Human Health Risks Concerning Food Waste Management

Elena-Diana Ungureanu-Comanita[1], Ersilia Lazar Cosbuc[1], Petronela Cozma[1], Camelia Smaranda[1], Maria Gavrilescu[1,2]

[1:] "Gheorghe Asachi" Technical University of Iasi, Faculty of Chemical Engineering and Environmental Protection, Department of Environmental Engineering and Management, 73 Prof. D. Mangeron Str., 700050 Iasi, Romania;
e-mail address: comanita_elena_diana@yahoo.com; mgav@ch.tuiasi.ro
[2:] Academy of Romanian Scientists, 3 Ilfov Street, 050044 Bucharest, Romania

***Abstract*— Over time, the enormous amount of waste, generated worldwide, induces threats to the environment. Most of the total waste, generated globally, is represented by food waste, which is produced annually. The most relevant sources are the food and beverage industry as well as households. The purpose of the study is to: (i) identify risk factors on human health generated by the production of food waste; (ii) analyze and highlight the best management alternatives for the recovery and recycling valuable components of food waste, to reduce the environmental impacts and human health risks and diminish the pressure on natural resources.**

***Keywords*— bio-based materials, biofuel, food waste, health risk, environmental impact**

I. Introduction

The food system, in general terms, includes all materials, processes and infrastructures related to trade, retail, transport, agriculture and food consumption [1]. European Union (EU) is one of the largest food producers in the world. Food consumption by Europeans has changed considerably over time (for example, compared to 50 years ago, we eat twice as much meat per capita) [1]. However, since 1995, beef consumption per capita has fallen by 10% [2]. Also, statistics have shown that the population of Europe eats much more fish, poultry, vegetables, sea-food, fruits [2]. This means that a third of the total food produced worldwide is wasted or stored as waste. The food sector, and the food waste sector, are among the key areas highlighted on the European Commission's "Roadmap to a Resource Efficient Europe" since September 2011 [3]. Although it is widely acknowledged that we dispose some of the food we produce as waste, it is quite difficult to make an accurate estimate on the food waste amount in the world [4]. The European Commission estimates that in EU alone, 90 million tons of food or 180 kg per person are disposed of as waste every year [2]. The sectors contributing the most to food waste generation are: processing and production (39%) and bakery (25%) [2], these two sectors accounting for 64% of EU food waste. The remaining percent comes from dairy, soft drinks, alcohol production and distribution, snacks sweets, frozen food and pasta [2] (Fig. 1).

According to the generating mode, food waste are grouped into three categories that include: avoidable - foods that are still edible but are wasted before being eaten (eg bread, vegetables, meat, etc.); unavoidable – food deriving from the preparation of food that are not, and could not, be edible (for example, meat bones, egg shells, pineapple skins etc.), potentially avoidable - food that the population consume and do not (for example, bread crusts), or food that can be edible, if cooked one way instead of another (such as potato skins etc.) [5, 6].

In Romania, the amount of household waste generated in 2018 was 13.178 tons; from this amount, about 47% is represented by organic food waste [7] (Fig. 2). Approximately one third of all the food in Romania is unnecessarily wasted annually. This quantity corresponds to about 2.55 million tons of food, which matches to the load of 127.500 trucks [8]. A Romanian citizen uses to throw over 350 grams of food every day, meaning 129 kilograms of food annually. Of this amount, 24% is cooked food, 22% - fruits, 21% - vegetables, 20% - bakery products, 11% - dairy products and 1% - meat [8, 9]. Therefore, these enormous amounts of waste have become increasingly important for the public and political agenda in recent years [10].

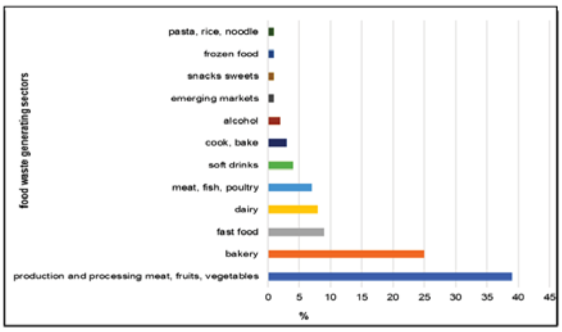

Fig. 1. Food sectors waste generators (year 2018)

Food is a precious commodity, and its production can require a lot of resources, while food waste is associated with very high economic and environmental costs, if inadequate food waste management is implemented which can lead to high risks to human health [11, 12].

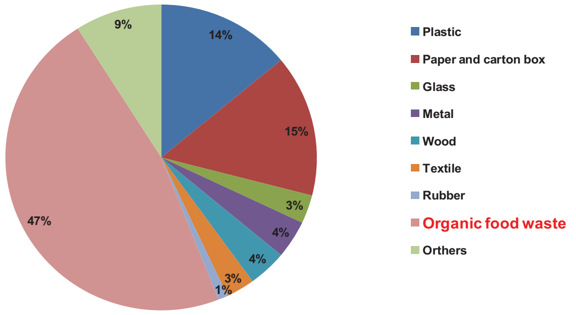

Fig. 2. The average composition of household waste in the world (year 2018)

In this paper we planned to identify the human health's risk factors due to inadequate food waste management and recommend best management alternatives for the recovery and recycling of food waste.

II. ENVIRONMENTAL IMPACTS GENERATED BY FOOD WASTE AND IDENTIFICATION OF RISK FACTORS ON HUMAN HEALTH

A. Human health risks generated by the presence of food waste in the environment

The categories of persons in distress as a result of improper food waste management include the population in areas where there is no adequate method of disposing of organic food waste, the most exposed being preschool children, waste workers, commercial workers [13]. Other groups of people at high risk of illness include the population living near not complying landfills or those who drink water contaminated either due to waste dumping or leakage from landfills [14, 15]. All these threats as consequences of scarce food waste management **produce severe human health diseases**: **skin and blood infections, eye and respiratory infections, intestinal infections, cancers, bone and muscle disorders**.

Due to their specific composition, this type of waste poses serious threats for health security since it can create favorable conditions for the survival and growth of microbial pathogens [15]. Directly or indirectly, food waste generated in the world affects well-being and human health in many ways. For example, the fermentation stage of food waste results in methane gas that affects climate change. Also, during the fermentation stage of food waste, pollutants are released into the atmosphere and can enable population exposure to chemicals and pathogens hazards as chronic or acute forms [16, 17]. Domingo and Nadal [18] demonstrate that during aerobic decomposition of organic solids a number of volatile organic compounds are released: alcohols, organic ketones, esters and acids that cause a number of direct effects on human health, such as changes in the respiratory pattern. Blanes-Vidal study [19] shows that the population exposed to higher levels of air pollution with emissions from the decomposition of biodegradable waste such as NH_3, suffers from increased respiratory problems and headaches. According to Yao et al. [20], the first ten volatile organic compounds from an anaerobic fermentation plant for waste disposal were methanethiol, dimethyl sulfide, dimethyl disulfide, carbon disulfide, styrene, m-xylene, 4-ethylene, ethylbenzene, 2-hexyl ketone and n-hexane at levels above the permissible carcinogenetic limit.

B. Impact generated by food waste in the environment

In addition to the social and moral aspects, the improper management of food waste leads to considerable negative effects on air, water, soil and energy resources, manifested by greenhouse gas emissions and contribution to climate change, pollution with fertilizers, pesticides and methane resulting from the decomposition of food that ends up in landfills. Considered to be the method of last choice in the waste hierarchy, especially for food waste, landfilling is associated with the generation of secondary pollutants such as those mentioned above, but also others and, likewise represents a waste of resources, such as the costs of waste transportation and management of landfill and pollutants resulting from anaerobic processes that takes place in the landfill due to lack of oxygen. Landfilling also causes alteration of landscape and habitats [21]. Depending on how they are built, landfills could also contaminate soil and water [22, 23]. Marine or coastal ecosystems can be severely affected by the improper management or disposal of food waste and not just for aesthetic reasons: the fact that animals remain trapped in this waste, as well as their ingestion, pose serious threats to many marine species [23]. Domingo and Nadal [18] demonstrate that increasing the global greenhouse effect in the process of aerobic decomposition of organic solids is one of the worst problems globally. An interesting study was provided by Read et al. [24] which evaluate the resources consumed or emitted to the environment by food waste. The authors found that the annual energy footprint of food waste per capita in the United States is 6-9 GJ. A recent global environmental footprint study by Reisch et al. [25] suggests that grains, fruit, and vegetables (field-grown foods) have a rather low impact, while products from ruminant animals have a high impact on GHG emissions. Using Life Cycle Assessment, Scherhaufer et al. [26] evaluated the environmental impacts of food waste in Europe in relation to the total food utilized. The results showed that one third of all impacts (eg global warming) generated by food waste come from greenhouse gas emissions during the production stage.

III. FOOD WASTE MANAGEMENT ALTERNATIVES TO REDUCE THE HUMAN HEALTH RISKS AND THE ENVIRONMENTAL IMPACTS

Food waste management is in accordance with EU waste legislation. Food waste were included in degradable waste category, separately until 2018 when Directive 2018/851/EC amending Directive 2008/98/EC on waste was adopted. By this Directive, article 4(a) defines food waste as "all food that has become waste" [27]. **The 2030 Agenda for Sustainable Development** aims to impose limits and measures on the management of food consumption and waste from food sectors [27]. **Objective 12.3 of the Sustainable Development Goals** focuses on reducing by 50% the global food waste per capita at retail and consumer levels, as well as reducing food losses along production chains and supply, until 2030 [2, 27]. Practices used in the past concerning uncontrollable depositing of waste are no longer supported by current policy on waste management because environmental protection standards have become more stringent at present and energy recovery, recycling of nutrients and organic matter become stringent [28, 29]. Actions on the correct management of food waste should be performed according to the waste hierarchy presented in Fig. 3, which considers that prevention, by minimizing of food waste is the most favorable option [30].

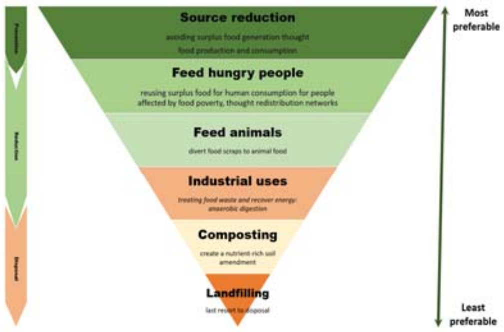

Fig. 3. The food waste management hierarchy (adapted upon Tavill [28])

The major methods of food waste management are [30]: **(i) Recycling** makes a positive contribution to reducing emissions, especially greenhouse gases, because the main objective of sustainable development is focused on the use of material resources from waste. Therefore, recycled materials reduce the stage of extraction or production of new materials. Even if the food production part generates less problems, it is not able to green the life cycle of the entire food system. It is therefore necessary to streamline all stages of this cycle, which includes transport, retail and consumption - more wasteful and environmentally unfriendly [31]. **(ii) Composting** food waste is a controlled aerobic process, through which organic waste is transformed into a stable, environmentally friendly compound that can be used for soil fertilization and conditioning, thus representing a natural fertilizer. **(iii)** The method of waste treatment - **anaerobic digestion** - involves the biological decomposition of food waste, similar to that in landfills, but under controlled conditions. The end results of anaerobic digestion produce bio-materials and biogas, which in turn can be valorized in sustainable ways. **(iv) Controlled disposal** of food waste can be applied only if a legal method is used - processing, incineration or storage. This method is one of the most unfavorable because it is the largest generator of emissions.

Over time, several new methods of food waste recovery have been studied and implemented. Some research showed that agro-industrial and food wastes can be remodelled into value-added bio-based materials such as bioactive products and biopolymers [32-34]. Ushani et al. [33] proposed some methods for conversion and production of sustainable energy from food waste using bioprocesses in the frame of sustainable bioeconomy. Some scenarios are taken into account and applied like: enzymatic valorization of food waste for production of biopolymers (polyhydroxybutyrate, polyhydroxialcanoates), biofuel (biodiesel, bioethanol). Also, some papers proposed the valorization of agri-food industry wastes (broccoli stalks, cauliflower cores, coconut shell wastes etc.) as adsorbents for the removal of heavy metals and dyes from wastewater [35, 36]. Important contribution were made in the production of biogas from food waste in anaerobic-aerobic system [37, 38]. Also, it was investigated with good results the use of some food waste as nutrient in wastewater treatment plants so as to transform it in energy [39]. Currently, there are a number of tools for assessing the environmental impact of various alternatives applied to reduce the volume of food waste. These tools include: Cost-Benefit Analysis (CBA), Life Cycle Assessment (LCA), Multi-criteria Decision Analysis (MCDA) [21, 40]. In the next study we will apply one of these three tools to evaluate the performances of the methods of treatment and recovery of food waste, from technical, economic and environmental point of views.

IV. Conclusions

In this paper, we have identified and discussed the risks generated by food waste for the environment and human health, as well as some alternatives to reduce the potential losses generated by them.

A number of studies were analyzed which have highlighted that the recovery of food waste as bio-based products and energy is a very good opportunity in the frame of bioeconomy, to ensure sustainable production and consumption and also reduce the human health risks and environmental impacts.

The paper identifies some elements necessary for the sustainable management of food waste, which will allow both their prevention and their use as secondary resources for materials and energy in order to avoid threats to the environment and health.

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References

[1] E.-D. Comaniţă, C. Ghinea, R.M. Hlihor, M. Gavrilescu, “Occurrence of plastic waste in the environment: ecological and health risks”, Environmental Engineering and Management Journal, **3**, 2016, pp. 675–687.

[2] FAO, The Food and Agriculture Organization, 2019, On line at: http://www.fao.org/platform-food-loss-waste/flw-data/en/.

[3] G.T. Tucho, T. Okoth, “Evaluation of neglected bio-wastes potential with food-energy sanitation nexus”, Journal of Cleaner Production, **242**, 2020, 118547,. https://doi.org/10.1016/j.jclepro.2019.118547

[4] A. Sorokowska M. Marczak· M. Misiak, M.M. Stefańczyk, P.Sorokowski, “Children older than five years do not approve of wasting food: An experimental study on attitudes towards food wasting behavior in children and adults”, Journal of Environmental Psychology, **71**, 2020, pp. 101467.

[5] A. Bernstad, J.La Cour Jansen, A. Aspegren, “Door-stepping as a strategy for improved food waste recycling behaviour – evaluation of a full-scale experiment”, Resources, Conservation & Recycling, **73**, 2013, pp. 94–103.

[6] D. Leverenz, S. Moussawel, C. Maurer, G. Hafner, F. Schneider, T. Schmidt, M. Kranert, “Quantifying the prevention potential of avoidable food waste in households using a self-reporting approach”, Resources, Conservation & Recycling, **150**, 2019, pp. 104417.

[7] F. Razza, F.D. Innocenti, “Bioplastics from renewable resources: the benefits of biodegradability”, Asia-Pacific Journal of Chemical Engineering, **7**, 2012, pp. 301-309.

[8] V. Stefan, E. van Herpen, A.A. Tudoran, L.Lähteenmäki, “Avoiding food waste by Romanian consumers: The importance of planning and shopping routines”, Food Quality and Preference, **28**, 2013, pp. 375.

[9] O. Augustin, M.L. Dumitraşcu, A.I. Nicolau, D. Borda, "Food safety knowledge, food shopping attitude and safety kitchen practices among Romanian consumers: A structural modelling approach", Food Control, **120**, 2021, pp. 107545.

[10] K. Schmidt, Ellen. Matthies, "Where to start fighting the food waste problem? Identifying most promising entry points for intervention programs to reduce household food waste and overconsumption of food", Resources, Conservation and Recycling, **139**, 2018, pp 1-14.

[11] I. Sadeleer, H. Brattebø, P. Callewaert, "Waste prevention, energy recovery or recycling - Directions for household food waste management in light of circular economy policy", Resources, Conservation and Recycling, **160**, 2020, pp.104908.

[12] E.-D. Comaniţă, C. Ghinea, R.M. Hlihor, I.M. Simion, C. Smaranda, L. Favier, M. Roşca, I. Gostin, M. Gavrilescu, Challenges and oportunities in green plastics: An assessment using the ELECTRE decision-aid method, Environmental Engineering and Management Journal, **14**, 2015, pp. 689-702.

[13] M. Gao, Y. Lin, G.-Z. Shi, H.-H. Li, Z.-B. Yang, X.-X. Xu, J.-R. Xian, Y.-X.g Yang, Z. Cheng, "Bioaccumulation and health risk assessments of trace elements in housefly (Musca domestica L.) larvae fed with food wastes", Science of the Total Environment, **682**, 2019, pp. 485–493.

[14] G. Zheng, J. Liu, Z. Shao, T.Chen, Emission characteristics and health risk assessment of VOCs from a food waste anaerobic digestion plant: A case study of Suzhou, China, Environmental Pollution, **257**, 2020, pp. 113546.

[15] Y.B. Man, W. Y. Mo, F. Zhang, M.H. Wong, "Health risk assessments based on polycyclic aromatic hydrocarbons in freshwater fish cultured using food waste-based diets", Environmental Pollution, **256**, 2020, pp. 113380.

[16] G. Zheng, J. Liu, Z. Shao, T. Chen, "Emission characteristics and health risk assessment of VOCs from a food waste anaerobic digestion plant: A case study of Suzhou, China", Environmental Pollution, **257**, 2020, pp. 113546.

[17] E.-D. Comaniţă, C. Ghinea, M. Roşca, I.M. Simion, M. Petraru, M. Gavrilescu, Environmental impacts of polyvinyl chloride (PVC) production process, E-Health and Bioengineering Conference (EHB), 2015, doi: 10.1109/EHB.2015.7391486.

[18] J.L. Domingo, M. Nadal, "Domestic waste composting facilities: A review of human health risks", Environment International, 2009, **35**, pp. 382-389.

[19] V. Blanes-Vidal, "Air pollution from biodegradable wastes and non-specific health symptoms among residents: Direct or annoyance-mediated associations?", Chemosphere, **120**, 2015, pp. 371-377.

[20] X.-Z. Yao, R.-C.Maa, H.-J. Li, C. Wang, C. Zhang, et al., "Assessment of the major odor contributors and health risks of volatile compounds in three disposal technologies for municipal solid waste", Waste Management, **91**, 2019, pp. 128–138.

[21] A. Cattaneo, G. Federighi, S. Vaz, "The environmental impact of reducing food loss and waste: A critical assessment", Food Policy, https://doi.org/10.1016/j.foodpol.2020.101890

[22] H. Williams, A. Lindstrom, J. Trischler, et al. "Avoiding food becoming waste in households-The role of packaging in consumers' practices across different food categories", Journal of Cleaner Production, **265**, 2020, 121775, https://doi.org/10.1016/j.jclepro.2020.121775

[23] H. Feng, X. Wang, J. Cai, S. Chen, "Discrepancies in N2O emissions between household waste and its food waste and non-food waste components during the predisposal stage", Journal of Environmental Management, **265**, 2020, 110548, https://doi.org/10.1016/j.jenvman.2020.110548

[24] Q.D. Read, S. Brown, A.D.Cuéllar, S.M. Finn, J.A. Gephart, L.T. Marston, E. Meyer, K.A. Weitz, M.K. Muth, "Assessing the environmental impacts of halving food loss and waste along the food supply chain", Science of The Total Environment, **712**, 2020, pp. 136255.

[25] L.A. Reisch, C.R. Sunstein, M.A. Andor, F.C. Doebbe, J. Meier, N.R. Haddaway, "Mitigating climate change via food consumption and food waste: A systematic map of behavioral interventions", Journal of Cleaner Production, 2020, https://doi.org/10.1016/j.jclepro.2020.123717.

[26] S. Scherhaufer, G. Moates, H. Hartikainen, K. Waldron, G. Obersteiner, "Environmental impacts of food waste in Europe", Waste Management, **77**, 2018, pp. 98–113.

[27] B. Redlingshöfera, S. Barles, H. Weisz, "Are waste hierarchies effective in reducing environmental impacts from food waste? A systematic review for OECD countries", Resources, Conservation & Recycling, **156**, 2020, pp. 104723.

[28] Yap H.Y., Nixon J.D., 2015, A multi-criteria analysis of options for energy recovery from municipal solid waste in India and the UK, **46**, Waste Management, pp. 265–277.

[29] M. Fortună, I.M. Simion, C. Ghinea, M. Petraru, P. Cozma, L.C. Apostol, R.M. Hlihor, D.T. Fertu, M.Gavrilescu, "Analysis and management of specific processes from environmental engineering and protection based on sustainability indicators", Environmental Engineering and Management Journal, **11**, 2012, pp. 333-350.

[30] G. Tavill, "Industry challenges and approaches to food waste", Physiology & Behavior, **223**, 2020, 112993, https://doi.org/10.1016/j.physbeh.2020.112993

[31] M.A. Parry, M.J. Hawkesford, Food security: increasing yield and improving resource use efficiency, Proceedings of the Nutrition Society, **69**, 2010, pp. 592–600.

[32] K.B. Arun, A.M. Raveendran Sindhu, P. Binod, A. Pandey, R. Reshmy, R. Sirohie, "Remodeling agro-industrial and food wastes into value-added bioactives and biopolymers", Industrial Crops and Products, **154**, 2020, pp. 112621.

[33] U. Ushani, A.R.Sumayya, G. Archana, J.Rajesh Banu, Jinjin Dai, "Chapter 10 - Enzymes/biocatalysts and bioreactors for valorization of food wastes", Food Waste to Valuable Resources, 2020, pp. 211-233..

[34] Y.F. Tsang, V. Kumar, P. Samadar, Yi Yang, Jechan Lee, Y.S. Ok, H. Song, K.-H. Kim, E.E.Kwon, Y.J. Jeong, "Production of bioplastic through food waste valorization", Environment International, **127**, 2019, 625-644.

[35] V.J. Landin-Sandoval, D.I.Mendoza-Castillo, A.Bonilla-Petriciolet, I.A.Aguayo-Villarreal, H.E.Reynel-Avila, H.A.Gonzalez-Poncea, "Valorization of agri-food industry wastes to prepare adsorbents for heavy metal removal from water", Journal of Environmental Chemical Engineering, **5**, 2020, 104067.

[36] R. Singh, P.V. Nidheesh, T. Sivasankar, Integrating ultrasound with activated carbon prepared from mangosteen fruit peel for reactive black 5 removal, Environmental Engineering and Management Journal, **18**, 2019, pp. 2335-2342.

[37] F. Aliasgari, H. Godini, M. Noorisepehr, N. Tafreshi, "Enhancement of biogas production from food wastes in a hybrid anaerobic–aerobic bioreactor by manure addition and lime-pretreatment of recycled leachate", Environmental Engineering and Management Journal, **18**, 2019, pp. 2673-2682.

[38] S. Mirmohamadsadeghi, K. Karimi, M. Tabatabaei, M. Aghbashlo, "Biogas production from food wastes: A review on recent developments and future perspectives", Bioresource Technology Reports, **7**, 2019, 100202, https://doi.org/10.1016/j.biteb.2019.100202

[39] A.A. Pilarska, K. Pilarski, B. Waliszewska, M. Zborowska, K. Witaszek, H. Waliszewska, M. Kolasiński, K. Szwarc-Rzepka, "Evaluation of biomethane yields from high-energy organic waste and sewage sludge: a pilot study for a wastewater treatment plant", Environmental Engineering and Management Journal, **18**, 2019, pp. 2023-2034.

[40] C. Conti, J. Bacenetti, D. Tedesco, "Earthworms for feed production from vegetable waste: environmental impact assessment", Environmental Engineering and Management Journal, **18**, 2019, pp. 2117-2122.