A preliminary investigation of associated chemicals in cigarette butt waste from the tourist beach area of North Jakarta, Indonesia

Deny Yogaswara*, *Muhammad* Reza Cordova, and *Ukis* Shofarudin

Research Center for Oceanography, The Indonesian National Research and Innovation Agency [BRIN], Jalan Pasir Putih Raya, Ancol Timur, Jakarta Utara, 14430, Indonesia

Abstract. Cigarette butts are among the most common and problematic forms of marine litter. However, there is limited research on the occurrence, abundance, and potential chemicals associated with cigarette butt waste in the environment. The study focused on investigating the occurrence, abundance, and chemical composition of cigarette butt waste on Ancol Beach, Jakarta, Indonesia, addressing a gap in knowledge regarding this prevalent and problematic form of marine litter. Despite Ancol Beach's regular cleaning efforts, cigarette butt waste was still widespread with an abundance of 1.136 pcs/m^2. However, this cigarette butt waste number is still less abundant compared to other regions. Chemical analysis of the cigarette butt waste revealed the presence of various chemical groups, notably aliphatic hydrocarbon compounds. The study emphasizes the importance of understanding and mitigating the environmental repercussions of the chemicals associated with cigarette butt waste and microplastic particles on the coastal ecosystem. Further research is urged to delve deeper into the emerging chemical pollutants present in cigarette butt waste spread in the coastal environments.

1 Introduction

Approximately 15% of the world's population is estimated to be smokers, with 5.6 trillion cigarettes sold annually [1]. The tobacco industry introduced filters in the 1950s to make smoking safer. To date, more than 90% of cigarettes use cellulose acetate fiber filters and several additional additives [2]. However, this has a negative effect on the environment when cigarettes are improperly discarded [3,4]. Over the last three decades, cigarette butts have become one of the most abundant forms of litter in the environment. An estimated 4.5 trillion cigarette butts are released into the environment annually [5]. The accumulation of cigarette butts near various public areas may have harmful consequences for aquatic environments, particularly after rainfall or flooding, while lingering buoyant in the water column for up to 20 days before settling into bottom sediments [6,7]. Some studies have investigated the ecotoxicological effects of cigarette butt waste in aquatic environments because of the high quantities of cigarette butts released into the aquatic environment [8]. The impact of cigarette

* Corresponding author : deny.yogaswara@brin.go.id

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butt waste on sentient creatures is comparable to the potential hazard posed by the chemical composition of cigarettes [9]. These compounds include nicotine, aromatic amines, polycyclic aromatic hydrocarbons, and other toxic elements [10–14]. Toxic cigarette butts can seep into aquatic ecosystems and endanger aquatic wildlife if released [15]. Cigarette butts are designed to absorb a portion of the tar and chemical compounds found in cigarette ashtrays, such as harmful heavy metals and organic compounds [16].

Some of the most toxic elements that are spread on sandy beaches are heavy metals [17], Polycyclic Aromatic Hydrocarbons (PAHs) [18], and pesticides [19]. These compounds are ubiquitous in the environment and have potentially adverse effects on organisms and public health owing to their toxic, carcinogenic, and mutagenic properties [20]. Cigarette butt waste has been found in the digestion of marine mammals, fish, birds, sea turtles, and other marine fauna because of the mistaken use of cigarette butt waste as food [21]. This is why they cause nasty digestive problems and even death [21,22]. In addition, they are carcinogenic and a permanent hazard to environmental and human health [23]. The proliferation of cigarette butts in aquatic environments, particularly along coastal zones, poses a significant hazard to the ecological balance between marine ecosystems and inhabitants.

Ancol Beach is a sandy beach region located on the north coast of Jakarta that has become a tourist destination. This commercial region is surrounded by numerous community activities, including communities, large ports, offices, and medium- and small-scale industries, in addition to tourism-related activities. In addition, Ancol Beach features significant tourist attractions that play a crucial role in Jakarta's economic development. The tidal pattern in this region is characterized by daily fluctuations, and the strength of tides decreases as they move towards the open sea. Ancol Beach was visited by approximately 9.28 million people in 2019 [24]. Plastic waste and microplastics, including cigarette filter waste, originate from tourism-related activities along with waste disposal practices from tourism activities, restaurants, and hotels operating within these tourist spots. Until now, Ancol Beach's plastic waste management method has been fairly effective, as it appears to be well-organized [25]. However, this approach must address the removal of plastic litter from beaches. Thus, this plastic debris management method has not been inadequate to solve the difficulties in the absence of credible scientific data on the quantity and potential to control plastic debris, including cigarette butt waste [26]. In Indonesia, cigarette butts are categorized among the ten most prevalent forms of stranded beach anthropogenic debris [27,28]. Furthermore, no cigarette butt waste and possible risk chemical content studies have been conducted on Ancol Beach or in Indonesia. This study is the first in Indonesia to investigate the chemical composition of cigarette butt waste in the commercial area of North Jakarta, particularly in the tourist beach area of Ancol Beach. This study aimed to determine the toxicant composition of cigarette butt waste found on North Jakarta tourist beaches to inform more effective waste management strategies in Indonesia and worldwide. Hence, this study is a preliminary phase to investigate the chemicals associated with cigarette butts and the potential risks of these substances in the environment.

2 Methods

2.1 Survey design and sample collection method

A systematic collection of cigarette butts was carried out on the sandy surface of Ancol Beach in North Jakarta, Indonesia (Fig. 1) with coordinates 6°7'11.00"S - 106°50'57.21"E and 6°7'6.25"S - 106°51'12.70"E. Sampling of cigarette butt waste was carried out independently without the help of volunteers to cover the entire sampling area and was accomplished in one day.

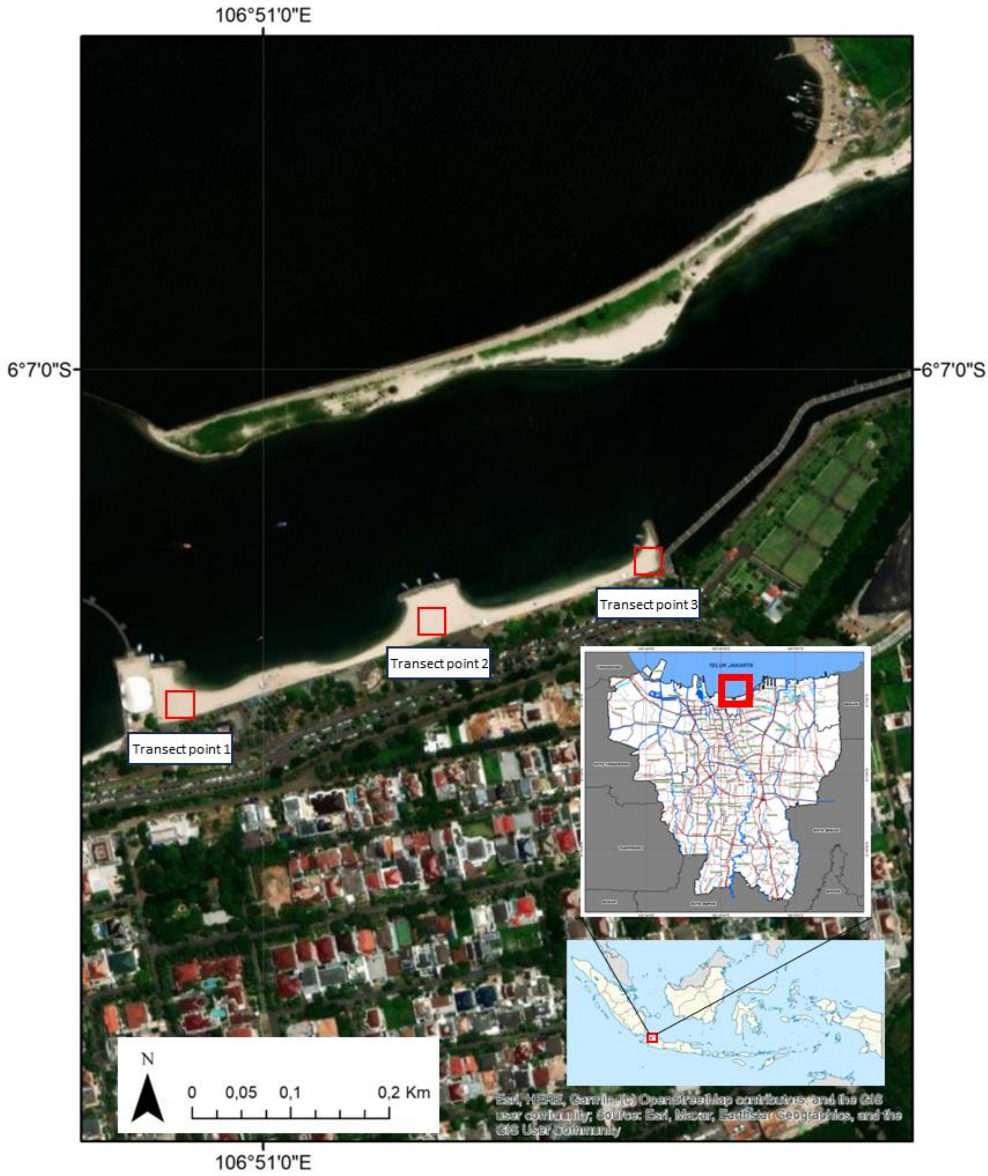

Fig 1. Site location of cigarette butts waste collection with three transects on Ancol Beach, Jakarta City.

This particular coastal zone was selected because of its composition of sand, ample shoreline stretching at a minimum distance of 500 m among three transect meters, and the absence of any impact from nearby rivers or streams [29]. The methods used for the sampling design and sample collection were derived from those developed by Thushari et al. [30]. Briefly, three transect zones measuring 3×3 meters square with triple duplicates were established along a 500-meter position parallel to the coastline, encompassing an aggregate area of 81 m^2. These transects were placed in supratidal conditions that were distinctly visible from the tidal limits. Sampling sites were selected within the highest-high and lowest-low-tide areas to capture all relevant data on cigarette butts present at these locations. Thereafter, each collected item was carefully placed into sterile sealed bags that were accurately labeled and stored for subsequent analysis.

2.2 Chemical content analysis in cigarette butts

In this study, we did not calculate the chemical levels of cigarette butt waste because of the limited instruments and infrastructure facilities in the laboratory. Therefore, we performed a qualitative analysis of the associated chemicals contained in cigarette butts using a Fourier Transform Infrared (FTIR) ATR spectroscopy instrument. The cigarette butt sample was split into two parts, and the internal side was used to analyze the associated chemical content through the detection of chemical functional groups. Qualitative analysis of the associated chemicals was conducted twice for each internal side of cigarette butt waste to obtain accurate and homogeneous results. FTIR with an ATR compartment enables the non-invasive and non-destructive detection of macro fiber cellulose acetate in cigarette butts, and the infrared absorptions of different types of plastics are known and available in the literature [31]. All cigarette butt waste was identified by FTIR and analysis of the functional group of the chemical components. All cigarette butt waste samples collected from the three transect areas were cleaned of tobacco residue and contents attached to the filter surface. Furthermore, the cigarette butt waste surface was cleaned using absolute ethanol to avoid interference with polymer readings. Cigarette butt waste identification of chemical functional groups was carried out using a Thermo Nicolet ™ iS5 FTIR Spectrometer. The experimental setup of FTIR was conducted in a single reflection mode with a resolution of 8 cm^{-1}, a range of 450–4000 cm^{-1}, and 32 scans [auto-accumulation mode] per analysis to increase the signal-to-noise ratio [32].

2.3 Quality control and quality assurance

The origin of cellulose acetate was used as a standard to compare the cellulose acetate that was identified for each cigarette butt waste. All laboratory glassware was rinsed with deionized distilled water and covered with aluminum foil and nitrile gloves worn by a person in a closed room [31].

2.4 Data analysis

The p-value of cigarette butt waste was evaluated by one-way ANOVA and the level of statistical significance [$p < 0.05$] was considered significant, and the information is reflected as mean ± standard deviation.

3 Results and discussion

3.1 Abundance of cigarette butt waste

A diverse range of cigarette brands with varying amounts of tobacco remaining on their filters were retrieved as waste in the form of cigarette butts from Ancol Beach. The collection involved smoked cigarette remnants, which were obtained through a survey conducted on 81 m squares spanning three transect zones with three replicates for each transect. This study found that the average abundance of transect 1, transect 2, and transect 3 were 0.74±0.23 pcs/m^2, 1.52±0.06 pcs/m^2, and 1.15±0.76 pcs/m^2 respectively from cigarette butts waste were found on the shores of Ancol beach (Fig. 2**)**. In addition, the significant factors of the abundance of cigarette butt waste from the three transects were followed by a one-way

ANOVA, and the statistical test did not show satisfactory significance when $p > 0.05$. The beach's appearance was marred by the presence of cigarette butt waste, which had a negative effect on how tourists perceived the "Sun, Sea, and Sand" experience [33]. Despite efficient environmental management services and numerous workers' daily efforts to clean up litter on Ancol Beach, residual cigarette butt waste remains uncleared from the area. Consequently, traces of cigarette butt waste continued to be visible along the sandy beach. The presence of such debris serves as an indicator not only of environmental consciousness but also of coastal pollution levels and supervision effectiveness concerning visitors frequenting the beach [34].

The highest abundance of cigarette butt waste was detected in the second transect area. In contrast, the lowest was detected in the first transect area (Fig. 2). The second transect area is the epicenter for events and entertainment for tourists, both domestically and internationally. At this point, there is a stage performance for music, arts, and other entertainment, as well as congregate areas of tourists. Consequently, the abundance of cigarette butt waste was higher than that in the first and third transect areas. The first and third transect areas are generally purposed as routes for visitors who will get off the tourist boat so that there is less cigarette butt waste.

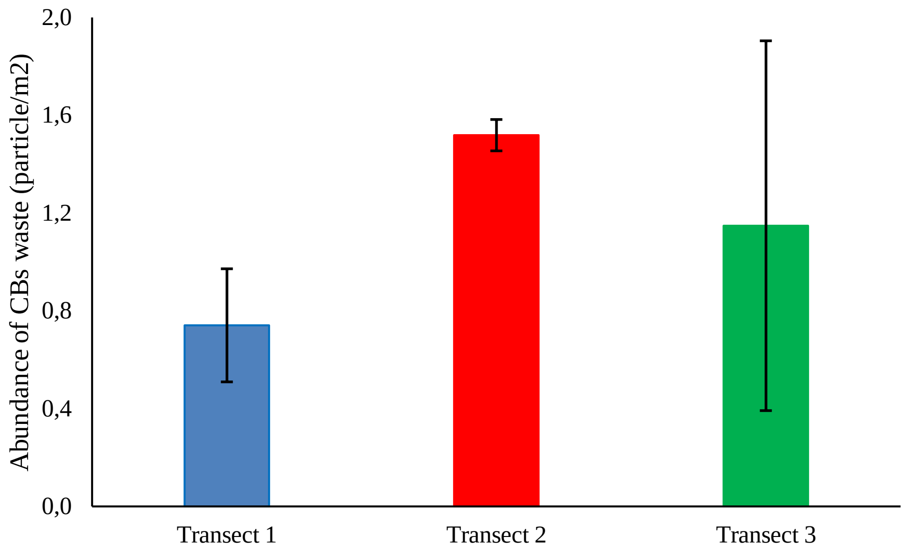

Fig. 2. The average abundance of transect 1, transect 2, and transect 3 from cigarette butts waste were found on the shores of Ancol Beach, North Jakarta.

Assessments of the abundance of cigarette butt waste worldwide were predominantly conducted in coastal environments, estuaries, and islands. In addition, quantitative studies on specific data related to cigarette butts are rare and simply focus on a few regions [35]. In this study, the average abundance of cigarette butt waste along Ancol Beach was lower than that in the Balearic Islands, Spain [36], Mar del Plata – Argentina [37], and Rio de Janeiro – Brazil [38], with abundances of 6.458 pcs/m^2, 4.053 pcs/m^2, and 2.025 pcs/m^2 respectively. The Ancol Beach Authority routinely managed and cleaned the beach and its surroundings. However, the abundance of cigarette butt waste in Ancol Beach was higher than that in The Azores, Faial Island, Portugal [39], Ueda – Japan [40], and New Taipei – Taiwan [41], with abundances of 0.492 pcs/m^2, 0.153 pcs/m^2, and 0.108 pcs/m^2 respectively (Table 1).

Many factors affect the presence of cigarette butt waste on beaches, such as sunlight intensity, wind velocity, current tides, riverine input, and the number of beach visits. The poor attitudes of smokers toward littering of the environment and mismanaging cleaning services are other key defining factors. Because it is non-heavy and effortless to be transported by wind, surrounding factors also have important determinants in the distribution of this cigarette butt waste. The accumulation of marine litter is defined by the beach position in relation to the intensity of the wind velocity (leeward or windward) [42,43]. Marine litter tends to accumulate in the windward areas. Commonly, cigarette butt waste can drift for a long time before drowning and is probably distributed by riverine input. Therefore, nicotine has been discovered in lakes and rivers [44].

Hence, anthropogenic activities have a huge impact on cigarette butt waste accumulation on sand beaches. A study by [45] demonstrated that the amount of cigarette butt waste discovered on sand beaches should not be linked to cigarettes smoked in situ. The movement to the sand beach from the pedestrian, roadway, and discharge channels can occur along the coastline at varying distances as well [35]. Beach in Southern Spain has 159 items of cigarette butt waste, which are affected by seasonality and number of beachgoers, beach location (urban, isolated, or countryside area), sand beach type, and frequency of beach cleaning service [46].

Table 1. The abundance of cigarette butt waste reported in previous studies.

Location	Cigarette butt abundance (pcs/m^2)	Sampling area	Covered area (m^2)	Reference
Aruba (Caribbean)	0.062	Island	41,881	[43]
Rottnest Island (Australia)	0.045	Island	5,061	[47]
Salt marshes (North Carolina)	0.012	Estuaries	49,937	[48]
Mar del Plata (Argentina)	4.053	Coastal	1,425	[37]
San Diego (California, USA)	0.055	Mainland	777	[49]
Ueda (Japan)	0.153	Mainland	3,200	[40]
The Azores, Faial Island (Portugal)	0.492	Island	1,000	[39]
Maui shoreline (Hawaii)	1.886	Coastal	500	[42]
Balearic Islands (Spain)	6.458	Beach	800	[36]
Mar del Plata and Villa Gesell (Argentina)	0.171	Beach	30,000	[50]
Cadiz (Spain)	0.002	Beach	100,000	[7]
British Coast	0.051	Beach	1,402,000	[51]
Belgian Coast	0.006	Beach	67,000	[52]
Bulgarian Coast	0.045	Beach	100,000	[53]
New Taipei (Taiwan)	0.108	Coastal	5,200	[41]
Mediterranean coast of Morocco	0.016	Coastal	108,051	[54]
Oman (Arabian Peninsula)	0.022	Beach	16,500	[55]
Rio de Janeiro (Brazil)	2.025	Beach	1,500	[38]
Ancol Beach (Indonesia)	1.136	Beach	81	This study

3.2 Chemical contents of cigarette butt waste

Various harmful chemical compounds associated with cigarette butts are predominantly derived from organic contaminants, such as PAHs and other organic contaminants [21], while the remaining are inorganic and other contaminants [56]. The chemical substances come from burning tobacco cigarettes, accumulate in the cigarette filter, and have the potential to be released into the environment due to physicochemical processes; consequently, they become pollutants in the environment and organisms [57]. In addition, the other compounds that appear in cigarette butt waste are probably affected by the dynamic tides that occur in Ancol Beach. The contaminant compounds contained in cigarette butt waste in Ancol Beach simply detected 2-3 contents before it was disposed of in the beach environment. After cigarette butt waste is disposed of in the beach environment for a particular period, it can contain 9-10 substances.

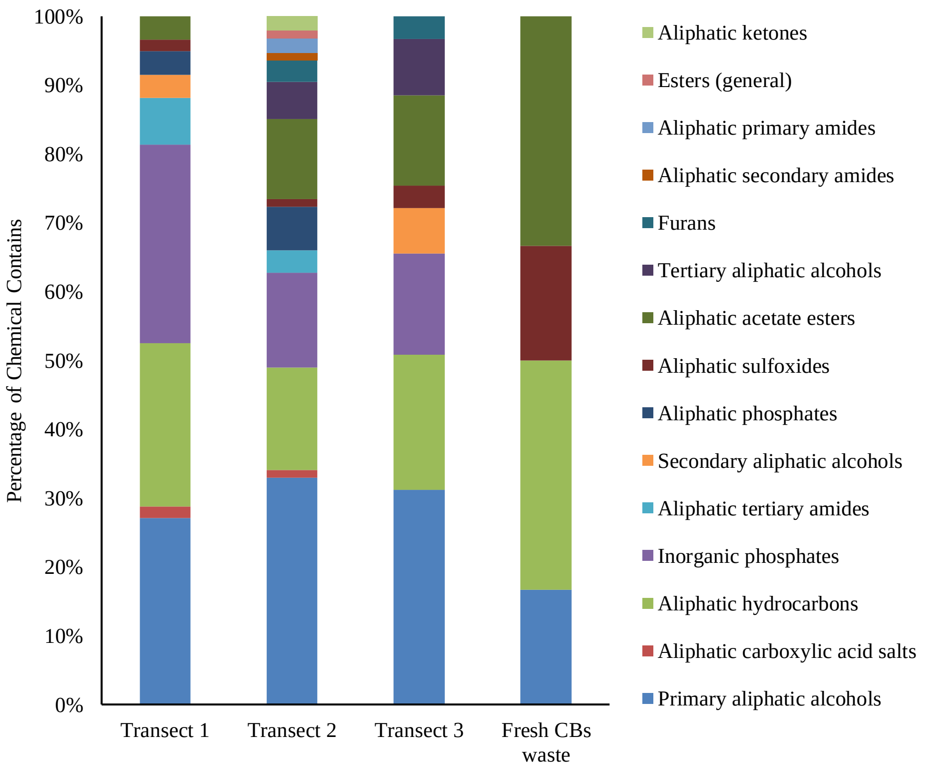

Fig. 3. The abundance comparison of chemical contains was detected in each transect with fresh waste of cigarette butts on Ancol Beach.

The top highest chemical contains were detected on cigarette butts in each transect as follows primary aliphatic alcohols, aliphatic hydrocarbons, and inorganic phosphates with average proportions were 30.19%, 19.33%, and 19.04% respectively (Fig. 3). In addition, the lowest chemical content was detected in cigarette butts: aliphatic carboxylic acid salts, aliphatic primary amides, aliphatic ketones, aliphatic secondary amides, and esters, with an average proportion of less than 1% of the total chemical contained in cigarette butt waste. Inorganic phosphate substances are often found in the environment as a result of the consumption of cleaning products, toothpaste, fire extinguishers, textile processing, water treatment, and horticultural fertilizers [81]; therefore, this substance is not found in fresh CBs. Furthermore, this substance can be adsorbed onto CB waste that has been disposed of in the environment within a certain period. Moreover, chemical substances [i.e., aliphatic acetate esters and aliphatic sulfoxide] adsorbed on cellulose in CBs waste can be easily biodegraded by organisms that possess cellulase enzymes or by photochemical degradation mechanisms. The acetyl group was first degraded in the stage of biodegradation of cellulose acetate in CBs waste [57]. Hence, aliphatic acetate esters and aliphatic sulfoxides in the CBs waste were lower than those in fresh CBs. Primary aliphatic alcohol is the predominant contaminant in cigarette butt waste because it is the main functional group that contains hydrocarbons as the main chemical substance in cigarette filters. A study by Slaughter et al. [19] found that adhesive compounds that glue together paper filters and salts of alkali metals from organic acids are chemical contents that are predominant in cigarette butts. These associated chemicals in cigarette butt waste are categorized as aliphatic (straight-chain) and aromatic (cyclic). Primary aliphatic hydrocarbons were more dominant than aromatic compounds [58]. On the other hand, the detected chemical content of fresh cigarette butt waste contained at least 3-4 substances, which originated from the combustion by-products of tobacco and nicotine in cigarettes. Furthermore, after cigarette butts are discharged into the environment, the cellulose acetate in the cigarette butts is able to absorb other pollutants so that they have the potential to become additional pollutants in the environment [59]. Pollutants deposited and accumulated in cigarette butts can be released into the environment owing to physicochemical effects, potentially adversely affecting environmental health [35].

As shown in Table 2, we identified 15 compounds in cigarette butt waste. These 15 chemical compounds have the potential to be hazardous to both the environment and the species with which they interact. Approximately 7000 harmful compounds are contained in cigarettes [10,32], some of which can easily leach into aquatic environments [13]. Nevertheless, our research is still limited in terms of identifying the chemical components in cigarette butts, but this suggests that additional toxicants may contaminate North Jakarta's aquatic environment. Evidence shows that these regions have been contaminated with heavy metals, persistent organic pollutants, and pharmaceuticals, posing a threat to their ecology [26,60–63].

Table 2. Associated chemicals contained in cigarette butts waste were identified in Ancol Beach.

Associated chemical	Potential risk	Reference
1. Aliphatic acetate esters	High toxicity, Irritation, and harmful to inhalation	[73]
2. Aliphatic carboxylic acid salts	Affects *Tetrahymena* population growth assay	[74]
3. Aliphatic hydrocarbons	A non-anion gap metabolic acidosis associated with hypokalemia and a fatal malignant arrhythmia, termed “sudden sniffing death”	[58]
4. Aliphatic ketones	Disturbance of skin, eyes, and respiratory tract	[75]
5. Aliphatic phosphates	Low toxicity in the environment and less toxicity for aquatic biota.	[76]
6. Aliphatic primary amides	Corrosively affects the skin and eyes irritation.	[77]
7. Aliphatic secondary amides	Corrosively affects the skin and eyes irritation.	[77]
8. Aliphatic sulfoxides	Induce cell death through activation both *in vitro* in a cochlear cell line and *in vivo* in the developing central nervous system in rats	[78]
9. Aliphatic tertiary amides	Low eyes irritation	[77]
10. Esters (general)	Diminished serum estradiol levels, prolonged estrous cycles, and no ovulation in the grown-up, cycling rodents	[79]
11. Furans	Caused change in hormone levels and cancer-causing substances in human	[80]
12. Inorganic phosphates	Can cause of eye and skin irritation	[81]

Associated chemical		Potential risk	Reference
13.	Primary aliphatic alcohols	Caused extreme headaches and was found some contained longer-chain alcohol	[82]
14.	Secondary aliphatic alcohols	No. environmental risk is foreseen for these compounds	[75]
15.	Tertiary aliphatic alcohols	Potent to disturbance of mice gene system	[83]

However, both unsmoked and smoked cellulose acetate filters are classified as hazardous [59,64]. Used cigarette butts exhibit a greater degree of toxicity than their unused counterparts [65]. This phenomenon was observed despite both types being potentially harmful because of the chemicals detected in tobacco smoke residues. Aldehydes and carbonyl compounds are products of chemicals that result from insufficient burning of tobacco constituents or their direct emission from unburnt tobacco [66]. The differential toxicity, fate, and bioaccumulation potential of cigarette butts in organisms or their surroundings may vary according to their chemical composition [19]. Conversely, marine creatures frequently confuse cigarette butts as a source of sustenance, leading to reports of their presence in the digestive systems of fish, sea turtles, and avian species with potentially lethal consequences [21]. Additionally, nicotine produced by a single cigarette butt can elevate the concentration of nicotine above a predetermined threshold [10,67].

According to toxicity studies, cigarette butts can have effects that range from sublethal to lethal. These include alterations in feeding rates, stunted growth, and hormonal imbalances [5,10,68–70]. In addition, the lethal effect of cigarette butts is evident in low-level organisms (microbes and invertebrates) and high-level organisms (fish) [19,64,70,71]. This may have affected the population dynamics of microorganisms inhabiting the seafloor [72].

3.3 Degradation of cellulose acetate polymer in cigarette butt waste

Based on the similarity of the polymer library, all cigarette butt samples were similar to cellulose acetate (CA), greater than 80%, indicating that they were chemically unchanged. The distinctive bands of the acetyl group at wavenumbers 1240, 1370, and 1750 cm^{-1} can be used to determine the CA composition of the cigarette filters (Fig. 4). Based on the analysis of cigarette butts, a relatively recent degradation process was observed in the three samples. This phenomenon can be attributed to two factors. First, it is suspected that these cigarette butts originated from coastal regions, including those brought by visitors or transported through ocean currents and rivers near this study [27,84,85]. Consequently, limited exposure has hindered the progress of significant degradation. The second possibility is that CA has low degradability in aquatic environments, even though cigarette butt waste has been used for a long time. This is in accordance with previous studies, which stated that the degradation of CA cigarette filters appeared to reach a plateau when less than 10% of the mass was degraded [86]. This can be explained by the rapid degradation of the external cellulose layer [87]. The low degradability of the filters can be explained by several reasons.

First, the properties of CA depend on the degree of substitution, which is the average number of acetyl groups per monomer [88]. In this sense, biological degradation can occur under specific environmental conditions, but the higher the degree of substitution, the lower the extent of biodegradation [86]. CA has been engineered to retain harmful substances, including tar, as the primary material used to manufacture cigarette filters. In normal conditions, cellulose acetate filters have low biodegradability [89] and can take up to 1.5 years to biodegrade [87]. On the other hand, cigarette butts waste is considered to be the main contributor to microplastic fiber contamination. More than 15,000 microplastic fibers make up the CA filter [87]. If cigarette butt waste is present in the environment, it is exposed to UV light, which eliminates the outer layer of the cigarette butt and causes UV exposure to the acetate fiber matrix [90]. Consequently, approximately 100 microplastic fibers are emitted into the environment. Deep-sea sediments are considerably contaminated with synthetic polymers, potentially due to the substantial contribution of microfibers from cigarette butts [87].

Furthermore, the deterioration mechanism of cigarette butt waste is influenced by microbial breakdown and environmental factors that rely on moisture and nutrient accessibility [59]. Nonetheless, this investigation failed to determine the microorganisms involved in cigarette butt waste degradation owing to restricted resources. It should be highlighted that additional research on degrading microbial content in cigarette butt waste can enhance comprehension regarding the aspects influencing degradation processes and provide assistance for better waste management. Hence, there is a grave situation involving toxic pollutants and waste disposal [22]. Owing to the toxicity of cigarette butt waste, the environment can be harmed. Chemicals from cigarette tobacco and its combustion accumulate in cigarette filters, easily dissolve in seawater, and pose a threat to marine life [91].

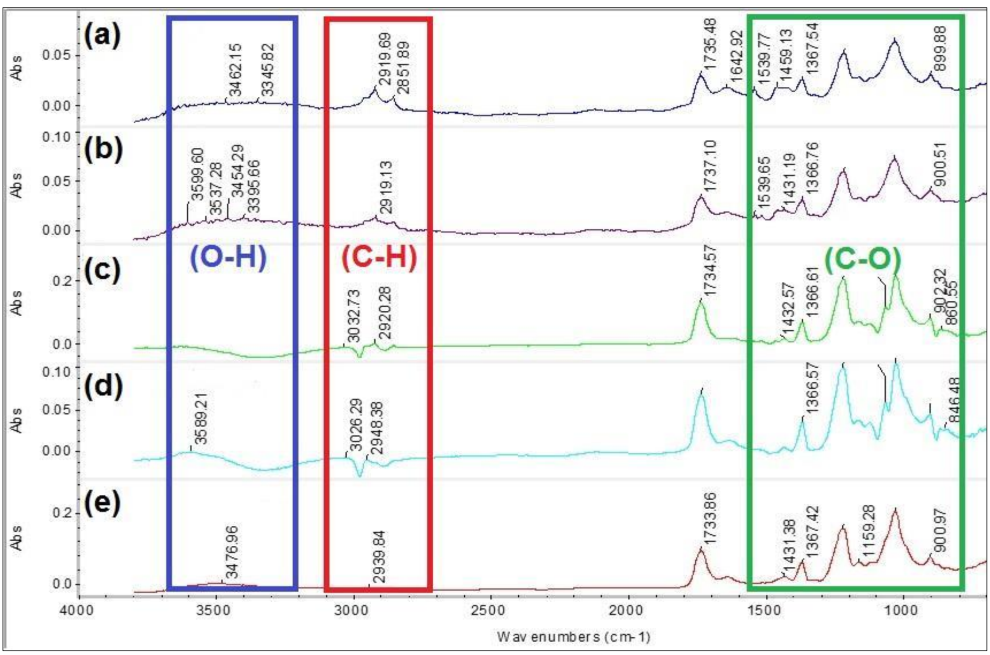

Fig. 4. The spectrum of FTIR analysis from cigarette butt samples at 20ºC consists of (a)] Original cigarette butt, (b) cigarette butt waste before being discharged to the environment, (c) cigarette butt from transect 1, (d) cigarette butt from transect 2, and (e) cigarette butt from transect 3.

Nonetheless, if observed more carefully, organic substrates containing certain functional groups (hydroxyl, alkyl hydrocarbons, and carbonyl) are susceptible to degradation when released into the environment, as illustrated by the absorbance chromatogram baseline in varying wavelength ranges for each group sample (Fig. 4). The absorbance peak at wavenumbers 3700-3200 cm^{-1} in the FTIR spectrum was recognized as the hydroxyl (O-H), alkyl hydrocarbons (C-H) were recognized at wavenumber 3000-2700 cm^{-1}, and the carbonyl (C-O) functional group was recognized at wavenumbers 1500-900 cm^{-1}. These functional groups generate the basic structure of cellulose in cigarette butts [32]. However, owing to the burning/heating of cigarettes, the chromatogram tailings of cigarette butts undergo several transformations. The functional group of alkane hydrocarbons did not exhibit any peak shift in the chromatogram because the hydrocarbon functional group of cigarette butts did not deteriorate when they were deposited on the beach. Meanwhile, the hydroxyl functional group was liberated from cellulose due to its hydrogen bond, and this link was broken when exposed to high temperatures [58]. It is possible that this substance is released and harmful to the environment and reacts with other chemicals.

4 Conclusion

Cigarette butt waste is still commonly found along Ancol Beach, even though the beach is routinely cleaned. Nevertheless, the average abundance of cigarette butt waste along Ancol Beach is lower than that in other regions such as Europe [Balearic Islands, Spain] and America [Mar del Plata, Argentina, and Rio de Janeiro, Brazil]. Identification of the chemicals contained in the cigarette butt waste revealed the detection of several chemical functional groups that are correlated with chemical substances, particularly the aliphatic hydrocarbon compound group (more than 60%). Therefore, this condition needs to be cautiously considered because the chemical substances associated with cigarette butt waste and microplastic particles have the potential to be released and adversely affect the ecosystem and coastal environment. It is necessary to conduct further studies on the amount of associated emerging chemical pollutants in cigarette butts that spread in the coastal environment.

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