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Source Apportionment of Microplastics in Environment from Sanitary Landfill – A Case Study of Muangpak Municipality Landfill, Thailand

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ABSTRACT

The controlling microplastics (MPs) at source is a management method that can effectively reduce the amount of contamination in the environment. The main source of MPs was landfills that the decomposition of solid waste, MPs has an impact on environmental quality especially the health of humans. This research was investigated of MPs contamination at landfill site in the Muangpak municipality for analysis of MPs quantitative and source apportionment of MPs. The results of the composition of municipal solid waste by quartering method found that biodegradable solid waste was as high as 36.27% followed by general solid waste of 35.97% which was mostly plastic waste and effect the contamination of MPs in the environment. The distribution of MPs in environmental found that highest abundance was 66.44% of leachate sludge pond 1 followed by leachate sludge pond 2 (26.30%), sediment of surface water (3.32%), leachate pond 1 (1.04%), leachate pond 2 (0.80%), groundwater point 3 (0.62%), groundwater point 1 (0.58%), surface water (0.53%) and groundwater point 2 (0.37%). The contamination of polymer types of MPs at higher densities of low density polyethylene (LDPE) and high density polyethylene (HDPE) than polypropylene (PP) was found in samples closest to landfill area especially leachate pond more than 90%. The source apportionment of MPs using statistical analysis found that plastic waste has correlated to occurrence of LDPE and plastic bottle waste has correlated to occurrence of HDPE that both types of plastic waste are related to the amount of general solid waste and recycle solid waste increases every year.

Keywords: sanitary landfill, municipal solid waste;, microplastics, source of microplastics, polymer types of microplastics.

INTRODUCTION

Quantity of municipal solid waste in the world is more than 2,200 million tons/year (EcoWaste Coalition, 2021). The municipal solid waste in Thailand was the second largest among the 10 countries in the Association of Southeast Asian Nations (ASEAN) after Indonesia while the rate of municipal solid waste was the fourth in the ASEAN countries equal to 1.05 kg/person/day after Singapore (UN Environment, 2017; Arumdani et al., 2021). The economic, social and environmental activities has a direct relationship to quantity of municipal solid waste (Saengchut et al., 2022), these activities have resulted in an increase in plastic packaging waste more than 50% and it was single-use (Europe, 2019; Praveena and Aris, 2021).

The municipal solid waste management of Thailand use landfill as the main method more than 90% while many studies have found that microplastics (MPs) to contaminate in the environment from plastic waste degradation in landfill. The degradation was caused by many factors that change the chemical structure of plastic waste such as acids, alkalis, water or enzymes (Andrady, 2011). The MPs were plastic particles with a diameter of less than 5 mm. easily dispersed in the environment around the landfill (Wang et al., 2017) such as 2–80 items/L of groundwater (Natesan et al., 2021), 8±3 items/L of leachate (Su et al., 2019) and 2,472.33±1,273.17 items/kg of soil from landfill area (Kusumarn Noppathip, 2020). In addition, MPs contamination in the general environment such as groundwater found 0.7×10^{-3} items/L (Mintenig et al., 2019) and soil of the agricultural area found 263 items/kg (Zhou et al., 2020). MPs contamination in the environment was mainly found in low-density such as polypropylene (PP) and polyethylene (PE) that the decomposition occurs from general solid waste and recycle solid waste (Europe, 2019; Kershaw et al., 2019; Yuan et al., 2022). Therefore, the environment closest to plastic waste has a high chance of MPs contamination. MPs have an impact on ecosystems, environmental quality especially the health of humans and animals (Wright et al., 2013; He et al., 2018). MPs have hydrophobic properties that can absorb contaminants such as persistent organic pollutants (POPs) or pesticides (Dichlorodiphenyl trichloroethane – DDT) (Law & Thompson, 2014) and then act as a medium to accumulate and transport toxic substances to the environment where the harm is caused by the indirect effects of exposure (Tang et al., 2020).

Landfills were the source of the release of MPs into the closest environment, i.e. surface water, groundwater, leachate and sediment. In this research, the aforementioned environmental samples were collected and a landfill site in the Muangpak municipality was selected for study due to the high quantity solid waste and it's a sanitary landfill. Thus, the quantified MPs study also shows the distribution of MPs in the environment as a database for landfill management and control.

METHODOLOGY

Study area

This study was conducted in of Nakhon Ratchasima province, the amount of municipal solid waste was 2,271 tons/day accounting for 13.44% of the total amount of waste in the Northeast. The Muangpak municipality landfill is a sanitary landfill area with the highest input volume after the Nakhon Ratchasima Municipality landfill. The quantitative analysis of MPs contamination including municipal solid waste classification were detected at each sampling in rainy season of Thailand because the large amount of water in the rainy season was the factor that results in the greatest dispersion of MPs (Amobonye et al., 2021), shown in Figure 1.

Sample analysis

The classified according to municipal solid waste types from landfill site in the Muangpak municipality by quartering method which divided into 4 parts of equal weight and 2 parts were

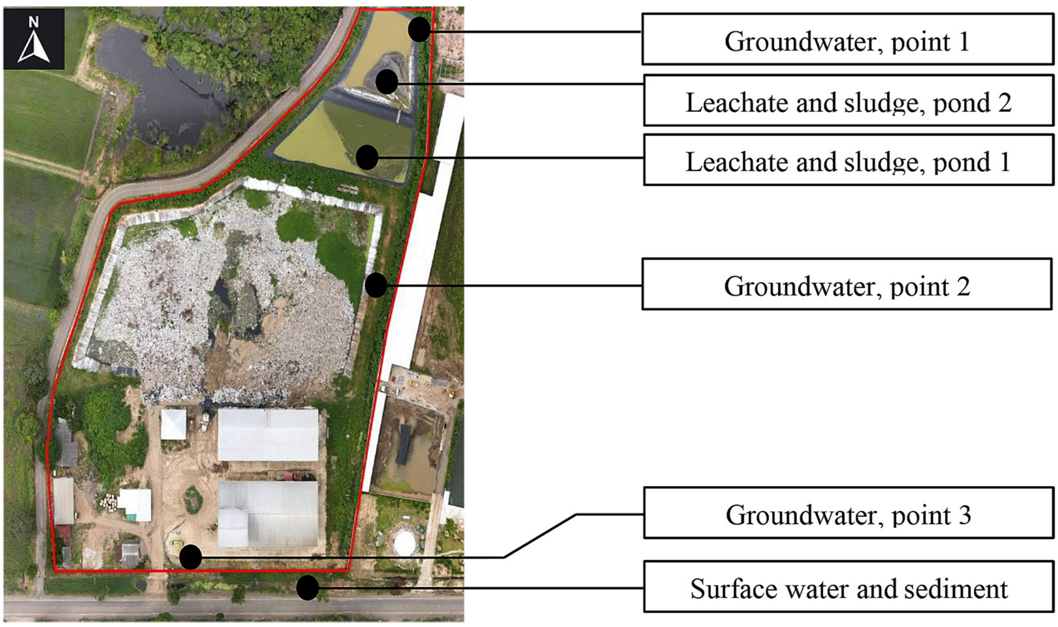

Figure 1. Microplastic sampling points in the Muangpak municipality landfill

selected for physical composition analysis. The waste was then characterized and the percentage of each constituent was calculated (Ephantus et al., 2021; Rojas-Valencia et al., 2012).

The analysis of MPs quantitative that contamination with leachate and sludge, groundwater, surface water and sediment by wet peroxide oxidation method (WPO) (Masura et al., 2015). The volume of 100 mL of water sample and 100 g of sediment were put into a glass beaker and dried at 90°C for 24 h. Then, 20 mL of Fe^{2+} 0.05 M and 20 mL of 30% Hydrogen peroxide were added to dissolve the organic matters, until the appearance of the solution was clear. After that, adding 6 g of NaCl and heat to 75°C on a hotplate-leave to separate densities for 24 h. The filtered with fiberglass filter paper (GF/C) with a pore size of 0.45 mm through vacuum filtration set-up and dried for quantification of the presence of MPs at room temperature and examined with a 40X dissecting stereo microscope. The polymer types of MPs in samples examined with a microscope fourier-transform infrared spectroscopy (FT-IR) from the frequency range 400–4,000 cm^{-1} (Veerasingam et al., 2021).

RESULTS AND DISCUSSION

Classification of municipal solid waste

A study of the composition of municipal solid waste in the Muangpak municipality landfill area in order to classify the types of municipal solid waste by quartering method. The result showed that the percentage of biodegradable solid waste was as high as 36.27% which is close to the percentage of general solid waste of 35.97% followed by recycle solid waste (25.38%) and hazardous solid waste (2.37%). The percentage of recycle solid waste and hazardous solid waste form Muangpak municipality landfill was according to the theory that has been studied (EcoWaste Coalition, 2021; UN Environment, 2017) while the percentage of biodegradable solid waste was lower than theory (must be more than 50%) because there was separation from the beginning and the percentage of general solid waste was more than theory (must be less than 3%) due to the increase packaging waste especially plastic waste is increasing rapidly each year (Cole et al., 2011; Letshwenyo et al., 2020) showed in Figure 2.

The abundance of microplastics in the environment

The distribution of MPs in environmental at landfill site in the Muangpak municipality include leachate and sediment, groundwater and surface water and sediment were detected at each sampling in rainy season of Thailand. The results shown in Figure 3 indicated that the distribution and abundance of MPs. The sampling area with the highest abundance of MPs was leachate sludge pond 1 with an average abundance of 2,453.08±870.37 items/kg followed by leachate sludge pond 2 with an average abundance of 971.17±456.18 items/kg. The Muangpak municipality landfill site has some open dumping areas resulting in sediment of surface water found third order with an average abundance of 122.67±78.11

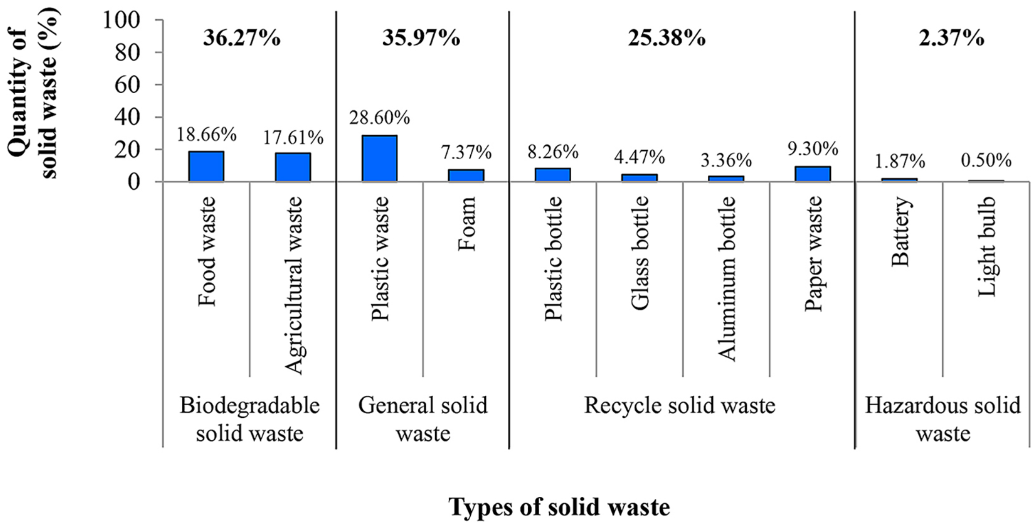

Figure 2. Municipal solid waste types from Muangpak municipality landfill

items/kg due to the environment closest to plastic waste has a high chance of MPs contamination (Su et al., 2016; Zhou et al., 2020). The high density of MPs is a factor that causes it to accumulate in the sediment (Kershaw et al., 2019; Yuan et al., 2022). The water samples found low quantities include leachate pond 1, leachate pond 2, groundwater point 3, groundwater point 1, surface water and groundwater point 2 with an average abundance of 38.33±17.36, 29.58±14.78, 22.92±5.94, 21.25±14.01, 19.58±8.53 and 13.75±6.17 items/L respectively. The MPs contamination of this research was similar to the quantitative of other studies (Natesan et al., 2021; Kusumarn Noppathip, 2020) which size of MPs easily dispersed in the environment around the landfill (Wang et al., 2017). The identification of different polymer types of MPs found in samples, MPs contamination has been studied in various environmental at landfill site using FTIR technique. The results analysis showed that 3 types of polymer covered in this research as shown in Figure 4, the highest percentage of polypropylene (PP) was found to be contaminated in groundwater every point including surface water and sediment at more than 50% due to its low density that can distribute further

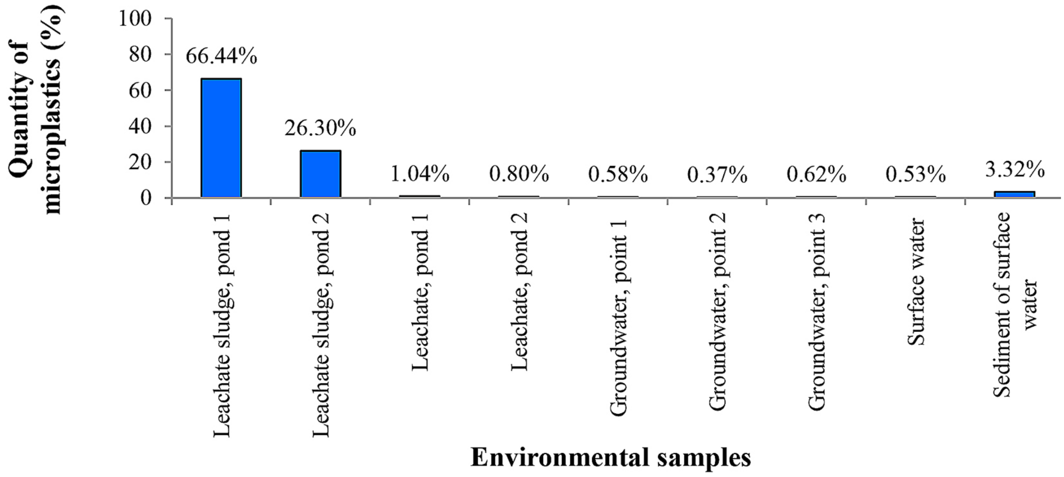

Figure 3. Microplastics abundance in the environment from sanitary landfill

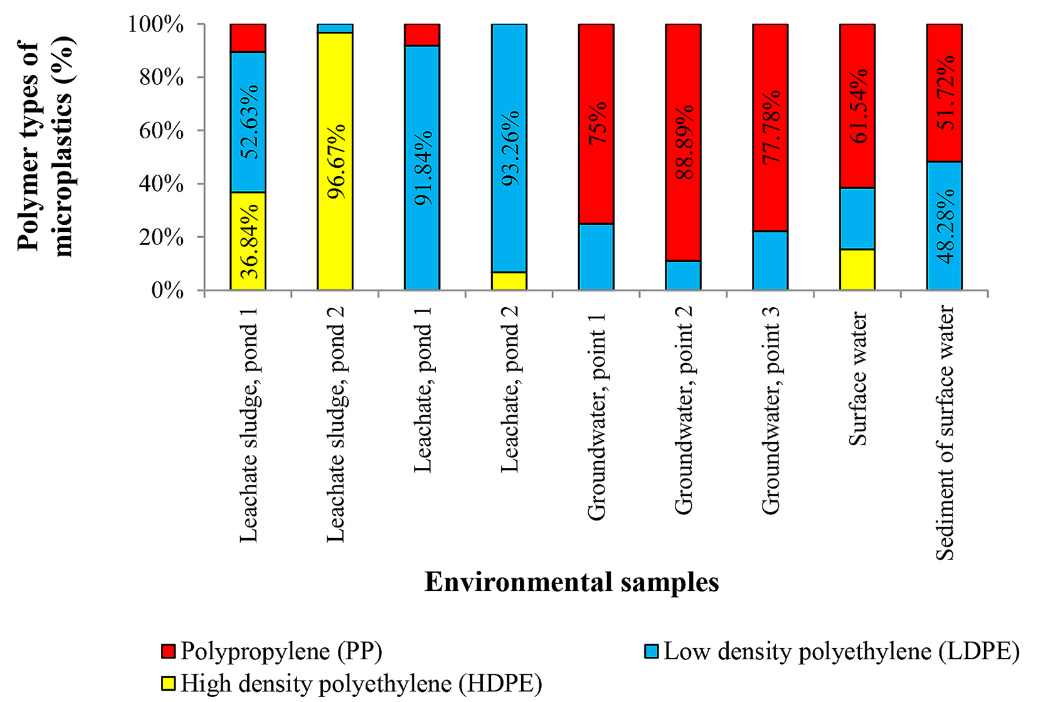

Figure 4. Polymer types of microplastics in environmental samples

than its source (Kershaw et al., 2019; Yuan et al., 2022). While low density polyethylene (LDPE) and high density polyethylene (HDPE) have higher densities, the highest contaminated was found in environmental samples closest to landfill area or wastewater receiving areas. Thus, density and distance of source to the environment were important factors in determining the types and quantity of MPs (Mintenig et al., 2019; Natesan et al., 2021; Zhou et al., 2020).

The source of microplastics in the environment

The source apportionment of MPs in environment from sanitary landfill using statistical software include Pearson Correlation at significant 0.05 level for correlation test of municipal solid waste type with polymer types of MPs and analysis of the influence of MPs source apportionment by multiple regression statistics, Stepwise method. The results of correlation found that the correlated value more than 0.6 (R>0.6) with agricultural waste and glass bottle waste of PP , plastic waste and plastic bottle waste of LDPE, paper waste and light bulb waste of HDPE. If considering the significance values of all 3 polymer types of MPs, it was found that LDPE has correlated to only plastic waste same as HDPE has correlated to only plastic bottle waste. As shown in Table 1. The Table 2 was analysis of the influence of MPs source apportionment found that 2 formats by polymer types of MPs, the LDPE type multiple regression showed the influence of 3 types of municipal solid waste on the occurrence of LDPE to 100% (R^2 = 1.000) were plastic waste (β = 0.817), paper waste (β = -0.438) and glass bottle waste (β = -0.098). The HDPE type multiple regression showed the influence of only 1 type of municipal solid waste on the occurrence of HDPE to 77.50% (R^2 = 0.775) was plastic bottle waste (β = -0.912), another 22.50% was due to other factors not considered. A high beta value indicates a high influence of municipal solid waste type, the occurrence of LDPE found that plastic waste has a higher beta value than paper waste and glass

Table 1. Correlation of each municipal solid waste type with polymer types of microplastics

Types of municipal solid waste		PP		LDPE		HDPE	
		Correlation (R)	Sig.	Correlation (R)	Sig.	Correlation (R)	Sig.
Biodegradable solid waste	Food waste	-0.239	0.698	0.038	0.952	0.148	0.812
	Agricultural waste	0.778	0.121	-0.294	0.631	-0.315	0.606
General solid waste	Plastic waste	-0.555	0.331	0.897*	0.039	-0.440	0.458
	Packaging waste(foam)	-0.640	0.245	0.125	0.841	0.372	0.537
Recycle solid waste	Plastic bottle	0.081	0.897	0.877	0.051	-0.912*	0.031
	Glass bottle	0.870	0.055	-0.694	0.193	0.001	0.998
	Aluminum bottle	0.149	0.811	-0.128	0.838	0.008	0.989
	Paper waste	-0.418	0.483	-0.455	0.441	0.763	0.133
Hazardous solid waste	Battery	-0.401	0.503	0.507	0.383	-0.182	0.770
	Light bulb	-0.512	0.378	-0.351	0.562	0.735	0.157

Note: * correlation is significant at the 0.05 level.

Table 2. Regression coefficient analysis between municipal solid waste types with polymer types of microplastics

Types of MPs	Types of municipal solid waste	Un-Std. coefficients		Std. coefficients	t	Sig.	R^2	Adjusted R^2	Std. error of the estimate
		B	Std. Error	Beta (β)					
LDPE	Constant	-13.537	0.244		-55.478	0.011	1.000	1.000	0.1078
	Plastic waste	14.116	0.034	0.817	412.694	0.002			
	Paper waste	-6.193	0.019	-0.438	-324.454	0.002			
	Glass bottle	-2.802	0.057	-0.098	-49.335	0.013			
HDPE	Constant	86.053	17.458		4.929	0.016	0.831	0.775	19.5901
	Plastic bottle	-35.111	9.141	-0.912	-3.841	0.031			

bottle waste while the occurrence of HDPE found that only plastic bottle waste had a beta value. The type of municipal solid waste mentioned above influences the distribution of MPs into the environment, this was consistent with the high percentage composition of total plastic waste (36.86%) in the Muangpak municipality landfill (Figure 2). The Europe report, Asia has the highest production and export of plastic pellets at 51% which was used to make more than 39.90% into packaging (Europe, 2019) and 44.10% of single-use types (Horton et al., 2017; Praveena and Aris, 2021). Thailand has produced up to 48% of packaging to satisfy consumers, causing used packaging to become waste immediately (TEI, 2021).

CONCLUSIONS

In this study, the source apportionment of MPs environmental at landfill site in the Muangpak municipality was investigated. The results showed the biodegradable solid waste was as highest percentages followed by general solid waste recycle solid waste and hazardous solid waste, the increases in plastic waste affect the contamination of MPs in the environmental. The highest abundance of MPs was sediment includes leachate sludge and sediment of surface water due to high density polymer types of MPs is a factor that causes it to accumulate in the sediment. The contamination of polymer types of MPs at higher densities of LDPE and HDPE than PP was found in environmental samples closest to landfill area especially samples of leachate pond. The polymer type density of MPs and distance from source were important factors in distribution. Thus, statistical analysis found that plastic waste has correlated to occurrence of LDPE type of MPs and plastic bottle waste has correlated to occurrence of HDPE type of MPs that both types of plastic waste are related to the amount of general solid waste and recycle solid waste increases every year. The type of municipal solid waste influences the distribution of MPs into the environment, mostly from packaging waste. It is necessary to reduce the use of single-use plastics, which is the main cause. Thus helping to reduce contamination of MPs into the environment.

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REFERENCES

1. Andrady, A.L. 2011. Microplastics in the marine environment. Marine pollution Bulletin, 62(8), 1596–1605.
2. Amobonye, A., Bhagwat, P., Raveendran, S., Singh, S. Pillai, S., 2021. Environmental impacts of microplastics and nanoplastics: a current overview. Frontiers in Microbiology, 12, p.3728.
3. Arumdani I.S., Puspita A.S., Budihardjo M.A. 2021. MSW handling of top 5 leading waste-producing countries in Southeast Asia. InIOP Conference Series: Earth and Environmental Science, 896(1), 012003.
4. Cole M., Lindeque P., Halsband C., Galloway TS. 2011. Microplastics as contaminants in the marine environment: a review. Marine pollution bulletin, 62(12), 2588–97.
5. EcoWaste Coalition 2021. Waste Trade in Southeast Asia: Legal Justifications for Regional Action. https://ipen.org/sites/default/files/documents/waste_trade_in_asean-final_revised.pdf [access: 10.10.2023]
6. Europe, P. 2019. An Analysis of European Plastics Production. Demand and Waste Data.
7. Ephantus M., Robert K., Paul N. 2021. An analysis of solid waste generation and characterization in thika municipality of Kiambu County, Kenya. Journal of Environmental Science and Engineering, 210–215.
8. He D., Luo Y., Lu S., Liu M., Song Y., Lei L. 2018. Microplastics in soils: Analytical methods, pollution characteristics and ecological risks. TrAC Trends in Analytical Chemistry, 109, 163–172.
9. Horton A.A., Svendsen C., Williams R.J., Spurgeon D.J., Lahive E. 2017. Large microplastic particles in sediments of tributaries of the River Thames, UK–Abundance, sources and methods for effective quantification. Marine Pollution Bulletin, 114(1), 218–226.
10. Kershaw P., Turra A., Galgani F. 2019. Guidelines for the monitoring and assessment of plastic litter in the ocean. GESAMP Reports and Studies, 99, 130.
11. Kusumarn Noppathip. 2014. Assessment Heavy Metals Contamination and Type of Microplastics in Municipal Solid Waste Landfill of Muang Kamphaeng Phet Municipality, Kasetsart University.
12. Law K.L., Thompson R.C. 2014. Microplastics in

the seas. Science, 345(6193), 144-145.

13. Letshwenyo M.W., Kgetseyamore D. 2020. Generation and composition of municipal solid waste: case study, extension 7, Palapye, Botswana. SN Applied Sciences, 2, 1–8.
14. Masura J., Baker J., Foster G., Arthur C. 2015. Laboratory Methods for the Analysis of Microplastics in the Marine Environment: Recommendations for quantifying synthetic particles in waters and sediments. NOAA Marine Debris Division, Silver Spring, USA.
15. Mintenig S.M., Löder M.G.J., Primpke S., Gerdts, G. 2019. Low numbers of microplastics detected in drinking water from ground water sources. Science of the Total Environment, 648, 631–635.
16. Natesan U., Vaikunth R., Kumar P., Ruthra R., Srinivasalu S. 2021. Spatial distribution of microplastic concentration around landfill sites and its potential risk on groundwater. Chemosphere, 277, 130263.
17. Praveena S.M., Aris A.Z. 2021. The impacts of COVID-19 on the environmental sustainability: a perspective from the Southeast Asian region. Environmental Science and Pollution Research, 1, 1–8.
18. Rojas-Valencia M.N., Nájera-Aguilar H. 2012. Analysis of the generation of household solid wastes, household hazardous wastes and sustainable alternative handling. International Journal of Sustainable Society, 280–299.
19. Saengchut P., Kongritti N., Viriya H. 2022. Applying of economic index data for municipal solid waste quantity prediction in Thailand. Asia-Pacific Journal of Science and Technology, 27(05).
20. Su L., Xue Y., Li L., Yang D., Kolandhasamy P., Li D., Shi, H. 2016. Microplastics in Taihu lake, China. Environmental Pollution, 216, 711–719.
21. Su Y., Zhang Z., Wu D., Zhan L., Shi H., Xie B. 2019. Occurrence of microplastics in landfill systems and their fate with landfill age. Water Research, 164, 114968.
22. Tang Y., Rong J., Guan X., Zha S., Shi W., Han Y., Liu G. 2020. Immunotoxicity of microplastics and two persistent organic pollutants alone or in combination to a bivalve species. Environmental Pollution, 258, 113845.
23. Thailand Environment Institute Foundation (TEI) 2021. Solid Waste During COVID-19. http://www.tei.or.th/en/ [access: 5.10.2023]
24. UN Environment 2017. Summary report: Waste management in ASEAN countries . http://www.rrcap.ait.ac.th/Publications/Waste_Management_in_ASEAN_Countries_Summary_Report.pdf [access: 5.10.2023]
25. Veerasingam S., Ranjani M., Venkatachalapathy R., Bagaev A., Mukhanov V., Litvinyuk D., Vethamony P. 2021. Contributions of Fourier transform infrared spectroscopy in microplastic pollution research: A review. Critical Reviews in Environmental Science and Technology, 51(22), 2681-2743.
26. Wang J., Peng J., Tan Z., Gao Y., Zhan Z., Chen Q., Cai L. 2017. Microplastics in the surface sediments from the Beijiang river littoral zone: composition, abundance, surface textures and interaction with heavy metals. Chemosphere, 171, 248–258.
27. Wright S.L., Thompson R.C., Galloway T.S. 2013. The physical impacts of microplastics on marine organisms: a review. Environmental Pollution, 178, 483–492.
28. Yuan Z., Nag R., Cummins E. 2022. Ranking of potential hazards from microplastics polymers in the marine environment. Journal of Hazardous Materials, 429, 128399.
29. Zhou B., Wang J., Zhang H., Shi H., Fei Y., Huang S., Barceló D. 2020. Microplastics in agricultural soils on the coastal plain of Hangzhou Bay, east China: Multiple sources other than plastic mulching film. Journal of Hazardous Materials, 388, 121814.