Circular economy and health: examples fromGreece with a focus on plastics

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Introduction: The complexity of assessing the health impact of hazardous waste is compounded by the variety of waste types, roughly categorized as (a) municipal, (b) agricultural, (c) e-waste, (d) hospital and (e) industrial, which in turn are associated with a broad range of contaminants, such as dioxins (PCDDs) and furans (PCDFs), toxic metals (Cd, As, Cr(VI), Hg), volatile and semi-volatile organic compounds (VOCs and SVOCs), polyaromatic hydrocarbons (PAHs), hydrogen sulphide (H_2S), particulate matter, methane (CH_4), pesticides, phthalates, and PCBs. Exposure to these compounds is highly variable and the waste management option selection is critical.

Given that waste management options are reflected in the type of compounds emitted and the respective health effects, it is important to keep in mind the share of the various waste management options employed across Europe. In the 28 Member States, 28% of municipal waste was recycled, 15% was composted (through aerobic and anaerobic processes), while 26% and 31% were, respectively, incinerated and disposed of in landfill. However, there is a large variability in approaching waste management across the EU; in Greece, landfilling accounts for 80.7%, composting only for 3.7% and recycling for 15.5% for an annual production 0.5 tn MSW/capita. In addition, informal activities around waste collection, sorting, treatment and disposal, and illegal flows and trafficking of hazardous waste represent a serious challenge. In any case, the transition to circular economy requires the fulfilment of different target MSW management option shares; by the year 2040, MSW disposal to landfill should account for only 10%, recycling for 65%while biowaste should be collected separately. The targets for packaging are even higher, where the minimum recycling target per material accounts as 30% for wood, 85% for paper, 55% for plastic, 60% for aluminium, 80% for metal and 75% for glass.

Among the various materials comprising MSW, plastics account for almost 14%. However, the plastic crisis, has induced many jurisdictions to pose bans on use of plastic bags and enhance plastic recycling in the respective municipal waste management systems. Still to date, however, landfilling remains the most common waste management practice in countries like Greece, despite enforced regulations aimed at increasing recycling, pre-selection of waste and energy and material recovery. Regarding plastic waste, there is a limited number of studies focusing on the adverse human health effects of plastic products and waste, the ubiquitous nature of plastic material notwithstanding. On the other hand, waste recycling is one of the main cornerstones of the EU waste management strategy. It offers many advantages contributing to the circular economy and the sustainable and efficient use of natural and man-made resources. However, waste recycling facilities may be associated with adverse health outcomes in the aftermath of industrial accidents involving the inadvertent generation of toxic chemicals and their release into the environment.

Materials and methods: To better identify the risks associated with plastics and the included plasticisers (additives that increase the plasticity or decrease the viscosity of a material) aiming at the improvement of efficiency of circular economy, estimation of the associated health impacts related to the life cycle of the materials has to be introduced. Towards this aim, exposome (that represents the totality of exposures from conception onwards, including the exogenous and endogenous exposures and modifiable risk factors that predispose to and predict disease). Unravelling it will help us understand the intricate web of relationships between environmental exposures, lifestyle, genetics and disease. Such a process implies that environmental exposures and genetic variance are reliably measured and linked through mechanistic analysis of toxicity pathways. To understand the interaction between environmental exposure and disease, we need to capture the biological perturbations initiated by chronic exposure to environmental stressors and identify the ones that overcome the homeostasis barrier inducing alterations of the cell/tissue environment and eventually disease phenotypes(Sarigiannis, 2015a; Sarigiannis, 2015b). The methodology proposed above, has been applied in the wider area of Athens, the capital of Greece which is populated with around 5 million inhabitants. The average amount of municipal solid waste is equal to 6 ktn/d (Hellenic Statistical Authority 2008). The average composition of the waste in Attica includes organics (42%), paper (29%), plastic (14%), metal (3%), and other material (6%). The average transportation distance of the MSW is 19 km. Two of the main MSW facilities in

Athens are the landfill in Fili and the plastic recycling plant of Aspropyrgos. The aim of the study is to identify (a) how the different waste management options (including in the analysis also the option of incineration) will affect exposure to plasticisers and (b) what are the effects on human health of the people leaving nearby a recycling facility in the case of an accidental event.

Results and discussion: For assessing the risk of plasticisers under the various MSW option, a comprehensive review of up-to-date information on plastic products and plasticizers used by the urban population was performed in order to build up the application-specific release/emissions inventory, accounting for their life cycle (life cycle analysis). This review included both plastic products (e.g. PET bottles, PVC material, polycarbonate products) and plasticizers used in food packaging. It has to be noted that particular attention has been paid in the life cycle analysis of the materials used for recycling. In a given material cycle, chemicals are constantly added and removed from the loop. If the rate of their addition, is higher than the rate of removal, accumulation of chemical contaminants in the newly manufactured products can be expected. Compounds of interest in this regard include bisphenol A, phthalates such as DEHP and DiNP, as well as DINCH, di-(2-ethylhexyl)adipate. The environmental fate analysis performed, included both multi-media contamination of POPs found in plastic waste and contamination of the food web including seafood. Integration of all human exposure routes and pathways to the toxic compounds contained in plastic was done at the level of systemic internal dose using the intake fraction methodology. We then parameterized properly the state-of-the-art generic physiology-based biokinetic (PBBK) model in the INTEGRA platform for these compounds and used it to reckon the biologically effective dose (BED) at the target tissues more closely associated with the putative adverse health outcomes considered in our study. Thus, we estimated the level of homeostatic perturbation induced by the BED at the target tissues. The extent of the perturbation was then used as the fundamental metric that was linked with adverse health outcomes reported in the literature to quantitatively assess the related health risk.From the analysis it was indicated that among the investigated technologies, higher risks for public health are associated with landfilling, followed by incineration, while recycling resulted in the lowest risk estimates. Overall the estimated risks of the investigated plasticizers seem to be low, since the estimated intake was 1 to 2 orders of magnitude below the respective tolerable daily intakes(TDIs). However, population exposure to plasticizers through landfilling is something that should be further investigated and the transition to recycling is expected to increase the safety levels of plasticizer use, if the main safety principles of material flow (rate of their addition is lower than the rate of removal) are respected.

To estimate the human health risks posed by recycling in an accidental event in a recycling facility, thecase study of the accidental fire that happened in the plastics recycling plant in Aspropyrgos on June 6, 2015 was demonstrated. The fire resulted in significant particle and gaseous emissions of several compounds related to plastic industry. In addition, release of dioxins and furans was a major concern, due to their persistence in environmental and biological matrices, as well as to their carcinogenic potency. Risk associated to the PCDDs/PCDFs emitted during the fire, required the estimation of the long-term internal burden of exposure associated to this event. The need for addressing long term exposure is associated to the fact that PCDDs/PCDFs are bioaccumulative and persistent, with a half-life time of almost 7.5 years in humans.To estimate the additional risk posed by exposure to the accidental event utilizing the INTEGRA platform was used. In addition to the above, blood samples of 50 individuals (including both children and adults) were taken and analysed for PCDDs/PCDFs levels, as well as for metabolomics analysis.Based on the background level of exposure to PCDDs/PCDFs of the general population the risk of chronic exposure was estimated (mean value) to be equal to $2.57 \cdot 10^{-7}$. For the population exposed over 6 days to the PCDDs/PCDFs fumes emitted from the recycling plant fire the respective risk (mean value) was up to $2.91 \cdot 10^{-7}$, indicating an increase of 13% in the 30-year cancer risk.In addition, untargeted metabolomics analysis indicated that increased levels of unsaturated vs saturated fatty acids were identified compared to controls (population non-exposed to the fumes). This finding could indicate perturbation of cholesterol homeostasis; the latter, is highly related to AhR deregulation, which in turn is involved in liver cancer associated adverse outcome pathways. The fact that the increase of the associated risk is in the range of 10^{-7}, indicates that the estimated risk is within the range of the background risk associated to PCDDs/PCDFs exposure from multiple sources.

Conclusions: Overall, the transition to circular economy passes through the increased share of recycling in the MSW management technologies. From the comprehensive assessment of the human health risks associated with recycling (both in the life cycle of the plastic materials including waste management, as well as in the case of an accidental event), the health benefits compared to the use of other MSW management options, outperform the potential risks of operational use or accidental events.

References

Sarigiannis, D., 2015a. Exposome science for public health protection and innovation. Toxicology Letters. 238**,** S12-S13.

Sarigiannis, D., 2015b. Unravelling the Exposome through integrated exposure biology. Toxicology Letters. 238**,** S229-S230.