Mapping Distribution and Chemical Levels of Nurdles in the Coastal Bend

Final Report

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Prepared by:
Xiangtao Jiang, Kaijun Lu, Jace Tunnell, and Zhanfei Liu
University of Texas Marine Science Institute
750 Channel View Dr Port Aransas, TX 78373
(361) 695-4732
Email: zhanfei.liu@utexas.edu

Submitted to:
Coastal Bend Bays & Estuaries Program
615 N. Upper Broadway, Ste 1200 Corpus Christi, Texas 78401

Executive Summary

Nurdles, which are the pre-production plastic pellets created for plastic manufacture, are now a major source of plastic pollution on beaches globally. In the coastal bend region of south Texas, nurdles have been found to be widespread on beaches based on the volunteer surveys of the "Nurdle Patrol" citizen science program since 2018. The potential risk that nurdles impose on local ecosystems varies from the detrimental effects caused by ingestion directly to their ability to act as "passive samplers" to accumulate environmental contaminants (e.g., heavy metals and persistent organic compounds) from the ambient environments indirectly. Therefore, it is of great importance to evaluate the nurdle pollution status and their associated contaminants to assess the potential impact of nurdles and their associated contaminants on the ecosystems. In this study, nurdles were collected from 24 sites in the coastal bend region, covering areas from the railway to the bay and barrier island beaches. The morphologies of nurdles and associated contaminants including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and mercury, a legacy heavy metal, were investigated. The results showed that nurdles collected varied in color, shape, and polymer composition. More than 80% of the nurdles were made with polyethylene, with the rest of nurdles made with polypropylene, polyester, polystyrene, polyethylene-vinyl acetate, polystyrene-co-acrylonitrile, and polyvinyl chloride based on the Fourier Transform Infrared Spectroscopy (FTIR) analysis. PCBs were not detected on nurdles. PAHs and Mercury on nurdles were detected sporadically among all sampling sites. The detected total concentrations of PAHs ranged from 92.59 to 1787.23 ng/g-nurdle, and the detected mercury concentration ranged from 1.23 to 22.25 ng/g-nurdle. Although the concentrations of contaminants were not in the acute toxic effect level, the detection of PAHs and mercury on nurdles suggested the potential risk of long-term chronic exposure to contaminants for the ecosystems, given the fact that nurdles are persistent in the region.

Acknowledgments

First and foremost, we would like to thank the Coastal Bend Bays & Estuaries Program (CBBEP) for funding this research. We would also like to thank the staff of CBBEP, particularly Adrien Hilmy, for their help and support throughout this study, and A&B Environmental Services for the contaminant analysis. Finally, we particularly would thank our undergraduate researcher Niki Conner who helped collect and analyze the nurdle samples.

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Introduction

Bays, estuaries and coasts in the Coastal Bend region, including the Nueces estuary, Corpus Christi Bay and the Mission-Aransas National Estuarine Research Reserve (NERR), San Jose and Mustang Islands and National Sea Shore etc., support many kinds of fish, invertebrates, coastal habitats, and other wildlife, and also provide seafood, recreation, and economic benefits to the local community. It was estimated that leisure-based tourism and commercial fisheries had created over $2 billion in local revenues annually since 2010 (Lee, 2012). Unfortunately, many human activities nowadays, such as oil and gas production and refining, petrochemical manufacturing, contaminants from industrial, and agricultural practices and sewage treatment discharge are threatening the health of bays, estuaries and coasts in this region and worldwide.

Large quantities of trash/plastic debris have been found along the shoreline of the Nueces estuaries and even the Gulf of Mexico (Wessel et al., 2019; Tunnell et al., 2020). Among them, nurdles, which are the pre-produced plastic pellets for final plastic products (Fotopoulou and Karapanagioti, 2012) released unintentionally into the environment at all stages of the plastic supply chain (Karlsson et al., 2018), are a significant source of plastic pollution along the beaches of the Nueces estuaries. Since September 2018, a large number of nurdles have been observed on Mustang and North Padre Islands. According to the surveys of the Gulf of Mexico citizen science program, *Nurdle Patrol*, over 150 nurdles in 10-minute surveys are frequently recorded on beaches along the Texas coasts since 2019 (Tunnell et al., 2020). Moreover, a growing body of literatures have shown that nurdles could be ingested by hundreds of marine species, such as turtle, fish, and birds, which would result in various adverse effects including intestinal blockage, decrease of food consumption, and increased pollutants exposure (Ryan, 1988; Graham et al., 2009; Gregory, 2009; Kühn et al., 2015).

Nurdles are typically made of hydrophobic polymers, such as polyethylene and polypropylene. Once dispersed in the environment via wind, surface currents and tides, hydrophobic nurdles have the potential to absorb organic contaminants from the ambient environment (Ogata et al., 2009; Jiang et al., 2021). A variety of persistent organic pollutants (POPs) including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and dichloro-diphenyl-trichloroethane (DDT) have been detected on nurdles collected from natural waters and beaches (Ogata et al., 2009; Rios et al., 2010; Zhang et al., 2015; Chen et al., 2018; Jiang et al., 2021). For example, total PAHs and PCBs concentrations of 1.6–14699.8 ng/g and 0–

642.4 ng/g, respectively, were detected on nurdles collected from beaches of Texas (Jiang et al., 2021). Concentrations of PAHs were in the range of 14.4–847.7 ng/g on floating plastic debris collected from the North Pacific Subtropical Gyre (Chen et al., 2018). As the sixth largest port in the United States, the Port of Corpus Christi accepts around 70 million metric tons of petroleum annually (City of Corpus Christi data). The well-developed petrochemical industries here also bring a huge amount of oil and gas wells and network of pipelines from wells to refineries, which all increase the possibility of release of petroleum hydrocarbons to the environment and the absorption of petroleum hydrocarbons by the dispersed nurdles. The combustion of gasoline and biomass also contributes to petroleum hydrocarbons in the environment. In addition to petroleum hydrocarbons, heavy metals and organochlorine pollutants, as the legacy pollutants, have been continuously detected in Corpus Christi and Nueces Bays since 1976 (White et al., 1980; Custer et al., 1998; Stunz et al., 2011), and these contaminants could also be absorbed by nurdles. Once the contaminated nurdles are ingested by marine organisms, the contaminants can be assimilated and accumulated in the organisms, and further passed along the food chain to humans through seafood consumption, thus having detrimental effects to estuary ecosystems and public health. However, there is very little information on the common contaminant levels on the vast dispersed nurdles along the shorelines of the Coastal Bend region, and the detailed characteristics of nurdles, including size, polymer types and physical appearance, also remain unclear. Thus, the objectives of this project were to (1) identify the polymer type of nurdles, (2) analyze absorbed chemical levels of nurdles collected within the Gulf beaches and bays of the Coastal Bend, (3) provide baseline data about the nurdle pollution and (4) assess the potential risks of nurdles on this coastal ecosystem. Nurdles were collected from the beaches and bays within CBBEP program area, and their plastic types and associated chemicals were determined. As part of the report, sampling locations, plastic types of nurdles, and concentrations of chemicals associated with nurdles were presented in map form. The analyzed chemicals on nurdles included the EPA 16 priority PAHs, 7 common commercialized PCBs aroclors, and 1 typical heavy metal- mercury.

Methods

Nurdle sampling

Nurdle samples were collected from March to April 2021 at 24 sampling sites along shorelines within the bay and Gulf beaches around the Coastal Bend region (Figure 1). Geographic coordinates of the study sites are listed in Table 1.

Currently there are no standardized methods approved by the USEPA or TCEQ for the sampling of plastic pellets (nurdles) in surface waters, or on sandy beaches. Therefore, the methods employed in this research were based on those published in peer-reviewed literatures (Tunnell et al., 2020; Jiang et al., 2021) and the experience of the UTMSI team with the nurdles. At each sampling site, around 300 nurdles were collected using dichloromethane-rinsed forceps, stored in 25 mL pre-combusted amber glass bottles at 4 °C in a cooler with ice in the field, and transferred to the 4 °C fridge in dark upon returning to the lab within the same day. Sampling duration of each site varied from 0.5–3 hours. Photos of all samples collected, including a picture of each container used during a sampling event, with all nurdles collected and a visible label, were taken at each site using the app "Theodolite" which stamps photos with geographic coordinates, time, date, and direction (Figure 2).

Nurdle characterization

In the laboratory, nurdles at each sampling site were transferred into a pre-combusted beaker with 500 mL ultrapure water and cleaned in an ultrasonic bath for 30 min; this cleaning process was repeated 3 times. The cleaned nurdles were then dried in pre-cleaned glass bottles and stored in a desiccator with silica gel before further analysis.

The abundance, shapes, colors, and weathering patterns of nurdles at each sampling site were recorded and measured. To identify the polymer composition, 30 of the total nurdles at each sampling site were randomly selected and analyzed using Fourier Transform Infrared Spectrometry (FTIR, AIM-9000 FTIR Microscope, Shimadzu). Polymer types of nurdles were identified by comparing the sample spectrum with standard spectrum from the library (LabSolutions IR Software, Shimadzu), as well as through comparisons with NIST standards. When comparing samples to the library, the match acceptance criteria ranged from 650-800 score (1000 as the highest match score), depending on the algorithm used to examine the sample. After characterization, nurdles from each site were transferred into 25 mL pre-combusted glass bottles and stored at 4 °C, in the dark, until analysis.

Chemicals Analysis

For the chemicals associated with nurdles, the EPA 16 priority polycyclic aromatic hydrocarbons (PAHs) were analyzed, including naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[g,h,i]perylene, indeno[1,2,3-c,d]pyrene, and dibenz[a,h]anthracene. Also analyzed were 7 common commercialized polychlorinated biphenyls (PCBs) aroclors including aroclor 1016, 1221, 1232, 1242, 1248, 1254 and 1260, and 1 typical heavy metal- mercury. For each group of associated chemicals (i.e., PAHs, PCBs, and mercury), 30 nurdles (~ 0.5 g) were randomly selected to constitute a batch representing the total nurdles collected at each site, and triplicate batches of nurdles from each site were selected and sent to the A&B Labs. The A&B Labs is NELAP-accredited and was selected to measure the chemicals concentrations according to EPA methodologies (i.e., EPA 8270D, EPA 8082A, and EPA 7470A). The qualification and quantification of associated organic chemicals (i.e., PAHs and PCBs) were analyzed by gas chromatography mass spectrometry (GC/MS) and mercury by cold vapor atomic fluorescence spectroscopy (CVAFS). The analytical methods to support the project were specified in Table 2. Based on the preliminary results of the chemical analysis from the A&B Labs, the archived selections (remaining nurdles from each sampling site) were split into either 3 or 6 portions by weight, depending on the total amount of nurdles remaining, and added to the corresponding replicates of the previous PAHs and/or PCBs samples of the same site in A&B Labs to increase the possibility/sensitivity of contaminant detections.

Results and Discussion

Nurdle abundance

A total of 24 sites were sampled in this project, with 4 sites next to the railways, 8 along the barrier islands, and the rest 12 in the bay area. Nurdles were sampled near the railway or from the wrack line for the bay and barrier island beaches using forceps. Among all the sites, an insufficient amount of nurdles for chemical analysis was collected at 3 of 24 sites due to low abundance. Specifically, only 5 nurdles were found at the Baffin Bay site, and 39 and 90 were found at the Blackjack Peninsula site and the Robstown site, respectively. For the other sites, 270–518 nurdles were collected per site (Table 1).

Nurdle characterization

Among all the sites except for the Baffin Bay site, 30 nurdles were randomly chosen to identify the polymer type by the FTIR (Figure 3). Among the 690 nurdles tested, 566 nurdles were made with polyethylene (PE), followed by 70 with polypropylene (PP), 23 with polyester (PES), 16 with polystyrene (PS), 8 with polyethylene-vinyl acetate (EVA), 6 with polystyrene-co-acrylonitrile (SA), and 1 with polyvinyl chloride (PVC). The polymer composition of nurdles from different sites is shown in Figure 4. For all the sites except for the Woodsboro and Sinton sites, the nurdles were dominated by PE, followed by PP, with the proportions higher than 70% and 10%, respectively. Nurdles from the Woodsboro site were dominated by PES (63.3%), followed by PS (13.3%) and SA (13.3%), whereas nurdles from the Sinton site were dominated by PE (43.3%), followed by PS (30%), PES (13.3%), and PP (13.3%).

The difference in the polymer compositions was dependent on sampling location. Sites Woodsboro and Sinton are located near the railway, where the nurdles could be released during transportation. However, nurdles from the bays and barrier island beaches may have been transported by coastal currents, during which nurdles made with light density polymer, such as PE and PP, could be more easily dispersed and trapped on the beaches.

In addition to the polymer identification, the morphology of nurdles including shape, color and weathering patterns was recorded and measured. The photo collection of nurdles samples from all the sites is shown in Figure 5. Nurdles from the railway sites (Sites 1, 2, 4, and 5) differed greatly from those of the bay and barrier island beaches (all the other sites). Nurdles from the railway sites had the unique color of pure white, grey, and blue, however, nurdles from the bay and barrier island beaches had common colors from clear to dark brown (Figure 6), which showed a strong signal of natural weathering. These color differences were driven by the composition of the nurdles and/or the weathering degree in the environment. Based on Jiang et al. (2021), the weathering degree of a given nurdles can be quantified by the yellowness index and surface corrosion area. Nurdles with yellowness index ≥ 40% (Ogata et a., 2009), or surface corrosion area ≥ 50% were categorized as weathered or having been in the environment for a long time period, residence time. Yellowed nurdles or nurdles with a larger corrosion area indicate stronger weathering. Nurdles sampled in this project showed different residence times in the environment, which suggested that they were released to the environment from different time locations. Moreover, considering the different colors and polymer compositions of the nurdles, although the exact sources or the number of spills of the nurdles remained unknown, it is clear that they were sourced from multiple spills/manufacturers.

Chemical concentration level

The PCBs on the nurdles were not detectable at any sites, whereas PAHs and mercury were detectable at some sites (Site 3, 11, 14, 17 and 21 for PAHs and site 3, 7, 9, 11, 12, 14, 16, 17, 19, 23 for mercury, Figure 7). The fact that PCBs were not detected was not unexpected. Jiang et al. (2021) measured PCBs on nurdles from Texas shorelines, and their results also showed that the detection of PCBs on nurdles was also rare, and the highest concentration of PCBs was found from the nurdles sampled from the Galveston Bay site, where the PCBs pollution is a known problem (Sericano et al., 1994; Oziolor et al., 2018). However, our studied sites in this project focused on bays and estuaries in south Texas and did not include Galveston Bay in this study.

The total concentrations of PAHs (∑-16 PAHs) in individual replicates of the detected sites varied up to 2 orders of magnitude, ranging from 92.59 to 1787.23 ng/g-nurdle, with highest concentration in one replicate of the nurdles from the Bob Hall Pier site. The composition of PAHs has been commonly used to indicate the source of PAHs, distinguishing petrogenic sources (e.g., oil spills) from pyrogenic sources (e.g., vehicle exhaust and incomplete combustion; Budzinski et al., 1997). Generally, low molecular weight PAHs with 2-3 rings are derived from petrogenic sources and high molecular weight PAHs with 4-6 rings are from pyrogenic sources. In this project, high molecular weight PAHs (4-6 benzene rings) were dominant at all the detected sites except for the Rockport site, with their proportions ranging from 65% to 100% of the total PAHs, suggesting that combustion of fossil fuel could be the primary source of PAHs on these nurdles. This may also be related to the fact that high molecular weight PAHs are more hydrophobic, thus likely being adsorbed more to hydrophobic nurdles. At the Rockport site, however, only the 2-ring PAH, naphthalene, was detected, suggesting a difference source of PAHs on nurdles at this site.

Compared to other relevant studies, PAHs on nurdles collected in this work was more sporadic. For example, Jiang et al. (2021) investigated concentrations of PAHs on nurdles collected from the beaches of south Texas. They detected PAHs on all replicates of nurdles at all sites, with similar concentrations from 5-2000 ng/g-nurdle, compared with this study. The major driven factor contributed to the sporadic detection of PAHs in this study could be the extraction method. The EPA method SW-846 8270D for the total PAHs extraction refers to the PAHs on the solid samples such as solid waste or sediments/soils, which could be easily sampled from the environment. Therefore, the minimum weight of the solid sample used in SW-846 8270D is 10 g, and the final metered volume of extraction fluid is not amendable. However, nurdles were in much lighter weight than sediments/soil, thus nearly impossible to collect 10 gram per sample from the environment. Although we increased the amount of samples using extra samples that were originally planned for archiving purpose, the weight for each replicate was only around 0.5 g, which made the detection very challenging. For example, the detection limit of PCB Anoclor 1061 raised from 1.67 µg/kg for 10 g solid samples to 33.3 µg/kg for 10 g solid samples. In addition, the polymer of nurdles affect the extraction efficiency of organic contaminants. The methods applied for PAHs and PCBs extraction in this study used dichloromethane, a go-to solvent for contaminant extraction. However, polymers such as PS and PES would be dissolved in dichloromethane and partly recrystallized during the concentration process of the extraction fluid, which would re-sorb some of the contaminants and may hinder the extraction, resulting in the below detection limit of these contaminants. Therefore, it is of urgent need to develop a suitable and standardized protocol to investigate contaminants on nurdles to better assess the potential risk of nurdles and their associated contaminants. For example, Jiang et al. (2021) just simply conducted the extraction in ultrasonic bath for 30 min, but such protocol needs to be approved by EPA.

The concentrations of mercury at individual replicates of the detected sites ranged from 1.23 to 22.25 ng/g-nurdle, with the highest concentration at the Yarborough Pass site. The concentration range of mercury on nurdles from this project was in a same magnitude as those sampled and quantified by Conkle et al. (2018), and was also similar to the total mercury concentration in sediment samples collected at the Nueces Bay during 2006 (Apeti et al., 2012).

In general, neither the mercury nor the PAHs were constantly detected from all the nurdle samples, with ca. 20% of total nurdles containing mercury, and ca. 12% of the total nurdles containing PAHs. Since the nurdles were randomly chosen to form a replicate for analysis and were not sorted by their weathering status, thus the highest concentration of contaminants detected could be contributed by heavily contaminated nurdles. However, more than one replicate of nurdles from the Nueces Bay site, TAMUCC beach site, and Port Aransas site contained both PAHs and mercury, suggesting that the nurdles from these three sites could be commonly contaminated. Based on the morphological analysis (i.e., Figure 5), nurdles from these three sites contained more weathered nurdles, either yellower or higher degree of surface corrosion, which may contribute to the commonly detected contaminants. It was reported that weathered plastic pellets tend to have higher concentrations of contaminants (Endo et al., 2005; Ogata et al., 2009; Jiang et al., 2021). Weathering creates more surface sites or areas on nurdles, on which natural organic matter can sorb and form biofilm, for example, and the biofilm may further facilitate the adsorption of contaminants from environments. Weathered nurdles tend to have longer residence time in the environment, which will increase the exposure to and chances of absorbing contaminants (Conkle et al., 2018; Liu et al., 2019; Jiang et al., 2021). Given the fact that the sorption of contaminants on plastics is often not irreversible (Endo et al., 2013; Liu et al., 2018; Liu et al., 2019; Jiang et al., 2021), nurdles could release contaminants to the ambient environments or be digested by marine organisms, which may lead to chronic toxicity or bioaccumulation in a long term.

Conclusion

In this study we investigated the polymer type, morphology, and concentrations of associated PAHs, PCBs, and mercury on nurdles collected from the shorelines of the Coastal Bend. The polymer compositions of nurdles were dominated by PE and PP, but varied from site to site, PES, PS, SA, and PVC nurdles were also identified. Nurdles stranded on the railways and beaches were sourced from multiple spills/manufacturers. The concentrations of contaminants on nurdles varied greatly between sites. PAHs and mercury on nurdles were generally detectable except for a few sites, whereas PCBs were not detected at all. Although the concentrations of contaminants were not in high toxic effect levels, the pollution status of the widespread nurdles and their associated nurdles is still of concern. It is urgent to develop suitable and standardized protocols to investigate the risk of nurdles and to regulate the spillage of nurdles.

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Figures

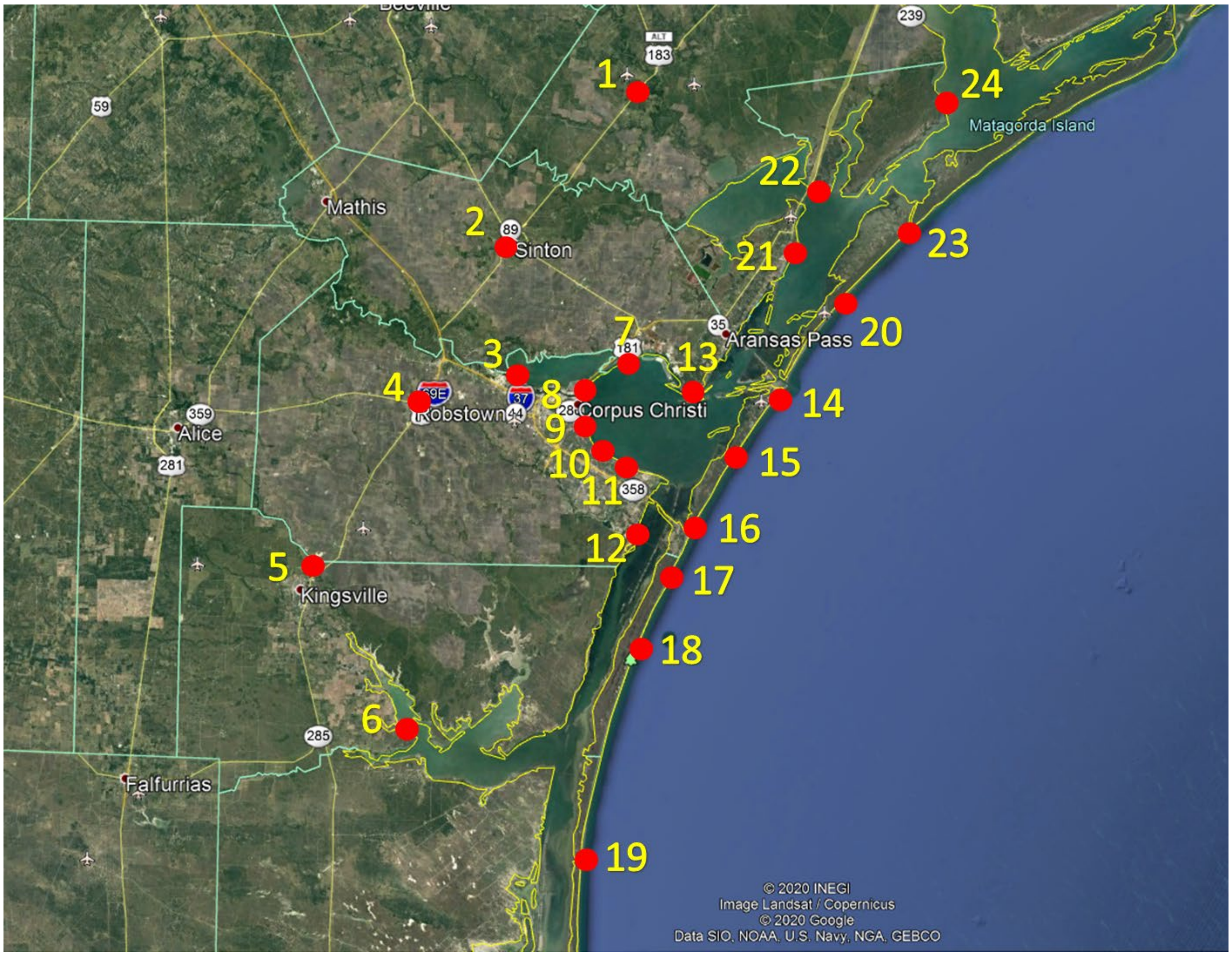


Fig. 1. Locations of sampling sites, as shown by red points on the map. The sampling locations are: 1. Woodsboro, 2. Sinton, 3. Nueces Bay, 4. Robstown, 5. Kingsville, 6. Baffin Bay, 7. Portland, 8. North Beach, 9. Cole Park, 10. Ropes Park, 11. TAMUCC beach, 12. Laguna Road, 13. Ingleside, 14. Port Aransas, 15. Mustang Island State Park, 16. North Packery, 17. Bob Hall Pier, 18. PINS- Malaquite Beach, 19. PINS- South, 20. San Jose Island, 21. Rockport, 22. Blackjack Peninsula, 23. Cedar Bayou, 24. Aransas National Wildlife Refuge (ANWR)

Fig. 2. Cole Park site sampling photo took via the app "Theodolite".

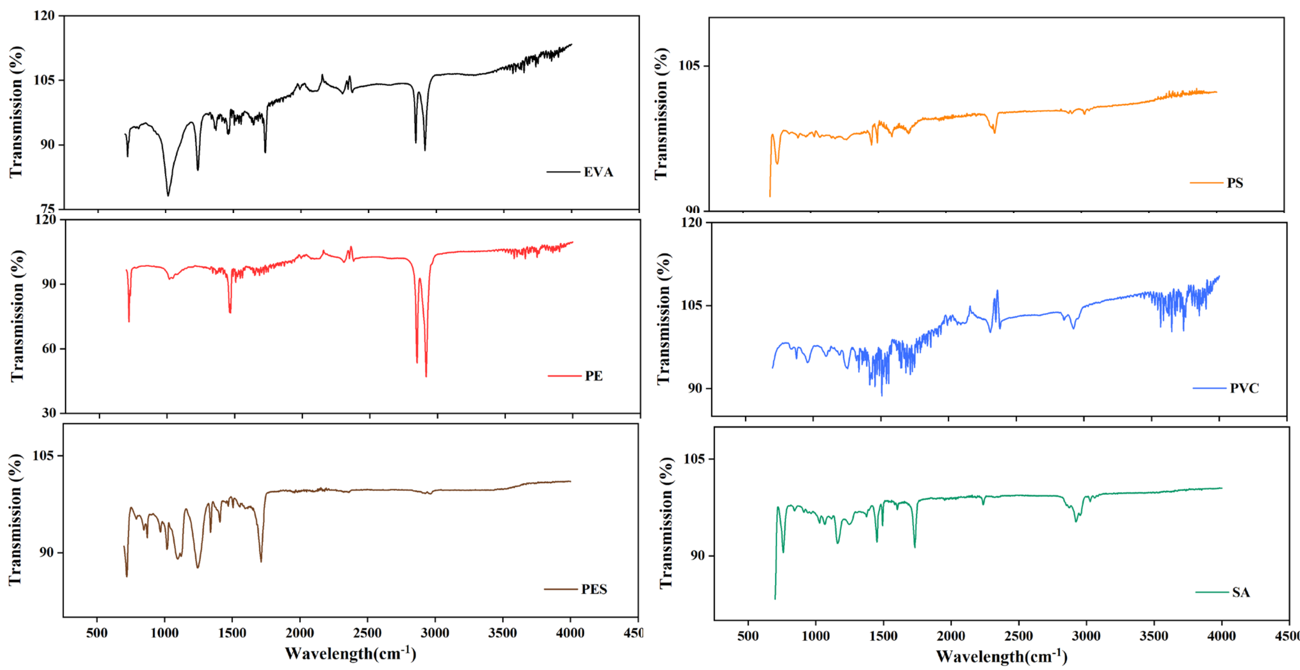


Fig. 3. FTIR spectrums of the common polymers of nurdles sampled from the shoreline.

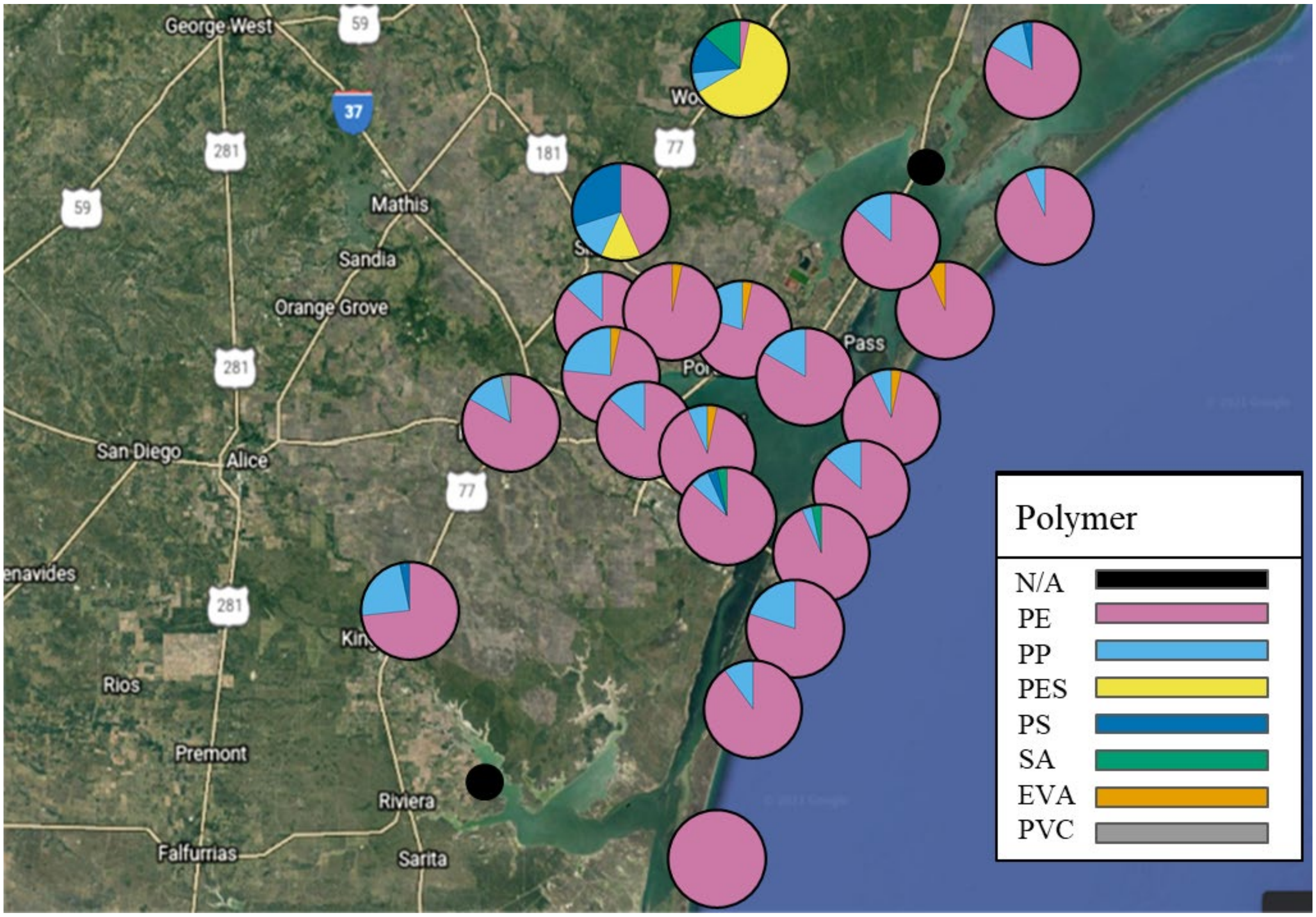
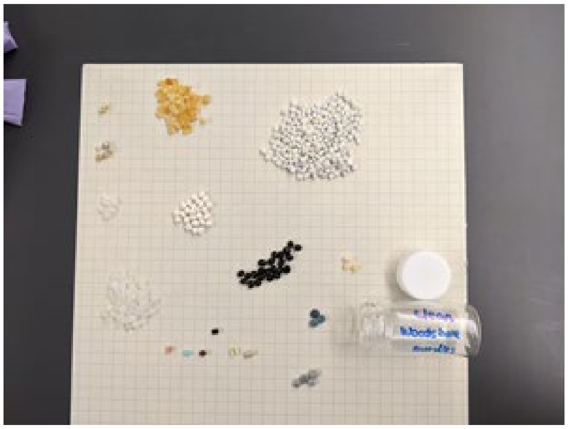


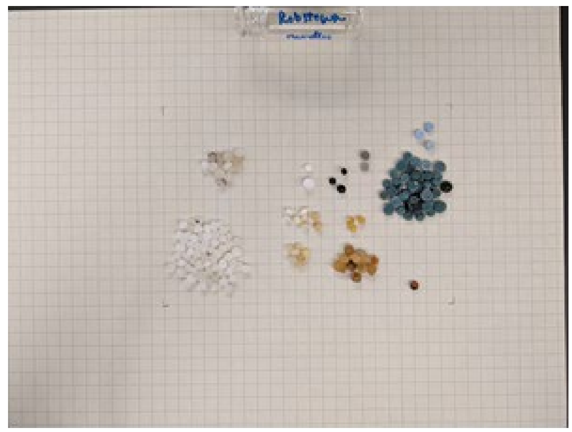
Fig. 4. Polymer composition of nurdles sampled from all the sampling sites, as shown by pie graph in different colors.



Site 1_woodsboro

Site 2_Sinton

Site 3_Nueces Bay

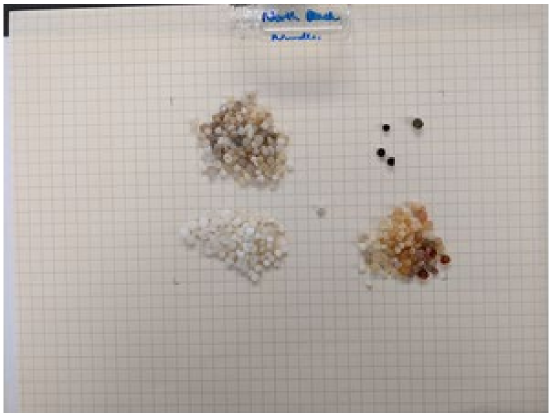


Site 4_Robstown

Site 5_Kingsville

Site 7_Portland

Fig. 5-1. Sorted nurdles of sites 1-7 based on their colors and shapes, photographed on 6 mm*6 mm squared paper.



Site 8_North Beach

Site 9_Cole Park

Site 10_Ropes Park

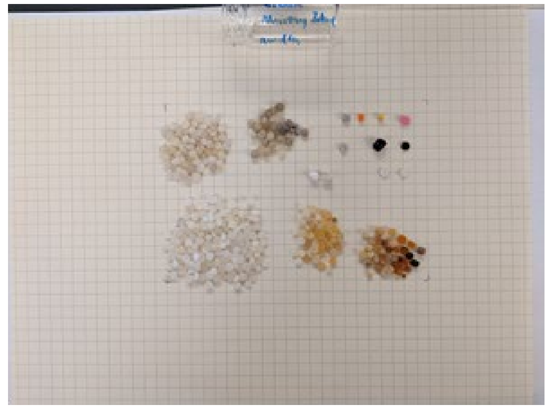
Site 11_TAMUCC

Site 12_Lagunaroad

Site 13_Ingleside

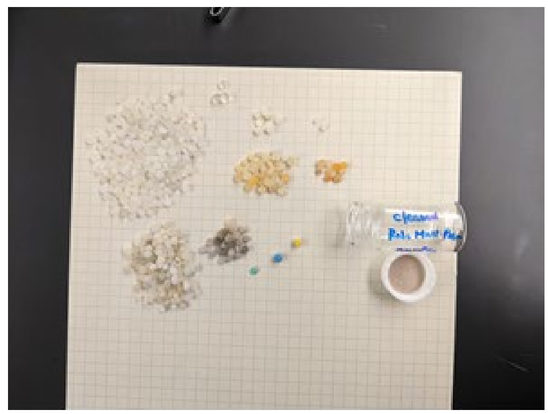
Fig. 5-2. Sorted nurdles of sites 8-13 based on their colors and shapes, photographed on 6 mm*6 mm squared paper.

Site 14_Port Aransas



Site 15_Mustang Island

Site 16_North Packery



Site 17_Robs Hall Pier

Site 18_Malaquite Beach

Site 19_PINS South

Fig. 5-3. Sorted nurdles of sites 14-19 based on their colors and shapes, photographed on 6 mm*6 mm squared paper.

Site 20_San Jose Island

Site 21_Rockport

Site 23_Cedar Bayou

Site 24_ANWR

Fig. 5-4. Sorted nurdles of sites 14-19 based on their colors and shapes, photographed on 6 mm*6 mm squared paper.

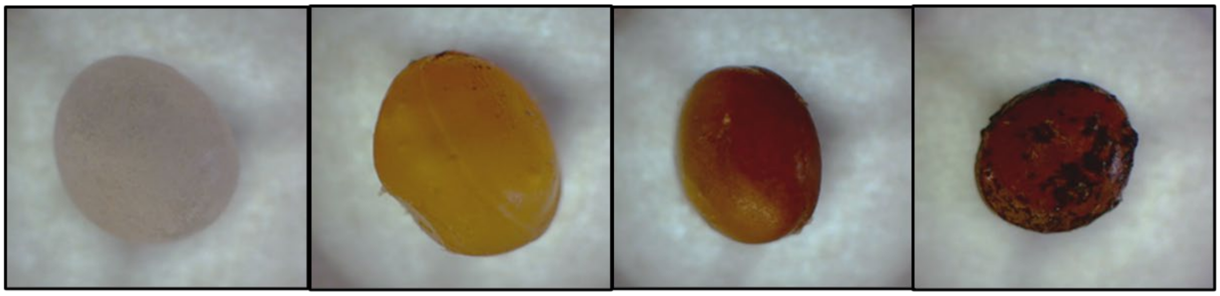


Fig. 6. Microscope photos of nurdles in different weathering status.

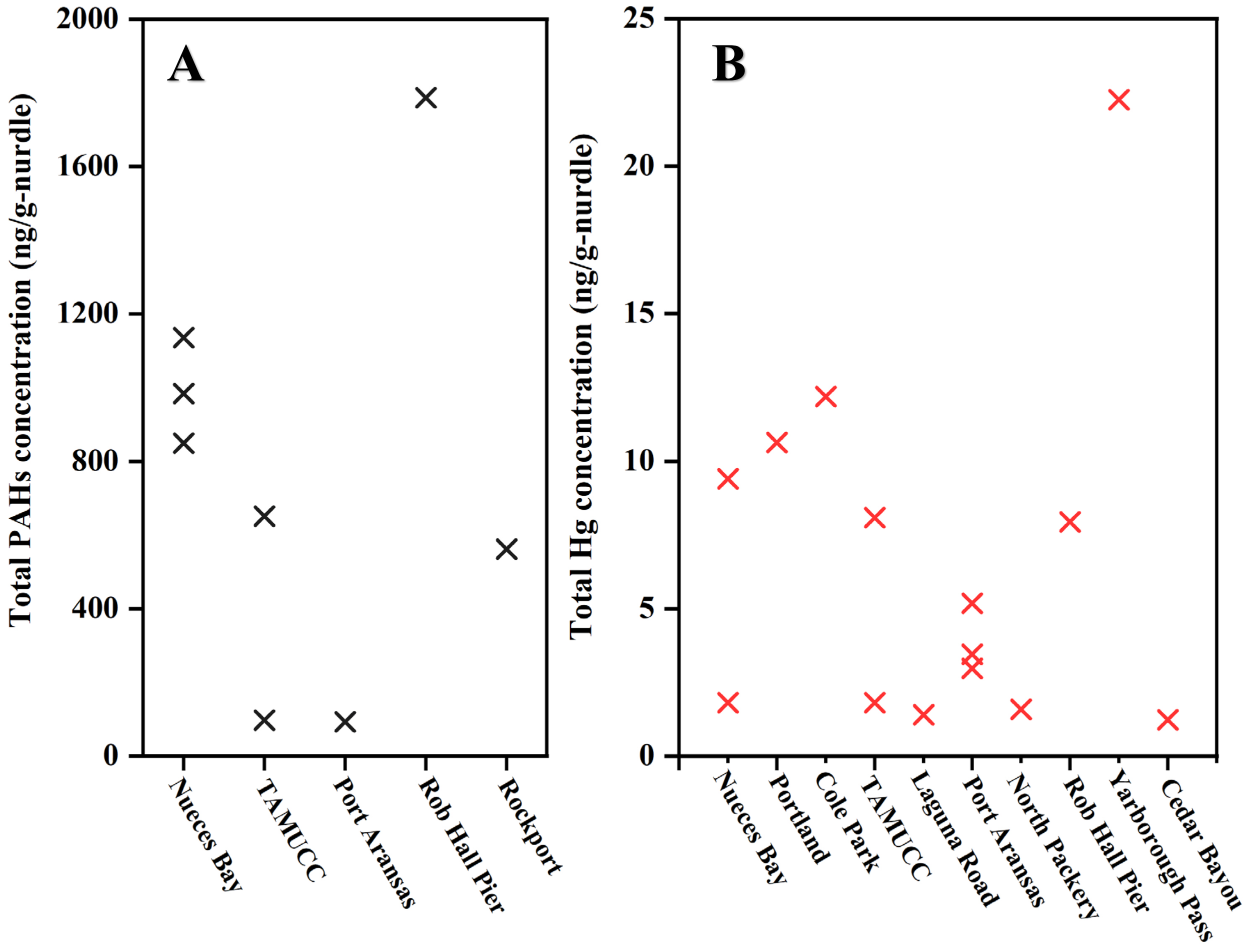


Fig. 7. Total concentration of PAHs (A) and Mercury (B) in nurdles from all the detected sampling sites.

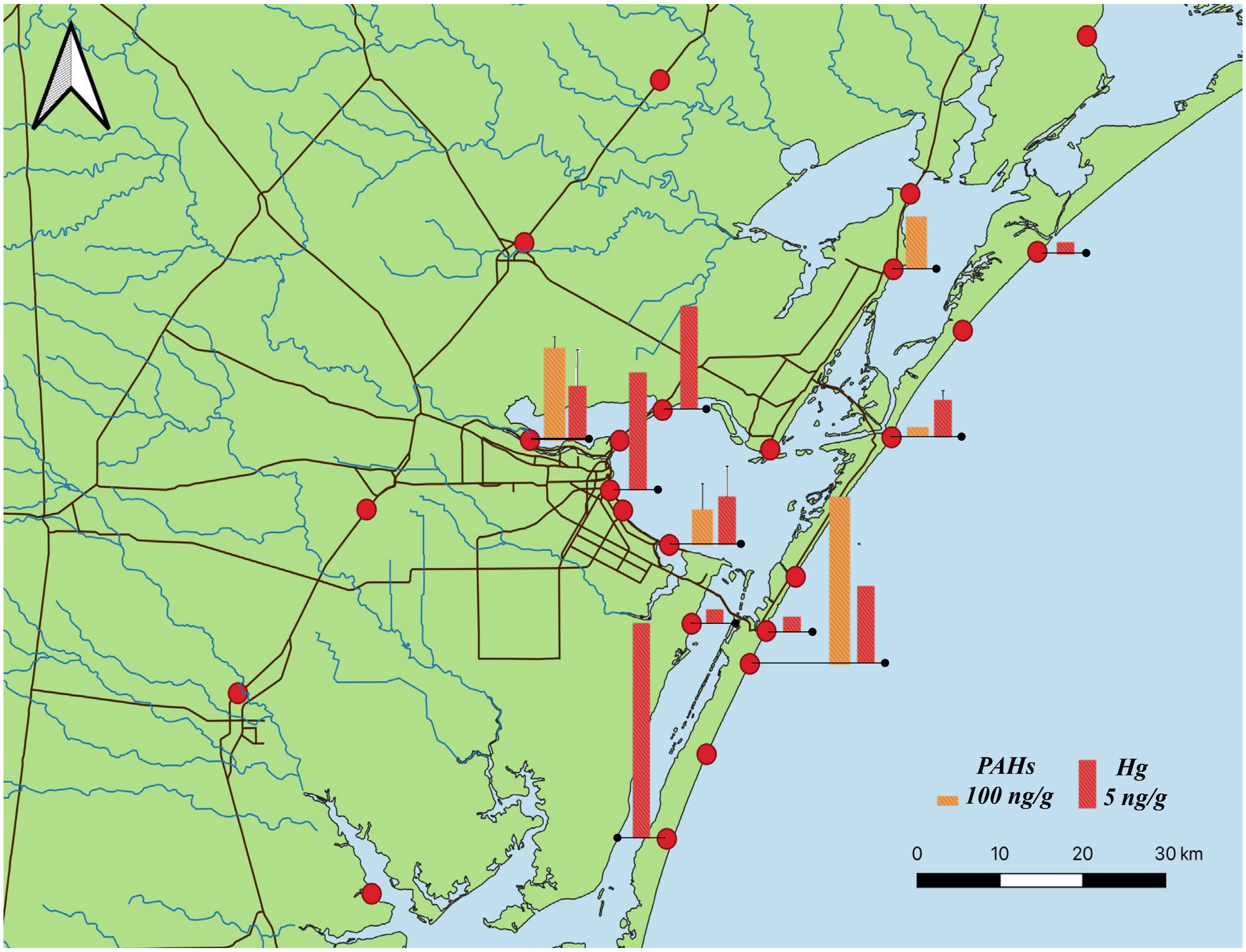


Fig. 8. Map of the detected PAHs and Mercury on nurdles from all the sites.

Tables

Table 1. Sample information of nurdles collected from the Coastal Bend region

Sites	Locations	latitude	longitude	Duration (min)	No. nurdles
1	Woodsboro	28.240689	-97.330941	30	419
2	Sinton	28.056224	-97.496571	60	455
3	Nueces Bay	27.833068	-97.489715	120	276
4	Robstown	27.7543564	-97.6890594	210	90
5	Kingsville	27.546299	-97.845983	50	309
6	Baffin Bay	27.31919	-97.682876	50	5
7	Portland	27.867021	-97.32781	70	298
8	North Beach	27.832366	-97.380179	210	322
9	Cole Park	27.776108	-97.391957	35	310
10	Ropes Park	27.753253	-97.376146	95	304
11	TAMUCC beach	27.714255	-97.319601	60	311
12	Laguna Road	27.625033	-97.292409	105	283
13	Ingleside	27.822392	-97.196418	80	297
14	Port Aransas	27.836152	-97.048402	35	306
15	Mustang Island State Park	27.67814	-97.165437	40	359
16	North Packery	27.616833	-97.20124	75	413
17	Bob Hall Pier	27.579582	-97.221391	35	433
18	PINS- Malaquite Beach	27.477228	-97.274093	30	518
19	PINS- South	27.38142	-97.322669	40	391
20	San Jose Island	27.95699	-96.961544	50	270
21	Rockport	28.026518	-97.046215	134	293
22	Blackjack Peninsula	28.111984	-97.025666	120	39

23	Cedar Bayou	28.046222	-96.870551	60	300
24	ANWR	28.290624	-96.810041	90	336

Table 2. Performance specifications for the chemical analysis.

Parameter	Sample matrix	Method	Instrument	Lab	Reporting Limit*	Units	Precision (%RPD or ‰)	Accuracy %Recovery
Naphthalene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Acenaphthylene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Acenaphthene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Fluorene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Phenanthrene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Anthracene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Fluoranthene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Pyrene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Benzo[a]anthracene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Chrysene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Benzo[b]fluoranthene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110

Benzo[k]fluoranthene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Benzo[a]pyrene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Benzo[g,h,i]perylene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Indeno[1,2,3-c, d]pyrene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Dibenz[a,h]anthracene	nurdle	SW-846 8270D	GC/MS	A&B labs	0.167	mg/Kg	≤ 10	90 - 110
Aroclor 1016	nurdle	SW-846 8082A	GC/MS	A&B labs	1.67	µg/Kg	≤ 10	90 - 110
Aroclor 1221	nurdle	SW-846 8082A	GC/MS	A&B labs	1.67	µg/Kg	≤ 10	90 - 110
Aroclor 1232	nurdle	SW-846 8082A	GC/MS	A&B labs	1.67	µg/Kg	≤ 10	90 - 110
Aroclor 1242	nurdle	SW-846 8082A	GC/MS	A&B labs	1.67	µg/Kg	≤ 10	90 - 110
Aroclor 1248	nurdle	SW-846 8082A	GC/MS	A&B labs	1.67	µg/Kg	≤ 10	90 - 110
Aroclor 1254	nurdle	SW-846 8082A	GC/MS	A&B labs	1.67	µg/Kg	≤ 10	90 - 110
Aroclor 1260	nurdle	SW-846 8082A	GC/MS	A&B labs	1.67	µg/Kg	≤ 10	90 - 110
Mercury	nurdle	SW-846 7470A	CVAFS	A&B labs	0.01	mg/Kg	≤ 10	90 - 110

*: The reporting limits for contaminants here were for 10g of solid samples, and the GC/MS was not in a selective ion monitoring (SIM) mode.