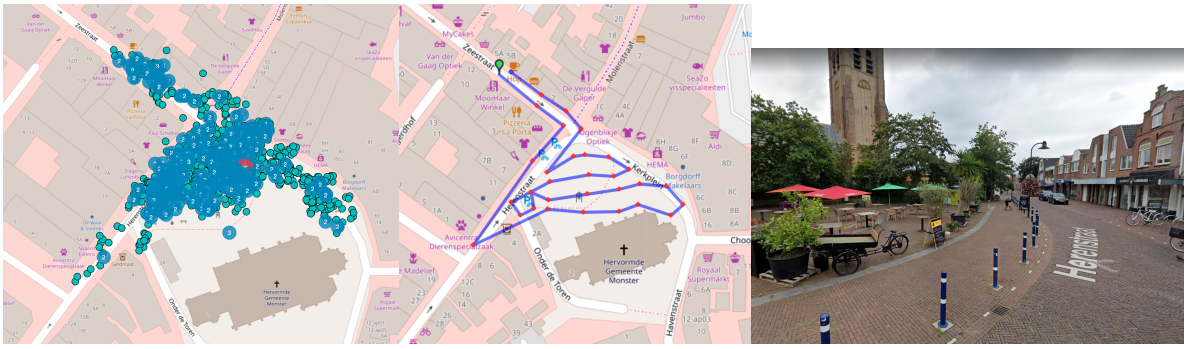
Municipality of Wageningen: High School





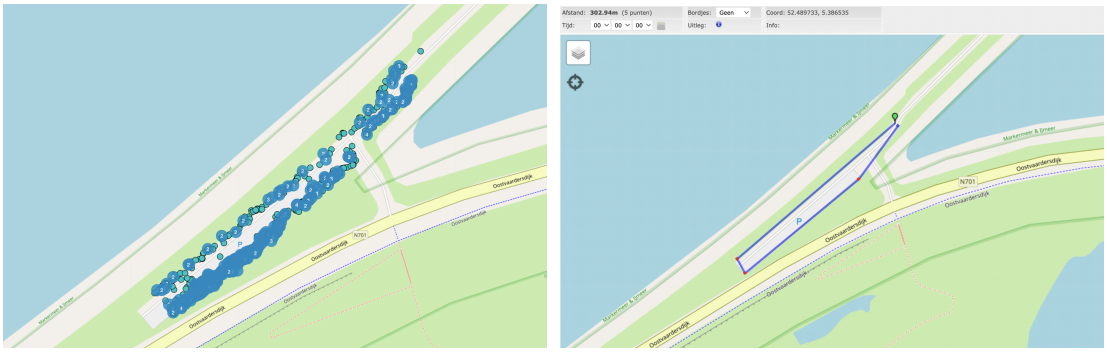
At the Wageningen Vakschool a total of 2,519 filters have been picked up and registered on the 10th of July. The total distance over which these filters have been picked up is 420 metres. This means that on average there are 5,997 cigarette filters per kilometre length. It would be very interesting to understand how many cigarette filters are found around schools and universities. Volunteers mentioned they collected a lot of filters around schools. In the Netherlands there is a smoking ban in and around schools, so it is necessary to understand why so many filters are found in the immediate vicinity of schools while there is a smoking ban. Furthermore, we would like to know what the pollution level per week is around schools.

City of Monster: Terrace at the church



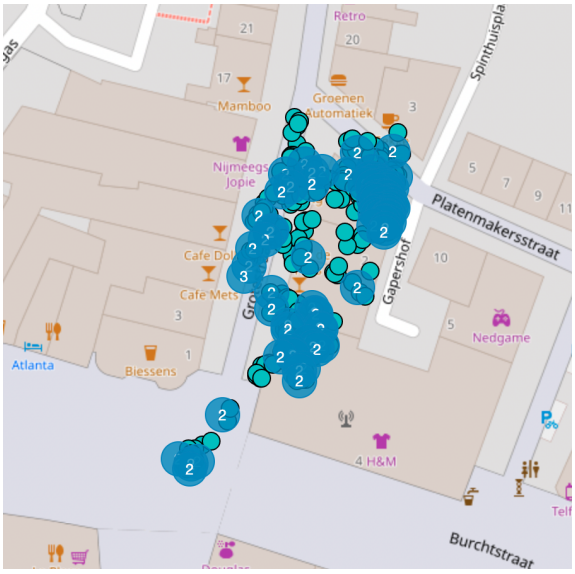
In the centre of Monster at the terrace near the church a total of 2,131 filters have been picked up and registered. The total distance over which these filters have been picked up is 498 metres. This means that on average there are 4,279 cigarette filters per kilometre length. At meeting places a lot of filters are found. Smoking seems to be a social event.

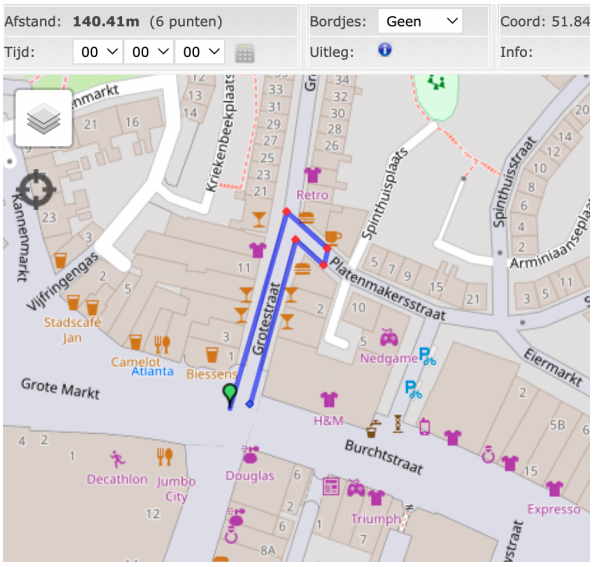
Parking Area at IJsselmeer near Lelystad



At the parking lot near the IJsselmeer a total of 1,428 filters have been picked up and registered. The total distance over which these filters have been picked up is 303 metres. This means that on average there are 4,713 cigarette filters per kilometre length. This parking lot gives visitors the opportunity to explore the recreation area the IJsselmeer. It suggests that at parking lots and near recreation areas the filter density is high.

City centre of Nijmegen





At the city centre of Nijmegen a total of 600 filters have been picked up and registered. The total distance over which these filters have been picked up is 140 metres. This means that on average there are 4,285 cigarette filters per kilometre length. It seems that shopping areas and the catering industry are hot spots for cigarette filters.

Overview of the number of registered cigarette filters and participating volunteers per day

Table 1 and Figure 1 display how many volunteers have registered filters each day from 10 June 2021 to 10 July 2021 throughout the Netherlands (red line in the chart). It is also shown how many cigarette filters have been registered per day (blue columns in the chart).

Date	Number of filters	Number of participating volunteers
10-06-2021	6,477	47
11-06-2021	7,634	47
12-06-2021	13,720	46
13-06-2021	8,666	44
14-06-2021	7,054	46
15-06-2021	10,582	55
16-06-2021	6,692	42
17-06-2021	10,701	45
18-06-2021	4,192	29
19-06-2021	10,324	37
20-06-2021	6,444	34
21-06-2021	5,613	30
22-06-2021	6,198	41
23-06-2021	6,134	50
24-06-2021	8,037	41
25-06-2021	8,239	43
26-06-2021	7,983	44
27-06-2021	9,769	38
28-06-2021	6,098	31
29-06-2021	5,101	23
30-06-2021	4,028	28
01-07-2021	5,462	37
02-07-2021	10,381	34
03-07-2021	10,881	49
04-07-2021	7,932	43
05-07-2021	7,269	42
06-07-2021	8,560	39
07-07-2021	8,334	51
08-07-2021	6,627	41
09-07-2021	12,777	49
10-07-2021	45,026	96
Total	**282,935**	

Table 1 - The number of registered cigarette filters and participating volunteers per day

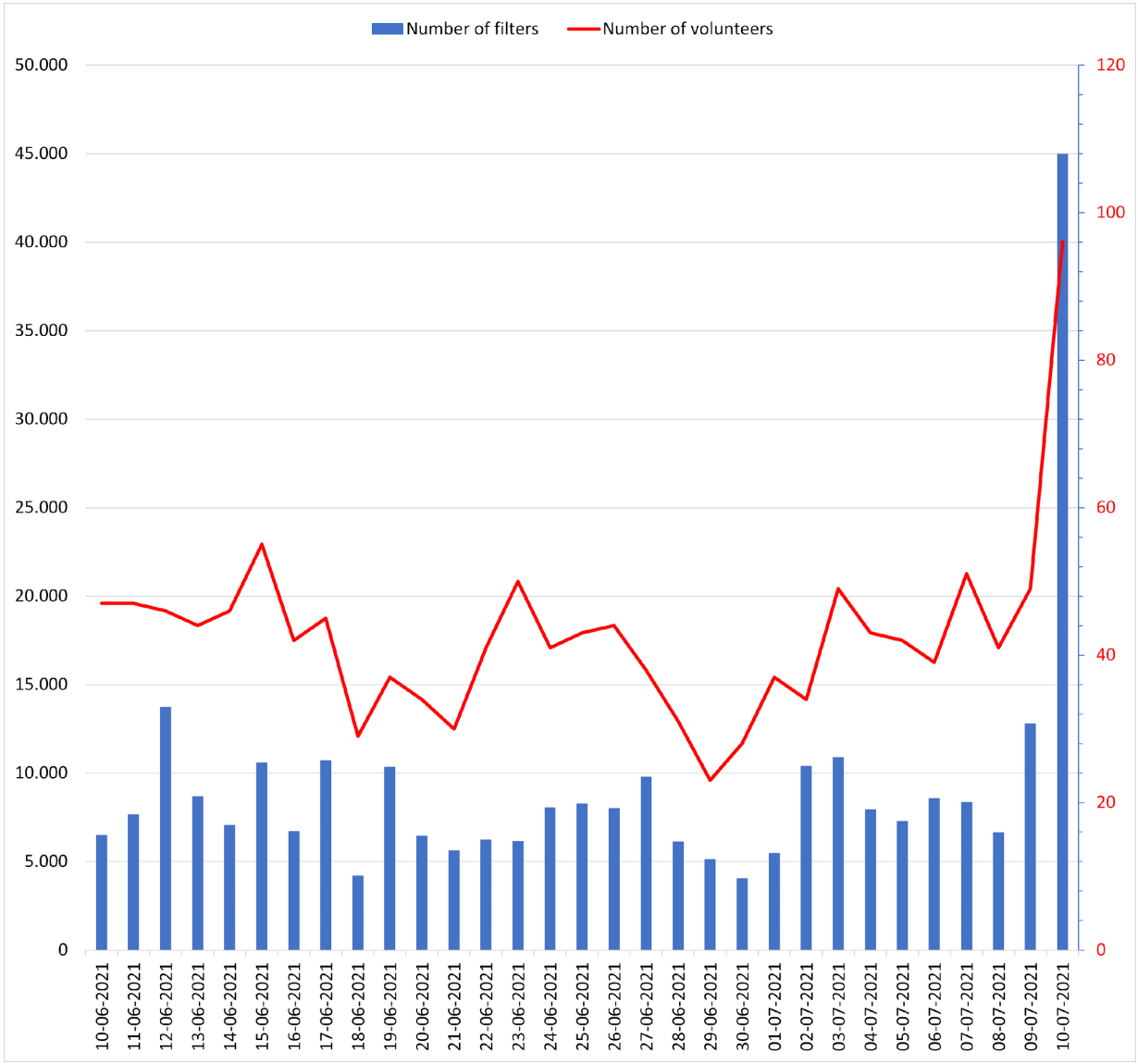


Figure 1 - The number of registered cigarette filters and participating volunteers per day

Overview per province

Table 2 and Figure 2 display how many cigarette filters have been registered per province from June 10 to July 10, 2021. It is also shown how many volunteers have registered cigarette filters. This number does not represent the number of unique volunteers: if a volunteer has participated more than one day, he/she will count as many times as the number of days that he/she has participated.

Province	Number of filters	Number of volunteer days
Gelderland	69,664	68
Noord-Brabant	56,861	52
Zuid-Holland	49,960	70
Utrecht	35,606	34
Noord-Holland	20,609	50
Overijssel	14,409	14
Flevoland	12,235	12
Limburg	11,577	23
Friesland	10,409	3
Drenthe	857	9
Zeeland	389	6
Groningen	359	4
Total	**282,935**	**Total volunteer days: 345** **Total unique volunteers: 299**

Table 2 - The amount of cigarette filters registered and the number of volunteers per province.

The red line and red numbers in the chart show the number of volunteers that have participated per province.

The blue columns and blue numbers in the chart represent the number of filters that have been picked up and registered per province.

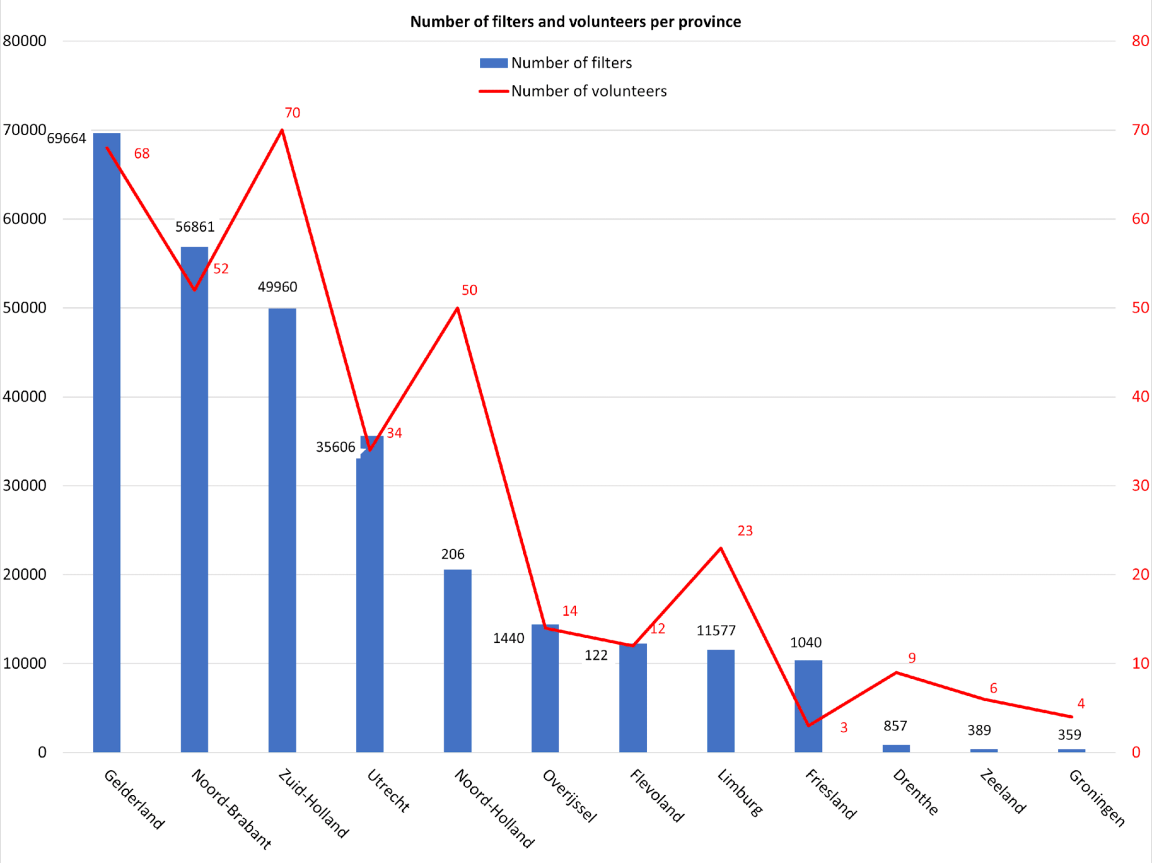


Figure 2 - The amount of cigarette filters registered and number of volunteers per province.

Top 30 municipalities with the highest number of registered filters

Figure 3 shows the top 30 of municipalities in which the highest numbers of filters have been registered in Litterati during the period from 10 June 2021 to 10 July 2021. In total, volunteers have been picking up filters in 172 municipalities in the Netherlands.

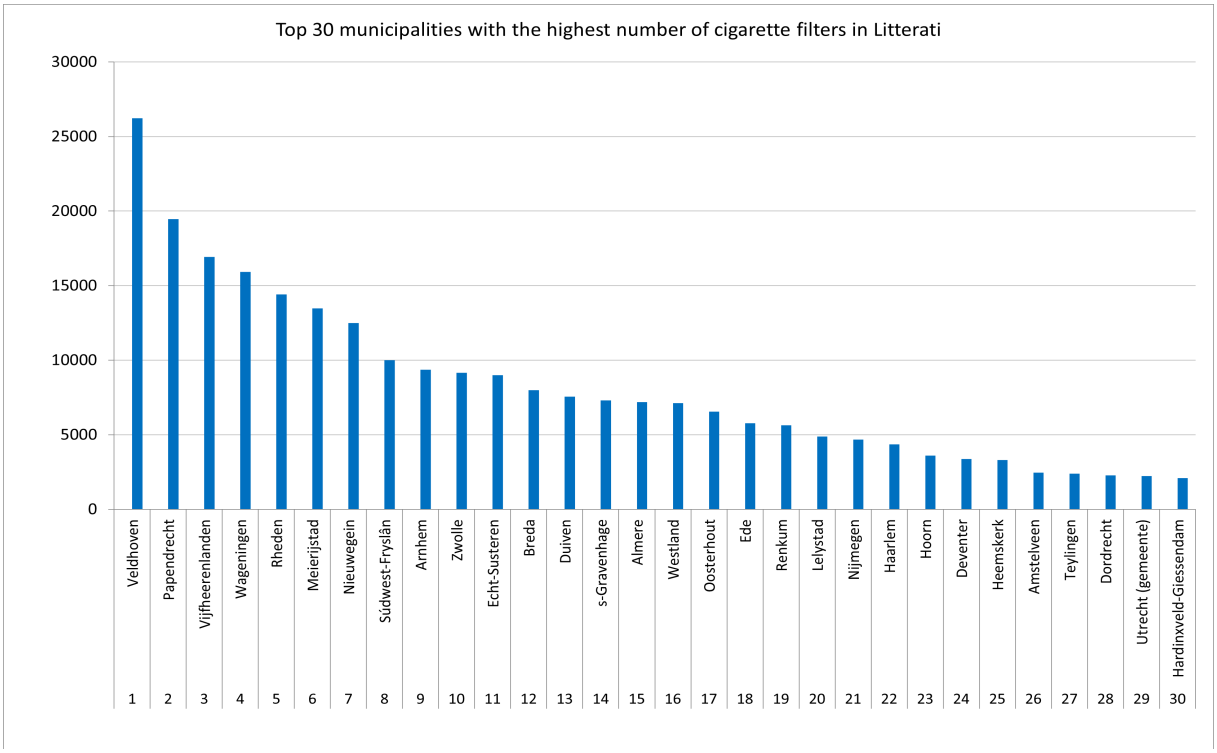


Figure 3 - Top 30 municipalities with the highest number of registered filters.

Because of the high number of cigarette filters which were collected during the Plastic Peukmeuk (*Plastic Butt Smut)* Campaign, we have decided that there should be a proper monitoring of cigarette filters that measures the degree of pollution. This monitoring was performed in September-October 2021 and will be covered in the next chapter.

Cigarette butts monitoring

Methodology

The methodology section describes the data collection and analysis process of the cigarette filters monitoring study. In short, we relied on volunteers to collect weekly information on cigarette butt pollution in ten different types of locations throughout the Netherlands for a total of six weeks. We then analysed the data to understand patterns and trends with regards to this type of pollution in the Netherlands.

In this section, we first describe the preparatory steps that were taken prior to the data collection process, which include the recruitment and training of the volunteers. We then provide some information about the tools used to collect the data and describe the data collection itself. In doing so, we focus on the information/variables collected and the way in which they were measured. Finally, we provided a summary of the analysis conducted on the data we collected.

Data collection preparation

The data collection for this report was done using citizen science[5]. Therefore, the data collection preparation consisted primarily of the recruitment and training of participants/volunteers that would collect data about cigarette filters throughout the Netherlands. To make sure that we could reach a sufficiently large pool of participants, we both posted the information about the project and the need for citizen scientists on our social media platforms and disseminated it among GoClean's networks of litter pickers.

Overall, we received 100 expressions of interest. We followed up by email and asked those who expressed interest in participating to indicate the number of locations they would like to collect data at and to rank their preference with regards to location types (out of the locations covered in the study, which were determined by us prior to the recruitment process). We then

[5] Citizen Science is defined by NWO as 'the practice of science by volunteers who are not connected to a research organisation as professional researchers, but who cooperate with – or are supervised by – professional researchers.'
Source: https://www.nwo.nl/en/citizen-science#:~:text=Citizen%20Science%20is%20defined%20as,are%20supervised%20by%20%E2%80%93%20professional%20researchers

matched the participants with location types, while keeping in mind their indicated maximum number of locations and their preferences. We communicated the assignment of locations to the participants by email. To inform and prepare the volunteers for the data collection process, our email also included detailed information and instructions regarding the tools used to collect the data and the various steps and stages of the process. Additionally, we organized an online meeting for those participants who had questions and/or were interested in getting more detailed explanations.

Tools used

In this study, our volunteers primarily used the Litterati app to collect weekly information related to cigarette filters in various locations. Litterati is a registration app for smartphones. In this app, the litter found is recorded through a photo and the photo is stored in the app with the coordinates of the location in which it was taken.[6]

The app was used for the registration of all of the cigarette filters included in this study. The filters registered by our volunteers were entered on a daily basis into our Litter Compass platform (in Dutch ZwerfAfvalKompas; an online analysis platform in which all Litterati data collected in the Netherlands can be analysed and labelled) on a daily basis. Then, once on the platform, the data entries were checked, provided with registration based on the COMB-method labels and enriched. Additionally, we also used segment functionality when collecting our data. This allowed us to capture the route the volunteers took and to record the time/duration of each monitoring session.

It is also important to mention that we made use of the challenges functionality in Litterati and created a separate (closed) challenge for each location type. The volunteers had to turn on the right challenge before uploading the photos to the app and turn off the challenge once the upload was completed. This meant that all the data collected by the volunteers for the same location type was stored in one challenge and all of the cigarette filters' photos uploaded within the same challenge were given the same location type tag. This in turn facilitated the analysis of data by location type.

Additionally, we also asked the volunteers to fill in two types of surveys regarding the characteristics and environment of the location in which they collected data. The first was a

[6] For more information about the app see: https://litterati.org/.

general information survey, which volunteers had to fill in when conducting the first (baseline) measurement; the second was a weekly survey that focused on time-varying information (such as weather conditions). Both types of surveys differed by location (i.e., each of the two survey types has 10 different versions that correspond to the 10 different location types).

In the final dataset that was used for the analysis we combined the information from all of the available sources. Thus, in our analysis we use data from the app (both from the ZwerfAfvalKompas and the segment information files) as well as from the one-time and weekly surveys.

Data collection process

Our data collection process consisted of the monitoring of the extent of cigarette filters' pollution in 10 location types (i.e., school, government building, parking, bench, recreation space, meeting spot, bus stop, grate drain, roadside, street) in 18 different sites (i.e., cities, towns, or villages) throughout the Netherlands, using Litterati and short surveys. These 10 locations can be also divided into eight hotspot locations (i.e., locations with high cigarette filters' pollution, as evident by previous cleaning experience) and two control locations (i.e., streets and roadsides with low levels of cigarette butt's pollution). Furthermore, the locations can also be divided based on the surface type into those with hard surface and those with soft surface. The inclusion of both hard and soft locations can be justified by the fact that the two types differ substantially with regards to the time and costs of cleaning cigarette filters, as in hard locations this can be done using specialized machines/sweepers, while that is not possible for soft locations.

Each location (with the one exception of grate drains) consisted of 100 square metres and the volunteers were free to decide on how the location will look like (e.g., whether it will be a square of 10 by 10 metres or a rectangle of 50 by 2 metres, or 25 by 4). The volunteers also measured the locations themselves during the first week (i.e., the baseline measurements) using tape measures or step lengths, and the exact same location was used for the entire monitoring process (i.e., for the 5 subsequent weeks).

Overall, the monitoring process looked as follows: during the first, baseline measurement, the volunteers determined which 100 square metres of their selected locations they will use for the monitoring. They then marked the coordinates of the location (to assure they investigate the same 100 square metres in the subsequent weeks) and took an overview photo, which was

uploaded to Litterati. Next, both in the baseline and the five subsequent measurements, the volunteers were asked to identify and document hotspots. Hotspots are defined as one square metre areas, within the designated 100 square metres, that are characterized by a relatively large number of cigarette filters. Each hotspot was photographed separately and uploaded to Litterati. Finally, during each of the measurements, the volunteers collected all of the cigarette filters that were found within the 100 square metres area. The volunteers were asked to take a separate photo of each of the filters collected and upload it to Litterati. Additionally, the volunteers were also asked to fill in a short survey during or shortly after each measurement, wherein for the first measurement the survey focused on time-invariant characteristics of the location and in the subsequent five measurements the survey focused on time-varying characteristics, such as the weather on the day of the measurement.

The data were collected by 88 volunteers in a total of 182 locations and the number of locations varied per volunteer (with some choosing one location and others choosing up to five locations for the weekly monitoring). The data collection consisted of six weekly measurements and took place between September 13 and October 24, 2021. The first week focused on the cleaning up of the location and thus is the baseline measurement and the subsequent five weeks were the actual measurement of the degree of contamination.

Main variables of interest

The main variable of interest in the study is the number of cigarette filters that accumulated over a week's time at a given location. Additionally, we also focused on the number of hotspots per week at a given location and the duration of the measurement (i.e., the time it took to collect all the cigarette filters from a given location at a given week).

The main distinctions drawn in the study are by location type. As mentioned above, we considered ten different location types - school, government building, parking, bench, recreation space, meeting spot, bus stop, grate drain, roadside, street – which can be further divided into hard and soft locations, depending on the surface type. Overall, we aimed to have a diverse sample of locations, wherein both busy and quiet locations (in terms of flows of people) were included. A detailed description of each of the locations is provided below.

School (hard location)

The schools included in the study included secondary schools or higher/vocational education institutes. The areas included in the measurements were overall paved but could also include the edge of the soft area (about 20 cm) as some filters could have been blown there from the paved area.

Bus stop (hard location)

This location type also included stops of other forms of public transport (such as tram or metro stops) but train stations were excluded. Drains that were at the stop were also included in the location but the street itself and particularly the other side of the street were not (as this could be a part of another stop, e.g., of the same bus going in the opposite direction).

Parking (hard location)

This location type included relatively busy parking lots at supermarkets and quieter lots in residential areas. The parking location could not overlap with a bus stop, a school or any of the other locations we considered. For the parking lots in residential areas, it was possible to include parking spots on both sides of a street, while excluding the street itself.

Government building (hard location)

This location type included municipality buildings, town halls, employment offices, as well as federal government buildings such as ministries. Again, the government building location could not overlap with another location we were investigating.

Bench (soft location)

This location type included benches in parks and the area measured could not include any hard surface (such as a paved road that leads to the bench). The focus for this location type was the soft area around the bench.

Meeting spot (soft location)

This location type consisted of places on soft surfaces, where groups of people tend to gather and either stand or sit together as well as eat and/or drink, chat, and smoke.

Recreation area (soft location)

This location type consisted of places on soft surfaces, where groups of people spend time together and perform a certain activity, such as playing sports, swimming, or fishing.

Grate drain (soft location)

This location type focused on drains that are often used as ashtrays (according to the volunteers' judgment). Volunteers were instructed to choose drains that can be opened at the top and where the cigarette filters can be fished out.



Street (hard location) and roadside (soft location)

These two location types served as the control locations. While the eight hotspot locations were selected based on their likelihood of being highly polluted, the control locations were selected based on the opposite. That is, these locations included streets and roadsides in which relatively few people pass and stop by and which therefore should have low levels of pollution. What is more, in the control locations volunteers were restricted to measuring a fixed 100 x 1 metre area, rather than having the possibility to choose the 100 square metre area themselves. Using the control locations allowed us to obtain information on cigarette butt pollution in 'average' areas that are not renowned to particularly suffer from this issue.

Data analysis

In the analysis we used primarily data from the Litterati segments. These data, particularly in the case of missing values, were supplemented with the general, non-segment data from Litterati and/or information from the weekly surveys that were filled in by the volunteers who collected the data.

The data analysis relied primarily on descriptive statistics, wherein we looked at the number of cigarette filters as well as hotspots per location type (i.e., the 10 different locations and hard vs. soft locations), measurement/week, and province. We also calculated the average time it takes to clean a cigarette butt by location type and measurement.

To provide some indication regarding the quality, and more specifically the validity, of the measurements used, we looked at the correlations between the number of cigarette filters collected, the number of hotspots identified and the duration of the measurement. The correlations between the number of cigarette filters and number of hotspots as well as the duration of the measurement are both strong and positive (and amount to 0.78 and 0.73, respectively). This implies that the number of hotspots and the measurement's duration are positively associated with number of cigarette filters (i.e., the more filters collected during a measurement, the higher the number of identified hotspots and the longer the duration of the measurement), which in turns suggests that the measures used are valid.

Results

The average number of cigarette filters per location type and per measurement is displayed in Figure 4. As can be seen from the figure, for all location types, the first measurement has a significantly higher average number of cigarette filters than the remaining measurements. There are also larger differences by location for the first measurement than all remaining measurements. This is to be expected as this is the baseline measurement and thus the number represents all filters accumulated at the location up to the time of the measurement (which also depends on how often these locations are cleaned by the local authorities), rather than the filters accumulated over a week's time as it is for the remaining measurements.

When looking at the average number of filters for measurements 2 to 6 it can be observed that, while there are some weekly fluctuations, for most locations there is a weak downward trend, wherein the average number of filters slightly decreases over time. The one major exception are schools, for which the weekly fluctuations are more substantial. This trend can also be confirmed when looking at Table 3, which provides the average number of filters per measurement for all locations combined.

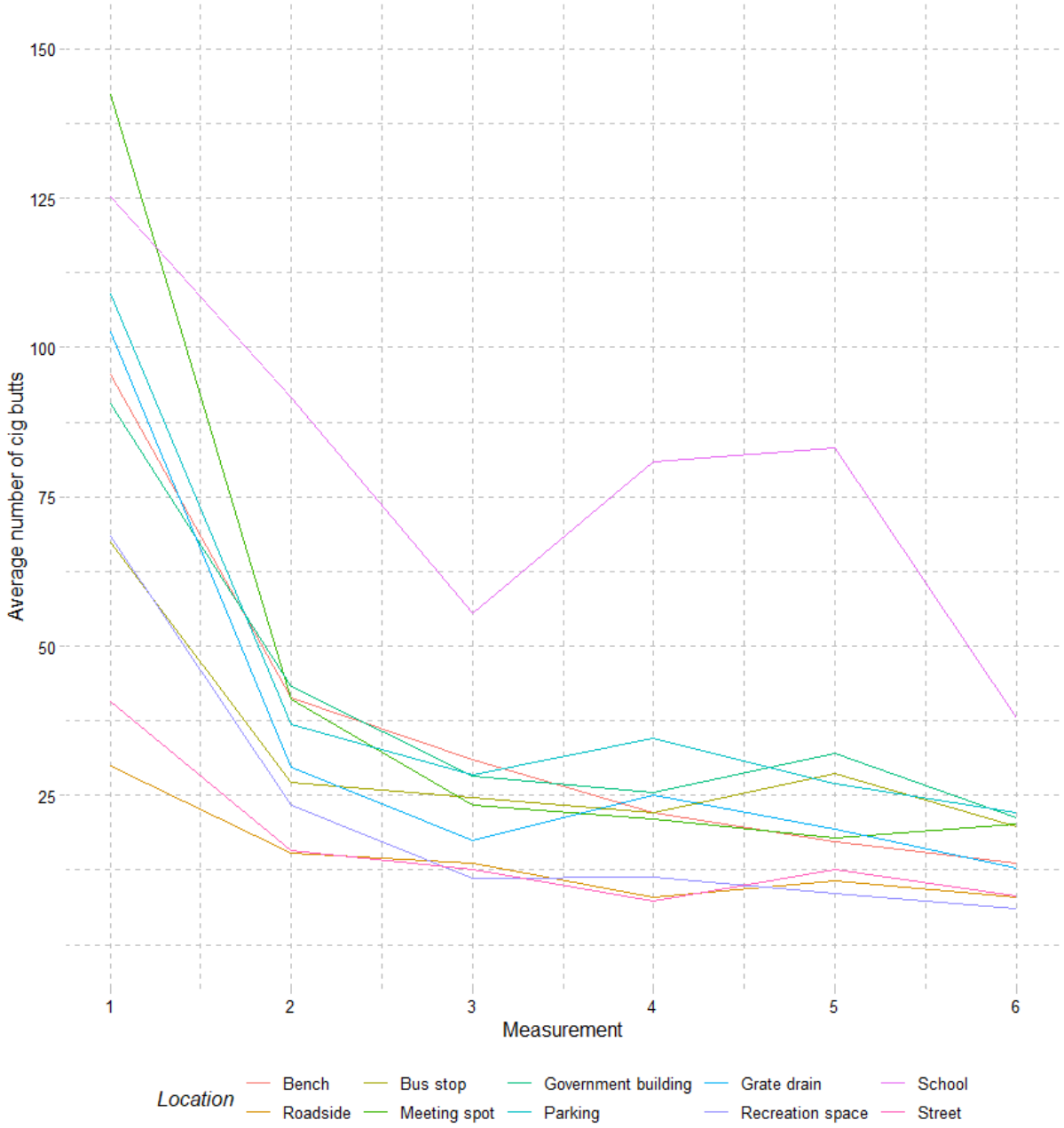


Figure 4 - Average number of cigarette filters per location and per measurement

Location	Average number of cigarette filters					
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
School	125.4	91.6	55.5	80.8	83.1	38.0
Government building	90.6	43.3	28.2	25.5	32.0	21.2
Parking	109.0	36.9	28.5	34.5	27.1	22.1
Bench	95.6	41.3	31.0	22.2	17.2	13.6
Meeting spot	142.3	41.1	23.3	21.1	17.9	20.2
Bus stop	67.3	27.2	24.7	22.0	28.8	19.7
Grate drain	102.7	29.7	17.4	25.0	19.4	12.7
Recreation space	68.4	23.4	11.2	11.3	8.5	5.9
Street	40.8	15.7	12.7	7.3	12.7	8.1
Roadside	29.8	15.3	13.7	7.9	10.6	7.9

Table 3 - Average number of cigarette filters per location and per measurement.

With regards to differences by location, as can be observed in Table 4 as well as Figure 5 below, school locations on average have a much higher number of cigarette filters than all other locations, both overall and per week (i.e., per measurement). When looking at the overall averages only, the schools are followed by government buildings and parking lots and then by benches, meeting spots, bus stops, and drain grates. The differences in the measurement-specific (weekly) averages for these six locations fluctuate over time and depend on the specific time-point considered. Finally, the three locations with the lowest overall and over-time average numbers of filters are recreation spaces, roadsides, and streets. As streets and roadsides are control locations, the low number of filters in those locations is to be expected. It is worthwhile noting though that while these control locations have overall lower numbers of filters, these numbers remain substantial suggesting that cigarette butt pollution is a problem that extends well-beyond the hotspot locations. Also, the overtime trends for the control locations are similar to those observed for the hotspot locations.

The large number of cigarette filters in schools can be attributed to the fact that many students as well as teachers smoke, and the large overtime fluctuations are related to the school holidays. Specifically, the drop in cigarette filters observed in week three is a result of the

autumn school holidays. Therefore, when schools are closed and students do not attend schools, the number of filters drops substantially. It is also worthwhile mentioning that, in the Netherlands, there is a no smoking policy in schools, which implies no smoking on school grounds and no ashtrays in the areas surrounding schools. Despite this, the study shows that schools have a problem with cigarette filters in their immediate surroundings. Put differently, right outside of school premises large amounts of cigarette filters were found. Therefore, the policy should be enforced more strictly and consistently by schools.

Location	Average number of cigarette filters overall
School	70.7
Government building	30.4
Parking	29.8
Bench	25.5
Meeting spot	25.2
Bus stop	24.5
Grate drain	21.6
Recreation space	12.2
Street	11.4
Roadside	11.2

Table 4 - Average number of cigarette butts per location, all measurements combined

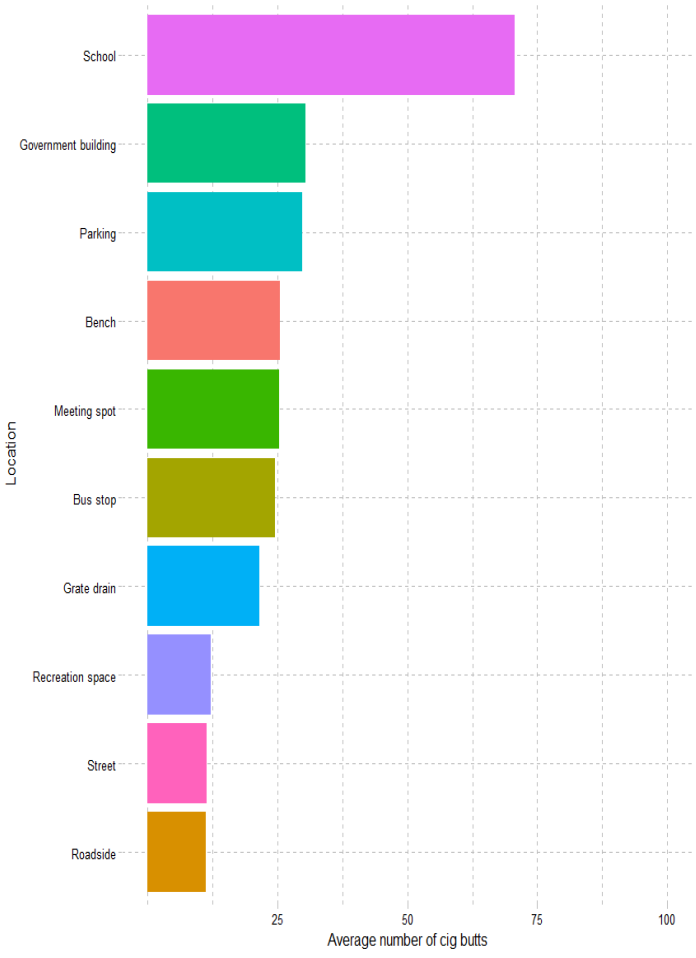


Figure 5 - Average number of cigarette butts per location, all measurements combined

The conclusions that can be drawn when looking at Figure 6 below, which depicts the average number of hotspots[7] per location (including only those who indicated one or more hotspots) for measurements 2 to 6 combined, are somewhat in line with the findings reported above. Namely, schools and parkings, in addition to having high levels of cigarette filters, also have a high concentration of hotspots. On the other hand, while government buildings have the second highest average number of cigarette filters, they have a relatively low number of hotspots. Also, meeting spots and to a lesser extent bus stops have a relatively high number of hotspots, while the average number of filters is rather low. These results should be treated with caution as hotspots were not clearly defined and for many of the locations no hotspots were reported and this analysis focuses solely on the measurements that reported one or more hotspots. More specifically, for government buildings and benches at least 25% of all measurements (from 2 to 6) included at least one hotspot, while for schools and bus stops slightly over 15% of the measurements included at least one hotspot and for meetings spots and grate drains this figure was slightly over 10%; for the rest of the locations the figure was (well) below 10%.

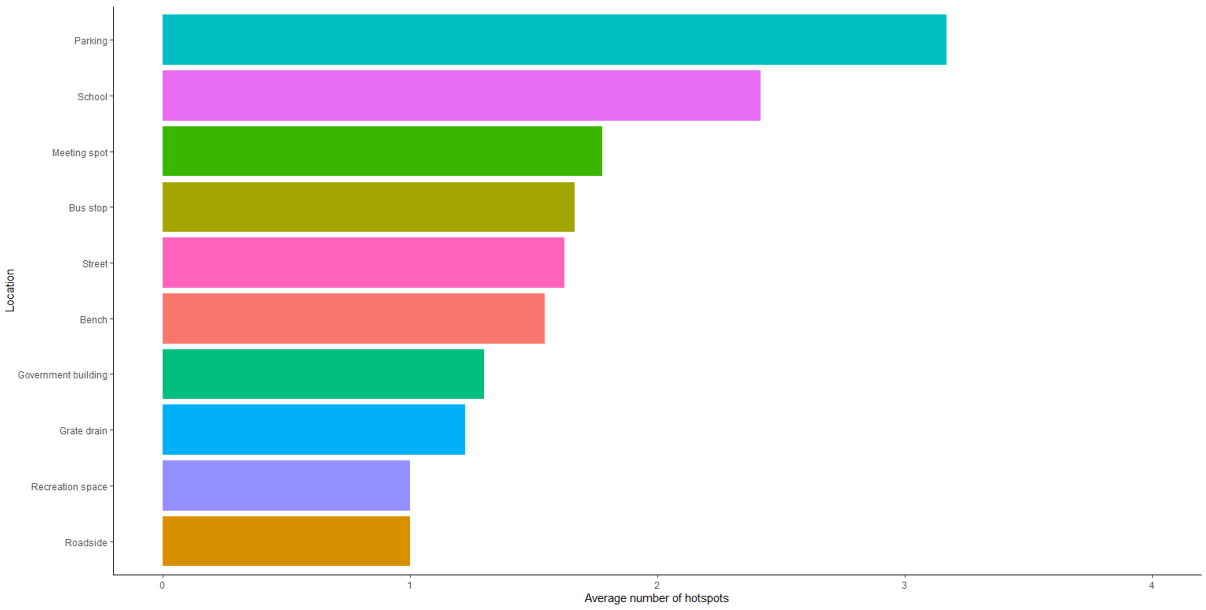


Figure 6 – average number of hotspots per location

[7] Hotspots are defined as small 1m^2 areas within the measurement areas of 100m^2 that are characterized by high concentration of cigarette filters.

When looking at Figure 7, which depicts per location the percentage change in the average number of filters from one measurement to the next (starting from measurement 2), it can be concluded that the average numbers of filters fluctuated considerably in relative terms. In particular there was a considerable change in the number of filters in the fourth and fifth measurements (compared with the measurements taken a week earlier). The relative changes in the average numbers of filters were most pronounced in the locations street, school, and grate drain. In these three locations the number of filters increased by 50% or more between two consecutive weeks. More specifically, for the street locations the average number of filters in the fifth measurement was about 75% higher than it was a week earlier, during the fourth measurement. For schools and drain grates the average number of filters in the fourth measurement, compared to the third measurement, was almost 50% higher. The bench locations appear to have the least over-time changes.

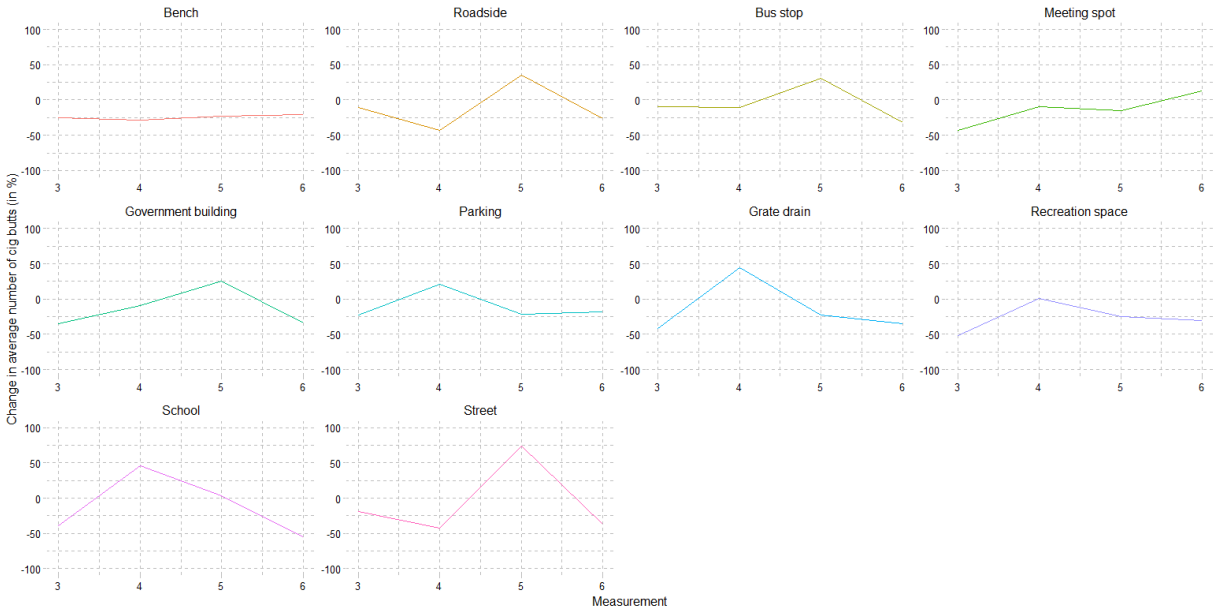


Figure 7 – Relative overtime change in average number of cigarette butts per location

Next, Figure 8 displays the average number of cigarette filters per measurement and per province in the Netherlands. Overall, it can be seen that Noord Brabant, Gelderland, Zuid-Holland, and Limburg have relatively high numbers of filters, followed by Noord Holland, Overijssel, Utrecht, Zeeland, and Flevoland, for which the numbers were somewhat lower. Finally, Groningen and Friesland had significantly lower numbers of filters than all other provinces. These figures should be treated with caution as the distribution of the locations was not geographically balanced (i.e., in some provinces there were many more locations than in others).

Figure 8 – Average number of cigarette butts per measurement and province

The differences in the number of filters by the location's surface type, i.e., hard versus soft, are presented in Figure 9 below[8]. As can be seen, the number of filters is lower in soft surface locations than hard surface locations, both when considering the overall average and the per-measurement, weekly average.

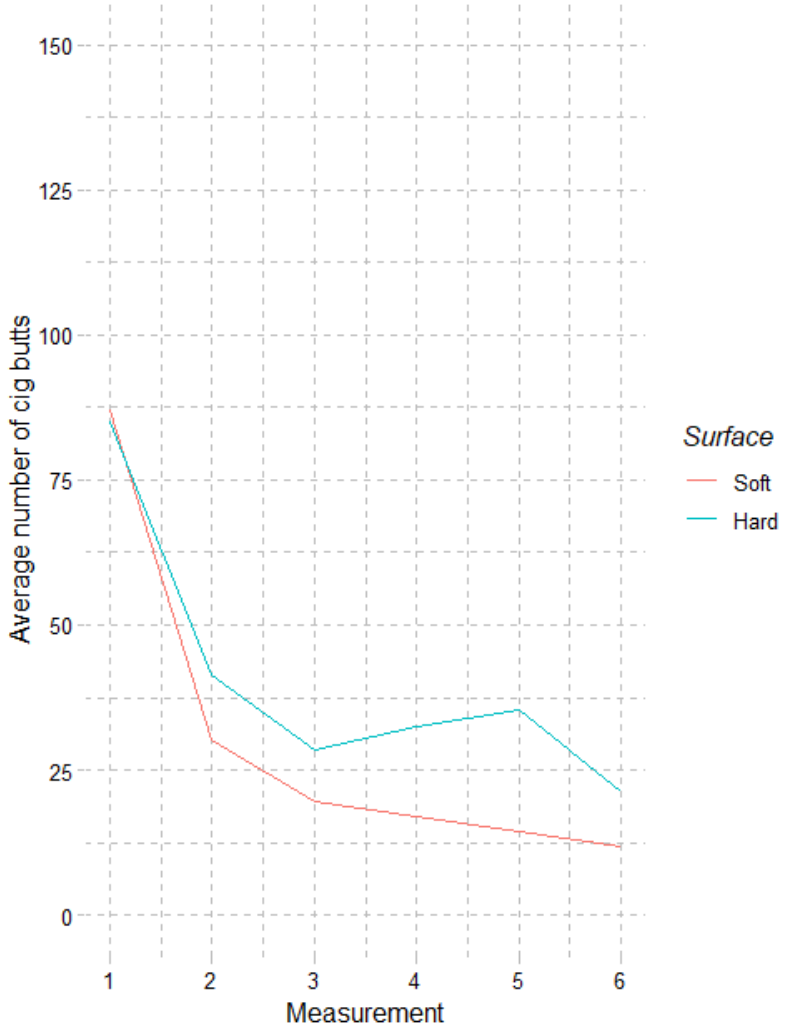


Figure 9 - Average number of cigarette filters, per surface type

[8] The division of the 10 original locations to hard and soft surface locations is as follows. Hard surfaces include bus stop, government building, parking, school, and street. Soft surfaces include bench, roadside, meeting spot, drain grate, and recreation area.

The average time it took to clean one cigarette butt per location is summarized in Figure 10 below. As can be observed the time it takes to clean one butt varies substantially by location, from 10 seconds for schools to just under 50 seconds for recreation spaces. This can be explained by the fact that when there are more filters per 100 square metres, it becomes easier and therefore faster to locate and collect filters. What is more, the cleaning time of soft surface locations was almost double compared to that of hard surface locations, as the former amounts to 27 seconds and the latter to 14 seconds.

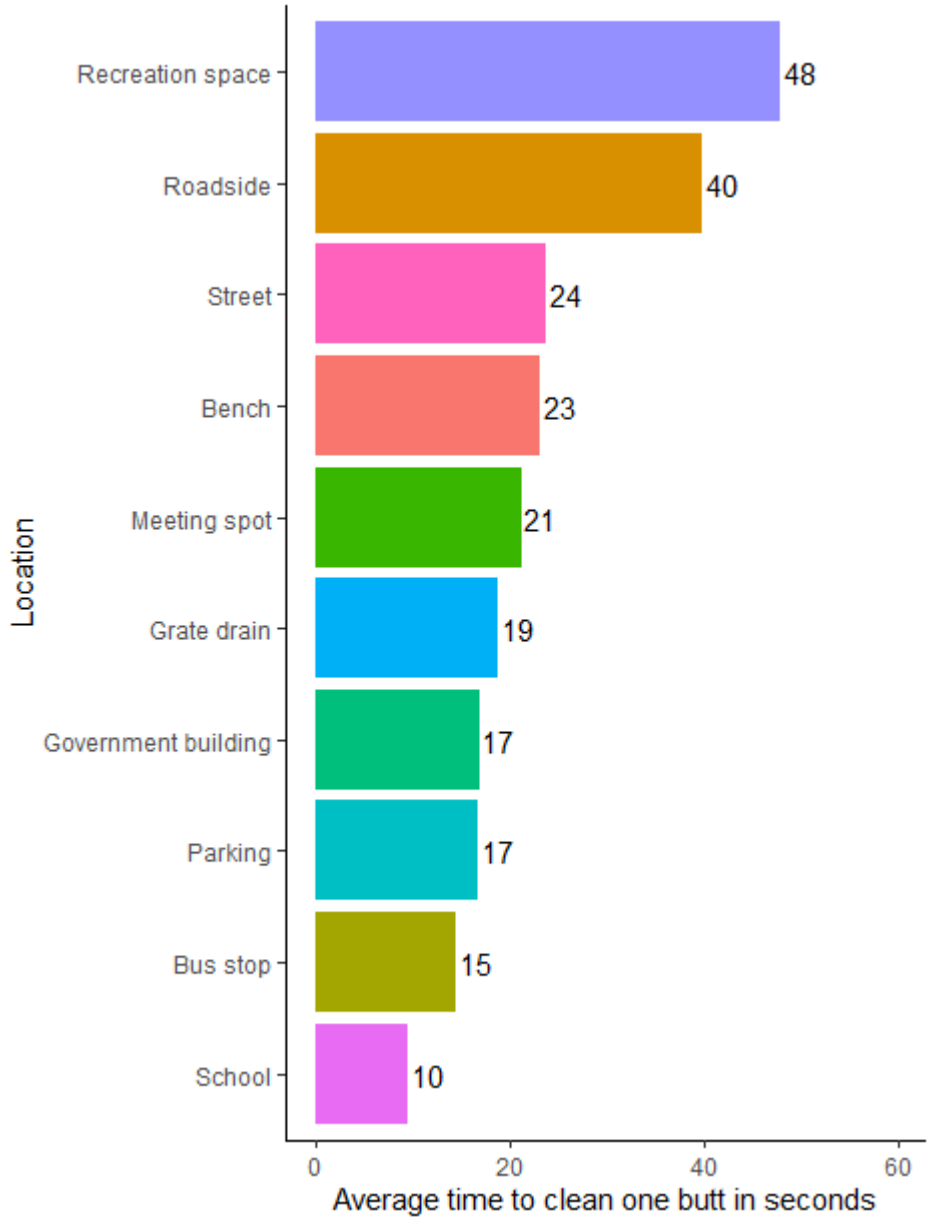


Figure 10 - Average time needed to clean one butt (in seconds), per location

Overall, it can be concluded that a non-ignorable number of cigarette filters was found at each of the locations considered in the study, including the control locations, and at each of the six measurements considered. This confirms the omnipresence of cigarette filters throughout the Netherlands and demonstrates how widespread this pollution issue is. Given the high numbers of cigarette filters in the first measurement and the decrease in the following 5 measurements, it can be argued that the government does not properly clean the cigarette filters. In addition, it appears that the average pollution level is about 26 cigarette filters a week. In order to prevent serious pollution by these filters, it is necessary to clear the filters at last on a weekly basis.

The costs of cigarette butt pollution

This chapter provides an overview of the costs involved with tobacco production and consumption, from cradle to grave. We were able to bring insight into the costs of manually clearing up cigarette filters by means of a calculation. We were not able to calculate the other costs which are caused by the tobacco industry because we do not have the correct information. However, these are costs that should definitely be taken into consideration.

We will deal successively with the costs of manual clearing and then the other costs associated with the production and consumption of tobacco. These include: machine cleaning of cigarette filters, law enforcement, fire caused by cigarettes (from houses and forests). In addition there may be hospital costs, information campaign costs, loss of income from tourism, damage to ecosystems and animals from toxins and plastics, environmental damage from cultivation of tobacco and land degradation, and pollution throughout the production process and transport of tobacco and tobacco products. A lot of water and energy is used for the cultivation of tobacco products, but cultivation also creates a lot of waste, including chemical waste

Cost overview when manually cleaning cigarette filters

During the 6 weeks citizen science monitoring of cigarette filters, there have been weekly measurements on hotspot and non-hotspot (control) locations which included both hard and soft surfaces. Each location was measured weekly and time was automatically tracked during these measurements. In total, over 1,000 measurements have been taken at 188 different locations throughout the Netherlands in cities, villages and rural areas.

The length of time per measurement can be used to calculate how much time it takes to remove one cigarette butt. And with this length of time, the wage costs for cleaning up one cigarette butt can also be calculated. The detailed calculation is in the appendix.

Conclusion

This calculation only includes **wage costs,** which means that other costs are not included such as material costs, transportation costs, processing costs, overhead, material depreciation, etc.

Calculations

Cleaning soft surfaces 2,417,724,920 filters in 18,178,383 hours manually costs € 261.405.148
Cleaning hard surfaces 3,944,709,080 filters in 15,530,351 hours manually costs € 223.326.447

Total cleaning 6,362,434,000 filters in 33,708,734 hours manually costs € 484,731,595

One full timer of 36 hours per week can be productive during 44 weeks on average (after deduction of national and private holidays, and other kinds of absence, such as sick leave). So one full timer can be productive 1,584 hours per year.

So to clean the butts every year a total of 33,708,734 hours divided by 1,584 hours per full time equivalent is needed. This requires 21,281 full timers whose daily job is only picking up cigarette butts!

Wage costs per manually cleared filter from soft surface: average € 0.11 per filter
Wage costs per manually cleared filter from hard surface: average € 0.06 per filter

As mentioned earlier, the calculations only describe wage costs as these costs can be precisely calculated with the available information. However, besides these wage costs, there are other costs involved with the production and consumption of tobacco.
Since not all information is available to us to make an accurate calculation of these costs, we will just describe them here with information we have from earlier studies.

Other costs involved in cigarette butt cleaning

For hard surfaces the mechanical clearing of cigarette filters is a good way to go, such as mechanical street sweeping, mechanical electric washing, manual washing, rain drain cleaning and water treatment processes. For all these processes expensive equipment should be hired or bought and to perform this work other costs like fuel, equipment, vehicle operations, maintenance and transportation to landfills should not be overlooked (Schneider et al., 2020; Stickel et al., 2012). There are also administrative tasks associated with the management and execution of each of these activities but often not directly included in the wage costs for cleaning the cigarette filters.

Other important costs of cigarette butt pollution

As mentioned earlier cigarette filters contain high levels of plastics and chemicals which are considered toxic to humans and animals. Because of the billions of cigarette filters which end up in the environment, the burden on nature is massive. They are a threat for ecosystems, rivers and oceans, humans, pets and other wildlife. The costs financially are difficult to calculate, but these secondary environmental costs may be enormous (Schneider et al., 2020).

Costs which should not be overlooked are law enforcement, which comes with high labour costs, although the proportion of law enforcement activities that can be attributed to deterring litter is likely to be very small in most cities and towns. Also litter prevention campaigns are costly and recurring activities to reduce litter. Cities are responsible for the maintenance of public works and must continuously engage in litter reduction activities (Schneider et al., 2020).

Other additional costs of tobacco product waste include emergency room treatments of cigarette butt ingestion by humans and animals as well as costs of damages due to fires in houses and forests caused by discarded filters (Schneider et al., 2020).

Tourism can be influenced by the way people look at a city. A clean and tidy environment is usually more highly valued when looking at destination features.

Cigarette filters have a negative effect on people's perception of cleanliness and therefore does not contribute positively to the attribution of positive destination traits. This has a negative effect on the hospitality industry and businesses.

Overall costs from the tobacco industry

Tobacco cultivation causes land degradation and impoverishes biodiversity. In addition, it causes soil erosion because it is usually planted as a single or monocrop. As a result, the topsoil is poorly protected against wind and water. In southern Brazil, tobacco cultivation has contributed greatly to the reduction of native forest cover. This reduction has resulted in less than 2% of its original size remaining today. This means that tobacco cultivation has a very negative effect on the natural environment.

In addition to the high environmental impact, it should not be forgotten that the production and transport of tobacco and tobacco products is also a source of environmental damage. Little attention has been paid to this element of the tobacco environmental lifecycle so far.

Other high environmental costs associated with the production of cigarettes are the use of large amounts of water, energy and other resources used in production and finally, the production of cigarettes generates a lot of chemical waste (World Health Organization, 2017).

Conclusions and policy implications

Cigarette filters are the most commonly found litter item worldwide. It is estimated that two-thirds of cigarette filters end up on the streets as litter each year; however, this could be a conservative estimate, as certain studies have put this number as high as 75 or even 90%. This means that the amount of cigarette filters that end up in the Netherlands as litter is somewhere between 6.3 and 8.5 billion. Most cigarette filters contain cellulose acetate (plastic), which causes them to be non-degradable. They are therefore a source of bulk plastic as well as microplastic pollution. Given that it has been estimated that 300 million kilos of microplastics enter our ecosystems per year, we argue that cigarette filters and specifically the microplastics that they contain constitute a major environmental problem.

We have argued above that the cigarette filter itself is largely superfluous. It does nothing to limit the health effects of cigarette smoke, but was instead introduced by cigarette manufacturers to give the impression that their product was not damaging to smokers. Furthermore, it has deleterious effects on natural ecosystems, introducing poisonous chemicals into water systems, and is essentially completely non-degradable. In short, the filter should be removed from cigarettes as it provides no benefits for health outcomes and only serves to create more pollution.

In addition to highlighting the scale of cigarette butt pollution, this report has also sought to understand why smokers do not dispose of their filters correctly, as well as offer some interventions that might possibly change this behaviour. Possible explanations for the former include personal (smokers' personal beliefs about litter), structural (the availability of safe places to dispose of filters), and social (smokers' role models who might possibly challenge their behaviour) factors. On the latter, existing research has indicated that awareness campaigns and more or different ashtrays are not effective. Only educating smokers on the fact that cigarette filters contain plastic proved to be helpful, possibly because only 45% of the smokers know that cigarette filters contain plastic. Furthermore, given that smoking is mostly a social activity, changing the social norms within a society has the highest effect on the proper discarding of cigarette filters. One option proposed to influence these social norms is to increase the number of role models that portray and implement the social norm of properly

disposing of cigarette filters. Finally, these role model methods should also be used to change the belief that cigarette filters make smoking safer in order to remove the cigarette filter from cigarettes again.

In this report we also attempted to more systematically estimate the degree of cigarette butt pollution by way of a six-week long experiment across the Netherlands. Our results are simple and confirm the results seen throughout the literature on this subject; cigarette filters are essentially omnipresent throughout the Netherlands and represent a systematic pollution issue nationwide. While some location types and municipalities suffer from greater levels of pollution, cigarette filters are a serious problem and require immediate attention. Given the high numbers of cigarette filters in the first measurement and the decrease in the following 5 measurements, it can be argued that the government does not properly clean the cigarette filters. In addition, it appears that the average pollution level is about 26 cigarette filters a week. In order to prevent serious pollution by these filters, it is necessary to clear the filters at least on a weekly basis.

We also attempted to provide an estimate of what this attention might look like, at least in monetary terms. Our data indicates that 21,181 full time employees would be needed to keep the Netherlands clean of the cigarette filters that are littered each year. This amounts to approximately € 0.11 per filter on soft surfaces and € 0.06 per filter on hard surfaces. The higher cost for soft surfaces is driven by the fact that it is easier to manually clean filters from hard surfaces. For soft surfaces manually cleaning cigarette filters seems to be the only option. Furthermore, although these costs only refer to wage costs and do not factor in fixed capital costs relating, for example, to machinery, or those relating to environmental degradation when growing tobacco, in addition to the perhaps immeasurable cost associated with more general harm to the natural world caused by the filters themselves.

In summary, our conclusions are as stark as they are straightforward. Cigarette filters cause tremendous harm to the natural world. The Ministry of Infrastructure and Water Management recently ordered a study to establish the steps needed to achieve a 70% reduction of filters that end up in nature by 2026. In view of the results of our research, we argue that this reduction can only be achieved if the filter is removed from the cigarette. Clearly more needs to be done to address the damage that cigarette filters are currently doing, as well as to prevent further harm through social and behavioural intervention. The costs of doing so might be large, but it is imperative that justice be done.

Reference list

Accijnsmonitor. (z.d.). *Overzichten, toelichtingen en downloads*. https://accijnsmonitor.nl/overzichten-toelichtingen-en-downloads/

Araújo, M. C. B., Costa, M. F. (2019). A critical review of the issue of cigarette butt pollution in coastal environments. *Environmental Research,* 172, 137-149. https://doi.org/10.1016/j.envres.2019.02.005

Araújo, M. C. B., & da Costa, M. F. (2021). Cigarette butts in beach litter: Snapshot of a summer holiday. *Marine Pollution Bulletin*, 172, 112858. https://doi.org/10.1016/j.marpolbul.2021.112858

Axelsson, C. & Van Sebille, E. (2017). Prevention through policy: Urban macroplastic leakages to the marine environment during extreme rainfall events. *Marine Pollution Bulletin*, 124, 211-227. https://dx.doi.org/10.1016/j.marpolbul.2017.07.024

Baran, W., Madej-Knysak, D., Sobczak, A., & Adamek, E. (2020). The influence of waste from electronic cigarettes, conventional cigarettes and heat-not-burn tobacco products on microorganisms. *Journal of Hazardous Materials*, 385, 121591. https://doi.org/10.1016/j.jhazmat.2019.121591

Belastingdienst. (2021). Handboek loonheffingen 2021, uitgave juli 2021 https://download.belastingdienst.nl/belastingdienst/docs/handboek-loonheffingen-lh0221t13fd.pdf

Belzagui, F., Buscio, V., Gutierrez-Bouzan, C., & Vilaseca, M. (2021). Cigarette butts as a microfiber source with a microplastic level of concern. *Science of The Total Environment,* 762, 144165. https://doi.org/10.1016/j.scitotenv.2020.144165

Beutel, M. W., Harmon, T. C., Novotny, T. E., Mock, J., Gilmore, M. E., Hart, S. C., & Holden, P. A. (2021). A Review of Environmental Pollution from the Use and Disposal of Cigarettes and Electronic Cigarettes: Contaminants, Sources, and Impacts.

Sustainability, 13(23), 12994. https://doi.org/10.3390/su132312994

Bonanomi, G., Incerti, G., Cesarano, G., Gaglione, S. A., & Lanzotti, V. (2015). Cigarette butt decomposition and associated chemical changes assessed by ^{13}C CPMAS NMR. *PLoS One*, 10(1), e0117393. https://doi.org/10.1371/journal.pone.0117393

Bonanomi, G., Maisto, G., De Marco, A., Cesarano, G., Zotti, M., Mazzei, P., & Incerti, G. (2020). The fate of cigarette butts in different environments: decay rate, chemical changes and ecotoxicity revealed by a 5-years decomposition experiment. *Environmental Pollution*, 261, 114108. https://doi.org/10.1016/j.envpol.2020.114108

Booth, D. J., Gribben, P., & Parkinson, K. (2015). Impact of cigarette butt leachate on tidepool snails. *Marine pollution bulletin*, 95(1), 362-364. https://doi.org/10.1016/j.marpolbul.2015.04.004

Castaldi, G., Cecere, G., Zoli, M. (2021). "Smoke on the beach": on the use of economic vs behavioral policies to reduce environmental pollution by cigarette littering. *Economica Politica*, 38, 1025-1048. https://doi.org/10.1007/s40888-020-00205-5

Currie, J. J. & Stack, S. H. (2021). Getting butts off the beach: Policy alone is not effective at reducing cigarette filter litter on beaches in Maui, Hawai'i. *Marine Pollution Bulletin*, 173, 1-8. https://doi.org/10.1016/j.marpolbul.2021.112937

Curtis, C., Novotny, T. E., Lee, K., Freiberg, M., & McLaughlin, I. (2017). Tobacco industry responsibility for butts: a Model Tobacco Waste Act. *Tobacco control*, 26(1), 113-117. http://dx.doi.org/10.1136/tobaccocontrol-2015-052737

Dannenburg, M., Waldschlager, C., de Bie, P., van der Lugt, L., & Maters, E. (2021). The butt in the drain: the unwanted side-effects of a smoke-free campus. Wageningen University & Research. https://edepot.wur.nl/550221

Dehdari, T. (2022). A qualitative exploration of Iranian smokers' experiences in terms of cigarette butt littering behaviour. *International Journal of Environmental Health Research,* 32(2), 417 425. https://doi.org/10.1080/09603123.2020.1769040

Dobaradaran, S., Soleimani, F., Akhbarizadeh, R., Schmidt, T. C., Marzban, M., & BasirianJahromi, R. (2021). Environmental fate of cigarette butts and their toxicity in aquatic organisms: A comprehensive systematic review. *Environmental Research,* 195, 110881. https://doi.org/10.1016/j.envres.2021.110881

Epperson, A. E., Novotny, T. E, Halpern-Felsher, B. (2021). Perceptions About the Impact of Cigarette Filters on the Environment and Smoking-Related Behaviors. *Journal of Adolescent Health*, 68, 823-826. https://doi.org/10.1016/j.jadohealth.2020.10.022

Farzadkia, M., Sedeh, M. S., Ghasemi, A., Alinejad, N., Kazemi, M. S., Jafarzadeh, N., & Torkashvand, J. (2022). Estimation of the heavy metals released from cigarette butts to beaches and urban environments. *Journal of Hazardous Materials*, 425, 127969. https://doi.org/10.1016/j.jhazmat.2021.127969

Green, D. S., Boots, B., Carvalho, J. D. S., & Starkey, T. (2019). butts filters have adverse effects on initial growth of perennial ryegrass (gramineae: Lolium perenne L.) and white clover (leguminosae: Trifolium repens L.). *Ecotoxicology and Environmental Safety*, 182, 109418
. https://doi.org/10.1016/j.ecoenv.2019.109418

Harris, B. (2011). The intractable cigarette 'filter problem'. *Tobacco control*, 20(Suppl 1), i10-i16. http://dx.doi.org/10.1136/tc.2010.040113

Healton, C. G., Cummings, K. M., O'Connor, R. J., & Novotny, T. E. (2011). Butt really? The environmental impact of cigarettes. *Tobacco control*, 20(Suppl 1), i1-i1. http://dx.doi.org/10.1136/tc.2011.043729

Hoek, J., Gendall, P., Blank, M. L., Robertson, L., & Marsh, L. (2020). Butting out: an analysis of support for measures to address tobacco product waste. *Tobacco control*, 29(2), 131-137. http://dx.doi.org/10.1136/tobaccocontrol-2019-054956

Joly, F. X., & Coulis, M. (2018). Comparison of cellulose vs. plastic cigarette filter decomposition under distinct disposal environments. *Waste Management*, 72, 349-353. https://doi.org/10.1016/j.wasman.2017.11.023

Kataržytė, M., Balčiūnas, A., Haseler, M., Sabaliauskaitė, V., Lauciūtė, L., Stepanova, K., Nazzari, C., Schernewski, G. (2020). Cigarette butts on Baltic Sea beaches: Monitoring, pollution and mitigation measures. *Marine Pollution Bulletin,* 156, 1-13. https://dx.doi.org/10.1016/j.marpolbul.2020.111248

Koroleva, E., Mqulwa, A. Z., Norris-Jones, S., Reed, S., Tambe, Z., Visagie, A., & Jacobs, K. (2021). Impact of cigarette butts on bacterial community structure in soil. *Environmental Science and Pollution Research*, 28(25), 33030-33040. https://doi.org/10.1007/s11356-021-13152-w

Lee, W., & Lee, C. C. (2015). Developmental toxicity of cigarette butts–An underdeveloped issue. *Ecotoxicology and environmental safety*, 113, 362-368. https://doi.org/10.1016/j.ecoenv.2014.12.018

Lima, C. F., dos Santos Pinto, M. A., Choueri, R. B., Moreira, L. B., & Castro, Í. B. (2021). Occurrence, characterization, partition, and toxicity of cigarette butts in a highly urbanized coastal area. *Waste Management*, 131, 10-19. https://doi.org/10.1016/j.wasman.2021.05.029

Marah, M. & Novotny, T. E. (2011). Geographic patterns of cigarette butt waste in the urban environment. *Tobacco Control,* 20(1), 42-44. https://doi.org/10.1136/tc.2010.042424

Montalvão, M. F., Chagas, T. Q., da Silva Alvarez, T. G., Mesak, C., da Costa Araújo, A. P., Gomes, A. R., ... & Malafaia, G. (2019). How leachates from wasted cigarette butts influence aquatic life? A case study on freshwater mussel Anodontites trapesiali. *Science of The Total Environment*, 689, 381-389. https://doi.org/10.1016/j.scitotenv.2019.06.385

Montalvão, M. F., Chagas, T. Q., da Silva Alvarez, T. G., Mesak, C., da Costa Araújo, A. P., Gomes, A. R., & Malafaia, G. (2019). Cigarette butt leachate as a risk factor to the health of freshwater bivalve. *Chemosphere*, 234, 379-387. https://doi.org/10.1016/j.chemosphere.2019.06.100

Morgan, J. C., Jeong, M., Mendel-Sheldon, J., Noar, S. M., Ribisl, K. M., Brewer, N. T. (2022). The impact of cigarette pack anti-littering messages. *Addictive Behaviors*, 126, 1-6. https://doi.org/10.1016/j.addbeh.2021.107184

Novotny, T. E., Lum, K., Smith, E., Wang, V., Barnes, T. (2009). Cigarettes butts and the Case for an Environmental Policy on Hazardous Cigarette Waste. *International Journal of Environmental Research and Public Health,* 6, 1691-1705. https://doi.org/10.3390/ijerph6051691

Novotny, T. E., & Slaughter, E. (2014). Tobacco Product Waste: An Environmental Approach to Reduce Tobacco Consumption. *Current environmental health reports*, 1(3), 208-216. https://doi.org/10.1007/s40572-014-0016-x

Oliva, M., De Marchi, L., Cuccaro, A., & Pretti, C. (2021). Bioassay-based ecotoxicological investigation on marine and freshwater impact of cigarette butt littering. *Environmental Pollution*, 288, 117787. https://doi.org/10.1016/j.envpol.2021.117787

Pascual, A., Felonneau, M. L., Guéguen, N., Lafaille, E. (2014). Conformity, obedience to authority, and compliance without pressure to control cigarette butt pollution. *Social Influence,* 9(2), 83-98. https://dx.doi.org/10.1080/15534510.2013.778214

Patel, V., Thomson, G. W., Wilson, N. (2013). Cigarette butt littering in city streets: a new methodology for studying and results. *Tobacco Control,* 22, 59-62. https://doi.org/10.1136/tobaccocontrol-2012-050529

Rath, J. M., Rubenstein, R. A., Curry, L. E., Shank, S. E., Cartwright, J. C. (2012). Cigarette Litter: Smokers' Attitudes and Behaviors. *International Journal of Environmental Research and Public Health*, 9, 2189-2203. https://doi.org/10.3390/ijerph9062189

Register, K. (2000). Cigarette Butts as Litter-Toxic as Well as Ugly. *Underwater Naturalist*, 25(2), 23-29. https://www.littoralsociety.org/uploads/2/8/2/8/28281631/un_v25_no2.pdf

Sagebiel, J., Karok, L., Grund, J., Rommel, J. (2020). Clean environments as a social norm: a field experiment on cigarette littering. *Environmental Research Communications,* 110. https://doi.org/10.1088/2515-7620/abb6da

Schneider, J. E., Scheibling, C. M., Peterson, N. A., Stigler Granados, P., Fulton, L., & Novotny, T. E. (2020). Online Simulation Model to Estimate the Total Costs of TobaccoProduct Waste in Large US Cities. *International journal of environmental research and public health*, 17(13), 4705. https://doi.org/10.3390/ijerph17134705

Selmar, D., Radwan, A., Abdalla, N., Taha, H., Wittke, C., El-Henawy, A., ... & El-Ramady, H. (2018). Uptake of nicotine from discarded cigarette butts–A so far unconsidered path of contamination of plant-derived commodities. *Environmental Pollution*, 238, 972 976. https://doi.org/10.1016/j.envpol.2018.01.113

Slaughter, E., Gersberg, R. M., Watanabe, K., Rudolph, J., Stransky, C., & Novotny, T. E. (2011). Toxicity of cigarette butts, and their chemical components, to marine and freshwater fish. *Tobacco control*, 20(Suppl 1), i25-i29. http://dx.doi.org/10.1136/tc.2010.040170

Smith, E. A., & McDaniel, P. A. (2011). Covering their butts: responses to the cigarette litter problem. *Tobacco control*, 20(2), 100-106. http://dx.doi.org/10.1136/tc.2010.036491

Song, M., Benowitz, N. L., Berman, M., Brasky, T. M., Cummings, K. M., Hatsukami, D. K., ... & Shields, P. G. (2017). Cigarette Filter Ventilation and its Relationship to Increasing Rates of Lung Adenocarcinoma. *JNCI: Journal of the National Cancer Institute*, 109(12). https://doi.org/10.1093/jnci/djx075

Stickel, B. H., Jahn, A., & Kier, B. (2012). The cost to West Coast communities of dealing with trash, reducing marine debris. https://static1.squarespace.com/static/612d95efbcf9590ffd8af54d/t/619afb306aa4fa4667746a7f/1637546808664/Cost_of_Dealing_With_Marine_Debris_Kier+Associates.pdf

Torkashvand, J. & Farzadkia, M. (2019). A systematic review on cigarette butt management as a hazardous waste and prevalent litter: control and recycling. *Environmental Science and Pollution Research,* 26, 11618-11630. https://doi.org/10.1007/s11356-019-04250-x

Torkashvand, J., Godini, K., Jafari, A. J., Esrafili, A., Farzadkia, M. (2021). Assessment of littered cigarette butt in urban environment, using of new cigarette butt pollution index (CBPI). *Science of the Total Environment*, 769, 1-6. https://doi.org/10.1016/j.scitotenv.2020.144864

Torkashvand, J., Farzadkia, M., Sobhi, H. R., & Esrafili, A. (2020). Littered cigarette butt as a well-known hazardous waste: A comprehensive systematic review. *Journal of hazardous materials*, 383, 121242. https://doi.org/10.1016/j.jhazmat.2019.121242

Truth Initiative. (z.d.). Tobacco industry interference. https://truthinitiative.org/our-top-issues/industry-influence

Valiente, R., Escobar, F., Pearce, J., Bilal, U., Franco, M., Sureda, X. (2020). Estimating and mapping cigarette butt littering in urban environments: A GIS approach. *Environmental Research,* 183, 1-9 https://doi.org/10.1016/j.envres.2020.109142

World Health Organization. (2017). Tobacco and its environmental impact: an overview. https://www.who.int/publications/i/item/9789241512497

Zafeiridou, M., Hopkinson, N. S., & Voulvoulis, N. (2018). Cigarette Smoking: An Assessment Of Tobacco's Global Environmental Footprint Across Its Entire Supply Chain. *Environmental science & technology*, 52(15), 8087-8094. https://doi.org/10.1021/acs.est.8b01533

Appendix

Calculation components

A. The monitoring of excise duty (Accijnsmonitor, z.d.) indicates that more than 9.5 billion ready-to-use cigarette filters were sold in the Netherlands in 2020. The exact number is 9,543,651,000.

   This calculation is based on the number of ready-to-use cigarette filters sold in the Netherlands. It should be taken into account that many cigarettes are bought across the borders (e.g. Germany or Belgium). In addition, many 'make your own' filter sleeves are used.

B. In a publication from 2017 (World Health Organization, 2017) that studied the effect of tobacco on the environment, the World Health Organization (WHO) states that on average 2/3d of the cigarette filters end up on the ground.

C. As of January 2022, the statutory minimum wage for 21 years and older with a 36-hour working week is € 11.06 per hour. We calculate with a rounded 30% surcharge on employer social security contributions (Belastingdienst, 2021). Of these social security contributions, the largest part consists of the compulsory contributions of the government employer to the statutory social insurances.

D. During the 6-week monitoring on cigarette filters, it was automatically tracked on each location how long it takes to weekly clean cigarette filters on 100 m² for one and a half months. Cleaning the filters from a soft surface is done manually and hard to clean with machinery. However, for a hard surface, it can be chosen to clean with machinery.

   The measurements show that manually cleaning a filter from a hard surface is almost 2 times faster than cleaning a filter from a soft surface. The data also shows that 62% of the filters were found on a hard surface, compared to 38% on a soft surface.

With this information, the cleaning speed can be determined which makes it possible to convert how many cigarette filters can be manually cleaned up per hour on average on a soft and hard surface:

Soft surface	133 cigarette filters per hour
Hard surface	254 cigarette filters per hour

Calculations cleaning costs per filter soft surface:

The detailed calculations based on the above-described information are executed as following:

How long does it take to clean cigarette filters from a soft surface?

1. Sold cigarette filters in the Netherlands per year: **9,543,651,000.**

2. From these cigarette filters, 2/3 ends up on the ground as litter: 9,543,651,000 x 2/3 = **6,362,434,000 filters that end up as litter.**

3. From these 6,362,434,000 filters that end up as litter in our environment, 38% ends up on a soft surface: 6,362,434,000 x 38% = **2,417,724,920 filters that end up on soft surface.**

4. In one hour, 133 cigarette filters can be removed from a soft surface, which means that it takes 2,417,724,920 : 133 = **18,178,383 hours a year to remove the cigarette filters from a soft surface.**

What is the hourly wage?

The hourly wage based on the statutory minimum wage is € 11.06. Increased by a surcharge of 30% social employer contributions, the cost price for the employer is calculated on 11.06 x 130% = **€ 14.38 an hour.**

What are the wage costs for cleaning cigarette filters from a soft surface?

This means that the wage costs are € 14.38 x 18,178,383 hours per year = **€ 261,405,148 a year** to remove cigarette filters from a soft surface.

Estimated cost per cigarette filter on a soft surface is then calculated as € 261,405,148 a year divided by 2,417,724,920 filters that end up on a soft surface = **€ 0.11 per cigarette filter** (the detailed amount is € 0.10812030).

Calculations cleaning costs per filter hard surface:

How long does it take to clean cigarette filters from a hard surface?

1. **6,362,434,000 filters end up as litter.**
2. From these 6,362,434,000 filters that end up as litter in our environment, 62% ends up on a hard surface: 6,362,434,000 x 62% = **3,944,709,080 filters that end up on hard surface.**
3. In one hour, 254 cigarette filters can be removed from a soft surface, which means that it takes 3,944,709,080 : 254 = **15,530,351 hours a year to remove the cigarette filters from a hard surface.**

What is the hourly wage?

The hourly wage based on the statutory minimum wage is € 11.06. Increased by a surcharge of 30% social employer contributions, the cost price for the employer is calculated on 11.06 x 130% = **€ 14.38 an hour.**

What are the wage costs for cleaning cigarette filters from a hard surface?

This means that the wage costs are € 14.38 x 15,530,351 hours per year = **€ 223,326,447 a year** to remove cigarette filters from a hard surface.

Estimated cost per cigarette filter on a hard surface is then calculated as € 223,326,447 a year divided by 3,944,709,080 filters that end up on a hard surface = **€ 0.057 per cigarette filter** (the detailed amount is € 0.05661417).

Acknowledgements

This Cigarette Filter report comprises the work of different authors and scientists. The GoClean Foundation thanks these scientists and authors for their contributions and in particular the following authors who drafted the various chapters of this publication:

Dr. Thomas E. Novotny
Jan Daamen
Dr. Paulina Karolina Pankowska
Richard Price
Suzan Klappers
Anina Baijens
Marloes Heebing

Special thanks to:
Bernadette Hakken (Peukenmeisje)
Babs Lommerse
Karl Beerenfenger

Our sincere thanks go to the following citizen scientists:

Addie Weenk
Alda Neevel
André Berbee
Andries Veurink
Anna van der Heijden
Anne Gentenaar
Anneke Schut
Annemiek Geverding
Ans Hoogenboom
Arjan Vermeulen
Arnold Verbakel
Arthur de Smidt
Axel Gunderson
Babs Lommerse
Bernadette Hakken
Bertyl Wissenburg
Bianca Tiegelaar
Cobie Rouwendal
Corina Zeeuwsmeisje
Dianne Mooij

Dico Fraters
Eline van der Veken
Els Quax
Floris van der Lingen
Frida Miedema
Govert Schipper
Gratia van Zeijl-Oldersma
Harrie Verberne
I. F. d. G.
Ingelies Schuurman
Irene Janssen
Iris Bogers
Ivo Rodermans, Zwerfie Rotterdam
Jan Daamen
Jan van Besouw
Jasper Fleers
Jelmer van Benthem
Jeroen Boland
Jessica & Alex
Jim Janssens
Jos Korthout
José Flipsen
Joyce Bosveld
Kirsten Oerlemans
Leo Peeters
Louis van Schie
Maarten Kerkhof
Maayke Boon van Ostade
Marielle van der Lee
Mario Montenegro
Marja Gerrets
Marjolijn Dannenburg
Marloes Heebing
Martina Schlenger
Melchior Spruit
Paul Brons
Paulina Pankowska
Peggy Blaauw
Regina Primera
René van der Meer
Richard Price
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Sander Kamphuis
Sanne Verhoef
Sheila van der Vleuten
Steven Mobron
Suzanne Maas
Suze Stiphout
Tiphaine Bresser
Ton Visser
Tosca Hoogveld
Wilma van der Horst
Wim van der Rijt
Yolanda Perquin-Folmer
&
those who wished to remain anonymous