Developing a framework for sustainable actions that civil society can undertake to mitigate the impact that microplastics have on human health.

A scoping review of literature.

Master Thesis

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Abstract:

Background

Each year the number of microplastics is increasing on a global level. Based on the current status quo, the number of microplastics will only continue to rise for the coming years as production levels increase. This presents many environmental and health challenges internationally. At this point we do not know exactly to what extent microplastics effect human health. However, available scholarship indicates that the potential for copious negative health effects is present. In addition, it is clear that there are many actions currently taken place to reduce the impact of microplastic pollution. While many of these initiatives are positive, they are not enough. This systematic literature review study focuses on the state of current sustainable actions as well as identifying gaps in research related to microplastics and human health.

Objectives

The purpose of this literature review was to develop a framework for sustainable actions that civil society can undertake to mitigate the impact that microplastics have on human health. Specifically, there was a focus on delineating the problem of microplastics through the lens of human health, assessing different strategies used for acting upon microplastics, developing a framework for future actions that can lead to sustainable interventions related to mitigating microplastics, and lastly identifying obstacles to implementing interventions.

Method

A scoping review of existing literature was done using a systematic method to collect and critically appraise research and to synthesize findings. A thorough search into PubMed, and Web

of Science has been conducted. A multi-stage filtering through inclusion-exclusion criteria to select the most relevant articles resulted in 19 articles out of 563. Specific data from the articles were charted in an excel matrix as well as grouping of similar topics to find common themes.

Conclusion

There is an increasing amount of research being done on the topic of microplastics in recent years. In response to this research and the threat of microplastics, there is also a clear global call to action. This call requires stakeholders at all levels to go beyond what is currently being done. The research also indicates that addressing gaps in knowledge is crucial to having a better understanding on the effects of microplastics as it relates to human health. Through an integrated and multifaceted approach involving various stakeholders we can achieve a better understanding of microplastics health effects as well as encourage sustainable actions to mitigate the problem itself. It is the hope that this review can act as a catalyst to fill research gaps as well as inspire sustainable actions that can create a lasting change for future generations.

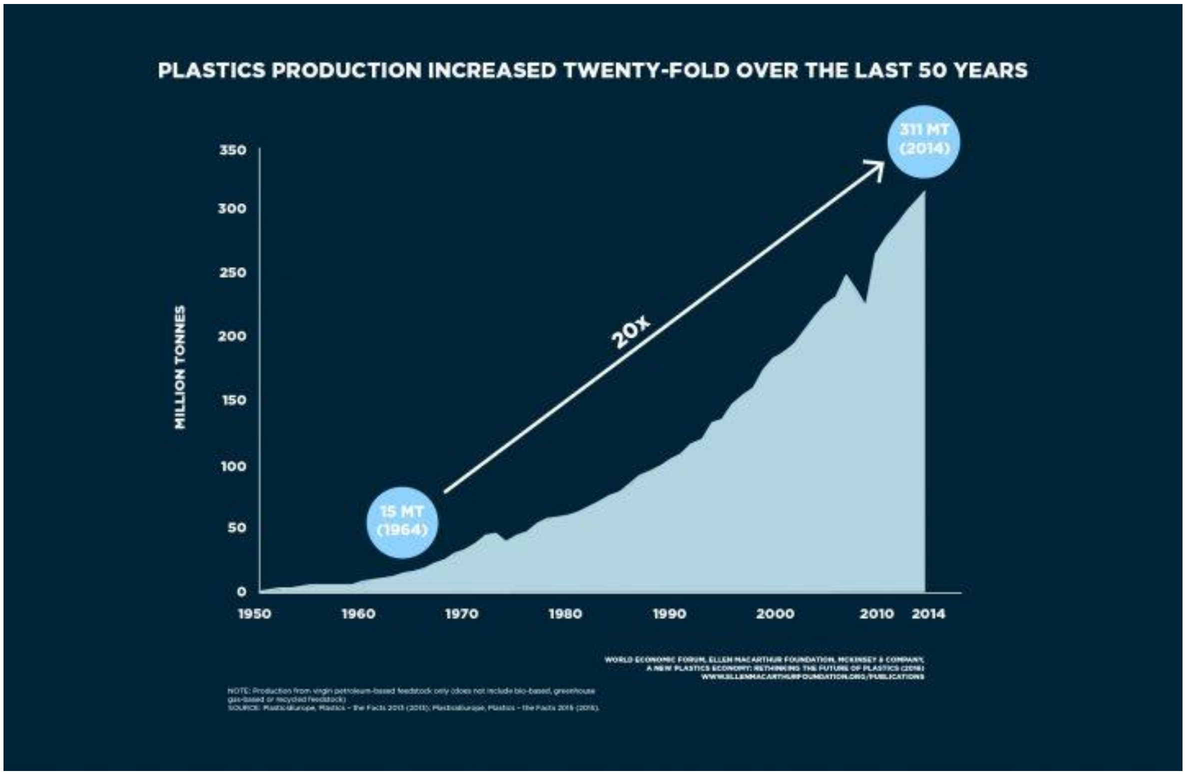
1. Background:

Over the past few years there have been numerous studies reporting the presence of microplastics found throughout the environment, raising questions and concerns about the impact that microplastics might have on human health (1). Civil society organizations (CSOs) have the potential to play a critical role as custodians for human and planetary health threatened by microplastics. CSOs, which are defined as collective actors not driven exclusively by state or market mandates and that seek to influence the way institutions respond to the needs of the vulnerable and marginalized populations they usually represent (2), need input to guide their work.

Plastics can be defined as numerous organic synthetic materials that are mostly polymers of high molecular weight and that can be made into objects, films, or filaments (3). The word itself derives from the Greek *plassein* meaning capable of being shaped or molded (4). Plastics are formed by the polymerization of small organic molecules called monomers, thus forming chains, that may or may not be branched and/or crosslinked (1). They are commonly derived from petrochemical sources and can be synthesized from fossil fuels (5). The most commonly used and abundant polymers are high-density polyethylene (HDPE), low-density polyethylene (LDPE), polyvinyl chloride (PVC), polystyrene (PS), polypropylene (PP) and polyethylene terephthalate (PET), which account for roughly 90% of the total plastic production worldwide (6). Plastics also contain additives to modify their properties and durability. Such additives include plasticizers and flame retardants (7). Plasticizers interact with the polymer chain to make the material more flexible and malleable (8). One example is bisphenol A (toxicant) based plasticizers (9), BPA being a monomer in the plasticizer production of plastics as well as a synthetic unit of polycarbonate polymers and epoxy resin (10).

The first synthetic polymer was invented in 1869 to provide a substitute for natural resources such as ivory, tortoiseshell, and horn (11). World War II accelerated the expansion of plastic production, which increased by 300% in the United States, as plastics were used in the war effort in everything from military vehicles to body armor (11) (12). Shortly thereafter, the use of plastics revolutionized the field of medicine, specifically succeeding in reducing the risk of infection to patients using sterile plastic packaging as well as one time use IV tubes, sterile gloves, catheters, and syringes (13). Today, plastic is found in everyday items such as bottles, bags, cellphones, and cosmetic microbeads, and is used in various industries such as fishing gear, automotive, electrical, construction, and textile (14) (15). The proliferation of plastic can be attributed to its malleability, strength, low cost, durability, heat resistant properties and light weight (13). As a result of their desirable attributes and extensive applications, the global production of plastics has followed a clear upward trend since the 1950s (see figure 1). Currently, there is a production of over 380 million tons of plastic produced worldwide every year (16). Considering the estimated worldwide population growth rate and current consumption and waste habits, plastic production is predicted to double by 2025 and more than triple by 2050 to an estimated 1800 million tons (1) (16).

Fig. 1 Increase in plastic production



Source: Eco Intelligent Growth - http://ecointelligentgrowth.net/plastics-strategy/

1.1 The cycle of plastics in the environment: From plastic to microplastic

Between 1950 and 2015 a total of 6.3 billion tons of primary and secondary plastic waste was generated, of which around 12% has been incinerated and 9% recycled, with the remaining 79% either being stored in landfills or having been directly released into the natural environment through littering or other methods (17). The management of plastic waste is increasingly an environmental issue. Incineration results in the emission of hazardous atmospheric pollutants including the greenhouse gas CO_2 (18). Recycling plastic is costly and tedious due to the collection, sorting, and processing of waste plastic (19). In addition, recycling can lead to quality loss due to downcycling where materials are re-used but as a lower-value product. Land filling occupies productive land rendering it unfit for other applications due to plastic leaching (20). As plastics are not readily nor completely degraded and are very stable in the ambient environment, their disposal throughout the environment has currently created a considerable pollution problem (21). Through mechanical, physical, chemical and biological processes, large plastic debris break down to smaller particles in the environment referred to as microplastics or nanoplastics. With respect to size, microplastics are generally referred to as particles smaller than 5 mm, and nanoplastics with a size less than 100 nm (6). Although other definitions are circulating, currently there has yet to be a consensus on accepted sizing.

1.1.1 Land pollution

Increase in human population density and the abundance of plastic debris accumulated in the terrestrial environment correlate positively (22). Due to inappropriately managed landfill sites, wastewater sludge, and plastic mulch from agricultural activities, plastic-related soil pollution is becoming a growing concern (23). Once in the soil, the fragmentation of plastics can occur at the surface level by oxidation increased through UV radiation and elevated temperatures (23). This breakdown process creates microplastics. These smaller plastic fragments can be incorporated into the deep soil by the burrowing activities of earthworms, and further transported by collembolans, insects and plants to deeper layers of the soil (23). In agricultural soil with expanding mineral types, cracks and fissures can appear when the soil dries. These cracks become open entryways for microplastics, which could potentially move to substantial depths (24). Due to the microplastics ability to be incorporated into deep layers of soil there is the concern of the potential distribution and transportation of microplastics into groundwater especially in areas of course soil and high groundwater (23).

1.1.2 Air pollution

Incineration of plastic waste is a major source of air pollution (26). The incineration of plastic releases toxic gases such as furans, mercury, polychlorinated biphenyls, persistent organic pollutants (POPs) and hazardous halogens into the atmosphere, polluting the air as well as having a negative impact on climate change (26). The by-products of plastic combustion are airborne particulate emission (soot) and solid residue ash (27). These by-products can travel thousands of kilometers, depending on prevailing atmospheric conditions, and ultimately end up in soil, crops, polar ice caps, freshwater ecosystems, and marine environments (26).

1.1.3 Marine pollution

Marine plastics can be transported by wind and are washed from land to surface waters during rainfall, especially with stormwater run-off. They then are transported in freshwater to seawater via rivers (6). Once plastic is in the sea, it can travel long distances and end up in all areas of the ocean. The effects are seen throughout the globe and found in intertidal ecosystems, deep sea-sediments, surface waters, polar regions and mid ocean islands (22). Due to its buoyancy plastic also accumulates on the surface of the sea, creating plastic accumulations that are called islands, the largest of which covers an estimated 1.6 million square kilometers (28). After time, the plastic becomes brittle and breaks down into smaller pieces, and eventually degrades further into microplastics when exposed to waves, UV radiation either under direct sunlight or in seawater (14). Microplastics become vectors for pollutants and heavy metal such as mercury (Hg) already found within seawater (29).

1.2 Impact on the environment

Research indicates that microplastic pollution has been shown to have a negative impact on the soil as well as the organisms within the soil. It has been demonstrated that additives found within microplastics can leach out into the soil environment (30). At the same time, microplastics can absorb toxicants including metals, persistent organic pollutants (POPs) polychlorinated biphenyls, polycyclic aromatic hydrocarbons (PAHs) and organochlorine pesticides (e.g. DDT, HCH) (31). This is due to their hydrophobic characteristic, posing a greater ecological threat (31). In contaminated soil the presence of microplastics hinders the absorption of water and nutrients by plant roots, as well as change plant biomass, tissue elemental composition, root traits, and soil microbial activities (32).

To date, only a few studies have examined the presence of microplastics in the atmosphere; one example taking place in Paris, where microplastics were measured in atmospheric fallout with an average of 118 particles/m^2/day (33). In addition to incineration, airborne microplastics can be produced by synthetic textiles, industrial emissions, and particles released from road traffic such as tire abrasion (34). The microplastics in the air are potentially transported and deposited into terrestrial and aquatic environments depending on various factors such as rainfall, wind and UV irradiation, leading to further contamination of the environment (34).

The environmental impact of microplastics is ubiquitous throughout the ocean. Coral reefs, for example, are threatened by microplastic pollution. Corals can ingest microplastics due to their micron-sized particle nature (35). Corals obtain energy by feeding on plankton to acquire important nutrients which are essential for their growth, development, and reproduction (36). The microplastic feeding mechanism of corals involves ingestion, retention of plastic fragments and digestion (37). The harmful effect of microplastics on corals specifically involves retention of plastic fragments in mesenterial tissue which leads to reduction in feeding capability and lowering in energy reserves (38). As coral reefs are foundational to the marine ecosystem functioning, this impact is profound (39).

1.3 Impact on animals

Microplastics are consumed by a wide variety of sea life due to their small size, long durability, and the extent to which they are omnipresent throughout the sea. Aquatic organisms consuming microplastic range throughout the entire trophic system, from plankton to predators; including mussels, crabs, fish, and sharks (6). After ingestion, the microplastics can remain trapped in the digestive tract (something that has been indicated for crustaceans and birds in the marine environment), be excreted, or translocate into the other tissues of the organism (14) (7).

When the rate of intake is greater than the rate of excretion or metabolic transfer, microplastics and associated toxins bioaccumulate (6). Biomagnification, or the increasing magnification of microplastics passed along the food chain, has also been documented. The amount of microplastics found seems dependent on the level of trophic transfer, with apex predators such as sharks potentially having some of the highest levels of microplastics and toxic contaminants (6).

One laboratory study demonstrated that after microplastic ingestion of the juvenile common goby (a small to medium sized ray-finned fish) in controlled conditions, there was a significant reduction in acetylcholinesterase (AChE) activity, as well as decreasing predatory performance (40). In the wild, a decrease of predatory activity could result in a reduction in capacity of juvenile gobies to catch prey and escape predators (40). Another study demonstrated that plastic ingestion in marine turtles can cause severe damage to their digestive system and obstruct the intestinal tract, reduce the feeding stimulus and stomach capacity, that in the time could lead to malnutrition, eventually causing death (41).

The harmful effects of microplastic ingestion are an issue of concern, especially in the case of sea birds. The toxic effect of plastic fragments as well as the potential for obstruction has negative effects on their body, which could cause alteration in the feeding behavior, reproduction, as well as higher mortality rates (42). In one study it was found that six species of sea birds: *Phalacrocorax bougainvillii*, *Pelecanoides garnotii*, *Pelecanoides urinatrix*, *Pelecanus thagus*, *Spheniscus humboldti* and *Larus dominicanus* have plastic fragments in their stomach region. It was also found that maximum ingestion capacity was detected in the case of *Larus dominicanus* which commonly feeds upon fishing nets, waste disposal products, and plastic containers (43).

1.4 Impact on humans

Seafood is consumed worldwide and approximately 3 billion people in the world rely on fish as their main source of protein (44). As a result, humans are exposed to microplastics through the consumption of fish and shellfish. Once microplastics are consumed they can be absorbed releasing toxicants causing physiological harm (44).

Human health effects depend on exposure concentrations of microplastics. Due to data gaps in microplastic research, there is insufficient information to assess the true amount of microplastics humans may be exposed to via food. Researchers have estimated that a European consumer of seafood can potentially eat approximately 11,000 plastic particles annually from shellfish alone, while Canadian researchers have estimated that the average person consumes between 74,000 and 121,000 particles annually through food consumption and the inhalation of airborne microplastics (45).

The severity of adverse health effects resulting from exposures depends on the nature of the toxic chemical, exposure characteristics, and individual susceptibility. Preliminary research has demonstrated several potentially concerning impacts, including enhanced inflammatory response, size-related toxicity of plastic particles, chemical transfer of absorbed chemical pollutants, and disruption of the gut microbiome (46).

When airborne microplastic particles are inhaled, immediate bronchial (asthma-like) reactions are the first response expressed (47). Adverse effects of particle toxicity are mainly attributed to inflammation, due to particle localization and of immune cells, producing cytokines, proteases, and reactive oxygen species (ROS) to combat the foreign material (48). In addition, chronic inflammation may lead to cancer, as a result of DNA damage (adducts and mutations) caused by oxidative stress and the evasion of detection by the immune system (49).

There has been research on microplastic concentration reported in drinking water as well (1). The hydrophobic nature of microplastics implies that they have the potential to accumulate in hydrophobic substances such as POPs and organochlorine pesticides (1). In addition, there is the concern that biofilms which are the result of the growth of microorganisms on microplastic surfaces also represent an added bacterial threat in drinking water (1). The recently published World Health Organization (WHO) report on microplastics in drinking water concluded that the health risk to humans may be low according to current knowledge, but more studies are indeed needed (1).

1.5 Managing microplastics

In addition to the risks to human health from ingestion of microplastics in drinking water, food or air, improved management of plastics and a reduction in plastic pollution holds multiple benefits for the environment and human well-being (1). In response to concerns about the impact of plastic and microplastic pollution, public awareness and engagement has increased. Activities have ranged from schools adopting educational activities on plastics, to civil society launching campaigns, as well as some industries pledging to reduce plastic use. Political commitment is also growing in many cases (1).

Ministers of Environment from 157 countries committed to significantly reduce single-use plastic products by 2030 at the 4th UN Environment Assembly in March 2019 (50). This followed an agreement at the previous Assembly to recognize the importance of long-term elimination of microplastics from the oceans (1).

A UK-based company Cynar Plc uses pyrolysis; a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen to convert end of life plastic into diesel for cars. One ton of plastic waste can be converted into 700l of diesel. Their current plant in Ireland has a capacity for up to 20 tons per day resulting in 14,000l of diesel (51).

Plastic Bank, founded in Canada is focused on reducing the amount of plastic waste in the environment and helping to alleviate poverty in developing countries. The organization has created stores in which impoverished people can exchange plastic waste for goods such as solar cell phone charging and sustainable cookstoves. They are established in rural areas throughout Haiti, the Philippines, and Brazil. The plastic received by the stores is then sold to companies and used to manufacture new products. (52).

According to the United Nations Environmental Program (UNEP), countries like Rwanda and more than 60 other countries from around the world are already taxing or banning single-use plastics, primarily plastic bags (53). In Rwanda, the ban is enforced through fines or jail time, and has helped boost the economy within the country due to the lessened costs of recycling and clean-up related to plastic waste (54).

In affiliation with UNEP, the ocean conservancy International Coastal Cleanup (ICC) comprises over 6 million volunteers in 90 countries to clean, preserve and protect the ocean and coastlines. Last year over 18 million pounds of trash were collected. Participants include, regional and international organizations, government agencies, members of the private sector, non-governmental organizations (NGOs), and the general public (55).

2. Problem Statement:

More research is undeniably needed to further evaluate the impact of microplastics on human health due to the paucity of information. One of the conclusions of the Food and Agriculture Organization (FAO) on food safety is that basic toxicological data on the consumption of microplastics in humans for a food risk safety assessment are essentially lacking (56). At the same time, it is imperative to gain a greater understanding of the relationship to health due to the pervasive nature of microplastics, coupled with the substantial amount of time they take to decompose (57). As this is a problem that is not going away on its own, it is important to determine ways to best address the current situation. Although actions are already taking place, there is more that can be done. Civil society requires the organization of research from various sources in order to act based on evidence. It is the hope that through this scoping literature review it will be possible to get a clearer picture of current knowledge, highlight research gaps, and recommend a framework for possible actions.

3. Objectives:

The purpose of this literature review was to develop a framework for sustainable actions that civil society can undertake to mitigate the impact that microplastics have on human health.

Specific objectives:

1. To delineate the problem of microplastics through the lens of human health.
2. To assess different strategies used for acting upon microplastics.
3. To develop a framework for future actions that can lead to sustainable interventions related to mitigating microplastics.
4. To identify obstacles to implementing interventions and propose possible solutions.

4. Methods:

A scoping literature review of existing literature was done using a systematic method to collect and critically appraise research and to synthesize findings. Its goal was to provide a comprehensive study of current evidence. There are various types of literature reviews including systematic literature reviews, narrative literature reviews, and theoretical literature reviews (58). A scoping literature review was chosen as it was deemed particularly useful to ensure that the information collected was exhaustive, would help to identify gaps in the research, as well as summarizing the ideas in the research field. There are 5 stages of framework to a scoping literature review as outlined in *The International Journal of Social Research Methodology* by Arksey and O'Malley in 2005 (59).

4.1 Developing a framework

The first step in the framework was to carry out a scoping literature review defined as: “to map rapidly the key concepts underpinning a research area and the main sources and types of evidence available and can be undertaken as stand-alone projects in their own right, especially where an area is complex or has not been reviewed comprehensively before” (60). It was guided by the following research question: *What is a set of viable actions that civil society can undertake for the improvement of health as it relates to microplastic pollution?*

For the scoping literature review I followed the preferred reporting items for systematic reviews and meta-analysis (PRISMA). PRISMA is an evidence based minimum set of items for reporting in reviews, which focuses on ways to ensure transparent and complete reporting of research. The PRISMA guidelines consist of a four-phase flow diagram as well as a 27-item checklist. The flow diagram describes the identification, screening, eligibility, and inclusion criteria of the reports that fall under the scope of a review. The checklist includes a 27-item recommendation list on topics such as title, abstract, introduction, methods, results, discussion, and financing. (61).

I used the following key words: microplastics, pollution, and human health using the logical connectors: and & or on the following databases: PUBMED and Web of Science to delineate the problem of microplastics through the lens of human health. In addition, I used the following keywords: microplastics strategies, solutions, and sustainable actions, using the logical connectors: and & or to assess different strategies used for acting upon microplastics.

The third step involved using the results of the scoping literature review to develop the framework for sustainable actions that civil society can undertake. This framework was discussed within the organization of GRID-Arendal during the internship period to identify obstacles to implementing interventions, and to establish possible solutions.

Data charting was done to evaluate the relationship between microplastics and human health as well as what actions civil society can undertake to improve the current situation as it relates to health. An excel matrix was designed for charting the data. The data was charted in the matrix according to the author, year of publication, study location, title, aims of the study, actors involved, and relevant findings.

5. Results:

5.1 Scoping Literature Review

This section presents the results of the scoping literature review, and the process of identifying and coding the literature into separated collections according to the content of each literature source. In addition, this section describes the process of extracting the results, as well as their labelling, categorization, and description. Lastly, this section offers a consolidation of all the findings from the literature reviewed.

5.2 Review of existing sustainable actions & human health and microplastics

5.2.1 Identification of potential studies

Two databases were selected for the search, specifically Pub Med and Web of Science. Pub Med was chosen due to its ability to produce publications focused on the life sciences as well as biomedical topics, while Web of Science was selected due its access to multiple databases targeting various academic disciplines. In order to achieve a comprehensive search both were chosen to be as thorough as possible, focused on their broad search spectrum and abundance of topic related material. The publications were examined in English only due to language limitations. The keywords were guided by the following research question: *What is a set of viable actions that civil society can undertake for the improvement of health as it relates to microplastic pollution?* Grey literature was not included as it provided over 14,000 articles which was not feasible to analyze due to time constraints.

Pub Med provided 257 hits, while Web of Science gave 306 hits for a total of 563 articles. A total of 395 articles were screened for title and abstract after 168 duplicates were removed. Out of the 395 articles a total of 375 were excluded based on relevance, with a total of 20 being selected. Out of the 20 articles, there were 10 that addressed human health and 10 focusing on sustainable actions which provided a balanced perspective of both topics. Out of the final 20 selected, there was one article that was excluded as the title and abstract were in English while the rest of the article was written in Spanish. This resulted in 10 articles on microplastics and human health, and 9 microplastics and sustainable actions articles, resulting in a total of 19 articles extracted. This still provided a balanced overview on both human health and sustainable actions. It should be noted that while the gamut of papers touched on human health or sustainable actions respectively, there were 4 that overlapped and discussed both. The articles that were selected focused on human health and sustainable actions (or both) overtly, while the other 375 that were excluded did not focus on the selected key words based on review of both the title and abstract. For the review, I followed the preferred reporting items for systematic reviews and meta-analysis (PRISMA). This ensured transparent and complete reporting of research based on the four-phase flow diagram, and clearly presented the different phases of the literature review. See flow chart below.

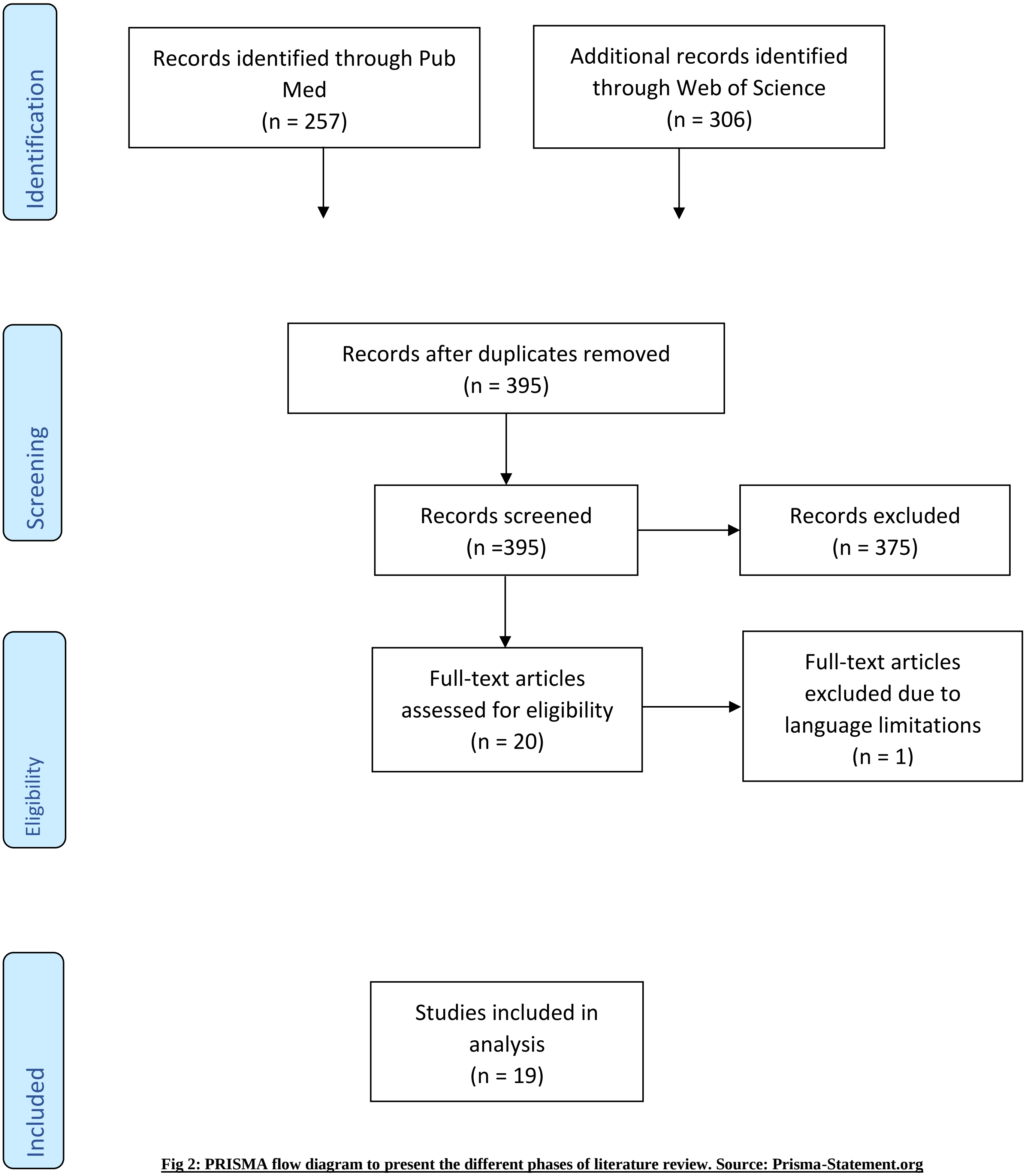


Fig 2: PRISMA flow diagram to present the different phases of literature review. Source: Prisma-Statement.org

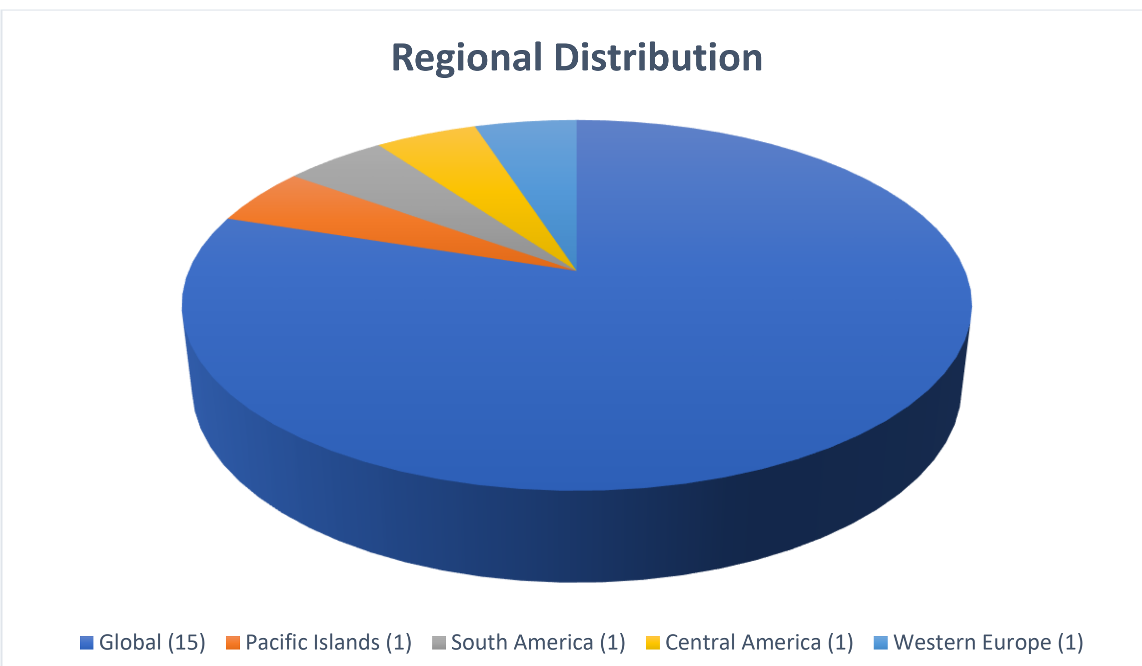
5.2.2 Coding and analysis of included literature

An Excel matrix coding sheet was used to extract and distill the essential information from each selected document. This included article title, author(s), year, geographic location, microplastic location (water, land, air), aim of the study, and relevant findings.

5.3 Structure of the findings

5.3.1 Regional distribution

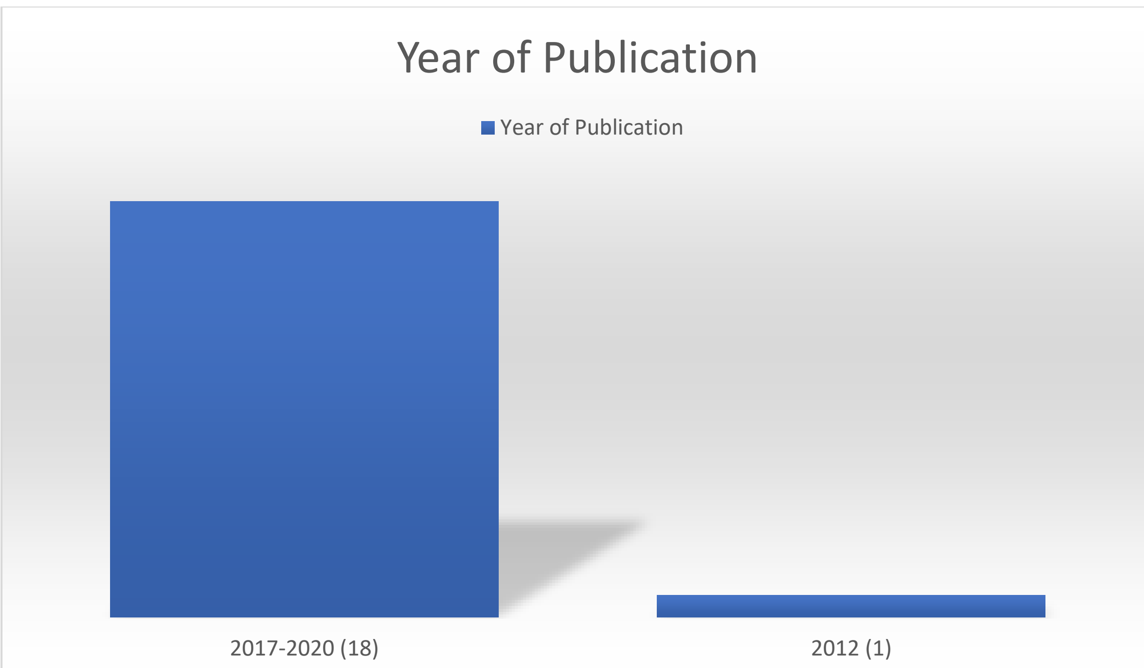
Out of the 19 articles selected, 15 of the papers focused on a global approach, meaning they did not reference a specific country or region in their research. The other 5 articles were evenly distributed with 1 region addressed in each paper. The following countries or regions were represented: Paris (Western Europe), Guatemala (Central America), Easter Island Ecoregion (South America 1) and the Pacific Islands (1). See Graph 1.



Graph 1. The regional distribution of selected research

5.3.2 Time of publication

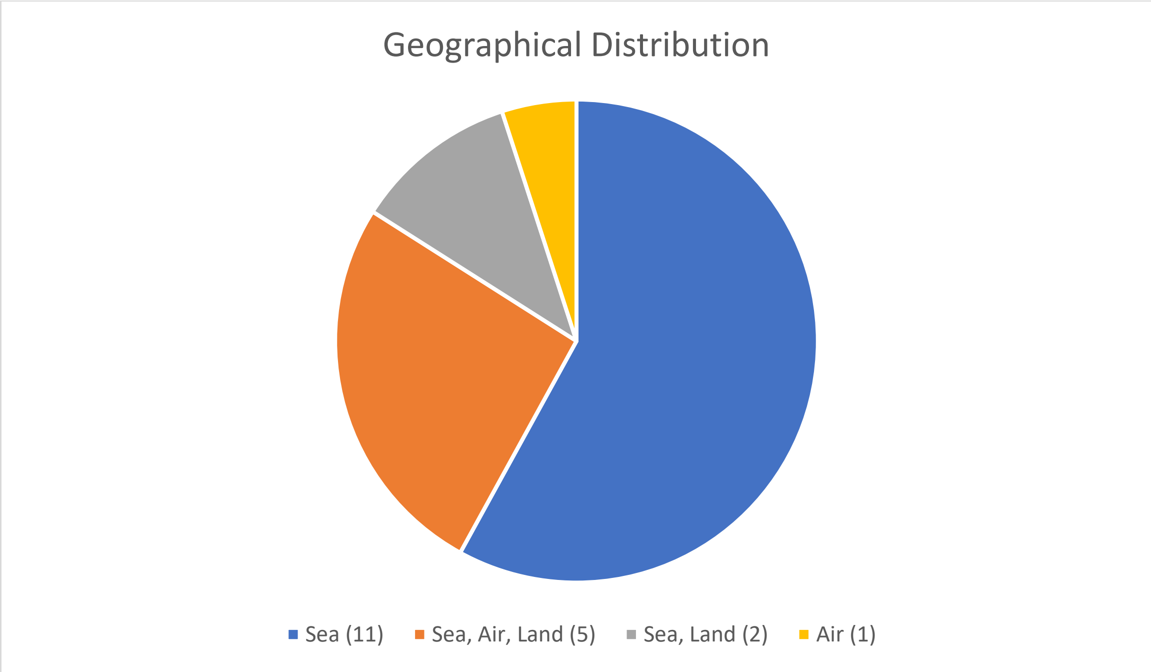
Even though the inclusion and exclusion criteria did not specify a timeframe for publication year, the majority (18) of the 19 selected were found within the years 2017-2020 with one outlier being 2012. Microplastics being a relatively recent topic could help to explain this weighted distribution. See graph 2.



Graph 2. Microplastic research according to year of publication

5.3.3 Geographical distribution

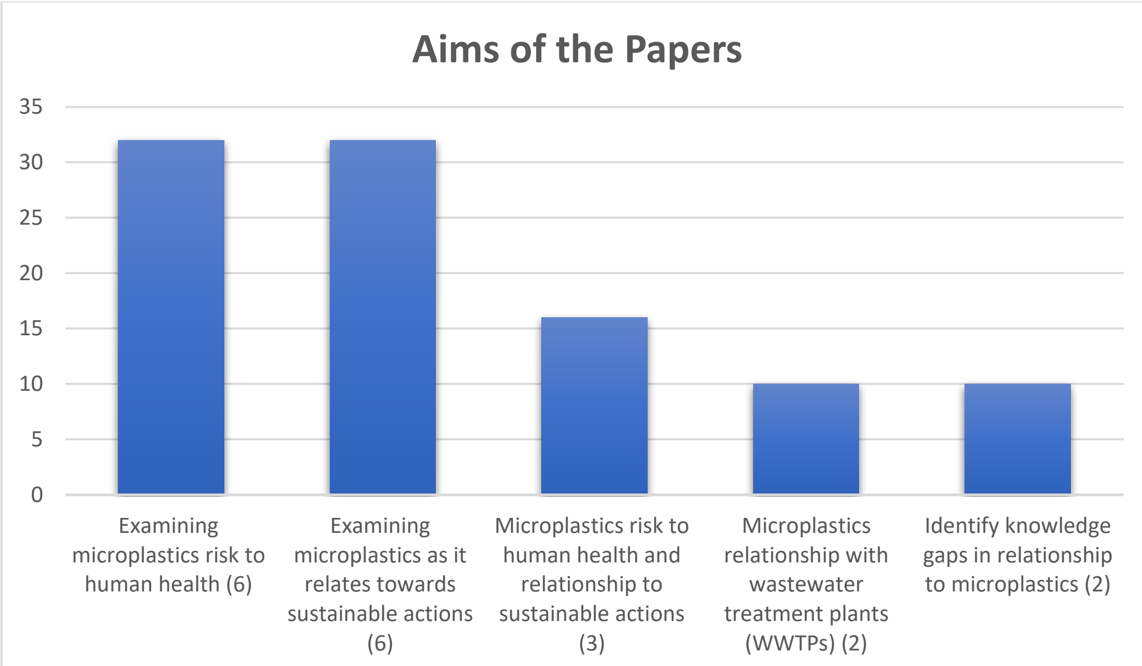
The main areas of focus for microplastics are found within sea, air, and land. The majority of the articles focused on the sea with 11 researching ocean microplastics exclusively. There were 5 articles focusing on sea, air and land. 2 articles covered sea and land, and 1 solely focused on air. See graph 3.



Graph 3. Indicating the focus of research based on geographical regions

5.3.4 Aims of the papers

The aims of the papers focused on various elements, with the majority being divided into categories. 6 papers examined the risk to human health by microplastics, while 6 papers examined microplastics as it relates to sustainable actions. 3 articles examined both risk to human health by microplastics and sustainable actions related to microplastics. 2 articles focused on the importance of studying microplastics relationship within wastewater treatment plants (WWTPs), and 2 focused on identifying knowledge gaps in relationship to microplastics. See Graph 4.



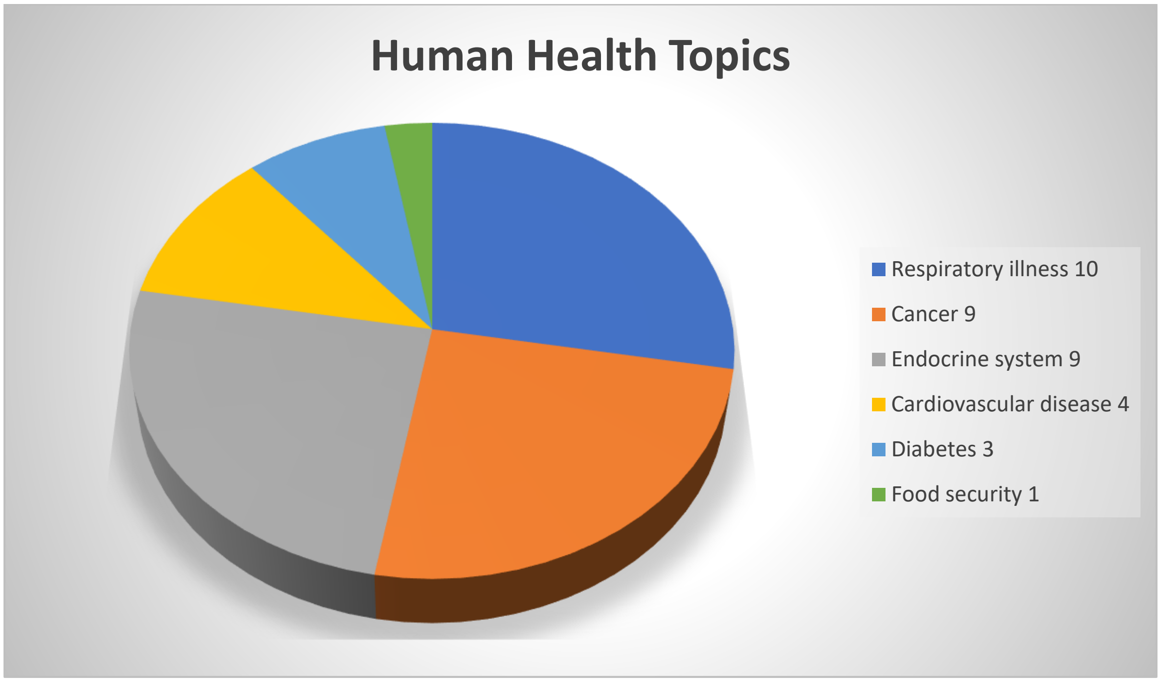
Graph 4. Indicating the various aims of research

6. Findings and discussion:

The findings of the papers can be distinguished between articles that focused on human health, sustainable actions, or overlapped, therefore addressing both topics. There were 7 articles that focused on human health, 8 articles focused on sustainable actions, while 4 articles overlapped touching on both topics.

6.1 Human health

The 6 most frequently covered areas of interest that emerged were focused on respiratory illness (10), cancer (9), the endocrine system (9), cardiovascular disease (4), and diabetes (3). It is interesting to note that out of 11 of the articles addressing human health, food security was only mentioned once (1). See graph 5.



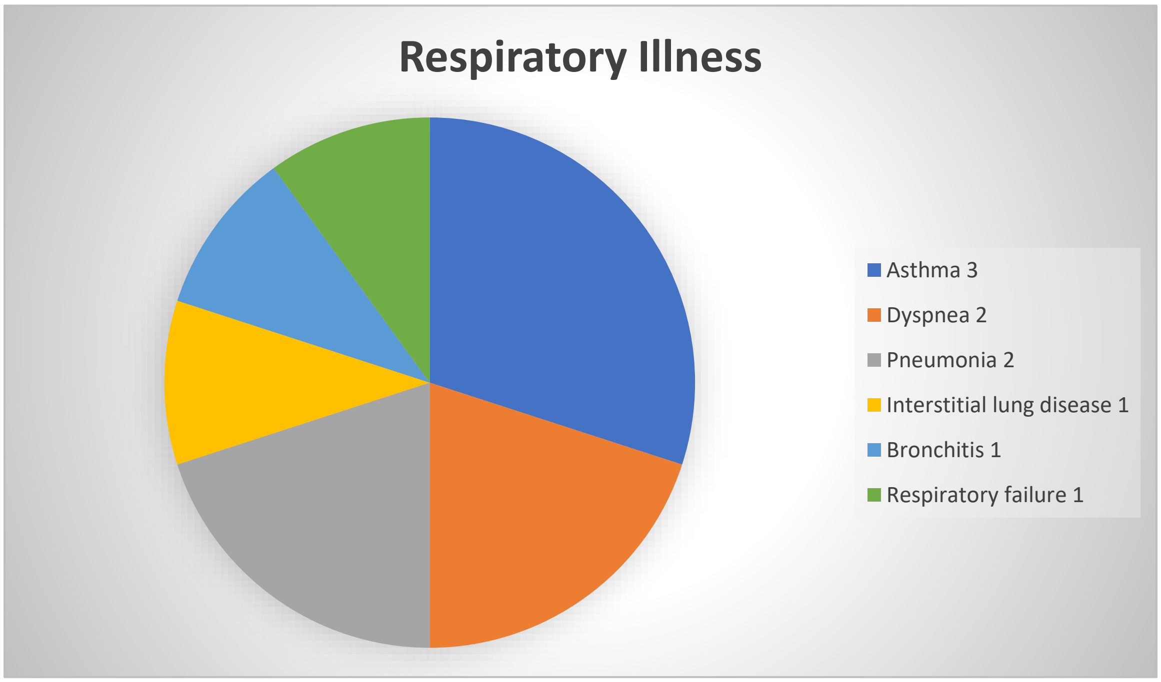
Graph 5. Indicating aspects of focus within human health

6.1.1 Respiratory illness

Within the topic of respiratory illness that was discussed in the research, asthma was addressed 3 times, dyspnea and pneumonia were mentioned 2 times, while interstitial lung disease, bronchitis, and respiratory failure were mentioned 1 time respectively. See graph 6.

In her study, Prata (62) examined microplastics in atmospheric fallout and indicated that, especially in exposed industry workers, inhaled microplastic particles can result in asthma-like bronchial reactions, interstitial lung disease, chronic pneumonia, bronchitis and respiratory failure. Furthermore, it was indicated that microplastic concentrations as low as 40 μg m^{-3} have the potential to cause death in asthma patients. Considering that airborne microplastics consist of fibers between 200-600 μm and that microplastic fibers of 250μm have been found in human lungs, it is possible that susceptible individuals are at great risk, based on their occupation and prior health background (62). The industries most at risk in this study were demonstrated to be textile and flock, while failure of clearance mechanisms was considered to be responsible for microplastic particle toxicity. This is similar to what Campanale et al. (63) found in their study indicating an additional human health concern for the public who were widely exposed to inhaled microplastic particles. Specifically, that under certain conditions related to ventilation, this exposure could result in asthma and chronic pneumonia based on individual metabolism and susceptibility.

In another study related to respiratory illness, Filho et al. (64) illustrated the hazardous human health effects of microplastic inhalation due to the common practice of burning plastic waste in individual backyards. This is an inadequate land-based waste management system found in many developing countries and specifically in this study throughout the Pacific Island States. This burning can result in dyspnea due to the airway and interstitial inflammatory response. Similarly, Prata (62) found dyspnea related to the same interstitial inflammatory response in occupational exposure to microplastics. This was demonstrated even when environmental concentrations were low. These studies highlight the human respiratory health risk due to microplastic inhalation. This was especially true in susceptible individuals exposed due to occupation, or in countries where burning personal plastic waste is a common method of disposal or is used as a replacement for firewood. It is important to note that the toxicological impacts and the extent of chemical transfer related to microplastic inhalation is currently uncertain and therefore requires more research to fully understand the depth of human health risk.



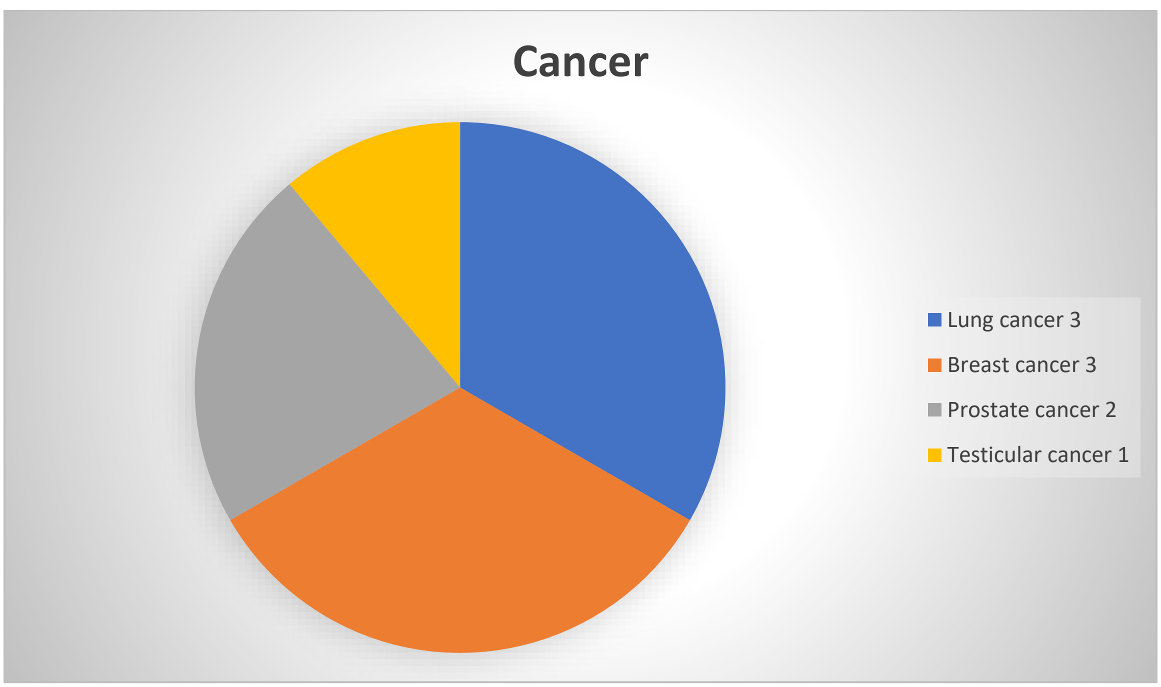
Graph 6. Indicating types of respiratory illness addressed

6.1.2 Cancer

Out of the total 19 papers, 9 dealt with cancer. Within the topic of cancer, 3 articles focused on lung cancer, 3 articles addressed breast cancer, 2 articles discussed prostate cancer, and 1 paper addressed testicular cancer. See graph 7.

Like the previous studies mentioned relating to respiratory illness (see 6.1.1), Karbalaei et al. (65) associated adverse health effects through the inhalation of microplastics specifically by chemical toxicity and through pathogen vectors. This study highlights that in the case of patients with lung cancer, human lung tissue was found to contain plastic fibers. In her study, Prata (62) emphasized the impact of air pollution and its association with mortality due to lung cancer. This can be attributed to the chronic airborne irritation which can result in DNA mutations. These mutations are caused by oxidative stress as well as inflammation promoting angiogenesis and mitogenesis causing a progression of malignant cells. Prata (62) therefore echoes previous studies emphasizing the inherent health risks of occupational exposure to concentrations of microplastic inhalation and the potential to induce gene mutation resulting in cancer. Furthermore, Prata (62) also emphasizes that depending on hydrophilicity, surface charge and size of inhaled particles there is the potential to induce toxicity in other organs due to translocation. Plastic particles can thus translocate to reach the circulatory system related to the increased epithelial and endothelial permeability related to inflammation. These studies also illustrate a very concrete connection between the cumulative burden of air pollution containing microplastics and the effect it has directly on cancer. This is not only from an occupational health perspective but as concentrations increase worldwide, the effect on the general population as well.

In addition to inhalation, Böckers et al. (66) postulates that microplastics enter the food chain via the uptake by marine animals and make their way into the human body via consumption. Moreover, almost all plastics contain additives. A widely used monomer used to produce both plastics and plasticizers is BPA, which is used in epoxy resins and polycarbonate plastics. BPA is an organic synthetic compound belonging to the group of diphenylmethane derivatives and bisphenols. Due to the size and surface texture of microplastics there is the potential for facilitated leaching of incorporated plasticizers relating to human consumption. Due to its toxic nature, ingestion of plasticizers can potentially cause alterations in reproductive functions by effecting hormones and interacting with the nuclear transcription factor estrogen receptor α (ERα/ESR1). ERα is mainly expressed in the breast, uterus and ovary and can alter gene expression in the human breast cancer cell line MCF-7, thus promoting breast cancer growth (66). It is therefore important to consider the prevention of plasticizer migration when considering future production of plastics to help reduce the risk of breast cancer as well as cancer in general. These studies also emphasize the importance of transparency as it relates to substances used in plastics specifically when considering additives.



Graph 7. Indicating types of cancer addressed

6.1.3 Endocrine system

Out of the total 19 papers, 9 dealt with the endocrine system. Campanale et al. (63) indicates that BPA has been proven to be an endocrine-disrupting chemical (EDC). This is identified as an exogenous substance that alters the hormonal activity and homeostasis of the endocrine system. EDCs essentially work to the detriment of the normal functioning of organs. They respond to hormonal signals and have the ability to mimic natural hormones, alter the pattern of synthesis and metabolism, as well as modify the expressions of hormone receptors. EDCs have been associated with various conditions and diseases such as the previously mentioned cancers such as breast, testes and prostate cancer (see 6.1.2). They have also been linked with reproductive problems. These include infertility & genital malformations, neurodevelopmental conditions like learning disorders, autism spectrum disorders, and metabolic disorders such as diabetes & obesity.

Barboza et al. (67) emphasizes that due to the physical structure and the size of microplastics in the environment, there is the potential to absorb very toxic metals such as mercury. Mercury is a naturally occurring heavy metal and can build up in the bodies of marine wildlife as methylmercury, which is highly toxic to humans. It is a common contaminant and global pollutant in the marine environment and has been demonstrated to accumulate with biomagnification in marine trophic webs. This increases concentrations in apex predators like tuna which is widely consumed by humans. Barboza et al. (67) describe how mercury has also been found to produce endocrine disrupting effects such as blocking thyroid hormone production. It does this by inhibiting hormone action and occupying iodine binding sites leading to hypothyroidism. In addition, there are adverse effects on the hypothalamus, thyroid, pituitary, adrenal glands and gonads (testis and ovaries). Both studies emphasize that while current studies related to xenobiotics and their health impacts are alarming, additional research must be done to further understand the direct impacts of microplastics on the endocrine system. One area that specifically requires further research, is the quantity related to the uptake of mercury that can potentially cause negative health effects.

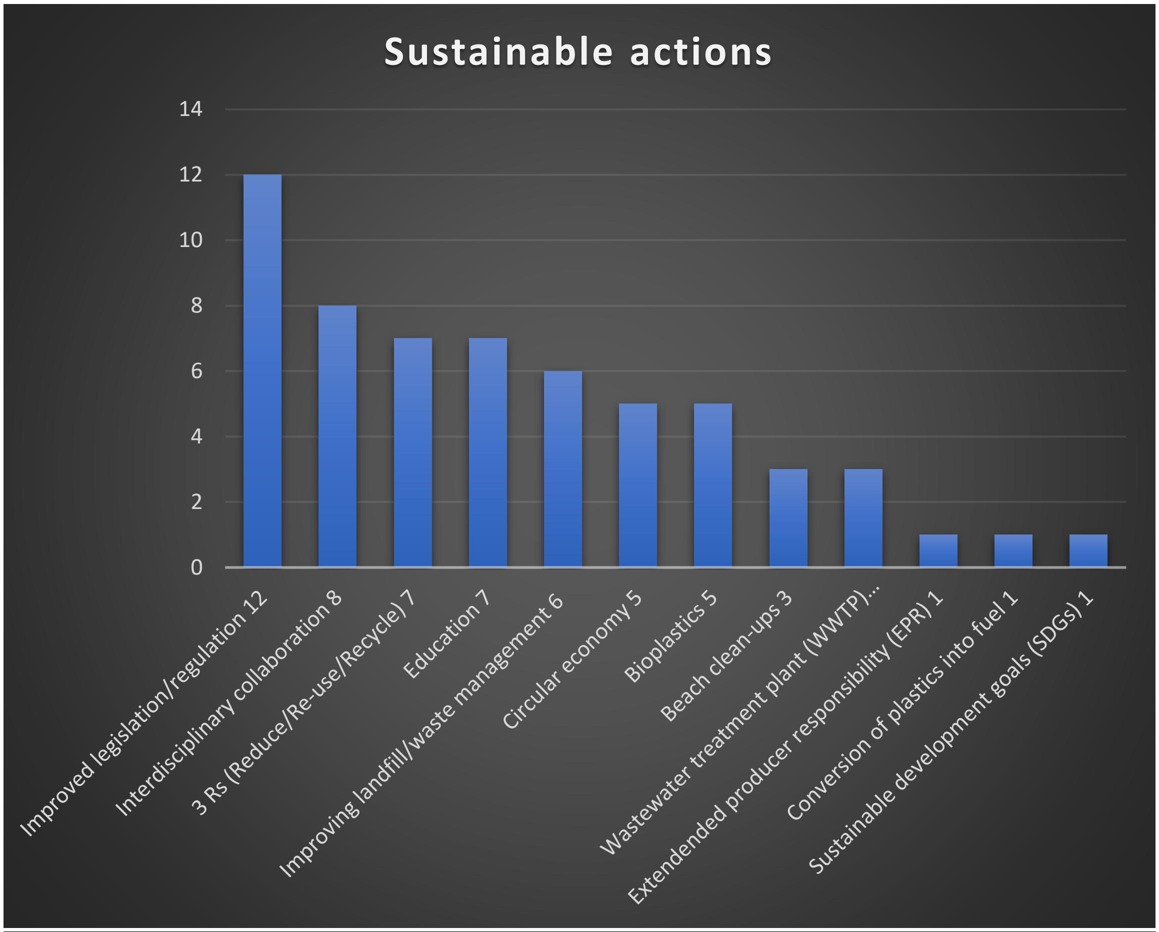
6.1.4 Food Security

The definition of food security, according to the FAO, is "food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (68) (69). The FAO focuses on four key pillars including 1. Food stability: the supply of food which can be affected by many aspects including economy, political issues, and climate change. 2. Food availability: focusing on having sufficient quantity and considers imported or locally produced food. 3. Food utilization: encompassing the entire food supply chain and considers from a hygienic point of view the processing, production and distribution of the food supply chain. 4. Food access: which includes economical and physical access to food and is affected by local infrastructure, purchasing power and income level (68) (69).

The universal nature of microplastics compromises the pillars of food utilization, food availability and food stability. This is especially true with food utilization, which requires the safe and efficient usage of food as well as nutritional awareness across various stakeholders. Due to the hazardous impacts of microplastics resulting in a considerable loss in fish stocks, food availability is also greatly affected. A population must always have access to adequate food to have food stability, and food containing microplastics is difficult to consider as adequate due to the potential health implications. As food security is only mentioned in one of the papers, further research should focus on developing better definitions of food security as it relates to microplastics in the future (68) (69).

7.1 Sustainable actions

Out of the total of 12 papers addressing sustainable actions, all 12 cited new or improved legislation/regulation as necessary to address the issue of microplastics. 8 articles mentioned interdisciplinary collaboration. 7 articles address the 3 Rs (Reduce/Re-use/Recycle), while 7 articles discussed education. 6 articles focused on improving landfill/waste management. Both circular economy and biodegradable plastics (bioplastics) were mentioned 5 times respectively. Beach clean-ups and wastewater treatment plant (WWTP) improvements were mentioned 3, times respectively. Lastly it is interesting to note that out of 12 papers, extended producer responsibility (EPR), conversion of plastics into fuel, and the sustainable developmental goals (SDGs) were only mentioned 1 time respectively. See graph 8.



Graph 8. Indicating aspects of focus within sustainable actions

7.1.1 Improved legislation/regulation

Improved legislation and regulation are essential when addressing the issue of microplastics from an international perspective. Some examples of organizations attempting to address legislation and regulation are the following:

1. The International Maritime Organization (IMO) introduced the International Convention for the Prevention of Pollution from Ships (MARPOL) in 1973, which was designed to prevent and reduce pollution of the marine environment by ships from accidental and routine operational

causes (70). It is referred to as MARPOL 73/78 as the convention was signed in 1973 and then added in 1978. It has been approved by 169 countries, which are responsible for 98% of the total worlds shipping transport by weight. Specifically, Annex V of MARPOL 73/78 regulates pollution with the prevention of releasing garbage by ships as well as the complete ban of the disposal of plastics into the sea. It also obligates governments to keep harbors and terminal facilities clear of garbage as well as requiring a garbage record book for any ship being able to carry over 14 persons and having a weight over 400 tons (70).

2. The Regional Seas Programme initiated in 1974 by the United Nations Environment Programme (UNEP) to address the degradation of the marine and coastal environment throughout the world, focuses on region specific activities and brings together various stakeholders including civil society, the scientific community and governments. The Regional Seas Programme engages 146 countries with comprehensive and specific actions through multilateral environmental agreements (70).

3. The Marine Strategy Framework Directive (MSFD) is a European directive that was established in 2008 and focuses on marine environmental policy by establishing a legislative framework for managing human activities and the sustainable use of Europe's marine waters. Based on EU legislation the MFSD has set up methodological standards for the marine environment (70).

In addition, many countries have banned microbeads from cosmetics, beginning with the Netherlands in 2016 (65). Other countries such as Canada, USA, Sweden, France, UK, Scotland, Wales, South Korea, and Taiwan followed the example, with many more countries proposing a similar ban in the future (65). Furthermore, many countries have banned single-use plastic bags including the regions of Africa, Asia, South America and Europe. Additional countries have established a plastic bag tax where no ban is in place (65). Another aspect to consider is the implementation of deposit return schemes in many countries, which generally leads to high levels of collection and at the same time provides a clean stream of secondary plastics for the recycling industry.

Legislation and regulation are not a silver bullet however and Hammer et al. (70) addresses the issue of what happens when this legislation is ignored, and illegal dumping occurs. It is clearly an impossible task to continuously monitor the entirety of the ocean. There is also the point that much of this legislation does not address the “downstream” issue of plastic debris already found throughout the marine environment.

It is important to consider the issue of primary and secondary microplastics as they are two separate sources of plastic pollution. Primary microplastics are small plastic particles designed for commercial use such as microbeads in cosmetics. Secondary microplastics on the other hand result from the breakdown or larger plastic items such as single use bottles and plastic bags. Karabaleie et al. (65) point out that while primary microplastics have been addressed in legislation there are no regulations established to address the impact of secondary microplastics. Secondary microplastics are a major contributor to global pollution. Therefore, management policies as well as improved legislation should be established to manage and control the spread of secondary microplastics in the environment. One must also keep in mind that there are many countries still without any formal rules or regulations regarding plastic pollution. Although legislation and regulation should be considered positive in many respects there are aspects which need improvement when looking to the future of addressing the issue of microplastics on a global scale.

7.1.2 3 R’s (Reduce Reuse Recycle)

The 3 R’s are designed to reduce the amount of plastic waste that is thrown away. This can be seen throughout various individual actions such as refusing plastic straws, and using cloth bags, & reusable water bottles. Recycling plastic also has the potential to create an economic incentive for waste pickers worldwide. Agamuthu et al. (71) highlights how millions of people make a living selling plastic waste they collect, sort and recycle. The actions of waste pickers cleaning up plastic contributes positively from an economic and environmental perspective. Despite this contribution, they receive little support from local government and often face dangerous working conditions due to the health impact of continuously being in close proximity to untreated waste. Therefore, future thinking towards recycling should consider improved working conditions for waste pickers as they are at times often the best and only source of plastic waste collection in many countries, and at no cost to local municipalities. Although recycling or reusing plastics is essential to prevent the environmental dispersion of waste, Sol et al. (72) points out that around 80% of plastics still end up in the ocean or in landfills every year. This amounts to around 4-12 million tons. In addition, although plastic recycling has doubled in Europe since 2006, only about 9% of the world’s plastics are recycled. According to Alexy et al. (73) even in the European Union (EU), only about 8.4 million tons of plastic waste is recycled, with one third being exported and only around 3.5 million tons of the recycled plastic waste entering into EU products. This is exacerbated by the current collection and sorting methods being inefficient and thus making recycling relatively expensive and especially difficult for small and medium size enterprises as well as many low- and middle-income countries (LMICs). The challenges of recycling are clearly significant and have much room for improvement. If future work is done well by looking at the negative aspects of the current recycling situation, there is the potential for many positive outcomes such as improved recycling capability in LMICs. This includes the creation of a significant number of jobs, economic improvement worldwide, and most importantly an increase in the uptake of recycled plastics into products we use.

7.1.3 Education

Educational interventions as it relates to microplastics are paramount for the world at large and especially important for today's youth, which will be inheriting the problem past generations have created. Therefore age-appropriate education is important in order to instill good habits at an early age as well as increase the possibility of students to spread their knowledge to others of all ages. Hammer et al. (70) emphasizes the importance of community education campaigns specifically by distributing brochures as well as giving lectures at local schools. Through education there is the potential for empowerment, which can act as an impetus to positive actions as it relates to waste management in the future.

Ashley et al. (74) focuses on the importance of environmental and ocean literacy through increasing awareness and knowledge. Ocean literacy enables behavioral change, where citizens can take sustainable actions and arrive at sustainable solutions to microplastic pollution. This is achieved by illuminating consequences and causes of microplastic pollution as well as highlighting the actions or behaviors that can make a positive change moving forward. Like the previous research done on the importance of education, Ashley et al. (74) focuses on the importance of youth with educational workshops for school students ages 11-15 and 16-18. This is achieved through the idea of creating "ocean citizens" who make informed choices which can improve the health of the ocean through attitude and behavioral change.

One must of course also consider education for students under 11 years old to be inclusive of younger students. To create a sustainable future there is the need for stakeholders from the government, NGOs, civil society, and other decision-makers to include similar kinds of education in all school curriculum. By increasing access to this information there is the capacity to create an ocean literate society with the end goal of establishing ocean literacy throughout the world. This can trigger behavior and lifestyle changes in a future generation that is knowledgeable and concerned with the growing microplastic pollution problem facing us today.

7.1.4 Circular Economy & Bioplastics

Circular economy refers to eliminating the continuous use of resources by creating a closed-loop system based on the 6 Rs, namely recycling, reusing, reducing, refurbishing, remanufacturing and recovering to minimize waste and pollution based on the living worlds cyclical model (75). This design, which is restorative and regenerative in nature, is in stark contrast to the linear economy, which is focused on the taking of resources, making, using, disposing and polluting which is currently seen throughout the world.

While many initiatives are arguably unsustainable and only apply to the short-term, Agamuthu et al. (71) refers to the circular economy as a solution that is long-term and sustainable. This is because it is based on the concept of returning and renewing plastic waste. The study applauds the concept as promoting plastic pollution reduction, creating behavioral change as well as enabling sustainable consumption and production patterns.

Alexy et al. (73) focuses on the importance of giving value to waste by offering financial incentives for consumers to return products instead of throwing them out. Since the adoption of a circular economic strategy, there has been a 30% increase in the recycling of polyethylene film in the plastic recycling industry. This is possible because of financial investments in recycling technology (73). The study also highlights how many stakeholders consider bio-based and biodegradable plastics as a sustainable solution in the context of a circular economy. This is based on the potential to move away from our reliance on fossil fuels.

While the decoupling of plastic production from fossil fuels is an important step, it is equally important to consider all the facets of biological plastic production, which is often presented as a green alternative to the current plastic production. The terms biodegradable and bio-based are often used interchangeably to refer to “bioplastics.” They are, however, two separate plastic designs. Bio-based plastics are made from biological (non-petroleum) sources whereas biodegradable plastics may be made in part from petroleum or bio-based sources and only degrade under very specific conditions.

In the case of biodegradable plastic, a UN environmental report noted that amongst other factors these kinds of plastics would often not completely biodegrade naturally, as the conditions for such are rarely met in marine environments (76). Specifically, some polymers can require prolonged temperatures of above 50°C to disintegrate, thus requiring industrial composters to do so (76). Furthermore, the report emphasizes a concern that misleading labels like biodegradable plastics may increase the chance that items are discarded inappropriately, therefore increasing the chances for pollution. Bio-based plastics are also difficult to effectively compost thus presenting additional problems. While the overall concept of a circular economy has the potential to change the way we deal with plastic waste positively, one must keep in mind all aspects of what other concepts refer to and strive for the improvement of biological plastic production wherever it is possible.

7.1.5 Beach clean ups

One approach to the mitigation of microplastics are beach clean ups, which involve the removal of marine debris from aquatic and coastal environments and can be led or facilitated by many civil society, private and government organizations. There are many positive aspects to beach clean ups according to Agamuthu et al. (71). They include raising public awareness and being able to measure in weight how much plastic waste has been collected. Smith et al. (77), on the other hand, argues that although beach clean ups aim to remove plastic materials and raise awareness of plastic waste, the extent to which these actions protect the environment as a whole or influence microplastic waste is unknown. It is also difficult to measure the impact of beach clean ups as they relate to preventing the "upstream" problem of plastic pollution leakage to begin with. This is exemplified by the Greenpeace quote: "If your bathtub was overflowing, you wouldn't immediately reach for a mop — you'd first turn off the tap, which is what we have to do with plastic production" (78). Beach clean ups can be seen a method to address plastic waste already existing in the environment, and to involve communities and people of all ages in the process of addressing pollution. This can foster agency and a sense of ownership and empowerment. However, without stopping current plastic production methods at their source there will always be an open tap to the problem we face.

This is further exacerbated by greenwashing; a practice in which industry or many companies market themselves as environmentally friendly and concerned with plastic waste, despite their actions indicating the opposite. One example of this is the Coca-Cola company, which uses green marketing like funding beach clean ups while at the same time systematically lobbying against regulation that would impose restrictions on single-use plastic bottles which are one of the biggest contributors to plastic pollution worldwide (79). Therefore, although beach clean ups are an important step in addressing plastic waste, in order to avoid cleaning with one hand while polluting with the next, it is important to be cognizant of big corporations attempts at funding beach clean ups and to hold them accountable for all actions.

7.1.6 Wastewater Treatment Plants (WWTP)

Wastewater treatment plants (WWTPs) play an important role when it comes to microplastics because they have the capability to remove microplastic particles before they are discharged into the environment, including aquatic and terrestrial environments. Freeman et al. (80) argues that although WWTPs play an important role when it comes to removing larger microplastics they are currently inefficient at removing particles less than 100 μm. The study indicates that this is due to the fact that influent and effluent have similar qualities to the smaller particles of microplastics making it difficult to decipher between the two. As a result of this non-removal, WWTPs contribute to the release of more than 100 billion microplastic particles into the environment annually. This has room for improvement (80).

Sol et al. (72) goes on to explain that this matter is made worse by the fact that 93% of the microplastics that are removed end up in sludge which is a byproduct of the wastewater treatment process. This is generally a semi-solid or solid residual. The sludge containing microplastics can be generally managed by incineration, landfill disposal or application to soil. Roughly 50% of sludge generated in North America and Europe end up in fertilizer. Once the microplastics are in the soil there is the possibility to absorb toxic pollutants such as pesticides. The same microplastics can also absorb contaminants found in the water stream of wastewater treatment. Therefore, there is the potential for an adverse effect on human health and the environment due to the concentration of contaminants in the wastewater treatment process as well as its potential for pollutant absorbability once in soil.

Furthermore, there are no regulations or policies related to wastewater treatment's removal of microplastics currently in place. Therefore, one option to remedy this problem is to have legislation requiring that sludge go through a further microplastic removal process within WWTPs. Such advanced treatment processes are illustrated by Sol et al. (72) as rapid sand filtration (RSF) which provide efficient and quick removal of suspended particles; reverse osmosis (RO) which uses a partially permeable membrane to separate out particles; and membrane bioreactors (MBR) which combine membrane filtration with conventional biological treatments. All three methods have the potential to improve microplastic wastewater treatment removal. Further research into available technologies as well as government collaboration to incentivize cooperation from the wastewater sector are vital to addressing the issue of regulating microplastics presence in WWTPs.

8. Strengths and limitations of this thesis:

Among the strengths of this thesis are that it identifies the sustainable actions and roles that global stakeholders such as government, industry, nonprofit organizations, communities, families, and individuals can play. In addition, it took a global focus that was able to address cross-regional learning. It also addresses societal issues like the complications of green washing by big corporations while emphasizing the international potential for a circular economy. It strengthens our understanding of microplastics and their impact on human health by identifying various potential health risks as well as gaps in knowledge. Another strength is that such a study involving PRISMA had not been done before and thus provided new insight and perspective. As a result, this thesis systematically examines the knowledge gap between human health and microplastics as it relates to sustainable actions.

Among the limitations of this thesis is that the field of microplastic research develops quickly and thus it is possible that at the time of publication, the information can be potentially dated as such. Furthermore, due to the technical approach combined with the currently available literature, the study scope ended up being limited to and only focused on certain regions. These included Western Europe, Central America, South America, and the Pacific Islands. Therefore, not all regions of the world could be fully represented. This could have been due to language constraints as well as not using grey literature. Another limitation was the time allotted for the writing of this thesis. It was a challenge therefore, to cover all material available as there was a large depth of study. Nonetheless, it is the hope that this thesis has the potential to guide future research and action.

9. Conclusion:

This thesis explored a framework for sustainable actions that civil society can undertake to mitigate the impact that microplastics have on human health. This was achieved through a scoping review of literature which looked at 19 papers reviewing sustainable actions related to microplastics and human health. Existing scholarship shows a strong need for more and deeper research related to microplastics and their effect on human health. Addressing the following gaps in the future are crucial for us to further our understanding:

- Providing a more comprehensive definition of food security as it relates to the impact of microplastics on human health.

- Investigating the inherent toxicological impacts, the extent of chemical transfer, as well as general health risks of occupational exposure to microplastic inhalation. This research should specifically address respiratory illness and the potential to induce gene mutation resulting in cancer.
- Standardization of data collection and analysis methods for international occurrence of microplastics and potential human exposure though food and drink.
- Researching the effect of plastic additives on human health including, but not limited to effects on the hormonal systems as well as their interaction with nuclear transcription.
- Data collection to identify the quantity related to the uptake of plastic associated toxicants that can potentially cause negative human health effects.

Although there are many positive measures taking place today, current measures are not sufficient. In response to the threat of microplastics, there is a clear global call to action that requires stakeholders at all levels to go beyond the status quo. The research indicates that there is not a one size fits all solution and thus there is the need for an integrated and multifaceted approach involving various stakeholders and taking into consideration various cultures and country's needs on multiple levels including global, regional, national, and the local level.

9.1 Global Level – towards binding regulation

Policy & legislation are essential to achieving the overarching goal of mitigating microplastic pollution on a global level. This requires the type of interdisciplinary collaboration that focuses on international governmental bodies and how they can work together to address a common cause.

Regulatory instruments and initiatives working internationally must consider conventions such as the MARPOL Convention (81). It is through these regulatory bodies that there is the potential to achieve the goals of various SDGs. The SDGs are especially important as they not only address microplastics relationship to human health, but they also help target directly sustainable actions related to microplastics. Examples include SDG 3: Good health and well-being, SDG 6: Clean water and sanitation, SDG 11: Sustainable cities and communities, SDG 12: Responsible consumption and production, SDG 13: Climate action, SDG 14: Life below water (protection of the seas and oceans), SDG 15: Life on land (restore ecosystems and preserve diversity), and SDG 17: Partnerships for the goals (82). In the future, it is through regulatory bodies that there should be a focus on moving away from non-binding legislation and instead creating international binding treaties that all countries can be held accountable for, adding the potential to create positive actions targeted towards the SDGs.

9.2 Regional Level – towards unity

Policy & legislation, interdisciplinary collaboration and the SDGs are equally important from a regional perspective because they help to channel actions and organize stakeholders. Regional conventions affecting microplastic pollution throughout the world play an important role as setting a strong example for all countries connected with that region. For example, the Bamako Convention prohibits the transboundary movement and specifically the import of hazardous waste into Africa as a region (81). This establishes a strong message to countries throughout the African continent. Through the fortification of regional level policy in the future, there can be a strengthening of entire regions and can create a trickle-down effect on an individual country level.

9.3 National & Local Level Government – towards equality

Policy & legislation, interdisciplinary collaboration, and the SDGs also play a central role at the national level. Other elements related to microplastic pollution however make more of an impact at this level. Recycling, for example, is carried out differently dependent on the country setting. Many high-income countries (HICs) have integrated country-wide recycling systems, while many LMICs have enhanced recycling opportunities mainly for wealthy areas. This however leaves impoverished, rural or geographically marginalized communities without coverage. Education related to microplastic pollution also shows an unequal distribution based on geographical location and/or income level. Integration of recycling and education at all income levels is essential as waste from one community has an effect on a global scale. When it comes to conversion of plastic into fuel and bioplastics at the national level, investments in technology and financially incentivizing businesses can be a way forward for improved options in the future. An example of this would be higher degradation capabilities for the field of bioplastics. From a local government perspective, there is a need for policies that improve the implementation and handling of landfill/waste management. In addition, developing a circular economy, WWTP improvements, as well as improving landfill/waste management and EPR.

9.4 Local Level – focus on education and a vision to enable willingness to change

At the local level, interdisciplinary collaboration, reducing, reusing, recycling, education, beach clean ups and improving landfill/waste management are grounded activities that contribute to the achievement of the SDGs. A complex policy response needs to be set in place that includes policy development, policy evaluation, and clear accountability measures and pathways. This helps to mitigate pervasive aspects such as greenwashing and at the same time hold plastic producers responsible for the pollution created by plastic production (EPR). This therefore needs to start from the local level and work its way up, while simultaneously being focused on a global-down perspective specifically focused on strong and transparent international government involvement. The response can be best achieved through the inclusion of civil society, local government, national, regional, and global levels with continued and lasting support from organizations like the United Nations (UN). Central to the local level is the idea of individual autonomy, which can be seen through making the choice to not use plastic as a consumer or to clean up one's local community or coastal area. Therefore, empowering individuals may lead to more changes at the local level but will not happen on its own.

Mahatma Gandhi expressed the idea that we must *"be the change we want to see in the world"* (83), however this is only the beginning and can only take us so far when it comes to microplastic pollution. There is the possibility to create change on the local level specifically starting with ourselves. However, it is misleading to infer that it is primarily the individual's responsibility when this can potentially re-direct the impact from the global level related to among other things, plastic production, and government legislation. This concept needs support across all levels so that the world can change, and we can finally see a mitigation to plastic pollution realized. The result of which provides us with a cleaner and healthier future for generations to come, produced by the sustainable actions we do today.

This systematic literature review study has drawn an outline of the present literature in the domain of microplastics as it relates to human health and sustainable actions. A thorough search of various databases has been conducted. After filtering through multiples stages, 19 articles were extracted of which 10 articles focused on microplastics and human health while 9 articles focused on microplastics and sustainable actions. This therefore provided a balanced overview on both human health and sustainable actions. This thesis has shown the delineation of microplastics through the lens of human health, and the assessment of sustainable actions related to mitigating microplastics to be a complex process and requiring further research in the future.

For this research to be successful there is a need for clear frameworks related to human health. Specifically with providing a more comprehensive definition of food security as it relates to microplastics. In addition, investigating the inherent toxicological impacts, the extent of chemical transfer, as well as general health risks of occupational exposure to microplastics. There is also the need for improved policy related to sustainable actions at multiple levels and involving various stakeholders. Civil society specifically needs structured and strategic support from government on the global, regional, national, and local level in the form of policy that facilitates community action and to mobilize and empower individuals to address microplastic pollution.

List of actions that civil society can undertake to mitigate the impact of microplastics:

- **Thinking green:** Reducing plastic waste specifically by using reusable bottles/containers, reusable bags instead of single use plastic, refusing plastic products whenever possible and recycling everything that has the capability to be recycled.

- **Sustainable consumption:** Making conscious consumer choices related to a focus and movement towards a circular economy. Researching considered brands for their policy before making purchases.

- **Organizing:** Using social media to involve friends, family and strangers to unite and form environmental groups that involve themselves in local education of all income levels as well as beach clean ups.

- **Getting involved:** To ensure there is an EPR/polluter pays principle for all plastic production.

- **Stepping up action:** Reaching out to politicians and demanding better international binding government regulation as well as improved occupational health conditions.

- **Following up:** To make sure promises made are promises kept.

At the same time recognizing that is not only the individual's responsibility but there is a requirement for government and business to also play its part, specifically through more transparency and less greenwashing. It is through the sustainable interdisciplinary collaboration amongst all stakeholders that there is the potential to mitigate microplastic pollution and thus have a positive effect on human health.

10. Conflict of Interest:

I declare that I have no conflict of interest.

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