Co-processing of RDF and Yangtze floating material

Every minute another truckload of plastic waste is ending up in our oceans, and if nothing is done, the amount is expected to triple by 2040.[1] In December 2020 one possible tool in the toolbox to stem this plastic tide was tested and demonstrated in the biggest river in China, the Yangtze River. The result: as much as 20,000tpa of plastic waste can be prevented from potentially reaching our oceans.

■ *by **Dr Kåre Helge Karstensen**, **Anneli Alatalo Paulsen** and **Palash Kumar Saha**, Foundation for Scientific and Industrial Research (SINTEF), Norway, and **Meijjia Liu** and **Dr Yan Dahai**, The Chinese Research Academy of Environmental Sciences (CRAES), China*

The Norwegian-funded project "Ocean Plastic Turned into an Opportunity in Circular Economy" (OPTOCE) investigates how the involvement of energy-intensive industries such cement manufacturing can increase the treatment capacity for non-recyclable plastic wastes in China, India, Myanmar, Thailand and Vietnam. These countries produce around 217,000tpd (79Mta) of plastic waste and have some of the highest releases of plastics into the sea.

These five countries also produce around 75 per cent of the world output of cement, steel and electric power, using huge amounts of coal and contributing a large share of global greenhouse gases. Replacing parts of this coal with non-recyclable plastic wastes may represent a win-win opportunity – preventing the plastic from ending up in the ocean, reducing the need for large amounts of fossil coal and indirectly reducing greenhouse gases by avoiding building new incinerators and landfills.

OPTOCE is currently investigating the feasibility of removing thousands of tonnes of non-recyclable plastic waste from large rivers, dumpsites, paper recycling industry and cities by co-processing this waste in local cement plants around Asia. The lessons learned from the pilot demonstrations will be shared in a regional multi-stakeholder forum.

Generation of plastic waste

An estimated 9.3bnt of newly-produced plastics was manufactured globally up to 2019.[2] Of this total, 6.3bnt have already ended up becoming plastic waste, with only nine per cent recycled, 12 per cent incinerated and 79 per cent dumped. This implies that more than 5bnt of plastic wastes are today accumulated in dumpsites, landfills and the natural environment around the world. This will slowly break down and be released into groundwater and rivers, constituting a continuous source of microplastics in the world's oceans.

Cement plant by the Yangtze River in China

China is one of the world's largest plastic producers and consumers, producing 81Mt in 2016, or about 29 per cent of global plastic production.[3] For several years, China received the bulk of scrap plastic from around the world, processing much of it into materials that could be used by manufacturers. Plastic waste and scrap imports were banned in early 2018, affecting the developed nations, who struggled to find places to send their waste, and the developing southeast Asian nations such as Thailand, Vietnam, and Malaysia, where the wastes were redirected to.

China generates around 440Mta of solid wastes. In 2019 plastic waste volumes reached ~63Mt.[4] The main treatment of solid waste is incineration and landfilling as only 11 per cent of collected plastic waste is recycled.[5]

Cement production in China

China is the world's largest producer of cement, accounting for about 58 per cent (or 2.4bnt) of global cement production in 2018. Co-processing is practised in more than 100 cement plants. The thermal substitution rate (TSR) is estimated to be below eight per cent. Co-processing is now an important pillar in the Chinese

Collection of floating material from the Yangtze River

waste management strategy and circular economy, and an integrated part of the National 13th Five-Year Plan on Ecological and Environmental Protection. The Chinese cement industry co-processes around 3.5Mta of raw municipal solid waste (MSW), containing 10-15 per cent plastic and 2Mta of refuse-derived fuels (RDF), containing 30-40 per cent plastic.

Pilot demonstrations

The OPTOCE project aims to showcase how the cement industry can participate by increasing the treatment capacity for non-recyclable plastic wastes and avoiding plastics reaching the ocean. Pilot demonstrations will be conducted in all countries to test and document the performance, ie, describe the circularity, plastic waste co-processing capacity, environmental performance, cost- and energy efficiency, need for pretreatment, limitations in types and volumes of plastic waste, etc.

The overall aim of these demonstrations is to provide a quantitative and qualitative assessment of how the participation of private industry can improve plastic waste management and prevent marine littering in each of these countries.

Pilot demonstration with floating material in China

Large amounts of floating material accumulate in the Yangtze River during the annual rainy season. The floating material must be collected to avoid damage to dams and their turbines but also to protect the river's environment and ecosystem.

A pilot demonstration with collected floating material and RDF from Zigui town was conducted in the Huaxin cement plant in Hubei province in December 2020. The floating material affects the river water quality and threatens the safety of the power generation facilities, as well as ship propellers, buoys and river transportation safety.

This material can be divided into the following three categories:

1. all-year-round municipal solid wastes and industrial wastes such as plastics, foams, other white pollutants and various waste appliances or products
2. trees and crop straws such as logs, branches, straws, and shrubs, forming the biggest category
3. a small amount of disaster-related floating materials such as animal bodies, wood, out-of-control buoys and wrecked ships.

Around 100,000m^3 of floating material is removed annually from 13 districts and counties in the reservoir area around Chongqing City.

Pre-treatment of floating material

The floating material was transported by barge from the dam area to a drying facility in Huaxin cement plant in Zigui. Hot flue gas from the waste heat recovery power generation was connected to the grate cooler of the cement kiln and used as a heat source to dry the floating material in a specialised dryer. Solar drying is used to dry smaller amounts. Once dried the floating material is crushed and sent to the precalciner of the cement kiln by a conveyor belt.

The Zigui plant co-processes floating material and RDF ~150 and 330 days per year, respectively.

Pilot testing

The dried floating material and the RDF have an average calorific value of ~2100kcal/kg but contain a higher

Table 1: testing conditions

Date	Test condition	Sampling
22 Dec 2020	Co-processing floating materials	From 12h, the floating materials were fed by the conveyor belt at a rate of 13tph.
		Between 14-22h, the staff of Huaxin (Zigui) and the sampling company took samples of the exit gas, coal, kiln feed, floating materials, clinker, kiln dust and bypass dust.
23 Dec 2020	Co-processing RDF	From 8h, RDF was fed by the conveyor belt at a rate of 13tph. Between 10-18h, the staff of Huaxin (Zigui) and the sampling company took samples of the exit gas, coal, kiln feed, floating materials, clinker, kiln dust and bypass dust.
24 Dec 2020	Baseline condition (coal only)	Between 8-16h, the staff of Huaxin (Zigui) and the sampling company took samples of the exit gas, coal, kiln feed, clinker and kiln dust.
After the test		Samples were labelled and sent for chemical and other analysis.

Table 2: characteristics of floating material and RDF used in the pilot test		
Parameters	**Floating material**	**RDF from Zigui**
Share of plastic waste (%)	13.91	12.27
Heat content (kcal/kg)	2223	1955
Estimated co-processing volumes in 2020 (t)	46,800	102,960
Estimated co-processing volumes of the plastic waste fraction in 2020 (t)	6510	12,633

concentration of chlorine and fluorine, as well as water, compared to coal. The calorific value of the coal normally used is 5800kcal/kg, meaning that the feeding rates had to be adjusted to the tolerance of the kiln; the by-pass was in operation during the test. Table 1 provides an outline of the three-day pilot demonstration conducted in December 2020.

Table 2 provides more details of the waste material used in the pilot test.

Process conditions and emissions

The coal consumption for each tonne of clinker produced decreased by 10.47 per cent and 6.44 per cent in co-processing floating material and RDF, respectively, while the thermal substitution rates (TSR) were 9.62 and 8.25 per cent, respectively.

The feeding rate of the kiln feed remained unchanged in co-processing of both floating material and RDF. The clinker production rate and the consumption of the kiln feed for each tonne of the clinker both increased slightly. The clinker produced complied with the quality limits specified in "Portland cement clinker" (GB/T 21372-2008), indicating that co-processing floating material did not cause deterioration in the physical and chemical properties of the clinker.

The concentration of air pollutants was in compliance with the limits specified in GB30485-2013 in all three conditions (some results for CO and NO_x are under further investigation). Although the chlorine content was higher in the floating material and RDF, it did not cause an increase in the dioxin emissions. Both particulate and gaseous heavy metals were sampled and analysed in the test, and showed to be lower than the limits stipulated in GB30485-2013.

Conclusion

A few ships can collect all the floating material generated upstream of a large dam in the Yangtze River during the rainy season. This part of the river, located mainly in the Hubei province, drains garbage and waste from millions of people and thousands of square kilometres of land. The collected floating material is brought upstream to the Huaxin cement plant, where it is dried, shredded and co-processed along with RDF from the town of Zigui. Both the RDF and the floating material contain around 10-15 per cent plastic, implying that this co-processing activity was removing or avoiding around 20,000t of plastic waste from reaching the East China Sea in 2020.

"Co-processing of the plastic waste fraction of floating material and RDF was also reducing coal consumption by ~20,000t, equivalent to a CO_2 emissions reduction of ~53,000t in 2020, making it a win-win solution..."

Co-processing of the plastic waste fraction of floating material and RDF was also reducing coal consumption by ~20,000t, equivalent to a CO_2 emissions reduction of ~53,000t in 2020, making it a win-win solution and a valuable part of a sustainable plastic waste management scheme. ■

REFERENCES AND BIBLIOGRAPHY

[1] THE PEW CHARITABLE TRUSTS AND SYSTEMIQ (2020) *Breaking the Plastic Wave – A Comprehensive of Pathways Towards Stopping Ocean Plastic Pollution.* SL: The Pew Charitable Trusts, 153p.

[2] GEYER, R, JAMBECK, JR AND LAW, KL (2017) 'Production, use, and fate of all plastics ever made' in: *Science Advances*, 3: e1700782. 19 July, p1-5.

[3] WANG, MARY H, HE YAODONG AND SEN BISWARUP (2019) 'Research and management of plastic pollution in coastal environments of China' in: *Environmental Pollution*, 248, 898e905. https://doi.org/10.1016/j.envpol.2019.02.098.

[4] LIU, J, YANG, Y, AN, L, LIU, Q AND DING, J (2021) 'The Value of China's Legislation on Plastic Pollution Prevention in 2020' in: *Bulletin of Environmental Contamination and Toxicology* https://doi.org/10.1007/s00128-021-03366-6 [Accessed 4 September 2021].

[5] OCEAN CONSERVANCY AND MCKINSEY CENTER FOR BUSINESS AND ENVIRONMENT (2015) *Stemming the tide – Land-based strategies for a plastic-free ocean*. Washington DC, USA: Ocean Conservancy/McKinsey Center for Business and Environment, 48p.

Collected floating material from the river has an average calorific value of ~2100kcal/kg