GAME OF WASTE

IRREVERSIBLE IMPACT

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GAMES OF WASTE, 2022

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GREENPEACE

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Executive Summary

The transportation of different types of waste from Western countries to Asia and Africa has been an ongoing process since the 1970s. When the increased waste production in Europe, the UK, and North America was combined with the unwillingness to dispose of this waste within the responsible country and the lack of development of related infrastructure, waste exportation had become an option. The power inequality in such practices called "waste colonialism" must be noted.

China used to be the destination of almost half of the world's plastic waste until 2018, then they ceased it with legislation called "National Sword", sending shock waves through the recycling industry. For waste exporting countries, this had created an "obligation" to find new waste destinations for their waste. After this, Turkey has become the destination for plastic waste, most of them coming from continental Europe and the United Kingdom. Before the Chinese ban in 2018, Turkey's monthly waste importation was 4,000 tonnes at the beginning of 2016, then it surged to 33,000 tonnes a month in early 2018. As Malaysia, Vietnam, and Thailand followed China's footsteps and put restrictions on plastic waste importation, Turkey has become the new plastic waste destination of Europe. According to Eurostat, the amount of plastic waste sent from Europe to Turkey has increased 196-fold since 2004. Turkey imported 656,960 tonnes of plastic from Europe in 2020.[1] Meanwhile, Turkey's capacity to recycle its own plastic waste remained in place. Together with the import of waste, various illegal activities were also brought to the public attention and international organizations published reports on such criminal activities, once again bringing up the fate of plastic waste circulating between countries under the disguise of recycling purposes.

As addressed in this report, one of the most common of these criminal activities is the illegal dumping of imported plastic waste, which is imported under the name of recycling purposes, in open areas, agricultural fields, and streamside and their open burning. These actions have extremely dangerous consequences for human and environmental health. Soil, water, and air are polluted, food production is poisoned, and other major health problems may occur as a result of dumping contaminated plastics into the environment and burning them in the open. To examine the impact of the dumping and open burning of waste plastics with unknown content on human and environmental health, samples were collected from soil, ash, water, and sediment, together with samples of plastic waste, from five different dumping sites in the Adana province. These samples were examined by Greenpeace Research Laboratories and by an independent laboratory. The sampling was conducted on 15-16 April 2021 following data reported by a Greenpeace Mediterranean and Germany investigation in October 2020 and by Greenpeace Mediterranean, the UK, and Germany in their April 2021 investigation. The sampling was carried out in illegal dumpsites of suspected imported plastic waste, previously documented by the Microplastic Research Group. The samples collected from the dumpsites were examined for chemical pollutants associated with the plastics themselves, or from the open burning of plastics.

The methodology and detailed results of the chemical analyses are presented in the analytical report.

[1] Eurostat and UK Trade Info, 2020.

MAIN FINDINGS

• In this study, the presence of hazardous chemicals was investigated, including toxic chemicals that are persistent, only breaking down very slowly in the environment. These chemicals can build up in the body and cause diseases in exposed people.

• The examinations were conducted on soil, ash, water, and sediment samples collected from five different locations in Adana province. At these sites, plastic waste imported mainly from European Union[2] states and the UK[3] is illegally dumped and burned in the open.

• The presence of a wide range of toxic chemicals, many of which are known to be produced during the process of burning plastics, was identified in ash and soil samples from all five locations.

• The plastic waste samples collected from dumping and open burning sites located in Çukurova/Karahan, Seyhan/Kuyumcular, and Yüreğir/İncirlik were found to contain various toxic organic chemicals as well as relatively high concentrations of diverse types of metals and metalloids.

• The heavy metals pollutants identified in the plastic pieces were consistent with those determined in the soil, ash and sediment samples. Organic chemical pollutants in the soil, ash and sediments were consistent with chemicals produced during the burning of plastic. These findings demonstrate that the toxic chemicals identified in the areas analyzed were caused by the plastics dumped and burned in these locations.

• Chlorinated dioxins and furans (polychlorinated dibenzo-p-dioxins and dibenzofurans) were found at high concentrations in the soil and ash samples. These are known, in the long term, to lead to severe health conditions, including cancer, by accumulating within the body.

• The total concentration of identified dioxins and furans in some of these soil samples are the highest levels ever detected in soil in Turkey to this day.

• In comparison to the control samples, which were collected from unpolluted soil from adjacent land, the concentrations of dioxins and furans determined in the survey areas were found to be approximately 400,000 times higher in Yüreğir/İncirlik field and 8000 times in Seyhan/Yenidam field.

• The total concentration of polychlorinated biphenyls (PCBs) in the soil samples collected from Yüreğir/İncirlik was found to be 30,000 times higher than the soil sample collected as a control.

• The concentration of polycyclic aromatic hydrocarbons (PAHs) determined in the soil samples collected from Yenidam was up to 35 times higher than the concentration of PAHs reported in previous studies of other regions in Turkey.

[2] Greenpeace Deutschland.Factsheet: Plastic Waste Exports to Turkey. 2021 https://www.greenpeace.de/publikationen/20210517-greenpeace-factsheet-plastikmuell-tuerkei.pdf

[3] Greenpeace UK. Trashed. 2021. https://www.greenpeace.org.uk/wp-content/uploads/2021/05/Trashed-Greenpeace-plastics-report-final.pdf

• In four samples, the concentration of one of the PAHs, benzo(a)pyrene – known as human carcinogen – was above limits for [residential] soils established in Turkey. Two of them, Çukurova/Karahan-2 (ash sample) and Yüreğir/İncirlik (ash sample), contained higher concentrations than both the values set for absorption through soil ingestion and skin contact and due to groundwater contamination. Benzo(a)pyrene concentration in Çukurova/Karahan-2 (ash sample) was 6 and 3.6 times higher, respectively, and in Yüreğir/İncirlik (ash sample) 2.3 and 1.4 higher, respectively, than the corresponding limit values specified in the Soil Pollution Control Regulation of Turkey.

• In all locations except for Seyhan/Kuyumcular, chlorinated benzene compounds (e.g. hexachlorobenzene), some of which can disrupt the hemoglobin metabolism, cause skin lesions and liver disease (porphyria cutanea tarda) were found.

• Certain metals and metalloids were found at elevated concentrations across all sites, including antimony, cadmium, copper, lead, molybdenum, tin, and zinc, all of which are known to occur in various types of plastics. Cadmium and lead are toxic metals that can persist in the environment long after release, and are able to accumulate in the body following repeated exposures.

• Despite the individual differences in terms of these heavy metals and metalloids at some locations, the Kuyumcular site contained cadmium and molybdenum at between 30 and almost 200 times higher than the levels found in the control samples; Incirlik site contained copper up to 90 times higher than in the control, tin up to 140 times, and antimony at around 500 times higher.

Heavy metals, like the cadmium and lead identified in this study, are a major concern for human and environmental health. Some of the organic pollutants that were detected tend to remain in the soil for a long time. These pollutants can, directly and indirectly, contaminate nearby surface water, and can leak into underground water sources. This pollution can potentially have hazardous impacts on the flora, the fauna (including microorganisms) and humans. Lead has no safe level in the blood and is known to impact the nervous system. Lead exposure can cause mental impairment, behavioral disorders and learning difficulties in children. Dioxins and furans (polychlorinated dioxins and furans: PCDD/Fs), certain heavy metals, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and certain fire retardants (FR) are toxic chemicals. Scientific studies have shown that they can have a health impact. Some chemicals, which were also found in this study, may be associated with growth disorders, hormonal disorders, reproductive disorders, organ damage (liver and kidney), cardiovascular diseases or respiratory diseases in children, and may trigger various cancers.

RECOMMENDATIONS

The following are the recommendations of Greenpeace Mediterranean in light of the findings determined within this study.

For International Public Opinion and Waste Exporting Countries

1. Ban plastic waste exports: The fact that unless the UK and German governments do not ban plastic waste exports to both OECD and non-OECD countries gives concerns for the illegal dumping and open burning activities identified in Turkey will continue in the future. Plastic waste exports must be banned. This is a requirement of the "precautionary approach", which is one of the basic approaches of international environmental legislation.

Both this research and the research published by Greenpeace Malaysia in 2020[4] have shown that plastic waste exports have negative environmental consequences in recipient countries, whether exported to OECD or non-OECD countries. Exporting countries are responsible for this environmental pollution and environmental crime as importing countries are.

2. Principles of "polluter pays" and "prevention": Germany and the UK, as a main exporting countries, are responsible for this environmental crime and preeminently responsible for solving the environmental problems caused by inappropriate plastic waste disposal in Turkey and other affected importing countries. This is in line with the principles of "polluter pays" and "prevention".

The first step for the states whose waste has proven to be polluting the environment should contribute to the cost of proper waste disposal and cleanup of uncontrolled dumping areas in Turkey.

3. Investigations and controls: Until export bans are in place in the exporting countries, effective monitoring and enforcement of the waste export industry is essential. Therefore, funding and personnel for monitoring and enforcement should be increased immediately to combat possible corruption, fraud, and illegal practices by licensed or unlicensed operators exporting waste to Turkey. Controls cannot be seen as an ultimate solution, nor detract from complete export bans – it would be logistically impossible to monitor and conclude with certainty what is being exported due to the volume of waste, the number of containers and space at ports.

4. Transparency is one of the most effective ways to prevent illegal and environmentally harmful waste management. In addition, the public has the right to know where their waste goes, where and how it is disposed of. There is a need for a standardized and streamlined online real-time reporting process that all stakeholders can access at any time. Establishing an integrated tracking system with all countries, monitoring waste export data in real time, would be a huge step towards preventing illegality.

5. Refill and reuse system: An action plan to develop alternatives based on refillable and reusable systems should be put into practice (such as deposit return schemes).

Priority should be given to a plastic pollution reduction plan that will radically reduce the production of single-use plastics, which is the most commonly found plastic in illegal dumping and open burning areas identified in Turkey.

[4] Greenpeace Malaysia, The Recycling Myth 2.0, 2020

6. Single use phase-out: Exporter countries, such as the UK and Germany, should urgently set and establish a delivery plan for a target to reduce single-use plastic, which should place particular emphasis on resource efficiency and waste minimization.

7. Exporter countries should introduce **Extended Producer Responsibility (EPR)** schemes designed to increase reuse and reduction of packaging as well as to eliminate non-recyclable plastics. This should be achieved through a combination of reuse and reduction targets and modulation of fees to incentivize eco-design, reuse and reduction and to penalize single-use packaging. Until waste export bans are in place, EPR measures should also hold the producer responsible for knowing that the waste they produce, if exported, is disposed of legally.

8. Internationally applicable models should be generated by introducing new controls on companies that manufacture and use unnecessary single-use plastic packaging for products, and by requiring companies to track products from the cradle to the grave to ensure transparency about plastic use, disposal and recycling.

To The Turkish Ministry of Environment, Urban Planning and Climate Change

1. Zero waste importation: As The Minister of Environment, Urbanization and Climate Change said at the end of 2019, Turkey should reach its goal of zero waste imports as soon as possible and immediately ban the import of all plastic waste.

In accordance with the Turkish Zero Waste Regulation, separate collection systems at the source of local waste should be expanded. Single-use plastics should be removed from use within a plan, and their production should be limited.

2. Further investigations and rehabilation plan: The Ministry of Environment, Urbanization, and Climate Change should carry out more detailed investigations in the affected areas. In particular, they should examine the risk of hazardous substances leaking into air, soil, and water resources.

A comprehensive rehabilitation action plan should be developed. This should involve the participation of citizens living in the region to clean and rehabilitate contaminated areas where imported plastic garbage is illegally dumped and burned.

3. Research commission: The Presidency of the Turkish Grand National Assembly should establish a research commission to investigate the environmental destruction that results from illegal activities, with special emphasis on illegal and bad practices related to plastic pollution and plastic waste management.

4. Health impact studies: The Ministry of Health should carry out studies into the health impact of the pollution from imported plastic waste, and provide preventive health support to the affected residents against possible adverse effects.

The Ministry of Food, Agriculture, and Livestock should take seriously the potential of contaminated agricultural lands and irrigation water due to illegal plastic waste dumping and open burning activities near agricultural production areas. It should initiate studies to demonstrate that the relevant areas are risk-free in terms of food safety.

5. Transparency: The Ministry of Trade should explain in real-time, and in a transparent manner, the volume and nature of plastic waste that particular companies are importing from each country. Together with the Ministry of Environment, Urbanization, and Climate Change, these waste importing companies should state how much they produce and how much process waste they produce. The Ministry should establish a system in which the fate of these process wastes can be monitored and make it available to all.

1. BACKGROUND

A. TURKEY

The waste plastic import activities of Turkey significantly increased when China banned its waste import back in 2018. Before the 2018 ban imposed by China, Turkey's waste plastic import was 4,000 tonnes a month in 2016, and increased to 33,000 tonnes in 2018.[5] Turkey became the largest buyer of Europe's plastic wastes in 2019 and 2020. In 2020, total of 659,000 tonnes of waste plastic was sent to Turkey from Europe: corresponding to 241 truckloads of garbage on a daily basis. The amount of plastic waste coming over from Europe has increased 196 fold in the last 16 years.[6]

In this chain of importation, mainly the wastes that are very expensive to dispose of or upcycle, are being sent to many other countries, especially Turkey. And the absence of an international convention on this matter until early 2021 has increased the unregulated activities in this area. However, the new plastic restrictions introduced by Basel Convention implemented on 1 January 2021 have shown some promise to limit the plastic waste trade. Similarly, the decision by the EU not to send waste to non-OECD countries hinted at upcoming regulations that will significantly change the course of the plastic waste trade. Right before these decisions were implemented, at the end of 2020, a serious spike occurred in the plastic waste trade (Gündoğdu and Walker, 2021).

Although Turkey has not adapted the Basel Convention Plastic Waste Amendments[7], which came into effect on January 1, 2021, it has imposed new bans in its national legislation and brought significant restrictions on the importation of plastic waste. First, a 50% quota was implemented (The quota application is determined according to the waste processing capacity of the importers), then the mixed plastic waste importation was banned, however, when the reporting of illegal activities continued to soar, the importation of Ethylene Polymer-Type 3915.10 coded plastic waste was banned: one of the biggest and most common disguises for these illegal activities.

In parallel with the importation of plastic waste, many illegal plastic waste dumping and burning activities have been reported in provinces like İzmir, Istanbul, and especially Adana. The plastic waste import was first brought to the forefront in 2018 with the news report of The Guardian[8], investigating the fate of plastic wastes exported by the United Kingdom to Turkey, and then reported further by many other international media outlets. As these news reports were being published, Greenpeace revealed that tonnes of mixed plastic garbage imported from Italy were being illegally stored in the backyard of a house located in the Kemalpaşa neighborhood of İzmir. This incident made it clear that some of the plastic wastes imported by Turkey were being illegally disposed of. The footage, later released by BBC in Adana, revealed that the plastic wastes brought from the UK were also being processed illegally.

[5] https://www.greenpeace.org/static/planet4-turkey-stateless/2019/09/c19ddece-c19ddece-plastik-atik-ithalat-raporu-gpea-plastic-waste-trade-research-briefing.pdf

[6] https://www.greenpeace.org/turkey/basin-bultenleri/turkiye-yine-avrupadan-en-cok-plastik-cop-alan-ulke-oldu/

[7] Basel Convention Plastic Waste Amendments

[8] Turkey's Plastic Waste Imports From The UK Are Booming – But At What Cost?" 2021. The Guardian.

PLASTIC WASTE IMPORTS TO TURKEY: A TIMELINE

SEPTEMBER 2019

AFTER COUNTRIES LIKE CHINA, VIETNAM, MALAYSIA, AND THAILAND RESTRICT PLASTIC WASTE IMPORTS, EUROPEAN COUNTRIES DIVERT MORE WASTE TO TURKEY.

GREENPEACE MEDITERRANEAN RESEARCH REVEALED THE ILLEGAL STORAGE OF GARBAGE BROUGHT FROM ITALY IN THE CITY OF İZMİR.

DECEMBER 2019

WHILE THE WASTE IMPORT QUOTA OF TURKISH PLASTIC WASTE IMPORT COMPANIES WAS **80%** OF THEIR WHOLE CAPACITY, THIS RATE WAS REDUCED TO **50%** BY MINISTRY OF ENVIRONMENT, URBAN PLANNING AND CLIMATE CHANGE.

MAY 2020

TURKEY BECAME THE LEADING BUYER OF EUROPE'S PLASTIC WASTE IN 2019:

IMPORTATION HAS INCREASED 173 TIMES IN THE LAST 15 YEARS[9].

JUNE 2020

BBC NEWS:

"IS THIS RECYCLING?"[10]

NEWS REPORT REVEALED THAT WASTE EXPORTS TO TURKEY ARE NOT ALWAYS BEING RECYCLED.

OCTOBER 2020

GREENPEACE GERMANY FIELD INVESTIGATION REVEALED UNPROPER WASTE IMPORTATION[11].

JANUARY 2021

MIXED PLASTIC IS BANNED.[12]

TURKEY PROVIDE NO REPORTING FOR BASEL CONVENTION'S PLASTIC WASTE AMENDMENTS.

APRIL 2021

TURKEY IS AGAIN THE LEADING BUYER OF EUROPE'S PLASTIC WASTE IN 2020:

THERE HAS BEEN A 241-FOLD INCREASE IN THE LAST 16 YEARS[13].

MAY 2021

GREENPEACE UK LAUNCHES ITS TRASHED REPORT[14].

THE RESULTS OF GREENPEACE UK AND GERMANY'S INVESTIGATIONS ARE REVEALED.

TURKEY ISSUES AN IMPORTATION BAN ON ETHYLENE POLYMER PLASTICS[15].

JULY 2021

POLYETHYLENE BAN IS PULLED BACK BY THE MINISTRY OF COMMERCE.

HOWEVER, THE MINISTRY OF ENVIRONMENT, URBAN PLANNING AND CLIMATE CHANGE MAINTAINS THE 1% CONTAMINATION LEVEL IN ITS IMPORTATION CRITERIA[16].

[9] Greenpeace Mediterranean, Türkiye'de Plastik Atık Ithalatı Son 15 Yılda 173 Kat Arttı, 2021.

[10] https://www.youtube.com/watch?v=hw6KR2vj_bc

[11] Greenpeace Deutschland. Europäisches Plastik in der Türkei. 2020

[12] Republic of Turkey Official Gazette Notice on the amendment of Import Inspection of Wastes Controlled for Environmental Protection (Product Safety and Inspection: 2021/3) Statement. 25.3.2021. No: 31485

[13] Eurostat data, 2020.

[14] Greenpeace UK. Trashed. 2021.

[15] Republic of Turkey Official Gazette Notice on Import Inspection of Wastes Controlled for Environmental Protection (Product Safety and Inspection: 2021/5) Statement. 18.5.2021. No: 31485

[16] Republic of Turkey Ministry Of Environment And Urban Planning, Directorate General of Environmental Impact Assessment, Permit and Inspection 16.7.2021. Beige No: 2021/16

B. GERMANY

Illegal waste exports to Turkey - non-recyclable plastic endangers residents plastic endangers residents and the environment.

In 2019, each German produced an average of about 72 kilograms of plastic waste, four kilograms more than in the previous year.[17] Global plastic consumption is increasing, especially due to the boom in to-go products during the Covid 19 pandemic.[18]

Recent research conducted by Greenpeace in 2021 reveals that apparently non-recyclable plastic waste has been exported from Germany[19] and the United Kingdom (UK)[20] to Turkey. The research team has uncovered ten uncontrolled landfills in the Adana region in southern Turkey and found mountains of plastic waste containing waste mainly from the United Kingdom UK and from Germany, Poland, and other EU countries.

The findings are accompanied by recent media reports[21-22], that about 400 containers of non-recyclable or difficult-to-recycle plastic waste from Germany are currently stored in Turkish ports and cannot be processed any further.[23-24] According to internal information from the recycling industry large German recyclers such as ALBA (Berlin, Nordrhein-Westfalen NRW, Niedersachsen, Baden-Württemberg), Meilo (Gernsheim, Hessen), or Lobbe (Iserlohn, NRW) are apparently involved in questionable business deals with now bankrupt export companies.[25-26-27] Because the exporting companies and the German authorities did not take any action to ship these containers back to Germany the Turkish government decided to ship around 37 of these containers to Vietnam for 'further treatment'.[28]

This example once again puts a spotlight on the absurdity of the plastic waste trade. Germany has the technology and the capacity to treat its waste properly at home. Instead, a trade takes place that transports not only the packaging waste but also the chemicals it contains abroad. The ones who suffer are the people and the environment in the importing countries.

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[17] https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/Abfallwirtschaft/_inhalt.html

[18] https://www.spiegel.de/wirtschaft/service/recycling-luege-die-neue-muellflut-durch-corona-a-00000000-0002-0001-0000-000172636952

[19] Greenpeace e.V. (2021): Zugemüllt – Wie Deutschland Plastikmüll recycelt Illegale Abfall-Exporte in die Türkei – nicht recyclebares Plastik gefährdet Anwohner:innen und Umwelt
https://www.greenpeace.de/sites/www.greenpeace.de/files/publications/20210517-greenpeace-factsheet-plastikmuell-tuerkei.pdf

[20] Greenpeace (2021): Trashed: how the UK is still dumping plastic waste on the rest of the world: https://www.greenpeace.org.uk/resources/trashed-plastic-report/

[21] https://www.wiwo.de/my/unternehmen/dienstleister/plastikmuell-aus-dem-gelben-sack-so-verschwindet-deutscher-haushaltsmuell-in-der-tuerkei/27163628.html?Echobox=1620303437&social=twitter&utm_medium=social#utm_medium=Social&utm_source=Twitter

[22] https://www.spiegel.de/wirtschaft/dubiose-muellexporte-in-die-tuerkei-a-2801d9bc-0002-0001-0000-000177514633?context=issue

[23] https://www.wiwo.de/unternehmen/handel/abfaelle-tuerkei-koennte-ueber-140-container-mit-plastikmuell-zurueck-nach-deutschland-schicken/27163356.html

[24] https://www.euwid-recycling.de/news/wirtschaft/einzelansicht/Artikel/fragwuerdige-exporte-in-die-tuerkei-aus-dem-dualen-system.html

[25] http://wiki.ban.org/images/f/fa/Container_Numbers_-_Germany_Vietnam.xlsx

[26] https://www.wiwo.de/unternehmen/handel/abfaelle-tuerkei-koennte-ueber-140-container-mit-plastikmuell-zurueck-nach-deutschland-schicken/27163356.html

[27] https://www.wiwo.de/unternehmen/dienstleister/plastikmuellexporte-warum-die-tuerkei-deutsche-abfaelle-zurueckschicken-will/27200268.html

[28] https://www.ban.org/news/2021/12/1/environmental-groups-move-quickly-and-block-the-export-of-german-plastic-waste-to-vietnam
https://www.ban.org/news/2021/12/15/green-groups-demand-immediate-return-of-german-plastic-waste

German and British plastic waste in wild landfills in Turkey

The volume of packaging waste in Germany rose to a total of 5.9 million tonnes between 2018 and 2019. Statistically, each German generated a record 227.55 kilograms of packaging waste (plastic, paper, cardboard, and other materials) in 2019. This puts Germany 50 kilograms above the European average per capita consumption of 177.38 kilograms.

According to Federal Environment Agency, 99.4 percent of the waste produced in Germany was recycled[29]. But what does "recycled" mean? More than half of the plastic waste for example is used as energy, i.e. incinerated, while 46.6 percent is recycled as raw material.[30] At the end of the day, however, only a fraction of the waste produced is used as so-called recyclate for the manufacture of new plastic products. A large part of the German plastic waste is exported to other countries where it is incinerated or ends up in landfills. In 2019, Germany was the largest exporter of plastic waste in the EU.[31] Although the export volume is continuously decreasing and has fallen by eight percent between 2019 and 2020. Nevertheless, the Federal Republic exported a total of 1 million tonnes of plastic waste to other countries in 2020. Approximately 46,000 containers are needed to ship such quantities.

Since 2018, the main receiving country for German plastic waste exports has been Malaysia: in 2020, the Federal Republic of Germany exported approximately 170,000 tonnes of plastic waste to Malaysia and exported 136,000 tonnes of plastic waste to Turkey in 2020. Other important export countries were the Netherlands, Turkey, Poland and Austria.[32] In recent years, however, more and more countries such as China, Malaysia, Vietnam and Thailand have restricted the import of plastic waste. These restrictions have not led to a reduction in plastic waste, however, but only lead to a shift of the problem to other regions of the world, such as Turkey. No other country received more exported waste from EU member states than Turkey. A total of 13.7 million tonnes of plastic waste was exported to Turkey[33]: This is almost as much as the Port of Hamburg's total export cargo throughout in the first quarter of 2020.[34]

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[29] https://www.umweltbundesamt.de/daten/ressourcen-abfall/verwertung-entsorgung-ausgewaehlter-abfallarten/verpackungsabfaelle

[30] https://www.umweltbundesamt.de/daten/ressourcen-abfall/verwertung-entsorgung-ausgewaehlter-abfallarten/kunststoffabfaelle#kunststoffe-produktion-verwendung-und-verwertung

[31] https://www.boell.de/sites/default/files/2020-11/Plastikatlas%202019%205.Auflage%20web.pdf?dimension1=ds_plastikat

[32] https://www.destatis.de/DE/Home/_inhalt.html

[33] https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/ddn-20210420-1?s=09

[34] https://www.hafen-hamburg.de/de/presse/media/broschuere/charts-pressekonferenz-1-quartal-2020---38072

2. Environmental impact of plastic disposal

The plastic waste disposal methods revealed in the examples of İzmir, Adana, and İstanbul pose significant risks in terms of both the environment and human health. Random disposal of plastic and other wastes to the environment and burning them in the open can cause heavy metals, dioxins, PCBs, and other toxic substances to mix into the soil, water, and air. Some of these chemicals can also end up in the food chain and some are known to be persistent for generations. Toxic gases produced by these burning processes cause health problems including asthma, cancer, hormone disruption, chronic headache, lung problems, chronic coughing, and heart attack (Petrlik et al. 2021).

According to a report published by IPEN (Petrlik et al. 2021), toxic chemicals known as "persistent organic pollutants" (POP), which are banned or are in the process of being banned globally under the Stockholm Convention (2019), were found in the eggs of free-range chicken around various plastic waste disposal areas (open burning areas like in Adana) and the waste facilities.[35] This included high levels of chlorinated dioxins and dioxin-like chemicals. The amount of some of these chemicals (PCDD/F, PBDD/F, PBDE, HBCD) was found to be at the highest level globally when compared against the other studies conducted before this report. This situation reveals that the said chemicals, which are produced during the processing or open burning of the plastic garbage, can enter the food chain.

A wide variety of chemicals are added to plastics during production processes to give them different properties. Some of these chemicals are inherently toxic, also plastics can produce new, and in some cases more toxic, chemicals when burned. For example, the burning process of highly common plastics called polyvinyl chloride (PVC) is known to produce chlorinated dioxins, furans and biphenyls (coplanar PCBs). Moreover, the combustion of plastics can release other persistent chemicals like polycyclic aromatic hydrocarbons (PAHs) and other toxic substances like certain heavy metals.

Countries importing plastic waste may also be importing a wide range of toxic pollutants, including heavy metals, together with these wastes. Therefore, plastic waste importation is not only a matter of economic activity but also a serious environmental and public health problem. Especially the difficulty of control and the contamination potential makes plastic wastes significantly risky after being imported, especially where the wastes are burned in the open.

[35] Dioxin is a term referring to a large group of chemicals. Dioxins and dioxin-like compounds are classified as persistent organic pollutants, and they are highly toxic with varying levels.

2.1. Toxic chemicals associated with plastics

Certain additive chemicals are used in the manufacturing process of the most commonly encountered plastic package wastes in the areas investigated within this report in order to render them more flexible, add colour, resist degradation, oil-resistant, or sterile. Some of these chemicals are potential chemical pollutants as well. These additives, some of which have been found as chemical pollutants in the environment, can pose a risk where plastics containing such chemicals come into contact with food, although additional regulation of chemical additives often apply for such food contact materials (EC 2004).

Plastic packages can contain many substances used or generated during their production, such as solvent residues, catalysts, impurities, oligomers, or degradation products. Groh et al. (2019) stated that there are 906 chemicals associated with plastic packages and 3377 substances that are likely to be related and reported that, within the scope of Classification, Labeling and Packaging (CLP) legislation issued by the European Chemicals Agency (ECHA) in compliance with United Nations Global Harmonization System, 63 out of 906 chemicals associated with plastic packages are hazardous for human health and 68 of these chemicals are hazardous for the environment. In addition, seven of these chemicals are classified as toxic and fifteen of them are considered endocrine disrupting by the European Union (Groh et al. 2019).

Therefore, the use of plastics as materials in contact with food, and burning them in the open like in the case of Adana poses significant risks for both human health and environmental safety. In addition, if plastics containing these chemicals are included in the recycling system, they can also be released during the recycling processes and when the plastic is used again in goods after being recycled. For example, there is significant evidence that certain types of phthalates, which are used as a plasticizer to add flexibility to plastic, increase the risk of reproductive disorders, allergies, and asthma, and has adverse effects on the neurological development of children (Kim et al., 2011; Robinson and Miller, 2016; Kardaş et al., 2019; Hilisnikova et al., 2021).

Many of the additives in plastics are known to remain in the environment for a long time without decomposition and accumulate in plants and animals, and some of them (e.g. UV-328) belong to the persistent organic pollutants (POPs) group proposed to be regulate under the Stockholm Convention.[36]

In addition, many types of plastics can also contain certain metals and these metals can be released when the plastics are burned in the open and potentially cause toxic effects by contaminating the local environment.

Therefore, serious public health and environmental safety problems can arise due to the production and consumption of plastics as well as the processing of the wastes generated after the consumption of plastics.

2.1.1. Persistent organic pollutants

Some Persistent Organic Pollutants (POP) can travel long distances due to their semi-volatile properties or attached to a particulate matter. POPs are highly resistant to degradation and tend to stay long-term in the environment, only breaking down slowly. Although some POPs can be generated by natural processes, they are generally produced as a result of human activities. Some of the POPs can be present in different environments and can be transferred between locations of different environments due to their properties (volatility, accumulation, adsorption ability).

Therefore, POPs can move between air and soil, soil and water, and water and air, moving between such mediums in a cycle. This is the reason why these pollutants can be found even in the farthest ecosystems, such as the poles. The ability of POPs to remain with little degradation for years can cause them to accumulate in the environment. They can also accumulate in human tissues through the food chain or direct exposure leading to various health effects.

Annex C of the Stockholm Convention lists following POPs that are unintentionally released (UNEP/BRS/2018/1/Rev.1).[37]

- **Hexachlorobutadiene (HCBD),**
- **Pentachlorobenzene (PeCB),**
- **Polychlorinated biphenyls (PCB)**
- **Polychlorinated dibenzo-dioxins/furans (PCDD/F),**
- **Polychlorinated naphthalenes.**

Some POP emissions caused by open burning practices of waste, including plastics, and their impact on health are presented in Table 2.1 as reported by Wiedinmyer et al. (2014).

[36] Turkey signed the Stockholm Convention in 2001 and accepted it in 2009. It is a convention on Persistent Organic Pollutants prepared by the United Nations Environment Program-UNEP and imposes prohibition and limitation on the use of substances that have adverse effects on the environment and human health with their persistent characteristics.

[37] http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP-CONVTEXT-2021.English.pdf

Table 2.1 Some POP emissions caused by open burning practices of waste and their impact on health

Pollutant	Estimated global emission due to open waste burning practices (tonnes/year)	Percentage of total global pollutant emissions	Potential health impacts
PAHs	334000	39	• Skin, bladder and lung cancer • Poor cognitive development
PCBs	123	-	• Lymphoma • Leukemia • Lung cancer • Reproductive disorders • Neurodevelopmental problems • Growth disorders
PCDD/Fs	0.206		
PBDD/Fs	0.08		

In this study, PAHs, PCBs, and PCDD/Fs from the above list of persistent organic pollutants were examined.

a. Polycyclic aromatic hydrocarbons (PAH)

PAHs have semi-volatile properties and are produced by incomplete combustion of organic matter. Although there are many sources of PAHs, they can be divided into natural and anthropogenic origins. Wild forest fires and volcanic eruptions are the leading natural sources of PAHs. These sources can be considered relatively small when compared against the significant amount of PAHs produced as a result of human activities (Gulcicek 2011). PAHs from an anthropogenic origin are produced as a result of several activities: incomplete combustion of organic matters during industrial activities, household heating, and energy production, fossil fuel usage for motor vehicles, disposal of plastics *via* burning or pyrolysis practices (Masih and Tanaja, 2006). Some PAHs can have carcinogenic and tumorigenic effects, in addition, some PAHs also have the potential to disrupt the endocrine system. Some PAHs are known to have a direct association with many types of cancer and are thought to cause permanent damage to the genetic structure (EFSA, 2008; EC, 2006; Zelinkova and Wenzl, 2015). Carcinogenicity of the PAHs examined in this study is presented in Table 2.2 according to a report prepared by the European Commission (Lerda 2011) in consideration of carcinogenicity levels of PAHs, where they are grouped in compliance with the International Agency for Research on Cancer (IARC) criteria.

Table 2.2 Human carcinogenicity classes of PAHs according to IARC Crieria

Group	PAHs included	Carcinogenicity levels
1 (G1)	Benzo[a]pyrene	Causes carcinogenic effects in case of exposure
2A (G2A)	Dibenzo(a,h)anthracene	Potentially carcinogenic in case of exposure
2B (G2B)	Naphthalene, Benzo(a)anthracene, Chrysene, Benzo(b/j)fluoranthene, Benzo(k)fluoranthene and Indeno(1,2,3-cd)pyrene	There is a possibility of causing carcinogenic effects in case of exposure
3 (G3)	Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene and Benzo(ghi)perylene	May not be likely to cause carcinogenic effects in case of exposure

In this study, 16 PAHs, which have been designated by the Environmental Protection Agency (EPA) as High Priority Pollutants, were investigated.

.b. Polychlorinated biphenyls (PCB)

There are 209 individual PCBs, although they have often been used as commercial formulations consisting of complex mixtures of PCBs that differ in their level of chlorination. The main sources of PCBs in natural environments include industrial activities like plastics, paper, iron, steel, and aluminum manufacturing industries, and electronic equipment (capacitor and transformers) manufacturing industry (Dedrick et al. 1987; Safe 1989). Incineration and recycling of plastic waste is also an important source of PCBs (Solorzano-Ochoa et al. 2012). Landfills can also be considered a source of PCBs, whether they are regular, irregular, or illegal (Melnyk et al., 2012). As PCBs have high toxicity, serious legal regulations are required to prevent human exposure (Quinete et al. 2014). Consumption of food and beverage contaminated with PCB, being in locations containing PCB that may result in inhalation, ingestion of or skin contact with PCB can cause serious impacts. The most common ways of PCB exposure include food, topsoil, potable and underground water, indoors, and workplaces (Faroon and Ruiz, 2016; Ivanciuc et al., 2006; Patandin et al., 1999; U.S.EPA, 2012). PCBs accumulate in adipose tissues of the body (Jackson et al., 2017; Park et al., 2007). This means that infants are in the highest risk group in terms of PCB exposure (Darwill et al., 2000). PCBs are known to disrupt the endocrine system of the body by mimicking hormones, causing adverse effects on the reproductive system (Mortensen et al., 2007). Some studies have reported an association between dioxins and PCBs and low sperm quality (Rodprasert et al., 2021). In addition, there is an association between increased PCB in serum and the risk of Endometriosis (chocolate cyst) in women (Prpora et al., 2009). Moreover, children of women exposed to high PCBs levels are found to have lower birth weight and demonstrate various behavioral disorders in comparison to children born to women exposed to far less PCBs levels.[38] It is known that PCBs can be transferred to the fetus via the placenta, and to newborn children via breast milk. Therefore, the impact of PCBs exposure on human health can continue for generations (EPA, 1999).

The impacts of PCBs on human health are not limited to those mentioned above. Human health studies reported the following (ATSDR 2000; Denham et al., 2005; De Roos et al., 2005; Faroon and Ruiz, 2016; Rylander et al., 2005; Rignell-hydbom et al. 2007; Vasiliu et al. 2006) health issues associated with PCBs:

1) Reproductive function can be impaired by high levels of PCB exposure;

2) Neurobehavioral and developmental disorders occur in newborn babies exposed to PCBs *in utero*, and long-term effects continue to develop up to school ag;.

[38] https://www.atsdr.cdc.gov/toxfaqs/tfacts17.pdf

3) High levels of PCBs in the blood can cause other systemic effects (e.g. liver injury and diabetes, thyroid and immune system disorders);

4) Exposure to PCB is shown to be associated with increased cancer risk (e.g. non-Hodgkin's lymphoma).

In this study, samples have been investigated for the presence of **18 PCBs including 12 PCBs that have toxicological properties similar to dioxins, hence, they are called dioxin-like PCB.**

c. Polychlorinated dioxins and furans (PCDD/Fs)

The chemicals called polychlorinated dibenzo-p-dioxins/furans (PCDD/Fs) are a group of persistent organic pollutants consisting of a large number of chemicals varying in the level of their chlorination. (Okay et al., 2009). The dioxins came to global attention with the Seveso Disaster in 1976. Thousands of people and living beings died due to the dioxin release as a result of an explosion at a chemical facility located in northern Italy on 10 July 1976 (Time, 2010). These pollutants are unintentional by-products that can be formed during some production processes in the paper, steel and chemical industries, and can also be generated during combustion of chlorinated organic materials including chlorinated plastics. They may be formed as a result of the combustion of coal, wood, and petroleum derivatives, incineration of domestic waste including plastics, and due to the high levels of temperature used for melting processes in iron and steel industries (Ruokojärvi et al. 1995). The processed wood can also release dioxins as by-products if burned. Due to their properties, dioxins tend to accumulate in soil and sediment in higher concentrations compared to other environmental compartments (such as air and water), and can persist for long periods of time. PCDD/Fs may enter the living organisms and accumulate in the adipose tissue. The adverse effects of PCDD/Fs had started to be taken seriously after the observation of toxic effects that the chemical named Agent Orange used in the Vietnam War had on humans, in part due to it being contaminated with PCDD/Fs.[39] The general public could be exposed to dioxins through various roots including through the air, water, and food chain, threatening human health (USEPA, 1994; Alcock et al., 1999; WHO, 1999). One contribution to dioxin releases into the environment is due to the unregulated open burning, or incineration of chlorine-containing plastics.

In general, a major portion of the population is exposed to varying levels of polychlorinated dibenzo-p-dioxins and dibenzofurans through the consumption of food like dairy products, eggs, animal products that are rich in fat, and some species of fish. Wildlife is also exposed to dioxins through their exposure to contaminated soil, water, sediments, and plants. This is how dioxins enter the food chain. In humans, breast milk is a major source of exposure to PCDD/Fs for infants (Lorber and Philips, 2002).

Seventeen different compounds of PCDD/Fs chemical group were analyzed in the samples taken from landfills around which citrus, corn, cotton, soy, and similar agricultural products are grown.

[39] https://en.wikipedia.org/wiki/Agent_Orange

2.1.2. Heavy metals and metalloids

Open burning of waste, including plastics, can lead to the release of various metals and metalloids, including but not limited to, cadmium, chromium, manganese, antimony, arsenic, lead (Cogut, 2016). In addition to gas emissions, open burning of waste creates potential air, water, and soil pollution by causing heavy metal accumulation both in fly ash and bottom ash. The amount and type of the released heavy metals vary significantly depending on the content of the burned waste.

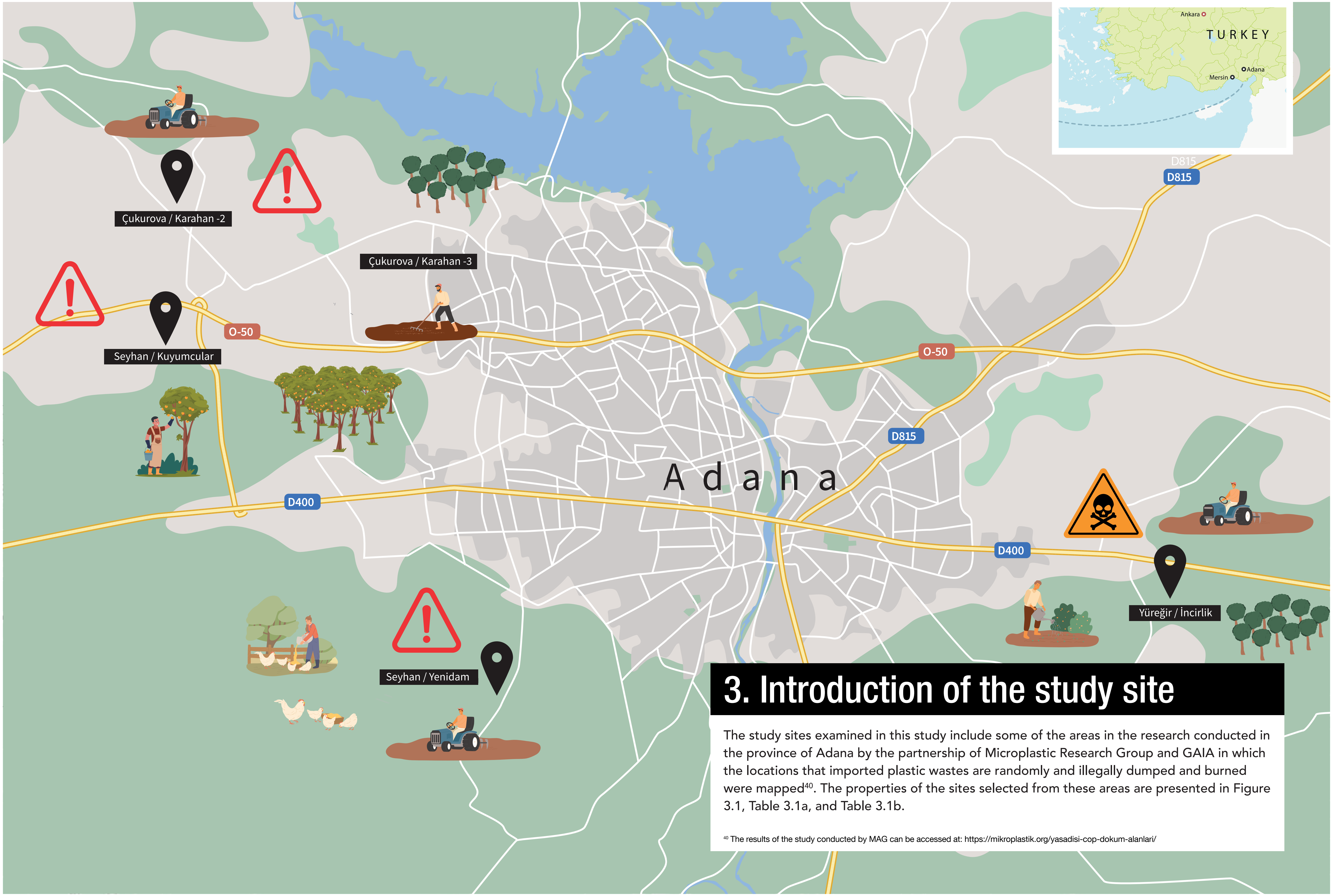
Cadmium and lead are toxic materials that can persist after being released into the environment and accumulate in the body in case of repeated exposure. Lead can cause irreversible damage in the nervous system, including its development in children, and may also affect the circulatory system, kidneys, and reproductive organs (ATSDR 2020). Cadmium is classified as carcinogenic for humans, and extended cadmium exposure can cause damage to the kidneys and bones (ATSDR 2012, IARC). High levels of copper and zinc exposure can cause potential toxic effects, including gastrointestinal disorders (ATSDR 2004, 2005), and even the lowest amount of copper can be toxic for aquatic organisms living in the water contaminated with copper (ATSDR 2004).

As a result, if a living organism intakes metals like zinc and cadmium, those metals remain inside the organism until excreted. However, some metals can be excreted faster while others can accumulate in the body. Metals can be converted into different types that can cause varying levels of toxicity during the time they remain inside the organism. Exposure to heavy metal with the aforementioned properties and its conversion into different forms can lead to severe acute and chronic effects. In some cases, damage caused by exposure to certain types of these metals can be irreversible.

Although heavy metals can be present naturally in the environment, the amounts can be greatly increased due to releases from human activities, especially close to point sources.

Especially paper, petrochemistry, plastic, mining, cement, energy, and many other industries are among those with a significant amount of heavy metal release. In addition, random and unregulated burning of plastic within domestic solid wastes can also cause high amounts of heavy metals to be released into the local environment. Heavy metals can be used during the production processes of plastics, including being used as additives. Therefore, it is possible for them to be released into the environment during the lifetime of the plastic, predominantly during end-of-life treatment involving burning. And their release into the environment can pose a health risk for both humans and other living organisms. In this context, a total of **18 different heavy metals and metalloids** were examined in this study, and their concentrations measured both in the plastics themselves and in soil and ash from the dumpsites.

Figure 3.1



3. Introduction of the study site

The study sites examined in this study include some of the areas in the research conducted in the province of Adana by the partnership of Microplastic Research Group and GAIA in which the locations that imported plastic wastes are randomly and illegally dumped and burned were mapped[40]. The properties of the sites selected from these areas are presented in Figure 3.1, Table 3.1a, and Table 3.1b.

[40] The results of the study conducted by MAG can be accessed at: https://mikroplastik.org/yasadisi-cop-dokum-alanlari/

Table 3.1a Descriptive information of the examined locations

Incirlik, Yüregir

Code	Type	Date	Sample location
TK21029	soil	15/04/2021	within site
TK21030	soil	15/04/2021	within site (different location to TK21029)
TK21031	ash	15/04/2021	within site (as TK21029)
TK21032	ash	15/04/2021	within site (as TK21030)
TK21033	soil-control	15/04/2021	agricultural crop growing land, 0.8 km north west of the site
TK21034	water	15/04/2021	pond within the dumpsite
TK21035	SP	15/04/2021	from material dumped within site

Yenidam, Seyhan

Code	Type	Date	Sample location
TK21005	water	16/04/2021	creek within dumpsite
TK21009	water	16/04/2021	creek (control sample), upstream of site, within industrial area
TK21006	ash	16/04/2021	burning area within site
TK21007	ash	16/04/2021	burning area within site (different to TK21006)
TK21008	soil-control	16/04/2021	agricultural field 1 km east of the site
TK21010	sediment	16/04/2021	creek within dumpsite, as TK21005
TK21011	sediment	16/04/2021	creek within dumpsite, as TK21005

Karahan, Cukurova

Code	Type	Date	Sample location
TK21012	soil-control	15/04/2021	agricultural field 0.7 Km east of Karahan-2, 0.4 Km east of Karahan-3
TK21013	SP	15/04/2021	Karahan-2: From material dumped within site
TK21014	soil	15/04/2021	Karahan-2: within site
TK21015	soil	15/04/2021	Karahan-2: within site (different location to TK21014)
TK21016	ash	15/04/2021	Karahan-2: within site (as TK21014)
TK21017	ash	15/04/2021	Karahan-2: within site (TK21015)
TK21018	SP	15/04/2021	Karahan-3: From material dumped within site
TK21019	ash	15/04/2021	Karahan-3: within site
TK21020	ash	15/04/2021	Karahan-3: within site (different location to TK21019)
TK21021	soil	15/04/2021	Karahan-3: within site (as TK21019)
TK21022	soil	15/04/2021	Karahan-3: within site (as TK21020)

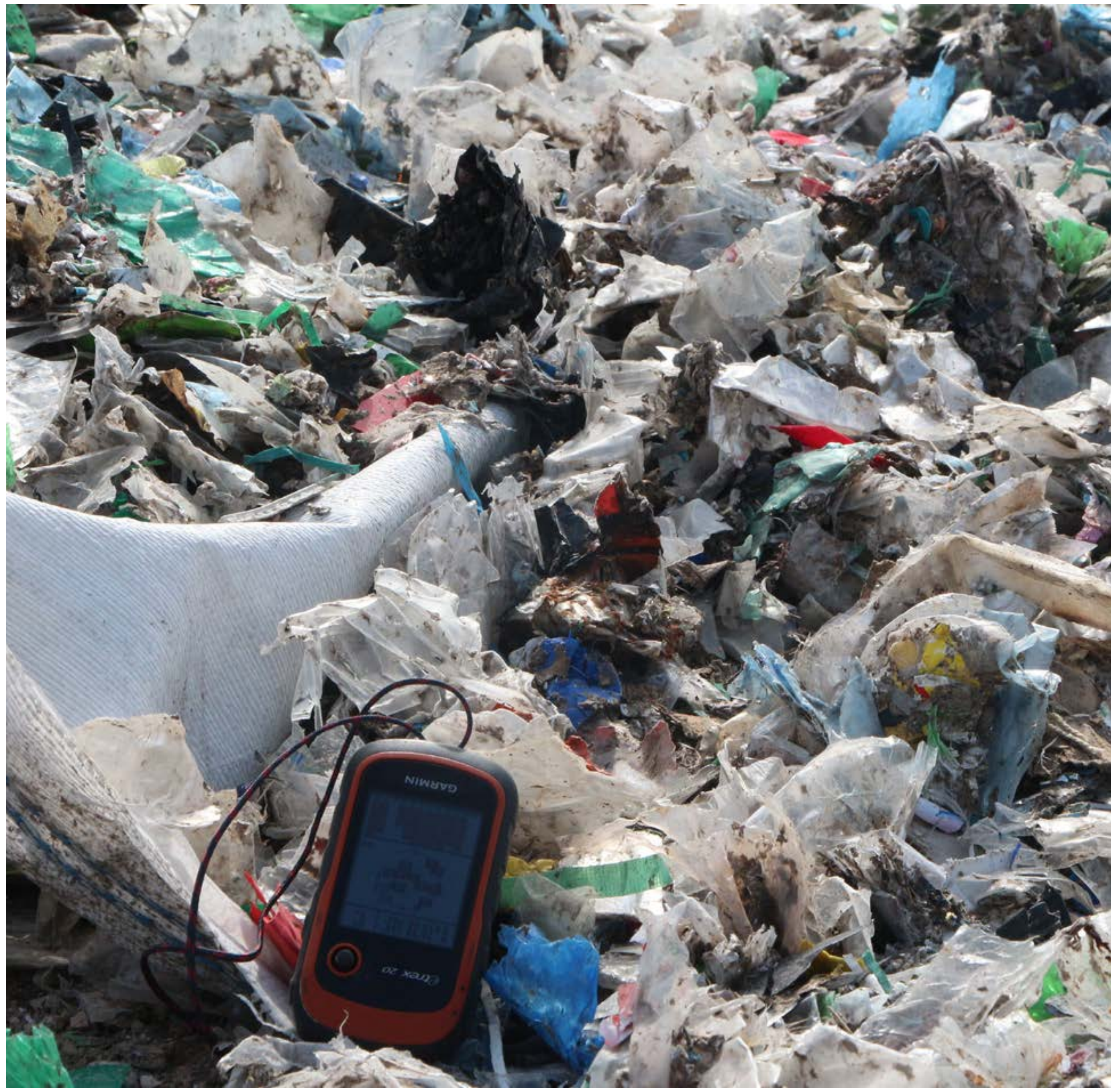
Kuyumcular, Seyhan

Code	Type	Date	Sample location
TK21023	soil	15/04/2021	within site
TK21024	soil	15/04/2021	within site (different location to TK21023)
TK21025	ash	15/04/2021	within site (as TK21023)
TK21026	ash	15/04/2021	within site (as TK21024)
TK21027	soil-control	15/04/2021	agricultural orchard land 0.4 km north east of the site
TK21028	SP	15/04/2021	from material dumped within site

Table 3.1b Coordinates of the examined locations

Site	Location	Sample code	N degree (º)	E degree (º)
Incirlik	Dumpsite	TK21029-32,34,35	36.972347	35.446314
	Control soil	TK21033	36.975852	35.437704
Yenidam	Dumpsite	TK21005-7, 10-11	36.966248	35.263696
	Control soil	TK21008	36.967441	35.274791
	Creek, Control	TK21009	36.981044	35.260326
Karahan	Control soil	TK21012	37.066612	35.194922
	Karahan-2 dumpsite	TK21013-17	37.065278	35.187054
	Karahan-3 dumpsite	TK21018-22	37.066984	35.190625
Kuyumcular	Dumpsite	TK21023-26, 28	37.032868	35.161887
	Control soil	TK21027	37.034283	35.165912

The common characteristics of all these sites are their proximity to agricultural fields and rangelands. The general characteristics of the visited sites are presented below.



Yüreğir/İncirlik

İncirlik dumpsite is within the borders of Yüreğir district and located in the middle of open agricultural fields in the south of Adana-Ceyhan road (E-5). There are peanut and cornfields around the area. In addition, there is an irrigation canal between the area and the E-5 road, and there are animal feed factories around the irrigation canal. The area is also very close to Hacı Sabancı organized industrial site. Following the reports on various news outlets, and the map of dumpsites published by the Microplastic Research Group, a pit was dug on the road leading to the site and vehicle access to the area was prohibited. The area already contains a significant amount of burnt plastic residue. The site is not only used for plastic garbage dumping but also as a dumpsite for other unidentified industrial wastes.

From this location, samples were collected from the soil under the waste dumpsite, from the ash of the burnt materials, and from a pond within the site. A control sample was taken for comparison purposes from a nearby agricultural field that is not affected by the dumping and burning activities. In addition, samples were taken for examination from the shredded plastics from the illegal plastic garbage in the area.

Çukurova/Karahan

Karahan dumpsite is within the borders of Çukurova district and consists of a group of garbage dumpsites around the Kabasakal cemetery to the north of Adana-Karaisalı road. There is also Rüzgarlı Tepe nearby, which is currently being used as an excavation dumping site. There are 3 separate spots within the related area, including Rüzgarlı Tepe, where imported plastic waste is buried. In addition, some of the plastic garbage and the ashes of the burnt materials in the sampling area called Karahan-3 were removed by the municipality. However, the soil surface of the related site remains contaminated. From these locations, samples were taken from 2 separate spots that are still being actively used for dumping and burning of imported plastic waste during the time of sampling. One of these sampling spots still contains high levels of burnt and unburnt imported plastic waste.

From the Karahan location, samples were taken from the soil beneath two different dumping sites together with ash of burnt materials, as well as a soil control sample from an agricultural field that was not affected by dumping and burning activities for comparison purposes. In addition, for each of these two dumpsites, a sample of shredded plastics was taken for examination from the illegal plastic waste.

Seyhan/Kuyumcular

Kuyumcular dumpsite is located at the entrance of Kuyumcular village, close to Karaisalı exit to the south of Adana-Mersin highway, and is surrounded by orange and olive gardens. The area is widely used as a waste dumping site, and the dumped plastic waste is covered with other ash-like industrial wastes, forming a filling that is approximately 2.5 meters in height. In the area, there are high levels of agricultural and animal husbandry activities, and the surrounding settlements are threatened by long-lasting garbage fires. Currently, a significant amount of buried plastic waste is present in the area, and illegal ash dumping activities are ongoing.

Soil and ash samples were taken at this location. The soil sample was taken from the soil below the dumpsite, the ash sample was from the burning materials, and the soil sample was taken from an area within a citrus orchard that was not under the influence of dumping and open burning activities to compare the results.

Seyhan/Yenidam

Yenidam dumpsite is located on a stream/irrigation canal on the road to the Adana Seyhan water treatment plant, on the southeast side of Adana Şakirpaşa Airport. The site is located on Tekel avenue, which leads to agricultural villages extending towards the inner parts of the Çukurova district of Adana. The dumping site extends across the area between the stream and the road, and it is being used as a dumping site for many animal product wastes and other plastic wastes. In addition, metal-containing plastic materials collected for sale by waste collectors are frequently incinerated in the area, and the remaining materials are cleaned by municipal teams from time to time upon complaints from citizens. It is noted that the remaining materials have been dragged into the stream in the past. Waste dumping and incineration activities are also frequently conducted in the area. There are many plastic production and recycling facilities near the area.

Currently, part of the area is being rehabilitated by the General Directorate of State Hydraulic Works, where the stream floor is being covered with concrete and converted into a canal.

In this location, samples were collected from the ashes of burned plastics, and water and sediment samples were taken from the affected stream. For comparison purposes, a soil sample was collected from an agricultural field that is not directly affected by the dumping and burning activities, and a water sample was taken from the upper parts of the stream, upstream of the dumpsite. In addition, a composite sample was taken for examination from the shredded plastics contained in the illegal plastic garbage in 4 different locations within the site.

4. RESULTS

Full details of the analyses and results[41] can be accessed from the analytical report in the **link.**

The analysis of illegally dumped plastic waste

The plastic waste samples collected from dumping and open burning sites located in Çukurova/Karahan, Seyhan/Kuyumcular, and Yüreğir/İncirlik were found to contain various hazardous organic chemicals as well as relatively high concentrations of diverse types of metals and metalloids.

These included various phthalate esters and terephthalic acid esters (plasticizers), chlorinated organophosphates (flame retardants), plastic stabilizing additives including butylated hydroxytoluene (BHT, a type of antioxidant), and plastic precursor chemicals such as benzophenone and styrene as well as some chemicals arising from partial degradation of the chemicals used in plastic production were detected in the collected plastic samples. Phthalate esters examined within the scope of the research, which are generally called "phthalates", were detected widely in all samples. The detected phthalates also included toxic phthalates, such as di-(2-ethylhexyl) phthalate (DEHP) and di-iso-nonyl phthalates (DiNP), which are prohibited especially in children's toys by the EU. DEHP is widely used in various goods made out of polyvinyl chloride (PVC) including medical devices, furniture, cosmetics, and personal care products. DiNP is a plasticizer that has been used in place of DEHP due to its toxic effects on human health, including its effects on the immune and reproductive systems as well as developmental impacts (ATSDR 2019). Both DEHP and DiNP are historically the most commonly used plasticizers involved in the production of soft children's toys (Bouma and Schakel 2001). The use of DEHP and DiNP and four other phthalates (DBP, DiDP, DnOP, and BBP) is prohibited in children's toys within the EU due to their adverse effects on human health (2005/84/EC). DEHP is also classified as a Substance of Very High Concern (SVHC) by the European Chemicals Agency (ECHA 2014) due to its highly disruptive properties. Phthalates can easily spread into the environment since they are not bound to plastic (Fierens et al., 2012). In this study, other related plasticizing chemicals were also detected in the samples of shredded plastic. Among these chemicals, terephthalic acid esters were found in all samples, and isophthalic acid esters were detected in all but one sample (Çukurova/Kuyumcular). In addition, alkyl alcohol 2-ethyl-1-hexanol, a chemical produced by partial degradation of DEHP, was found in all samples (González-Márquez et al. 2019).

Different plastic additive chemicals were found in some of the sites. Two chlorinated organophosphates, which can be used as flame retardants, were found in Çukurova/Karahan-3 location; benzophenone, a UV stabilizer, was found in Çukurova/Karahan-2, and antioxidant BHT was found in Yüreğir/İncirlik region. And other alkyl phenols closely related to BHT were also found in all samples. The details of the organic pollutants within the examined plastic residue are presented in Table 4.1.

[41] Greenpeace Research Laboratories (GRL) Analytical Results 2022-01, Hazardous chemical contaminants in samples of surface water, soil, ash, sediment and waste plastic from waste dumpsites in Turkey, January 2022

Table 4.1 Summary of results of organic compounds identified in shredded plastic samples determined by GC/MS.

Site	Karahan-2	Karahan-3	Kuyumcular	İncirlik
Sample code	TK21013	TK21018	TK21028	TK21035
STATISTICS FOR ISOLATED AND IDENTIFIED COMPOUNDS				
Number of compounds isolated	80	78	65	104
Number of compounds identified to >90%	42	44	41	61
Percentage identified to >90%	53%	56%	63%	59%
NAME OF COMPOUNDS AND GROUPS IDENTIFIED TO >90%				
HALOGENATED COMPOUNDS				
chlorinated organophosphate		2		
PHTHALATE ESTERS & RELATED COMPOUNDS				
di-(2-ethylhexyl) phthalate	1	1	1	1
di-isobutyl phthalate			1	
dinonyl phthalate, linear & branched	2		1	2
Dimethyl phthalate	1	1	1	1
other unidentified phthalates	16	10	19	9
terephthalic acid esters	2	2	2	1
isophthalic acid ester	2	1		

Site	Karahan-2	Karahan-3	Kuyumcular	İncirlik
Sample code	TK21013	TK21018	TK21028	TK21035
NAME OF COMPOUNDS AND GROUPS IDENTIFIED TO >90%				
OTHERS				
polycyclic aromatic hydrocarbons (PAHs)	1	1	1	3
styrene				1
diphenyl methane derivatives	1			
benzophenone / acetophenone	1			1
butylated hydroxytoluene (BHT)		1		1
butylated hydroxytoluene derivative	1	1	1	1
alkyl phenols	3	5	2	2
alkyl alcohols	2	1	1	2
alkyl aldehydes	2	1	1	2
alkyl amide		2		1
ethylene glycol derivative				1
benzoic acid ester derivative		1		
fatty acid ester	6	10	8	14
hydrocarbons		1	2	14
other compounds	1	3		4

Across all three regions where plastic waste was collected, antimony, cadmium, copper, tin, and zinc were generally found in significant concentrations within the plastic samples. Although to a lesser extent, the concentrations of lead and molybdenum were also relatively high. However, the copper and lead concentrations detected in the plastic wastes taken from the Çukurova/Karahan-2 site were significantly low in comparison to the other samples. In general, the concentrations of these metals and metalloids were lower than those found in the samples of shredded plastic waste examined in a study conducted within similar dumpsites in Malaysia (GRL 2019). The cadmium concentrations, which are found in very low concentrations (below 1 mg/kg) in the environment under normal conditions, were found to be significantly higher (up to 18 mg/kg in Çukurova/Karahan-3) despite being lower than other metals (Alloway 1990, ATSDR 2012). The concentrations of antimony and tin are similarly low in the environment under normal conditions (typically lower than 2 mg/kg and 10 mg/kg, respectively, in uncontaminated soil) therefore they were also found in significantly high concentrations within the plastic wastes.

Although the samples examined consisted of different types of plastic pieces, the concentrations for each metal/metalloid detected in three separate sub-samples taken from each sample were similar. However, there were some noteworthy exceptions for all sites. For example, one of the three sub-samples of shredded plastics collected İncirlik site and analyzed contained significantly higher concentrations of copper (2030 mg/kg) in comparison to the other two sub-samples collected from the same mix plastic. Similar situations were also true for zinc in Seyhan/Kuyumcular and tin in Çukurova/Karahan site. These results reveal that, despite mechanical spalling, the concentrations of individual metals or metalloids can vary significantly across different sections of the dumped plastic, and even between sub-samples collected from a small area of the total plastic waste deposition within the whole site. A wide variety of metals and metalloids, including those identified in the plastic samples analyzed in this study, are known to originate from various types of plastics, polymer production processes and from their intentional use as additives like filling materials, stabilizers, pigments, or flame retardants in plastic formulations (Hahladakis et al. 2018, Jaffe and East 2007, Matthews 1996).

It is known that metals and metalloids, including the metals examined in this study, cause various environmental and health problems. For example, cadmium and lead are toxic materials that can persist after being released into the environment and accumulate in the body in case of repeated exposure. Lead can cause irreversible damage in the nervous system, including its development in children, and may also affect the circulatory system, kidneys, and reproductive organs (ATSDR 2020). Cadmium is classified as carcinogenic for humans, and extended cadmium exposure can cause damage to the kidneys and bones (ATSDR 2012, IARC 2012). High levels of copper and zinc exposure can cause potential toxic effects, including gastrointestinal disorders (ATSDR 2004, 2005), and copper can be toxic for aquatic organisms living in the surface water contaminated with even very low amounts of copper (ATSDR 2004).

The metals and metalloids in the plastic tend to remain in the ash residue when plastic waste is incinerated, but some can also escape into the atmosphere. During the combustion process, metal and metalloid compounds can transform into different chemical forms that are generally more mobile in the environment in comparison to the original compounds in the plastics. As a result, these compounds can pollute the soil beneath by leaking out from the ashes, and can be spread to wider areas as the ashes travel via wind, rain, as well as human and animal activity.

While many of the organic chemicals inside the plastics can be destroyed through incineration at lower temperatures, some of them can contribute to the formation of new compounds that have highly hazardous properties. The presence of chlorine source within the plastic or the additives, this can generate new chlorinated compounds such as chlorinated dioxins and furans, or PCBs.

Soil and Ash Analyses

Organic Chemical Pollutants

A large number of hazardous organic pollutants were identified in ash and underlying soil samples at all sampling locations, especially in the Yüreğir/İncirlik site (the list of isolated chemicals can be found in Table 4.2a and 4.2b). These pollutants were different from those contained in the shredded plastics sampled from these sites, indicating that these are compounds that can be produced as a result of mixed plastic waste burning. In particular, the presence of high levels of chlorinated compounds, which can be produced during the burning process of chlorinated materials like polyvinyl chloride (PVC), indicated that a wide range of types of plastic waste was incinerated in the related sites. Certain chemicals originating from open burning practices of plastics, like chlorinated benzenes, were present in every study site, suggesting that these sites are widely used for open burning of mixed plastic wastes (Table 4.2a and 4.2b).

Table 4.2a Summary of results of organic compounds qualitative* analysis in samples determined by GC/MS

Site	Yüreğir/Incirlik			Seyhan/Yenidam		
Sample code	TK21029	TK21031	TK21033	TK21006	TK21008	TK21010
Sample type	soil	ash	soil (control)	ash	soil (control)	sediment
STATISTICS FOR ISOLATED AND IDENTIFIED COMPOUNDS BY QUALITATIVE ANALYSIS						
Number of compounds isolated	242	270	29	233	49	245
Number of compounds identified to >90%	96	98	3	75	11	67
Percentage identified to >90%	40%	36%	10%	32%	22%	27%
NAME OF COMPOUNDS AND GROUPS IDENTIFIED BY QUALITATIVE ANALYSIS >90%						
HALOGENATED COMPOUNDS						
di-to tetrachlorinated benzenes	9	8		5		1
penta- & hexachlorinated benzene	2	2		2		
PCBs (mono- to dichlorinated)	6	2		2		
DDT degradation products (p,p'-DDE)			1		1	
benzenamine, 2,4,6-trichloro-	1					
benzenes, chloroethenyl-	2					
benzene, bromo-	1					
benzene, bromodichloro-	1					
p-terphenyl, 4-chloro-	1					

Site	Yüreğir/Incirlik			Seyhan/Yenidam		
Sample code	TK21029	TK21031	TK21033	TK21006	TK21008	TK21010
Sample type	soil	ash	soil (control)	ash	soil (control)	sediment
NAME OF COMPOUNDS AND GROUPS IDENTIFIED BY QUALITATIVE ANALYSIS >90%						
OTHER GROUPS						
polycyclic aromatic hydrocarbons (PAHs) and derivatives	13	6	2	6	3	5
terpenes, terpenoids & their derivatives						4
biphenyl & its derivatives	3	6		4		
terphenyl and its derivatives	5	2		4		
quaterphenyl & its derivatives	2			2		
styrene	1					
other aromatic hydrocarbons		1		1		1
1H-indole & its derivatives						1
1H-indene derivatives	1	2		2		
alkylated benzenes	11	18		9		22
aliphatic hydrocarbons	32	49		34	6	26
furans & benzofurans	3			3		
butylated hydroxytoluene (BHT)						1
alkyl thiols						1
steroids and precursors					1	2

* The aim of qualitative analysis is to identify the name of a compound. In case there were several compounds identified that belong to the same chemical group, the name of the group is presented indicating the number of compounds detected.

Table 4.2b Summary of results of organic compounds qualitative* analysis in samples determined by GC/MS.

Site	Karahan	Karahan-2			Karahan-3		Kuyumcular		
Sample code	TK21012	TK21014	TK21015	TK21016	TK21019	TK21021	TK21023	TK21025	TK21027
Sample type	soil (con)	soil	soil	ash	ash	soil	soil	ash	soil (con)
STATISTICS FOR ISOLATED AND IDENTIFIED COMPOUNDS									
Number of compounds isolated	49	165	29	273	295	122	14	255	80
Number of compounds identified to >90%	22	35	27	90	73	39	11	55	4
Percentage identified to >90%	45%	21%	93%	33%	25%	32%	79%	22%	5%
NAME OF COMPOUNDS AND GROUPS IDENTIFIED TO >90%									
HALOGENATED COMPOUNDS									
di- to tetrachlorinated benzenes		3	5	3	5	8	5	4	
Penta- and hexachlorinated benzene		1	2			2	1		
OTHER GROUPS									
polycyclic aromatic hydrocarbons (PAHs) and derivatives		5	3	21	2	7	3	2	
terpenes, terpenoids & their derivatives	1		2						
biphenyl & derivatives		1	1	5	1	1		2	
terphenyl and derivatives		1		4	1	1	1	1	
styrene						1			
other aromatic hydrocarbons		2	1	1		1			
1H-indole & derivatives			1	1					
1H-indene derivatives				1					
alkylated benzenes				15	10	1	1	16	
aliphatic hydrocarbons	20	20	11	37	54	15		30	3
furans & benzofurans						1			
steroids and precursors	1					1			
Other compounds		2	1	2					1

* The aim of qualitative analysis is to identify the name of a compound. In case there were several compounds identified that belong to the same chemical group, the name of the group is presented indicating the number of compounds detected.

Table 4.3

Pollutant organic chemicals whose concentrations were examined in all locations within the scope of the study

PAHs

Naphthalene	Fluoranthene	Benzo(a)pyrene
Acenaphthalene	Pyrene	Dibenzo(a,h)anthracene
Acenaphthene	Benzo(a)anthracene	Indeno(1,2,3-cd)pyrene
Fluorene	Chrysene	Benzo(ghi)perylene
Phenanthrene	Benzo(b/j)fluoranthene	
Anthracene	Benzo(k)fluoranthene	

Dioxin and Furans

2,3,7,8-TetraCDD	2,3,4,7,8-PentaCDF	Sum PentaCDD
1,2,3,7,8-PentaCDD	1,2,3,4,7,8-HexaCDF	Sum HexaCDD
1,2,3,4,7,8-HexaCDD	1,2,3,6,7,8-HexaCDF	Sum HeptaCDD
1,2,3,6,7,8-HexaCDD	1,2,3,7,8,9-HexaCDF	OctaCDD
1,2,3,7,8,9-HexaCDD	2,3,4,6,7,8-HexaCDF	Sum TetraCDF
1,2,3,4,6,7,8-HeptaCDD	1,2,3,4,6,7,8-HeptaCDF	Sum PentaCDF
OctaCDD	1,2,3,4,7,8,9-HeptaCDF	Sum HexaCDF
2,3,7,8-TetraCDF	OctaCDF	Sum HeptaCDF
1,2,3,7,8-PentaCDF	Sum TetraCDD	OctaCDF

Polychlorinated biphenyls

PCB 77	PCB 126	PCB 28
PCB 81	PCB 156	PCB 52
PCB 105	PCB 157	PCB 101
PCB 114	PCB 167	PCB 138
PCB 118	PCB 169	PCB 153
PCB 123	PCB 189	PCB 180

In this study, chlorinated benzenes (from di- to hexachlorinated) were identified in numerous samples. Hexachlorobenzene, one of these chemicals, could be formed during the combustion of chlorine-containing materials like PVC (EEA 2005) or during the disposal of PCBs (Ahling & Lindskof 1978) and is released into the environment. Chlorinated benzenes have various hazardous properties for human health and the environment (ATSDR 2006, 2014, 2015). Hexachlorobenzene (HCB), detected in all stations except Seyhan/Kuyumcular site, is a persistent chemical that can bioaccumulate in the food chain and is toxic to a wide variety of organisms, including humans. These chemicals are listed as persistent organic pollutants by many international conventions (Stockholm Convention 2019; EEA 2021). Biphenyl, triphenyl, and quaternary phenyl derivatives as well as other aromatic hydrocarbons including alkylated benzenes were also detected in almost every site, especially in the samples of ash. Some of these chemicals are among those that could be released during the burning of two types of plastics (PE and PET) (Tomsej et al., 2018). The observations conducted on-site revealed that both types of plastic are commonly found among the imported waste.

Both ash and soil samples collected from the Yüreğir/İncirlik site had a wide range of organic chemicals. Among the samples collected from all study sites, the highest number of organic chemicals was determined there. The highest number of chlorinated benzenes in both ash and soil samples was determined at this station. In the ash sample collected from Seyhan/Yenidam station, many chlorinated benzene specimens (including penta- and hexachlorobenzene), various mixtures of aromatic hydrocarbons (PAHs, biphenyl, triphenyl, and quaterphenyl derivatives, and a number of alkylated benzenes), and a number of long-chain aliphatic hydrocarbons were detected (no soil sample was collected from Yenidam study site). Similar to the other study sites, the soil samples collected from both Çukurova/Karahan-2 and Çukurova/Karahan-3 locations contained a wide variety of chemicals including chlorinated benzenes (including penta- and hexachlorobenzene), aromatic and long-chain aliphatic hydrocarbons. However, unlike the Yüreğir/İncirlik and Seyhan/Yenidam sites, only a few biphenyl and triphenyl compounds were identified and no quaterphenyl compounds were found. Furthermore, styrene, which is a product of incomplete combustion of polystyrene, was found in the soil sample collected from the Seyhan/Karahan-3 study site. The range of the organic chemicals identified in the soil sample collected from Seyhan/Kuyumcular study site was similar to that of those found in Seyhan/Karahan site, except for some aliphatic hydrocarbons.

Persistent Organic Pollutants

The list of the persistent organic pollutants from the sites examined during the study is presented in Table 4.3. All of these persistent organic pollutants were investigated in the samples of ash and soil collected from Çukurova/Karahan (1 and 2), Seyhan/Kuyumcular, and Yüreğir/İncirlik study sites. In addition, all relevant POPs were investigated in ash and control soil samples collected from the Seyhan/Yenidam location. The locations of the samples where hazardous chemicals are analyzed may vary. Detailed results of which analyzes were made from which sample taken from which location are given in the relevant sections of the report.

The values of the investigated chemicals are presented in µg/kg and ng/kg (1000 ng/kg = 1 µg/kg), and the dry weights for soil and sediments were taken into consideration. The obtained values were then compared with the results of the samples collected from the control locations where no garbage dumping took place. Thereby, the chemical profile of the study sites arising from different activities or natural processes has been determined independently from dumping and burning practices, and it has been attempted to understand what sort of change that the waste dumping activities cause in relation to the amount of these chemicals.

4.1.2. Polycyclic aromatic hydrocarbons (PAH)

Within the scope of this study, 16 PAHs (Table 4.3), which are considered priority pollutants by the United States Environmental Protection Agency (US-EPA), were investigated. The obtained results were compared with the control samples collected from the related sites and presented in Table 4.4. As can be seen in Figure 4.1 and Table 4.4, the total amount of 16 PAHs detected in both ash and soil samples collected from all study sites was significantly higher than the control samples of soil. The amount of benzo(a)pyrene was found to be significantly high in all sites. In addition, the widespread presence of all PAH types in ash samples reveals that the areas where plastic waste is burned are at significant risk of pollution by PAHs. Benzo(a)pyrene, benzo(b) fluoranthene, and dibenzo(a,h)anthracene measurements conducted within the scope of the study were compared against the generic values (in mg/kg) specified in 08.06.2010 dated “Regulation regarding point source land pollution and soil contamination control” (TKKY, 2010). To better understand the obtained results, the values that are found in the soil samples collected from the dumping sites within this study were also compared with the control soil samples taken from unpolluted areas.

Although the limit values specified in TKKY regulation are high, the benzo(a)pyrene concentrations, particularly those contained in the ash samples collected from Karahan-2 and Yüreğir/İncirlik locations, were found to be significantly higher than the limits in TKKY, which are stated to be hazardous in case of soil ingestion and absorption through skin contact, or risk groundwater contamination (Figure 4.2). The ash sample collected from the Karahan-2 station was found to be 6 and 3.6 times these two limit values, respectively, and the ash sample collected from Yüreğir was found to be 2.3 and 1.4 times the limit values, respectively. Benzo(a)pyrene has been defined as a Group 1 carcinogen by the IARC and it is known that it can cause carcinogenic effects even at low levels of exposure. Therefore, such high levels of benzo(a)pyrene have the potential to cause serious risks for human health in the relevant sites and their nearby areas.

Similarly, the concentration of benzo(b)fluoranthene found in the ash sample from the Yenidam location was 1.2 times the limit related to soil ingestion and absorption through skin contact in TKKY, and the concentration of dibenzo(a,h)anthracene found in the ash sample from Karahan-2 location was found to be 1.3 times of this limit.

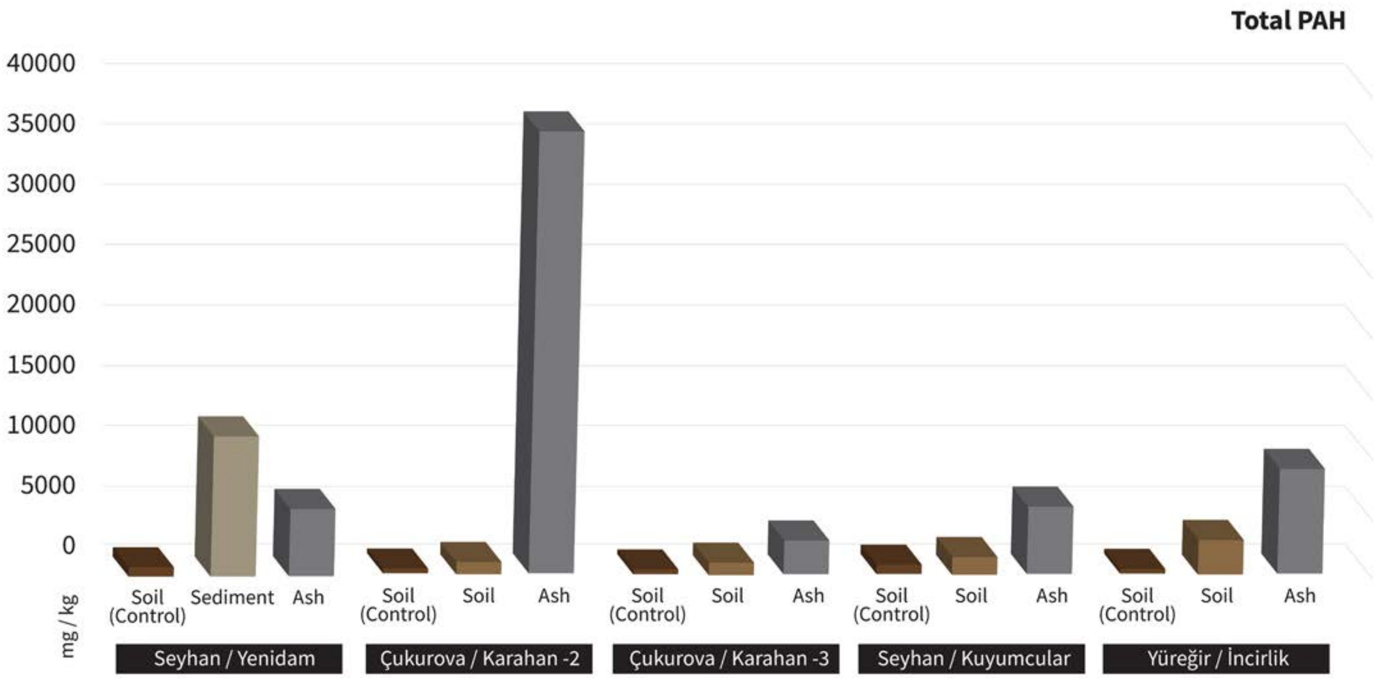


Figure 4.1. Distribution of sum of 16 PAHs, which are considered highly toxic by EPA, according to stations and location of soil samples taken for control purposes.

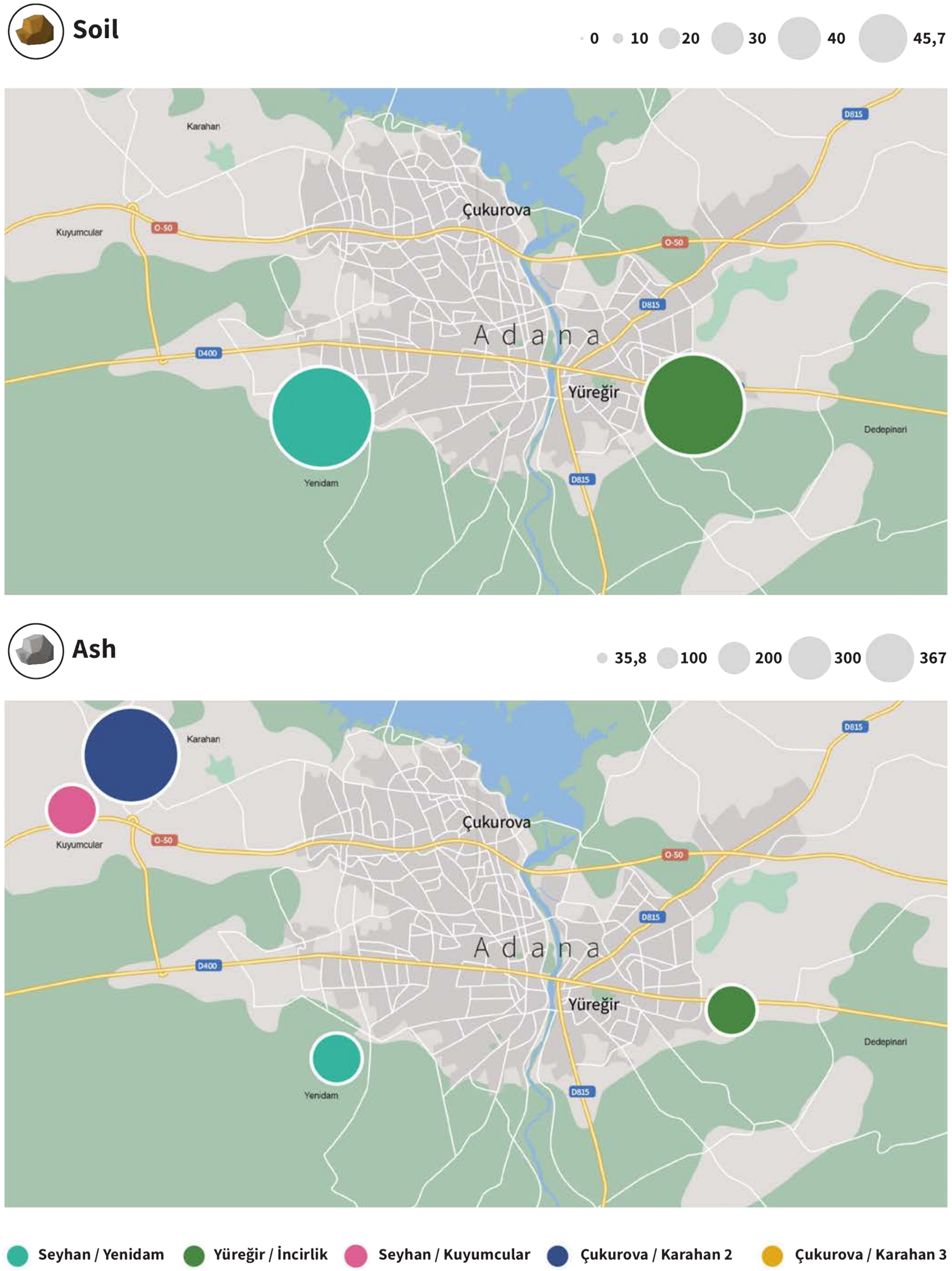


Figure 4.2. Amounts of Benzo(a)pyrene, a carcinogen classified as Group 1, in soil and ash samples. Size legends indicate benzo(a)pyrene concentration.

Table 4.4 The total concentration of all PAHs within each class was detected in soil and ash samples collected from all locations according to IUCR carcinogenicity classification (μg/kg dw). nd: not detected. Results for Seyhan/Yenidam represent concentration of PAHs found in sediment samples

Sample type	IUCR Class	Çukurova/ Karahan-2	Çukurova/ Karahan-3	Seyhan/ Kuyumcular	Seyhan/ Yenidam	Yüreğir/ İncirlik
Soil	G1	nd	nd	nd	46	43
	G2A	nd	nd	nd	nd	14
	G2B	186	119	195	10,961	1,385
	G3	81	120	127	848	1,833
	NA	nd	nd	13	20	10
Ash	G1	367	36	77	62	139
	G2A	75	12	15	25	35
	G2B	23.925	1.527	2.578	2.693	4.160
	G3	11.732	1.285	3.189	2.869	5.376
	NA	1.620	70	155	142	223

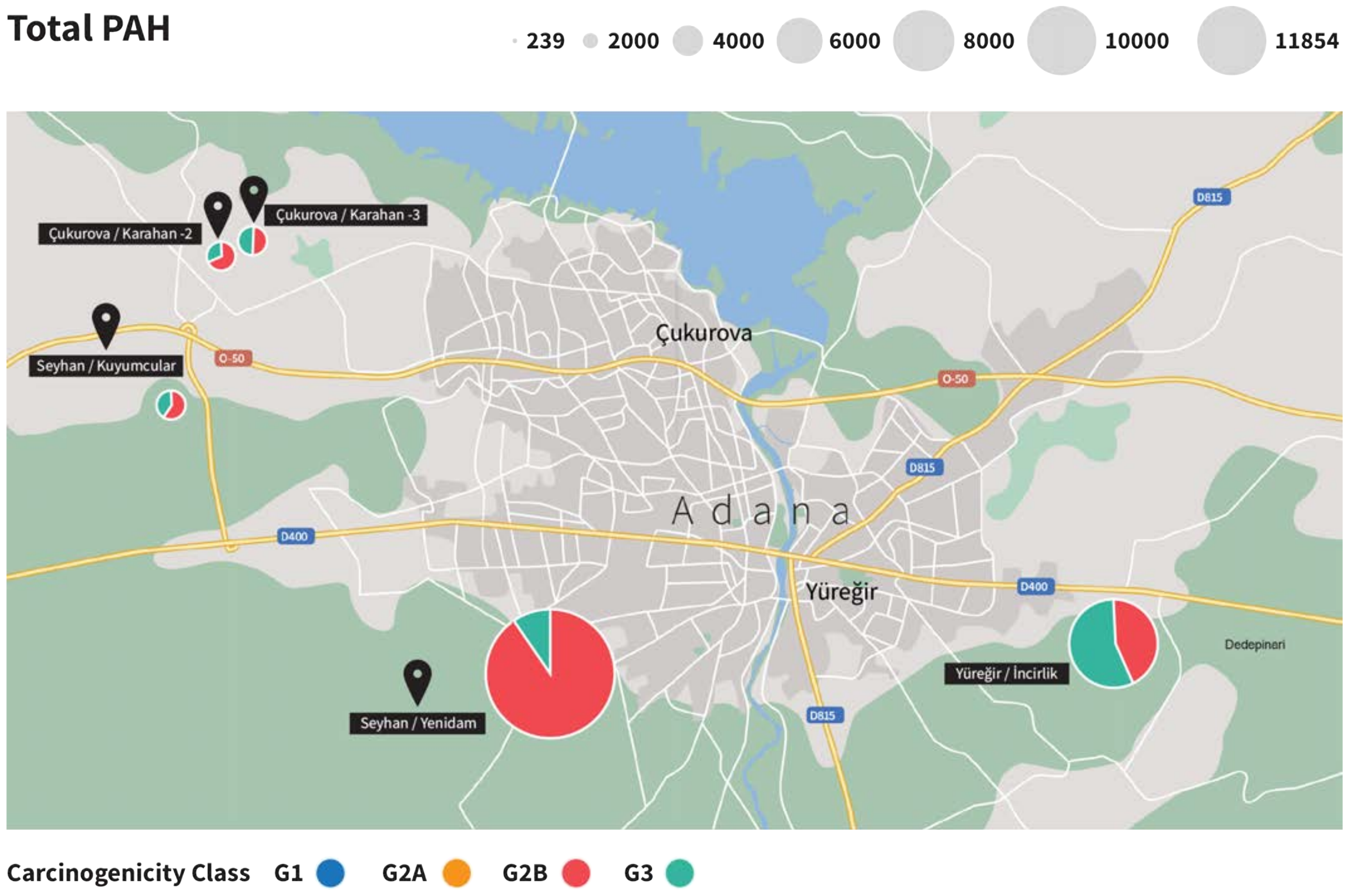


Figure 4.3. PAH levels based on their carcinogenicity levels and related totals found in soil/sediment samples. The size of the circles reflect the total amount of PAH, and the colors represents different IUCR carcinogenicity classes.

The examination of total PAH amounts showed that the relevant amounts are between 2 and 10 times higher in both ash and polluted soil in comparison to the control soil samples. When compared against previous studies about PAH amounts in soil from different locations, these values found in this study are significantly higher. In a study conducted by Çetin et al. (2017) in İstanbul, the average amount of 15 PAHs, which are also examined in this study, was reported to be 684 µg/kg dry soil, Bozlaker et al. (2008) reported 341 µg/kg dry soil for İzmir/Aliağa region, Odabaşı et al. (2010) reported 4192 µg/kg dry soil for the soil affected by an iron-steel factory in Hatay/İskenderun, Gülçiçek (2011) reported 1651 µg/kg dry soil for Kocaeli province, and Çetin (2016) reported 1077 µg/kg dry soil for Kocaeli as well.

In all these concentrations, it should be noted that the studies may demonstrate varying results depending on the distance from the center of the industrial activity and the intensity of the activities, which may be a source of PAH. The values of the related chemicals found in studies conducted in different countries and different regions of Turkey are presented in Table 4.5.

The amounts of PAH detected in different countries and different regions of Turkey (including the current study). Concentrations in this table are just examples from the different countries and they are not average or median values for the countries.

Location	Total of 16 PAH (µg/kg)	Source
China	776	Hong et al. (2020)
Japan	243	
South Korea	55.4	
Vietnam	179	
India	307	
Spain	166	Nadal et al. (2004)
Portugal	112	Augusto et al. (2010)
Poland	25 - 45 (range)	Indeka et al. (2009)
Aliağa/İzmir	338	Bozlaker et al. (2008)
Kocaeli	1651	Gülçiçek (2011)
İstanbul	0 - 203(range)	Kıstaubayeva (2015)
Dilovası/Kocaeli	49 -10512 (range)	Yurdakul et al. (2019)
Adana	10.9 -11900 (range)	This study

Many other researchers (e.g. Hong et al., 2020) previously reported that air temperature can have an effect on the mechanism of PAH accumulation and evaporation (Li et al., 2010). Ambient temperature and PAH distribution in the soil is known to have an inverse relationship. This situation raises the possibility that PAHs, which can evaporate into the air with the temperature rise, can be transported to very long distances via air movements. In particular, PAHs, such as tricyclic phenanthrene, become volatile at high temperatures and may precipitate again at higher altitudes with cooling air. Thus, these polluting chemicals have the potential to mix with irrigation and drinking water as the snow at higher altitudes (e.g. Taurus Mountains) starts to melt with warming weather. As the PAH exchange between air and soil was not investigated, the discussion on the presence of such exchange was out of the scope of this study. However, attention should be paid to such risk and more detailed and seasonal PAH monitoring studies should be conducted.

4.1.3. Polychlorinated biphenyls (PCB)

In this study, 12 different dioxin-like PCBs and 6 non-dioxin-like PCBs were examined. The obtained results are presented in Figure 4.4 and Table 4.4.

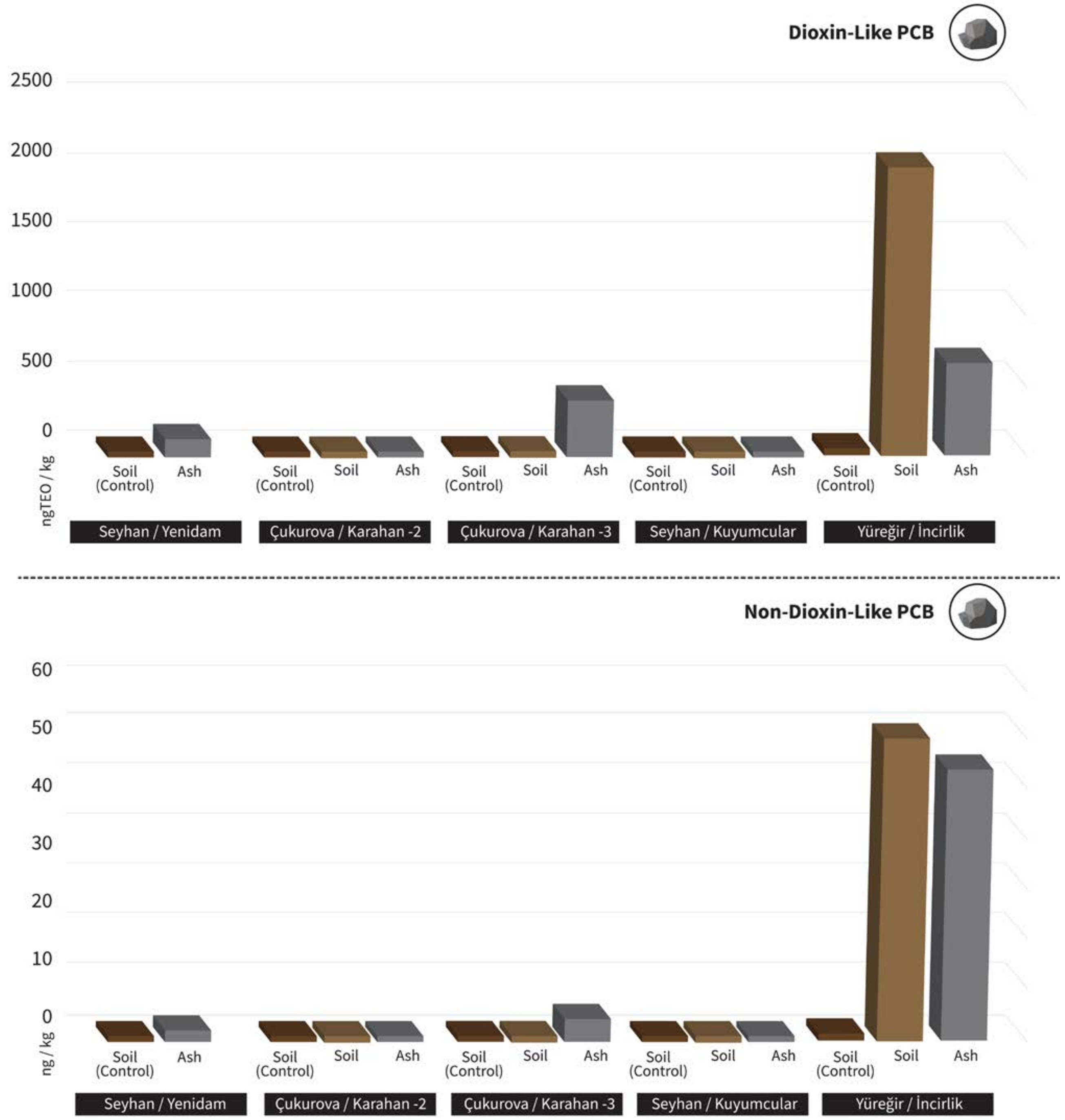


Figure 4.4. The total amount of dioxin-like and non-dioxin-like PCBs in samples of soil (including control) and ash samples according to stations

Table 4.4 **The total amounts of dioxin-like and non-dioxin-like PCBs in samples of soil (including control) and ash samples according to stations. For dioxin-like PCBs, the values are given as toxic equivalency (TEQ) concentrations, obtained after multiplying the amounts of each dioxin-like PCBs with the toxic equivalence coefficient specified in WHO (2005), are given. Values for non-dioxin like PCBs are given in mass concentrations. nd - not detected**

Location	Matrix	Dioxin-like PCB TEQ concentration (ng/kg dw)	Non-dioxin-like PCB concentration (µg/kg)
Seyhan/Yenidam	Control soil	0.000444	nd
	Ash	64.4	1.16
Çukurova/ Karahan-3	Ash	213	2.51
Yüreğir/İncirlik	Soil	2050	50.2
	Ash	650	nd

The total PCB mass concentration measured in the soil collected from the Yüreğir/İncirlik site was found to be almost 30,000 times that of the control soil from the same area. Although they are not directly comparable, total PCB levels present in the ash samples collected from the sampling sites were found to be approximately 1000 times higher than the control soil in the Seyhan/Yenidam location, approximately 7000 times higher in the Yüreğir/İncirlik location and approximately over 3000 times higher than control soil in Çukurova/Karahan-3 site.

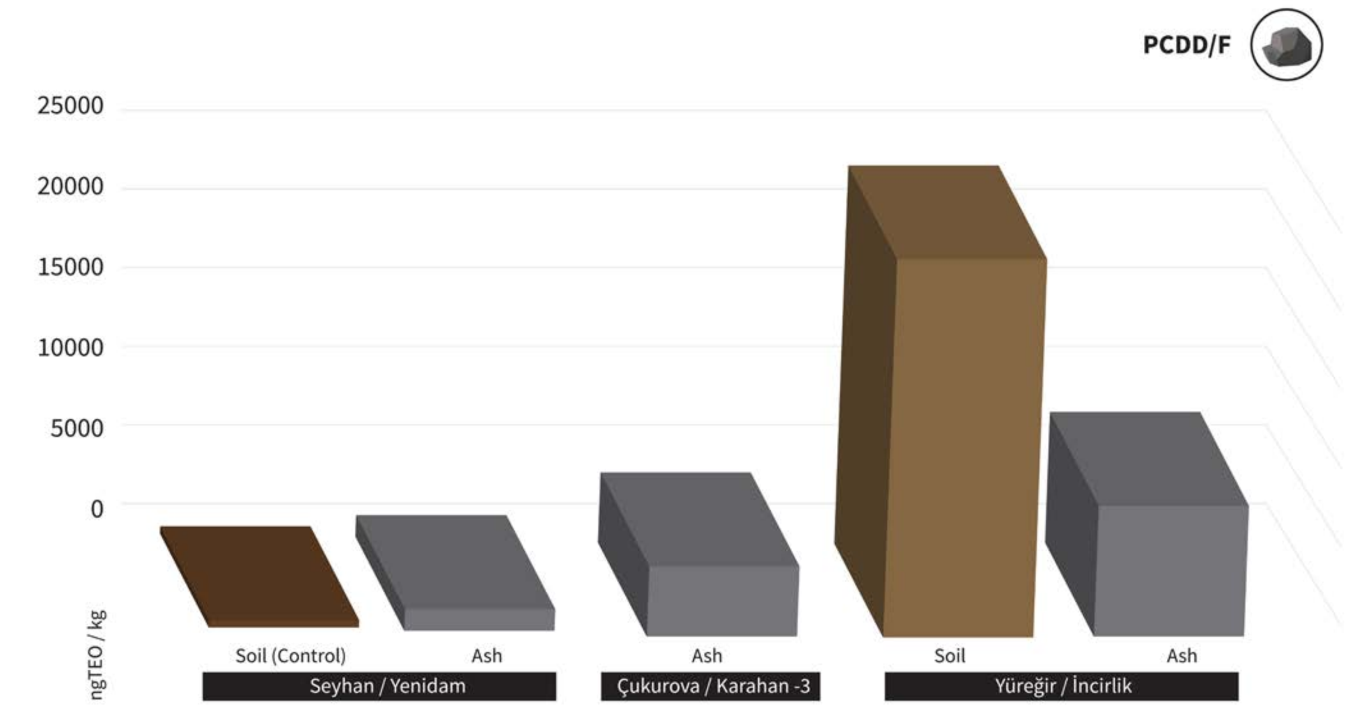
When evaluating concentrations for PCBs and PCDD/Fs, toxic equivalency factors (TEQs) are often used. TEQ concentrations are obtained by multiplying the detected quantities with some coefficients determined for each pollutant by the World Health Organisation (WHO). Based on the evaluation of TEQ values obtained by this method, the highest TEQ values for PCBs were found in the İncirlik location, following the same pattern as seen which is similar to for PCB mass concentrations (Table 4.4). In Turkey, there is no limit regulation specified for TEQ values of PCBs in soil, and there are only a few regulations regarding the concentration of commercial PCB mixtures (PBPTKHY).[42] Therefore, the PCB levels detected in this study were compared with the values obtained from the control soil and with the values obtained from similar studies in the literature. However, taking the composition properties of commercially available PCBs into consideration, a very approximate comparison can be made between the PCB limit values specified for commercial PCBs in Turkey and the values obtained from the present study. This comparison, however, will only be indicative. Therefore, it has been found that the soil and ash samples collected from the İncirlik study site have total PCB levels that are 5.2 and 1.3 times higher, respectively, than the limit values for soil in Turkey assigned for a technical PCBs mixture in terms of potential groundwater pollution. In a study conducted in the İzmir/Aliağa industrial area, the total PCB concentration in the soil, which also contains the PCBs that are investigated in this study as well, was reported to be 44 µg/kg (Bozlaker et al. 2008). In a different study conducted in Hatay-İskenderun, another industrial area in Turkey, the PCB concentration in the soil was reported to be 19 µg/kg (Odabaşı et al., 2010).

One of the possible routes of human exposure to PCBs is a dermal contact with PCBs contaminated soils. In addition, it is highly likely for the pollutants in the soil to be transmitted through the skin to the living organisms that come into contact with the soil. It has been demonstrated in previous studies that the exposure to the PCBs (including skin contacts) can cause various cancer problems. (Man et al. 2013; Man et al., 2011).

[42] https://www.resmigazete.gov.tr/eskiler/2007/12/20071227-3.htm

4.1.4. Dioxins and furans

Within the scope of this study, 17 PCDD/F compounds (commonly referred to as dioxins and furans) were analyzed in the samples taken from dumpsites around which citrus, corn, cotton, soy, and similar agricultural products are grown. The obtained results are presented in Figure 4.5 and Table 4.5.



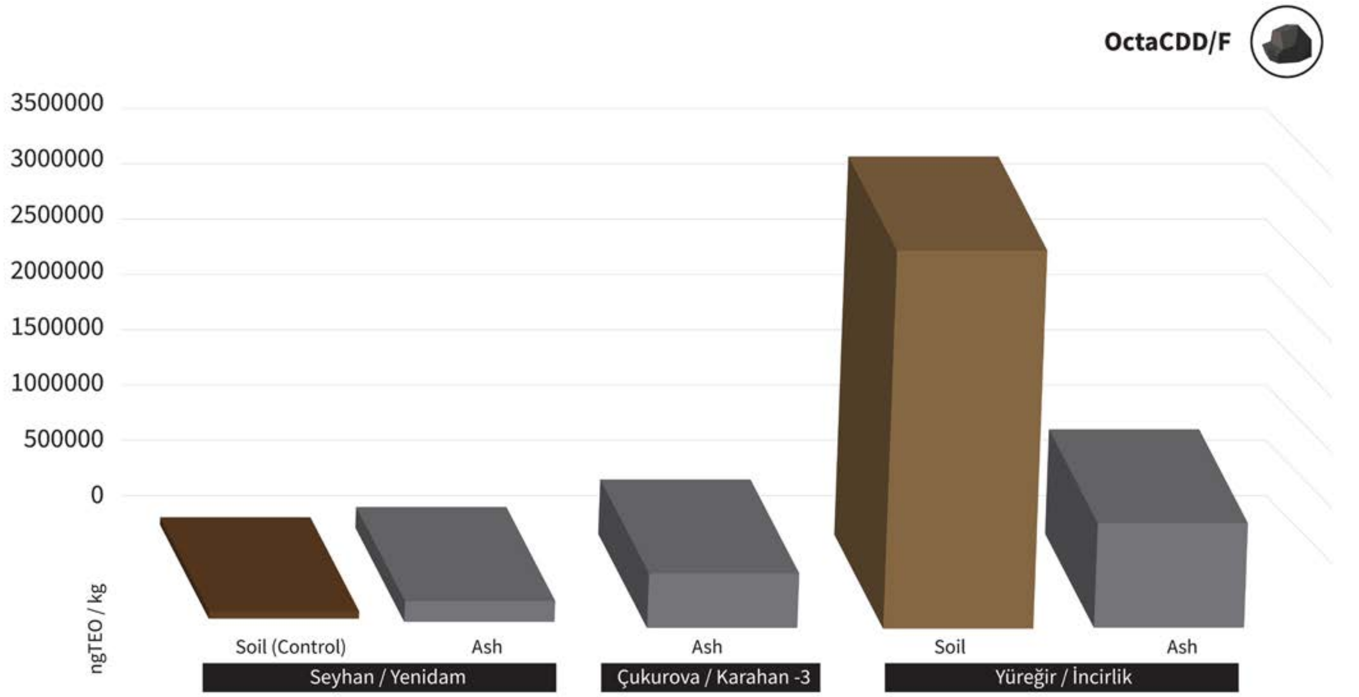


Figure 4.5. The amounts of dioxins and furans in the control soil, soil and ash according to stations

PCDD/Fs are formed during combustion of wastes containing chlorinated organic compounds (e.g., PVC plastics, industrial wastes contaminated with PCBs, pesticides, chlorinated flame retardants, among others). When such wastes are combusted at waste incineration plants, both flue gas and ashes formed during the process may contain significant amounts of PCDD/Fs. Under normal conditions, ash forming at a solid waste incineration plant can contain up to 1000 ng TEQ/kg dioxin and furan (Vehlow and Seifert 2012). If there is an advanced filtration system and incineration unit, this value can be decreased to 100 ng TEQ/kg. However, it can also be as high as 5000 ng TEQ/kg in a plant with a worse filtration system (Vehlow and Seifert 2012). These values are likely to occur in incineration plants that are assumed to be controlled, and it is possible to say that these facilities put considerable effort to achieve the highest possible incineration performance. However, waste burning activities conducted out in the open area are expected to contain less than 1000 ng TEQ/kg dioxins and furans in the ashes (Vehlow and Seifert 2012).

Therefore, based on the values obtained in this study, the amount of PCDD/Fsat concentration of 456 ng TEQ/kg in the ash collected from the Seyhan/Yenidam study site can be described as high in comparison to those reported for wastes' open burning activities. Similarly, PCDD/Fs detected in the ash collected from the Çukurova/Karahan-3 site at concentration of 2910 ng TEQ/kg, are considerably high for open non-industrial waste burning. Moreover, the determination of PCDD/Fs at 8200 ng TEQ/kg in the ash samples collected from the Yüreğir/İncirlik study site may suggest that industrial chlorine-containing wastes were also burned in the area. The highest concentration of PCDD/Fs at 22700 ng TEQ/kg was detected in the soil sample collected from the Yüreğir/İncirlik study site, which indicates an extreme pollution in the area by these toxic chemicals, and this value is approximately 22 times higher than the amount found in the ash formed at an average waste incinerator (Vehlow and Seifert 2012).

In addition, the levels of PCDD/Fs detected in dumpsite samples in the current study were extremely higher than those collected from the corresponding unpolluted areas (e.g., control samples). For example,the soil sample collected from the Yüreğir/İncirlik study site had a TEQ value of approximately 400,000 times higher than the control soil sample. It was also the case for the ash sample from the Seyhan/Yenidam location, with PCDD/Fs TEQ value that was 8000 times higher than the control soil sample at Seyhan/Yenidam, which are though not directly comparable due to a difference in a matrix, but still indicative of the considerable contamination.

The profile of individual PCDD/Fs, in particular, hepta- and octachlorodioxins were found to be the most dominant congeners in this group of pollutants, indicating that they originate from similar sources.

In Turkey, there is no limit regulation based on TEQ for dioxins and furans in terms of soil pollution. The only dioxin specified in the regulation in Turkey is for one specific PCDD, 2,3,7,8-tetrachlorodibenzodioxin (2,3,7,8-TCDD) which has the highest TEQ factor, and the limit values are determined as 4 μg/kg and 2 μg/kg for soil ingestion and skin contact and for transport of pollutants to groundwater, respectively. In comparison to the values determined in the present study, all four ash and soil samples analyzed for 2,3,7,8-TCDD (among other dioxin congeners) (Seyhan/Yenidam ash sample, Çukurova/Karahan-3 ash sample, Yüreğir/İncirlik soil and ash samples) were found to be higher than these concentration limits for this compound in soil as set in the regulation. The concentration of 2,3,7,8-TCDD (1050 μg/kg) measured in a soil sample collected from Yüreğir/İncirlik study site was found to be 260 and 525 times higher, respectively, than these regulatory limits set for ingestion/skin contact and potential groundwater pollution. The amount of Dioxin/Furan detected in this study has been determined to be one of the highest among the measurements made and published in Turkey so far (Bakoglu et al., 2005; Okay et al., 2009; Aslan et al., 2010; Kilic et al., 2011; Karademir. et al., 2013).

Table 4.5

The amounts of dioxins and furans (PCDD/Fs) in the control soil, and in soil ash from dumpsites according to location. The toxic equivalency factor (TEQ), obtained after multiplying the amount of each compound with its toxic equivalence coefficients specified in WHO (2005), are given.

Location	Matrix	PCDD/Fs TEQ concentration (ng/kg dw)
Seyhan/Yenidam	Control soil	0.0591
	Ash	455
Çukurova/ Karahan-3	Ash	2890
Yüreğir/İncirlik	Soil	22600
	Ash	8180

4.1.5. Metals and Metalloids

For all sites, relatively high concentrations of a wide range of metals and metalloids were found in samples of ash and soil. Although differences were found between sites, a broadly similar pattern of contamination was common to all sites, with elevated levels of antimony, cadmium, copper, tin, zinc, lead, and molybdenum commonly found. This is the same range of metals and metalloids found at relatively high concentrations within the plastic wastes collected from these sites.

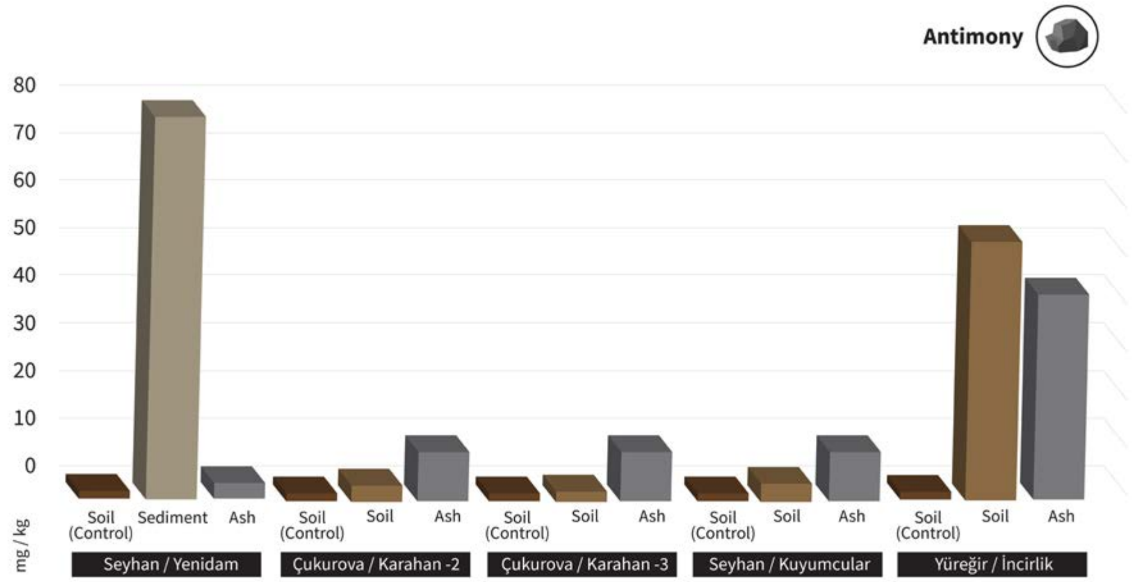
The heavy metal and metalloid values obtained from the soil and ash samples collected from the relevant study sites are presented in Figure 4.6 and Table 4.6. In the Seyhan/Yenidam site, the soil layer beneath the dumping site was covered with asphalt, therefore, no soil sample was collected from that area. However, sediment from a creek within the Yenidam dumpsite provides an indication of the accumulation of these pollutants released to the local environment, in a similar way to soil

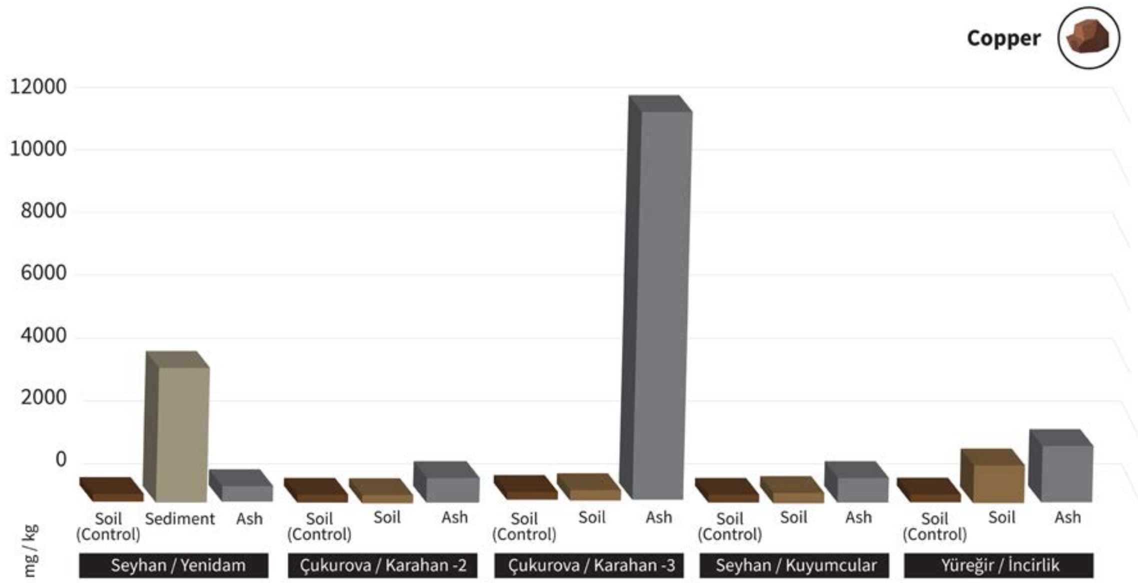
The heavy metal and metalloid levels in the soil samples from all sites (except Yenidam) were generally found to be contaminated with a similar range of metals and metalloid to that found in the ash samples from the same area. In some cases, concentrations in soil were similar to those in overlying ash, though levels of these notable metals and metalloids in ash were generally higher than in the corresponding soil. In the soil samples collected from control areas, which were nearby but not directly affected by the dumping and open burning activities, no pollution similar to that found in the illegal dumping and burning site was detected. In line with these findings, it can be concluded that illegally dumped imported plastic waste creates significant heavy metal and metalloid pollution within the dumpsites.

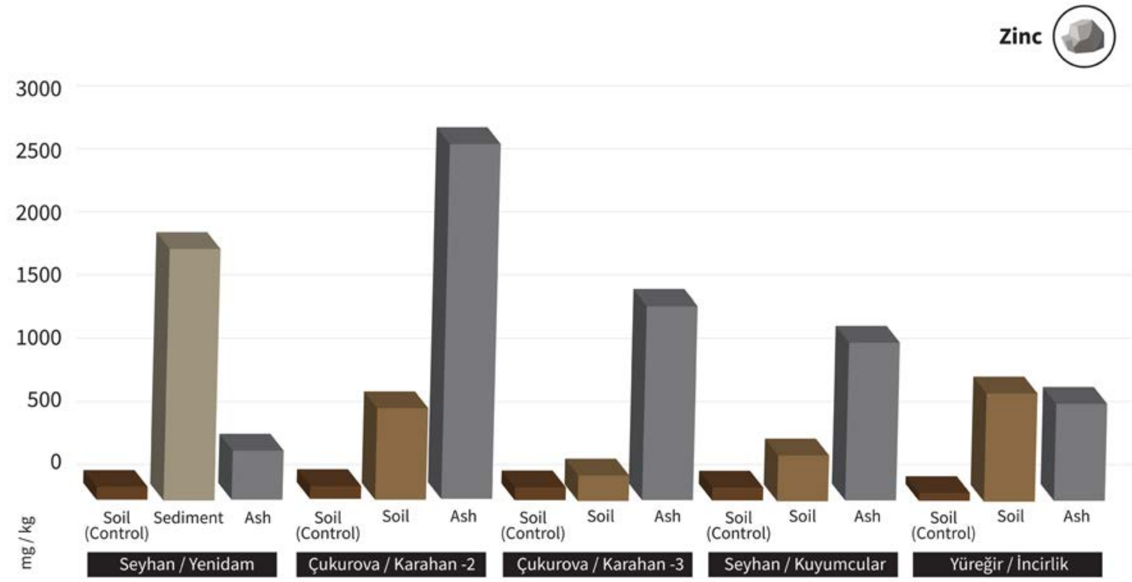
The similarities between the ash and the soil beneath in terms of levels of these pollutants were more apparent at the Yüreğir/İncirlik study site. It was determined that levels in the soil were similar to the high levels contained in the ashes collected from this area. Some of the metal/metalloid pollutants detected in soil at this study site were found to be even higher than the soil limits stipulated in TKKY. The antimony concentrations (49.2-60.4 mg/kg) present in the soil samples were higher than the limits for soil ingestion and absorption through skin contact set in TKKY, and approximately 30 times the limit specified for risk of underground water pollution. Despite some differences for individual heavy metals and metalloids at some locations, the levels of key metals/metalloids detected in the soil samples collected from almost all dumping sites were found to be up to 10 times higher than the levels found in the control samples, though far high differences were seen for individual metals/metalloids at certain sites. For example, the soil samples collected from Çukurova/Karahan-2 location contained 10 to 35 times higher levels of antimony, cadmium, and zinc, and the soil samples from Seyhan/Kuyumcular were found to contain 30 to 200 times higher levels of cadmium and molybdenum when compared against their respective control samples. Soil from the Incirlik site, however, was contaminated to an even greater extent, including copper concentrations up to 90 times that in the control soil, tin up to 140 times, and antimony at around 500 times the control soil concentration.

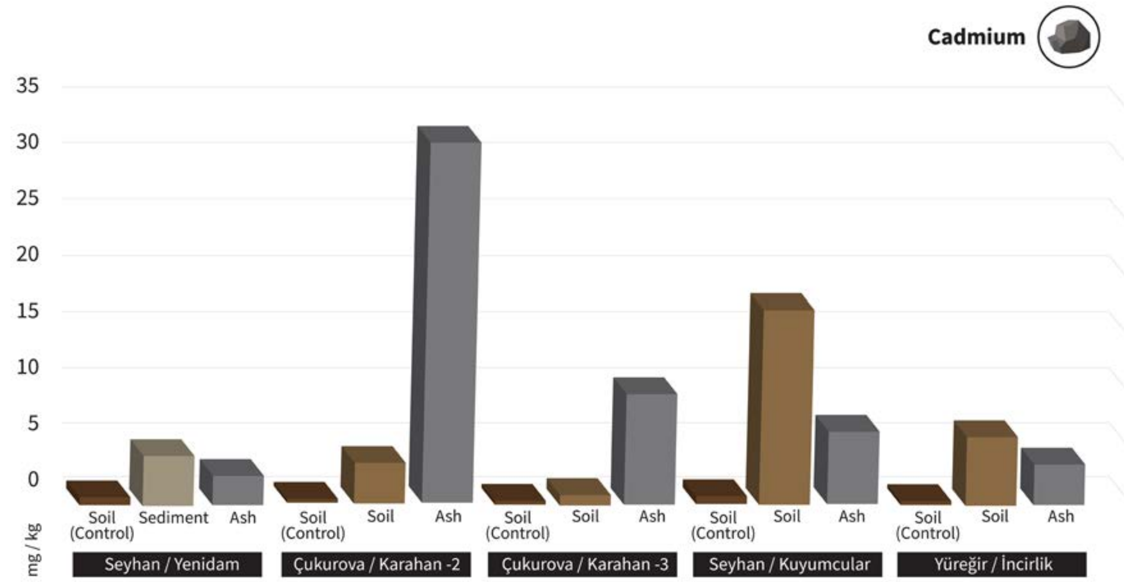
As noted above, high levels of the same heavy metal and metalloid were also found in the ash samples. For example, the ash sample collected from Çukurova/Karahan-3 site had more than 23500 mg/kg of copper, and the levels of copper, lead, molybdenum, tin, and zinc found in ash samples from some of the other locations were above 1000 mg/kg. The heavy metal and metalloid amounts in the ash samples collected from the stations examined were found to be similar to, or higher (far higher in some cases) than the values measured in the shredded plastic pieces taken from the same areas. Although ash is a different material to soil, comparing their metal and metalloid levels can prove useful for understanding the pollution risk at hand. The metal levels in the ash samples varied significantly between study sites.

Figure 4.6. The amounts of antimony, copper, zinc, tin, lead, cadmium and molybdenum in sediment, soil and ash, which are found to be quite high compared to the control soil.









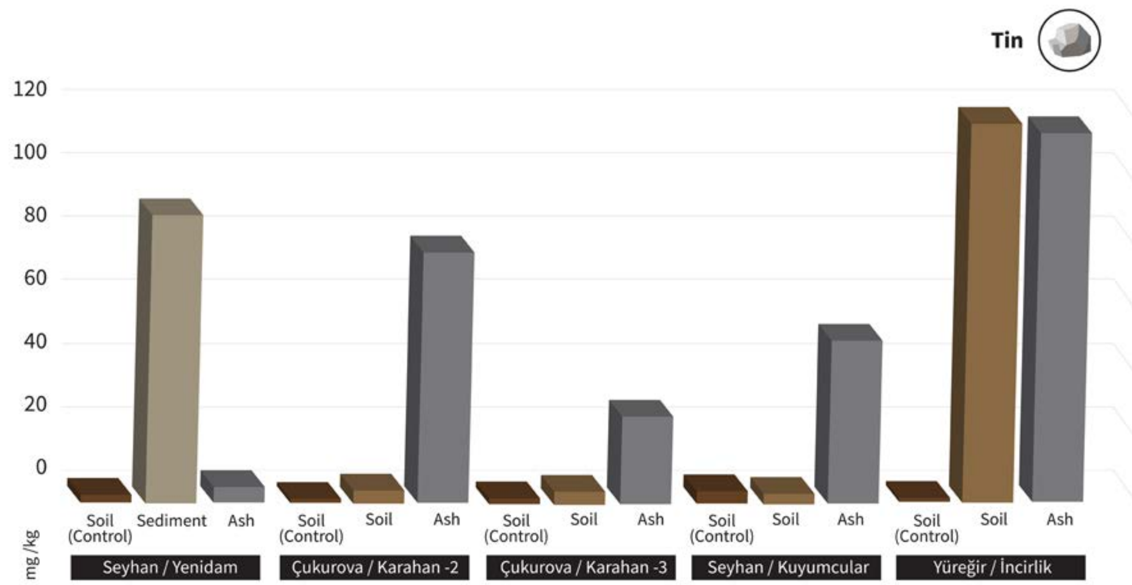
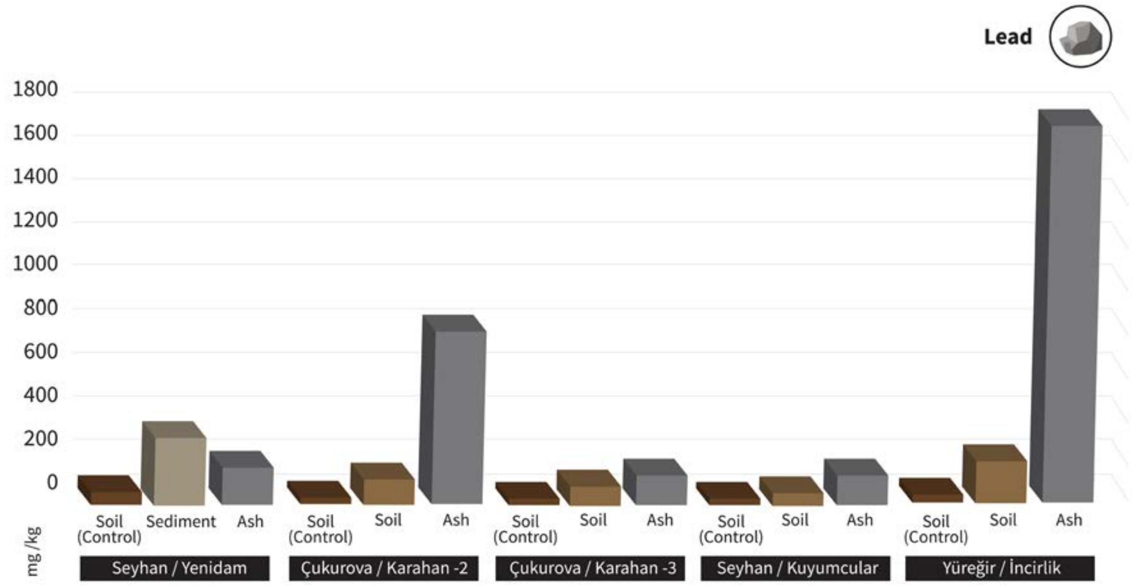


Figure 4.6. The amounts of antimony, copper, zinc, tin, lead, cadmium and molybdenum in sediment, soil and ash, which are found to be quite high compared to the control soil.



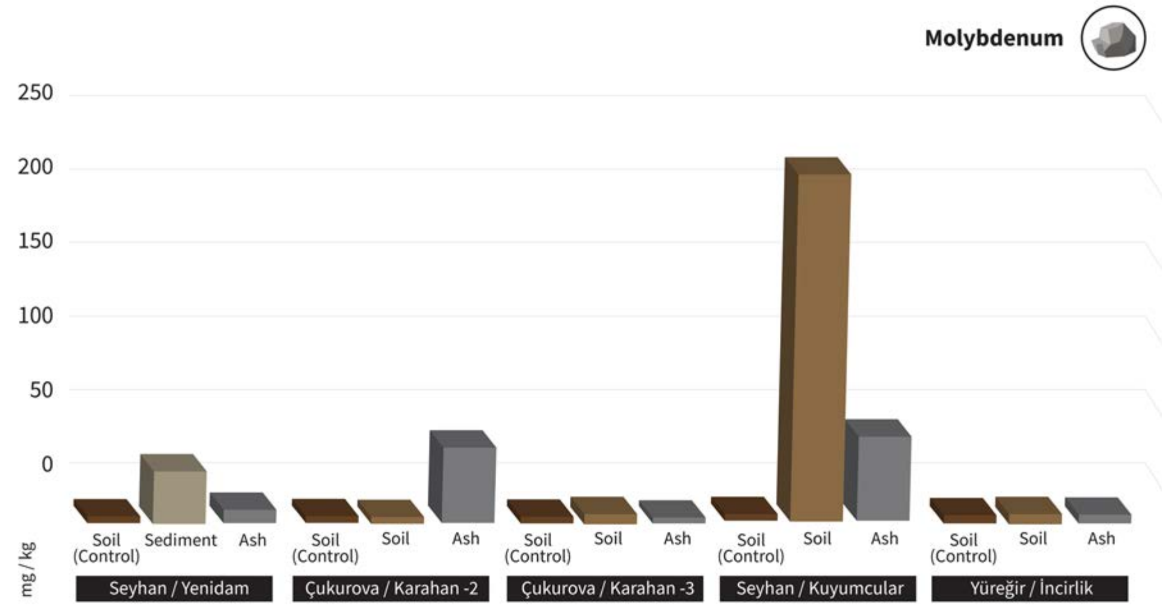


Table 4.6 The amounts[43] of antimony, copper, zinc, tin, lead, cadmium and molybdenum in sediment, soil and ash, which are found to be quite high compared to the control soil. Full list of the metals can be found in the analytical report

Location	Matrix	Antimony	Cadmium	Copper	Lead	Molybdenum	Tin	Zinc
Seyhan/Yenidam	Control soil	0.1	0.53	25.2	37.3	0.4	1.4	59
	Sediment	1.7	2.12	143	157	2.1	3.4	394
	Ash	76.1	4.04	3970	279	13.2	86.3	1950
Çukurova/ Karahan-2	Control soil	<0.1	0.31	17.8	13.6	0.8	0.8	46
	Soil	2.1	2.87	36.8	95.5	0.6	2.6	633
	Ash	11.3	32.1	208	808	19.2	77.0	2710
Çukurova/ Karahan-3	Control soil	<0.1	0.31	17.8	13.6	0.8	0.8	46
	Soil	0.4	0.41	31.9	54.4	0.6	1.5	108
	Ash	10.6	9.57	11900	131	2.7	24.0	1380
Seyhan/ Kuyumcular	Control soil	0.3	0.4	17.0	12.4	1.4	3.3	60.5
	Soil	0.8	17.3	32.1	22.8	220	1.6	334.8
	Ash	11.4	6.0	209.0	141.5	38.1	50.0	1158.5
Yüreğir/İncirlik	Control soil	<0.1	0.25	15.0	14.7	0.2	1.1	41
	Soil	54.8	5.84	968	206	3.0	116	741
	Ash	42.7	3.63	1290	1740	2.9	115	681

[43] The data in the table is average values where more than one sample of each type was analysed from a site.

Water Analyses

Within the scope of the study, water samples were collected and analysed from a stream, where the land bordering the stream was being actively used for illegal waste dumping and open burning activities, in the Seyhan/Yenidam location, and from a pond near the illegal dumping and burning site at Yüreğir/İncirlik location (findings are presented in Table 4.7 and 4.8).

Table 4.7 **The result summary of the organic compound analysis using GC/MS method conducted on the stream water samples collected from the Yenidam location and the surface water samples collected from İncirlik location.**

Location	Yüreğir/Incirlik	Seyhan/Yenidam	
Sample code	Pond	Stream within dumpsite	Stream, upsteam of dumpsite (Control)
NUMBER OF CHEMICALS IDENTIFIED THROUGH ISOLATION			
Number of isolated chemical compounds	25	52	29
Number of compounds identified to >90%	9	22	9
Percentage identified to >90%	36%	42%	31%
NAME OF COMPOUNDS AND GROUPS IDENTIFIED TO >90%			
HALOGENATED COMPOUNDS			
Chlorinated organophosphates	2	2	2
PHTALATE ESTERS AND RELATED CHEMICALS			
dibutyl/diisobutyl phthalate	2	2	2
dimethyl/diethyl phthalate	2	2	1

Location	Yüreğir/Incirlik	Seyhan/Yenidam	
Sample code	Pond	Stream within dumpsite	Stream, upsteam of dumpsite (Control)
NAME OF COMPOUNDS AND GROUPS IDENTIFIED TO >90%			
OTHER CHEMICALS			
Oxygenated polycyclic aromatic hydrocarbons		1	
Triethyl phosphate	1		
BHT and its derivatives		1	
Benzophenone derivative		1	
5-Desin-4,7-diol, 2,4,7,9-tetramethyl-	1	1	1
alkyl phenols		3	1
alkyl amid		1	
phenyl sulfone/ sulfonamides		2	1
diethylene glycol derivative		1	
benzoic acid ester derivative	1		
fatty acid ester			1
pesticides and fungicides		3	
other compounds		2	

Table 4.8 **Concentrations of the key metals and metalloids (µg/l) in (Filt)ered and (W)hole, unfiltered, samples of creek water from the Yenidam and surface water from the İncirlik plastic waste dumpsites in Turkey.**

Site	Yüreğir/Incirlik		Seyhan/Yenidam			
	Pond		Stream within dumpsite		Stream, upsteam of dumpsite (Control)	
	Filt	W	Filt	W	Filt	W
Antimony	0.8	0.9	0.6	0.6	0.4	0.4
Cadmium	<0.05	0.14	<0.05	0.07	<0.05	0.07
Copper	0.2	1.3	5.6	10.1	3.4	5.0
Lead	0.3	2.3	0.3	3.8	0.8	1.1
Molybdenum	6.5	7.8	8.6	9.7	1.3	1.4
Zinc	<2	7	19	41	12	17

Surface water taken from the pond at Yuregir/Incirlik location was found to contain several phthalate esters, an organic chemical group found in waste plastics from all areas, as well as two chlorinated organophosphates. An alkyl-diol (2,4,7,9-tetramethyl-5-decyne-4,7-diol), which is used in many manufacturing processes to provide antifoam and surfactant properties and is considered highly toxic to aquatic life, was also detected in this area. In addition, triethyl phosphate, another organophosphorus compound, was also found in the water sample collected from the Yüreğir/İncirlik study site. This compound is used in many different applications, including as a plasticizer in resins, plastics, and gums (Flem et al., 2018). The pond water did not contain metals or metalloids at concentrations above values specified in the literature for uncontaminated surface water.

The analysis conducted on the water sample collected from the stream in Seyhan/Yenidam, where dumping and open burning activities have taken place, revealed a variety of organic chemical pollutants, including phthalate esters, chlorinated organophosphates, and alkyne-diol, similar to the water sample from Yüreğir/İncirlik location. However, these chemicals were also identified in the control samples collected from the stream located at the upper areas of the Seyhan/Yenidam study site, where there were no dumping activities nearby.

In the Seyhan/Yenidam location, an antioxidant BHT derivative was not detected in the water sample collected from the control location but was found in the stream water in the dumping and open burning site. Although this chemical was not found in any of the ash or soil samples in this study, the presence of BHT and BHT derivatives was detected in the plastic wastes from all sites. Diethylene glycol dibenzoate, a type of plasticizer with many uses including in polyvinyl acetate (PVA) emulsions and PVC coatings, was also detected in the Seyhan/Yenidam water sample. In the stream water collected from the dumping and burning site relatively higher concentrations of dissolved copper, manganese, and molybdenum were found when compared against the concentrations detected in the control sample from the same area.

In freshwater environments, many metals and metalloids accumulate in sediment and sludge over time, along with many organic chemicals with poor water solubility. In the sediment collected from the Seyhan/Yenidam

location, BHT s was detected, which is closely related to the BHT derivative found in the stream water within the dumping site. Sediment samples could not be collected from the control location for comparison purposes as the stream has been converted into a canal at this location with a concrete bottom.

Other toxic organic chemicals identified in the sediment collected from the dumping and open burning site were found to have similar diversity and range with the chemicals detected in ash and soil samples from all study sites, rather than those found in surface water and plastic samples (PAHs, including naphthalene and phenanthrene, as well as dichlorobenzene and a wide variety of alkyl benzenes and long-chain hydrocarbons).

Among metals and metalloids in the sediments, copper, lead, and zinc concentrations were found to be up to 5 times higher than the typical levels applicable for unpolluted freshwater sediments, and antimony, cadmium, and molybdenum concentrations were found to be just above the typical levels found in unpolluted sediments (ATSDR 2004, 2005, 2019, 2020; Smedley & Kinniburgh 2017). The range of the metals and metalloids found at higher than typical background concentrations was in parallel to those detected at high levels in the ash samples collected from this area, except for tin and antimony. Considering that the region surrounding Seyhan/Yenidam study site is an industrial area, the potential contribution of other plastic storage and recycling facilities to the contamination detected in the stream sediment within the illegal dumping and open burning area should not be ignored.

5. CONCLUSION

This study reveals extensive contamination with hazardous chemical pollutants caused by the illegal dumping and open burning of imported plastic waste at five different locations in Turkey's Adana province. The pollutants – comprising many hazardous organic chemicals, as well as heavy metals and metalloids – were found both in the soil at the sites and in the ashes created by burning practices.

The analyses conducted on the ash residues from these five locations show that contamination was predominantly due to organic chemical pollutants produced during the combustion process of plastics, as well as metal and metalloid pollutants present in the plastic waste. Some of the organic chemical pollutants identified in the area are not only toxic but highly persistent, and can biologically accumulate once they enter the food chain. Contamination similar to that in the ash was also found in the soil under the ash, indicating that these highly toxic chemical pollutants were transferred to the soil in these dumping sites after being formed as a result of burning.

After the samples were gathered, plastic waste and the ashes formed after combustion have been partially cleared in some of these areas. The authorities should publicly detail how the relevant dangerous materials were handled and disposed of, as well as what public health and environmental health precautions are taken. While some of the ash and plastic waste has been partially removed, the polluted soil residues remain below and require urgent attention. This contaminated soil continues to pose a significant risk to the environment and to human health. The authorities need to clearly and unequivocally explain the disposal method used for the contaminated ash. Otherwise, the area that the waste is transferred to, the employees transferring the waste, and the settlements along the way may have been contaminated with materials containing high levels of polychlorinated dibenzodioxins/furans (PCDD/Fs), which are especially toxic.

In order to prevent the toxic chemicals identified in these areas from contaminating soil, air, water, and even the food chain, plastic waste importation must be completely banned. The authorities should investigate whether areas similar to the Adana example exist across the country, and if so, these areas should be cleared safely and responsibly. Looking more broadly, the production and use of plastics should be addressed. Steps should be taken to prevent toxic chemicals used in manufacturing and disposable plastics should be gradually eliminated, in order to significantly reduce and eventually stop plastic waste production.

The case of Adana demonstrates that the plastic waste trade, which could be defined as waste colonialism, exposes the ecosystems of the Global South, as well as the people living there, to high levels of hazardous chemicals from the waste of developed countries.

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ABBREVIATIONS

BBP: Benzyl butyl phthalate

BHT: Butylated hydroxy toluene

DBP: Dibutyl phthalate

DEHP: Di-(2-ethylhexyl) phthalate

DiNP: Diisononyl phthalate

DnOP: Di-n-octyl phthalate

GAIA: Global Alliance for Incinerator Alternatives

GC/MS: Gas Chromatography-Mass Spectrometry

HBCD: Hexabromocyclododecane

HCB: Hexachlorobenzene

IARC: International Agency for Research on Cancer

IPEN: International Pollutants Elimination Network

POP: Persistent Organic Pollutant

mg/kg: Milligram per kilogram

nd: not detected

ng/kg: Nanogram per kilogram

OECD: Organisation for Economic Co-operation and Development

PAH: Polycyclic aromatic hydrocarbon

PBDD/F: Polybrominated dibenzodioxins/furans

PBDE: Polybrominated diphenyl ether

PBPTKHY: Regulation on Control of Polychlorinated Biphenyls and Polychlorinated Terphenyls

PCB: Polychlorinated biphenyl

PCDD/F: Polychlorinated dibenzodioxin/furan

PE: Polyethylene

PeCB: Pentachlorobenzene

PET: Polyethylene terephthalate

POP: Persistent organic pollutants

PVC: Polyvinyl chloride

SP: Shredded plastics

TEQ: Toxic equivalency concentration

TKKY: Regulation Regarding Point Source Land Pollution and Soil Contamination Control

UV: Ultraviolet

µg/kg: Microgram per kilogram

µg/l: Microgram per liter

2,3,7,8-TCDD: 2,3,7,8-tetrachlorodibenzo-p-dioxin

GAME OF WASTE
IRREVERSIBLE IMPACT

GREENPEACE