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Chemistry and Effect of Nicotine, Smoking Pollution and Stopping it under Section of Law

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ABSTRACT

"Chemistry," includes a brief description of technologies used by cigarette manufacturers in a limited number of cigarette brands marketed as "reduced-exposure" or "lower-yield" products. These commercial products have not been met with widespread consumer acceptance. The following section, "Biomarkers," focuses on the manufactured tobacco-burning cigarette consumed by the majority of smokers in the United States and elsewhere. The review on "Chemistry" describes the chemical components of cigarette smoke and addresses aspects of product design that alter the components of cigarette smoke and factors affecting delivery of smoke to the smoker. In most cases, the data reported for chemical levels in mainstream smoke were derived under standard smoking conditions described by the U.S. Federal Trade Commission (FTC) and the International Organization for Standardization (ISO). These standard conditions are puff volume of 35 milliliters (mL), two-second puff duration, one-minute puff frequency, and butt length defined as either 23 millimeters (mm) for nonfilter cigarettes or the length of the filter overwrap paper plus 3 mm. When alternative smoking regimens are used, levels of potentially harmful substances in smoke emissions usually differ from those measured under standard conditions. (For more details, see "Delivery of Chemical Constituents into Tobacco Smoke" later in this chapter.) When people smoke, they do not use the puff volume and puff frequency programmed into smoking machines, and smoking habits vary significantly from person to person and cigarette to cigarette. Consequently, actual exposures to and doses of components of smoke cannot be derived from values obtained with machine smoking. Cigarette smoke is a complex mixture of chemical compounds that are bound to aerosol particles or are free in the gas phase. Chemical compounds in tobacco can be distilled into smoke or can react to form other constituents that are then distilled to smoke. Researchers have estimated that cigarette smoke has 7,357 chemical compounds from many different classes .In assessing the nature of tobacco smoke, scientists must consider chemical composition, concentrations of components, particle size, and particle charge. These characteristics vary with the cigarette design and the chemical nature of the product.

Scientists suggested an approach to identify the chemical components in tobacco smoke with the greatest potential for toxic effects. They considered the risk for cancer, cardiovascular disease, and heart disease. Using this approach, these investigators found that 1,3-butadiene presented by far the most significant cancer risk; acrolein and acetaldehyde had the greatest potential to be respiratory irritants; and cyanide, arsenic, and the cresols were the primary sources of cardiovascular risk. Other chemical classes of concern include other metals, N-nitrosamines, and polycyclic aromatic hydrocarbons (PAHs). This evaluation, along with the Hoffmann list of biologically active chemicals, was used to select the chemicals. Other chemical components with potential for harm will be identified as analysis of tobacco smoke becomes more complete and cigarette design and additives change.

KEYWORDS: *smoking, pollution, nicotine, law, chemistry, effects, tobacco, chemicals, disease*

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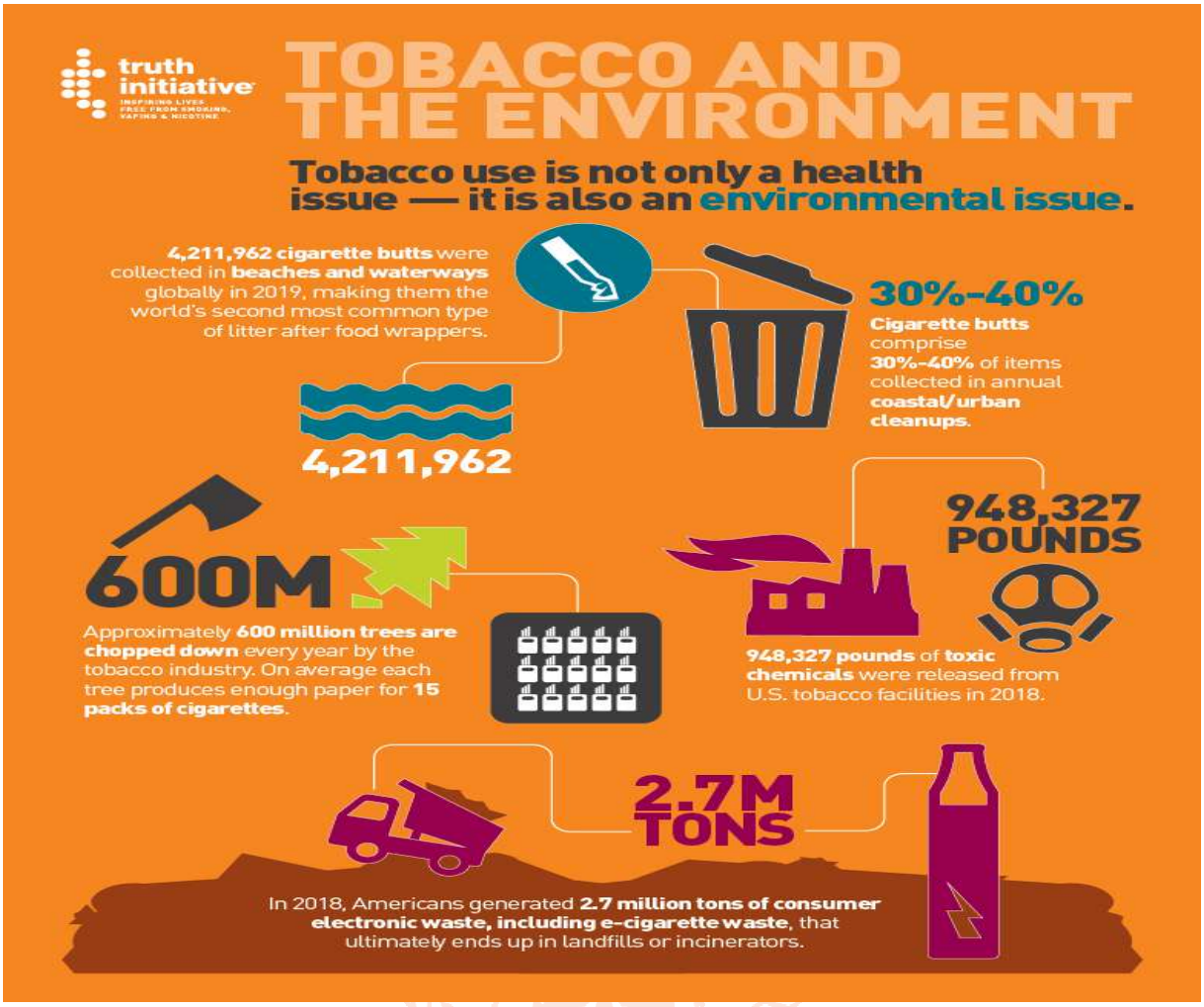
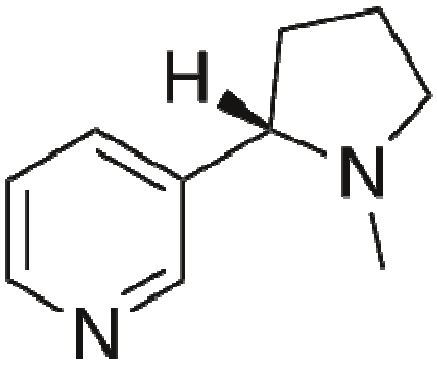
INTRODUCTION

Given that the largest U.S. cigarette companies sold about 217 billion cigarettes to wholesalers and retailers nationwide in 2018, it's no surprise that cigarette butts are the most frequently littered item in U.S. beaches and waterways and second most littered item globally. Cigarette butts are often disposed of in the environment, on streets, sidewalks, and other public areas, and may then be carried as runoff to drains and ultimately end up polluting rivers, beaches, and oceans.[1,2]



Because cigarette butts are primarily made of plastic filters that don't biodegrade, the butts that aren't eaten by wildlife simply pile up on shorelines or at the bottom of bodies of water. The problem isn't limited to cigarettes. Retail e-cigarette sales more than doubled, with a 122.2% increase in total units from September 2014—May 2020. This increase in single-use e-cigarette products will eventually become tons of e-cigarette waste as these products reach end-of-life. Disposing of e-cigarette waste in an environmentally safe and friendly way is a growing problem, especially given the rise of single-use and disposable e-cigarettes. E-cigarette cartridges, such as JUUL pods, are single-use products that contain plastic, electronic and chemical waste and many of them may also end up as litter. Inexpensive, flavored disposable e-cigarettes such as Puff Bar, which doubled their market share in just 10 months from August 2019 to May 2020, are gaining popularity and further contribute to e-cigarette waste.

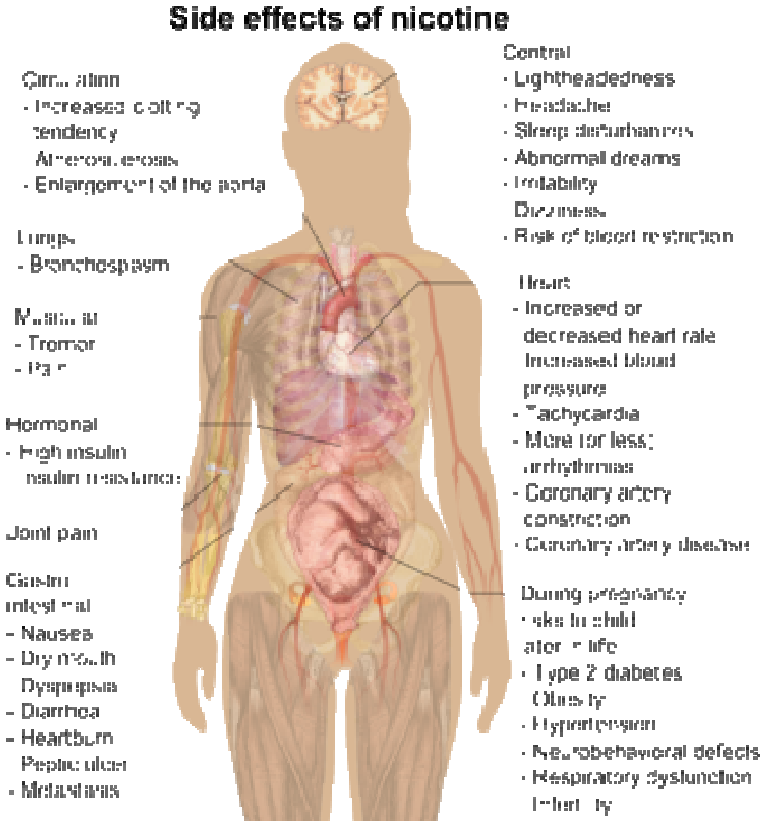
Cigarettes are most commonly categorized as a health problem, but they are a huge environmental problem as well. The entire life cycle of a cigarette has an impact on the environment – from growing the tobacco to throwing away the butt and beyond. Tobacco growth and cultivation causes deforestation. Trees are often cut down to make room for tobacco plants. Once tobacco plants have been harvested, they are "cured." Sometimes the curing is done by air drying, but often tobacco is cured by burning wood to heat the air, which speeds up the process.



Chemical structure of nicotine

Nicotine is a naturally produced alkaloid in the nightshade family of plants (most predominantly in tobacco and *Duboisia hopwoodii*) and is widely used recreationally as a stimulant and anxiolytic. As a pharmaceutical drug, it is used for smoking cessation to relieve withdrawal symptoms. Nicotine acts as a receptor agonist at most nicotinic acetylcholine receptors (nAChRs), except at two nicotinic receptor subunits (nAChRα9 and nAChRα10) where it acts as a receptor antagonist. Nicotine constitutes approximately 0.6–3.0% of the dry weight of tobacco. Nicotine is also present at ppb-concentrations in edible plants in the family Solanaceae, including potatoes, tomatoes, and eggplants, though sources disagree on whether this has any biological significance to human consumers. It functions as an antiherbivore chemical; consequently, nicotine was widely used as an insecticide in the past, and neonicotinoids, such as imidacloprid, are some of the most effective and widely used insecticides.

Nicotine is highly addictive unless used in slow-release forms. Animal research suggests that monoamine oxidase inhibitors present in tobacco smoke may enhance nicotine's addictive properties. Tobacco with reduced nicotine (denicotinized tobacco) acutely reduces nicotine withdrawal, raises striatal dopamine and is also investigated as add on therapy to standard therapy to quit smoking. An average cigarette yields about 2 mg of absorbed nicotine. The estimated lower dose limit for fatal outcomes is 500–1,000 mg of ingested nicotine for an adult (6.5–13 mg/kg). Nicotine addiction involves drug-reinforced behavior, compulsive use, and relapse following abstinence. Nicotine dependence involves tolerance, sensitization, physical dependence, psychological dependence, and can cause distress. Nicotine withdrawal symptoms include depressed mood, stress, anxiety, irritability, difficulty concentrating, and sleep disturbances. Mild nicotine withdrawal symptoms are measurable in unrestricted smokers, who experience normal moods only as their blood nicotine levels peak, with each cigarette. On quitting, withdrawal symptoms worsen sharply, then gradually improve to a normal state.



Nicotine use as a tool for quitting smoking has a good safety history. Animal studies suggest that nicotine may adversely affect cognitive development in adolescence, but the relevance of these findings to human brain development is disputed. At low amounts, it has a mild analgesic effect. According to the International Agency for Research on Cancer, "nicotine is not generally considered to be a carcinogen. The Surgeon General of the United States indicates that evidence is inadequate to infer the presence or absence of a causal relationship between exposure to nicotine and risk for cancer. Nicotine has been shown to produce birth defects in some animal species, but not others. It is considered a teratogen in humans. The median lethal dose of nicotine in humans is unknown, but high doses are known to cause nicotine poisoning.

It's estimated that 600 million trees are cut down every year to produce tobacco products and cigarette-manufacturing machines use up to four miles of paper an hour to roll and package cigarettes.Cigarettes are made from tobacco leaves that originally absorbed all their carbon from the atmosphere as they grew. When you smoke them you're just returning this carbon so the net effect is zero. But tobacco agriculture also generates greenhouse gases of its own, in the form of CO2 from the diesel used in farm machinery and NO2 from fertiliser - not to mention the CO2 attributed to packaging, distribution and advertising.[3,4]

Cigarettes

- Cigarette butts comprise 30%-40% of items collected in annual coastal/urban cleanups.
- Cigarette butts are the most prominently littered item on U.S. roadways, retail areas, storm drains, loading docks, construction sites and recreational areas.
- In 2019, cigarette butts were the most littered item in U.S. beaches and waterways, with close to a million (900,178) pieces collected.
- 4,211,962 cigarette butts were collected on beaches and waterways globally in 2019, making them the world's second most common type of litter after food wrappers.
- 12,089 cigarette lighters, 58,672 cigar tips and 33,865 tobacco packages or wrappers were removed from U.S. waterways in 2015.
- 86% of smokers consider cigarette butts to be litter, but 75% of smokers throw them on the ground or out of a car window.
- Smokers litter as many as 65% of their cigarette butts.

E-cigarettes

- E-cigarette-related waste is potentially a more serious environmental threat than cigarette butts because it contains metal, circuitry, single-use plastic cartridges, batteries and toxic chemicals in e-liquids.
- E-cigarette manufacturers do not provide guidance to consumers on how to dispose of used devices or pod/cartridge products, and there are no receptacles or specific processes in place.
- A Truth Initiative survey found that almost half (46.9%) of e-cigarette device owners said that the e-cigarette/vape device they currently use does not provide any disposal information such as where to send used batteries or empty pods. The survey also found that more than half (57.8%) of those who had vaped in the past 30 days found it inconvenient to dispose of e-cigarette waste responsibly.

Cigarette filters are made from cellulose acetate, a plastic which only degrades under severe biological circumstances, such as when filters collect in sewage. In practice, cigarette butts tossed on streets and beaches do not biodegrade.

- Under optimal conditions, it can take at least nine months for a cigarette butt to degrade.
- The sun may break cigarette butts down, but only into smaller pieces of waste which dilute into water/soil.

Growing concerns over the impact of tobacco waste on the environment, as well as the substantial costs of cleanup, have prompted states, municipalities and institutions to enact a variety of policy actions. For example, 317 municipalities prohibited smoking on beaches and 1,531 prohibited smoking in parks as of October 2017.[5,6]

Unlike cigarette butts, e-cigarette waste cannot biodegrade even under severe conditions. E-cigarette cartridges discarded on streets mix with leaf litter and get pushed around by weather events, eventually breaking down into microplastics and chemicals that flow into storm drains to pollute waterways and wildlife. The DEA advises to contact local waste departments about their household hazardous waste (HHW) program to see if they accept e-cigarettes, and if that is not an option, remove the battery (if possible) and bring the battery to recycling. After the battery has been removed, the rest of the e-cigarette can be brought to DEA prescription take-back days.

Tobacco cultivation is responsible for a myriad of environmental problems, including land and water pollution due to pesticides. Tobacco plants are prone to many insect pests, and therefore tobacco farmers

are forced to use pesticides to keep the plants healthy**.** Not only do tobacco growers often get sick from the pesticides, but the pesticides also leach into the soil and water.

Tobacco cultivation is a source of air pollution, and cigarettes also have a significant effect on air pollution while they are being smoked. When cigarettes are burned, they create more than 7,000 chemicals. At least 69 of these chemicals are known to cause cancer, and many are poisonous.

Nicotine use for tobacco cessation has few contraindications. It is not known whether nicotine replacement therapy is effective for smoking cessation in adolescents, as of 2014. It is therefore not recommended to adolescents. It is not safe to use nicotine during pregnancy or breastfeeding, although it is safer than smoking; the desirability of NRT use in pregnancy is therefore debated. Randomized trials and observational studies of nicotine replacement therapy in cardiovascular patients show no increase in adverse cardiovascular events compared to those treated with placebo. Using nicotine products during cancer treatment is counter recommended, as nicotine promotes tumour growth, but temporary use of NRTs to quit smoking may be advised for harm reduction. Nicotine gum is contraindicated in individuals with temporomandibular joint disease. People with chronic nasal disorders and severe reactive airway disease require additional precautions when using nicotine nasal sprays. Nicotine in any form is contraindicated in individuals with a known hypersensitivity to nicotine.

A study in Italy found that cigarettes release 10 times as much particulate matter into the air as a diesel engine. Smoke from cigarettes and from tobacco cultivation is contributing to climate change. It's well established that second hand smoke is extremely dangerous. Some advocates have been using environmental arguments and law to protect people from harmful smoke in indoor environments as well. In addition to pollution during the cultivation process, tobacco products create a huge amount of waste after they have been consumed. In 2009, tobacco products—primarily cigarette butts— comprised nearly 38% of all collected litter items from roadways and streets. In 2010, over one million (1,181,589) cigarettes or cigarette filters—enough to fill 94,626 packs—were removed from American beaches and inland waterways. Cigarette butts are toxic to animals and children that may swallow them, they pollute groundwater, and they leach chemicals into soil. Compounding this problem is the waste from other items related to smoking such as cigarette packages and lighters or matches. Cigarette butts and other tobacco-related trash are a massive environmental problem. Tobacco and its negative impacts on the environment are a violation of human rights, such as the right to clean air and water, as well. Many countries now included the right to a healthy environment in their Constitutions, and tobacco threatens that right.

On the other hand, smokers live 10 years less than non-smokers on average. If those people didn't smoke, they would have lived for another decade driving their cars, using electricity and buying things. This would generate much more CO2 than all the cigarettes they ever smoked. So smoking actually reduces global pollution, simply by eliminating the polluters!

Discussion

- Cigarette butts cause pollution by being carried, as runoff, to drains and from there to rivers, beaches and oceans.
- Preliminary studies show that organic compounds (such as nicotine, pesticide residues and metal) seep from cigarette butts into aquatic ecosystems, becoming acutely toxic to fish and microorganisms.
- In one laboratory study, the chemicals that leached from a single cigarette butt (soaked for 24 hours in a liter of water) released enough toxins to kill 50 percent of the saltwater and freshwater fish exposed to it for 96 hours.
- Another laboratory study found that cigarette butts can be a source for heavy metal contamination in water, which may harm local organisms.
- A study of the effects of roadside waste on soil found that patterns of hydrocarbon levels in the soil were similar to those of littered cigarette butts. This indicates that the chemicals in the soil had seeped out of cigarette butts. Some hydrocarbons are carcinogenic.[7,8]
- Both the batteries and e-cigarette devices contain hazardous substances such as lead and mercury.
- Lithium-ion batteries in e-cigarettes have been known to explode and cause fires in garbage trucks and waste management plants if damaged or exposed to extreme heat. According to a California survey, 56% of the fires at waste facilities between 2016-2018 were reported to have been caused by batteries, mostly lithium-ion ones.
- Incompletely used liquid cartridges and refills contain nicotine salts and heavy metals, which

can leach into soil and waterways or be ingested by wildlife.

- Before lithium-ion batteries can be placed in the trash, they need to be fully discharged and cooled, submerged in cold saltwater for two weeks — covered securely with a lid — and wrapped in newspaper.

The air pollution emitted by cigarettes is 10 times greater than diesel car exhaust, suggests a controlled experiment, reported in Tobacco Control. Environmental tobacco smoke produces fine particulate matter, which is the most dangerous element of air pollution for health. Levels indoors can far exceed those outdoors, because new engine models and lead free fuels have cut the levels of particulate matter emissions from car exhausts, say the authors.

The controlled experiment was carried out in a private garage in a small mountain town in northern Italy. The town enjoys very low levels of particulate matter air pollution A turbo diesel 2 litre engine was started and left idling for 30 minutes in the garage, with the doors closed, after which the doors were left open for four hours. The car was fuelled with low sulphur fuel. Three filter cigarettes were then lit up sequentially, and left smouldering for a further 30 minutes. The nicotine and tar content of each cigarette was 1 mg and 11.2 mg, respectively. A portable analyser took readings every two minutes during the experiments. Combined particulate levels in the first hour after the engine had been started measured 88 ug/m3. Those recorded in the first hour after the cigarettes had been lit measured 830 ug/m3: 10 times greater. The diesel engine exhaust doubled the particulate matter levels found outdoors at its peak; the environmental tobacco smoke particulate matter reached levels 15 times those measured outdoors.

Nicotine is classified as a poison. However, at doses used by consumers, it presents little if any hazard to the user. A 2018 Cochrane Collaboration review lists nine main adverse events related to nicotine replacement therapy: headache, dizziness/light-headedness, nausea/vomiting, gastro-intestinal symptoms, sleep/dream problems, non-ischemic palpitations and chest pain, skin reactions, oral/nasal reactions and hiccups. Many of these were also common in the placebo group without nicotine. Palpitations and chest pain were deemed "rare" and there was no evidence of an increased number of serious cardiac problems compared to the placebo group, even in people with established cardiac disease. The common side effects from nicotine exposure are listed in the table below. Serious adverse events due to the use of nicotine replacement therapy are extremely rare. At low amounts, it has a mild analgesic effect. At sufficiently high doses, nicotine may result in nausea, vomiting, diarrhea, salivation, bradyarrhythmia, and possibly seizures, hypoventilation, and death.

Growing and manufacturing tobacco products

- 813,925 pounds of toxic chemicals were released from U.S. tobacco facilities in 2018. This number is down from 1,312,796 pounds in 2015 likely in part due to the decline in cigarette smoking and the industry's shifting focus to newer electronic products.
- Research has found that growing tobacco contributes to deforestation, especially in the developing world. Deforestation for tobacco plantations promotes soil degradation and "failing yields" or the capacity for the land to support the growth of any other crops or vegetation.
- Tobacco farmers typically clear land by burning it. But this land is often agriculturally marginal and is abandoned after only a few seasons, contributing in many cases to desertification. Burning increases greenhouse gas levels by generating water and air pollutants, and decreasing forest cover which would otherwise absorb the 16 million metric tons of CO2 produced by tobacco production. Shutting down the tobacco industry would equate to taking 16 million cars off the streets every single year.
- Tobacco production uses up more water and wood, and has more pesticides applied to it, than most other crops, further affecting water supplies and contamination of the soil.[9,10]

Cigarettes

- Approximately 600 million trees are chopped down every year by the tobacco industry. On average each tree produces enough paper for 15 packs of cigarettes.
- Tobacco farming and the tobacco industry are a sizeable contributor to deforestation in many countries around the world.

E-cigarettes

- Since e-cigarettes quickly rose in popularity in an under-regulated environment, we know little about how e-cigarettes are manufactured and the environmental impact of the production process. Thus far, research and policy on e-cigarettes has focused on the youth epidemic and lack of regulation rather than the product's environmental impact.
- E-cigarette companies were required to submit information by September 9, 2020 on the

environmental impact of their products as part of applications to the Food and Drug Administration to keep their products on the market, but this information is not yet publicly available.[11,12]

Industry accountability for tobacco waste

- Many e-cigarette manufacturers simply direct users to hazardous waste/electronic waste disposal companies, which often don't accept e-cigarettes.
- From the cellulose acetate of cigarette butts to e-liquid residue and batteries, waste management and hazardous waste disposal plants are not currently equipped to handle either type of waste. Federal regulations have not yet caught up to the need for guidance on disposal.
- Starting in 2019, the Drug Enforcement Agency (DEA) began accepting e-cigarette devices and cartridges during their annual National Prescription Take Back Day, although the DEA cannot accept devices containing lithium ion batteries.
- Currently, there is no industry guideline for recycling e-cigarettes in the U.S and no documented baseline standards for end-of-life disposal by manufacturers. There is no requirement in place to hold manufacturers accountable for the post-consumer waste they helped produce or to devise a clear and safe system to dispose of these items as hazardous materials or e-waste.
- Even though guidance exists on best practices for holding companies like tobacco manufacturers accountable for reducing or disposing of the post-consumer waste that results from use of their products, they are not currently enforced across the industry by any governing body including the Environmental Protection Agency.
- States and local agencies that have the authority to enforce hazardous waste penalties can help reduce the environmental impact. As of January 2020, the EPA states that, violators of hazardous waste requirements can incur civil penalties of up to $75,867 per day. In 2006, Washington state became one of the first states in the nation to pass a law putting the responsibility for recycling e-waste on the producer, not taxpayers. Manufacturers that produce electronics were required to pay for and manage their recycling.[13,14]

Results

Being around tobacco smoke is bad for you, even if it's someone else's smoke.

When someone smokes a cigarette, most of the smoke doesn't go into their lungs. It goes into the air, where anyone nearby can breathe it. Smoking is banned in many public places. But many people are still exposed to second hand smoke, especially children who live with parents who smoke. Even people who try to be careful about where they light up may not protect those around them.

It can come from a cigarette, cigar, or pipe. Tobacco smoke has more than 4,000 chemical compounds, at least 250 are known to cause disease. Exposure to second hand smoke raises the risk -- by as much as 30 percent -- that others will get lung cancer and many other types of cancer, it can lead to emphysema, and it is bad for your heart. Smoke makes your blood stickier, raises your "bad" LDL cholesterol, and damages the lining of your blood vessels. Eventually, these changes can make you more likely to have a heart attack or stroke. Kids are particularly at risk for the effects of second hand smoke because their bodies are still growing and they breathe at a faster rate than adults.

These conditions have been linked to secondhand smoke exposure in children:

- Sudden infant death syndrome (SIDS)
- More respiratory infections (such as bronchitis and pneumonia)
- More severe and frequent asthma attacks
- Ear infections
- Chronic cough

Tobacco Industry Negligence

The tobacco industry is responsible for producing much more than tobacco products — they are guilty of creating hundreds of thousands of pounds of cigarette and e-cigarette waste each year. Cigarette and e-cigarette waste present serious threats to the ecosystem and requires a long-term solution. Instead of accepting responsibility for their products, tobacco companies are using the environmental problems associated with tobacco products as a ploy for positive press attention.

Some tobacco companies have included reducing the amount of cigarette butts in the environment as part of their sustainability goals. For example, American Spirit continues its "inspirational" themed environmental messaging in 2021 with a new "Stronger Together" slogan and reaffirmation of their goal to help recycle a half-billion cigarette butts by 2025, and Philip Morris International claims it endeavors to reduce plastic litter from its products by 50% from 2021 to 2025 as part of its "Our World Is Not an Ashtray" initiative. Campaigns like this are hypocritical and misleading to the public. The tobacco industry not only created this new waste stream in the first place, they are trying to cover up

their harmful practices through misdirection and public displays of eco-activism.[15]

Smoking during pregnancy is especially dangerous to the developing baby. It's tied to premature delivery, low birth weight, SIDS, limited mental ability, trouble with learning, and ADHD. The more cigarettes a mother-to-be smokes, the greater the danger to their baby.

How to Avoid Secondhand Smoke

It's simple: Avoid being around people who are smoking, and try to convince those around you who smoke to quit. Anyone who does smoke should do so outside, as far away from other people as possible.

Your home is probably the most important place to keep smoke-free, especially if you have children. Keeping kids (and adults) far away from smoke can help lower their chances of having respiratory infections, severe asthma, cancer, and many other serious conditions.

Policies to protect the environment

Tobacco manufacturers need to be held responsible for the extreme amounts of waste that their products create and to facilitate the environmentally safe disposal of their products — both combustible and electronic. Strong local regulations coupled with financial penalties to reduce the amount of e-cigarette waste are needed to reduce the negative environmental consequences from their products. Increasing consumer awareness of the environmental toxicity and dangers posed by discarding cigarette and e-cigarette related waste into landfills and encouraging smokers and vapers to quit using these products altogether are the best ways to protect the environment from tobacco product waste.[16]

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