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Ecological and health impacts of plastic debris on Pacific Islands

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Abstract

Plastic debris is a worldwide problem. This is particularly acute in the Pacific region, where its scale is a reason for serious concern. There is an obvious need for studies to assess the extent to which plastic debris affects the Pacific. Therefore, this research aims is to address this need by

undertaking a systematic assessment of the ecological and health impacts of plastic debris on Pacific islands. Using pertinent historical qualitative and quantitative data of the distribution of plastic debris in the region, this study identified pollution and contamination trends and risks to ecosystems, and suggests some measures which may be deployed to address the identified problems.

Key-words

Plastic debris – Waste- Pollution- Environment – Health - Pacific

1. Introduction: Historical Data, Evidences of Plastic Debris, and Waste Management in the Pacific Region

Since the discovery of polyurethanes (PU) by Bayers and his co-workers in 1937, leading to the first introduction of plastic materials in 1955 (Feldman, 2008), the global production of plastic has increased considerably. The use of plastic is manifold: from packaging to the production of toys and straws, to plastic cutterly. In many countries, plastic materials are not properly disposed of. As a result, the world's ocean and land are infested with plastic debris (Rudduck et al., 2017; Lebreton et al., 2018; Bond et al., 2018; Le Guern, 2018), including the Pacific region (Figure 1), (Chowra, 2013; Jambeck et al., 2015; United Nations, 2017; Lavers and Bond, 2017; Forrest and Hindell, 2018).

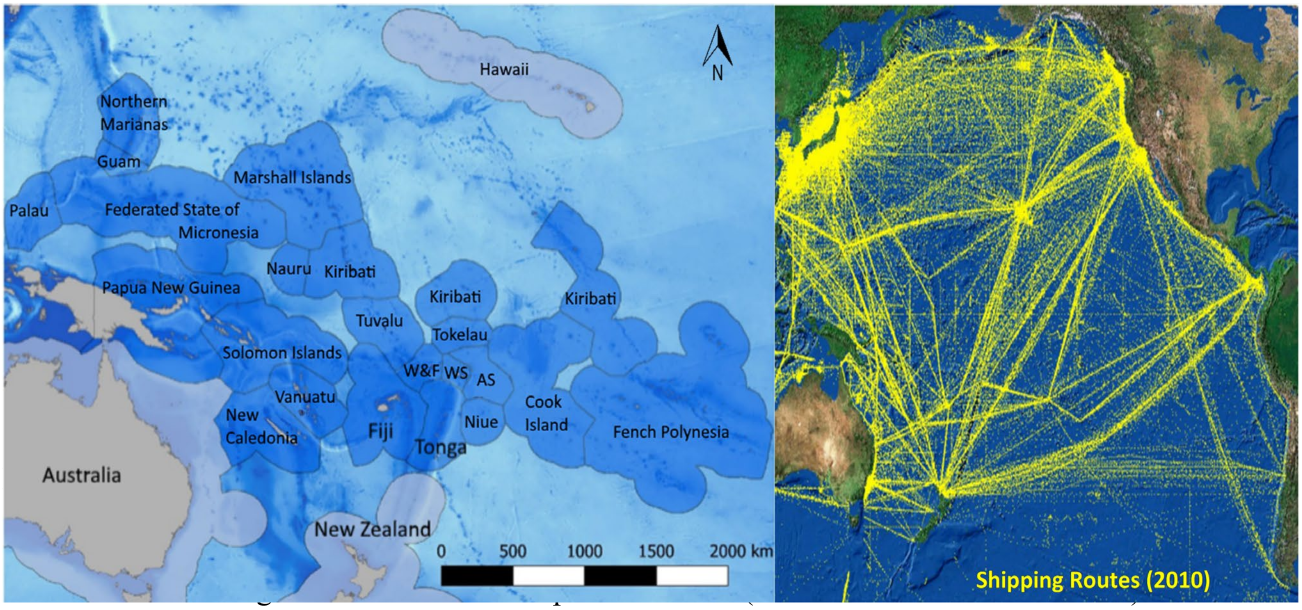
Increasing marine plastic litter, which can be found in the ocean gyres of the North and South Pacific, a waste intensive tourism industry, as well as difficulties in adequate waste collection and management, all contribute to the increasing deposition of plastic litter in the Pacific region (Lachmann et al., 2017). The most prominent accumulation of marine garbage and plastic waste, the so-called Great Pacific Garbage Patch, comprises a span of 1.6 million square km and is influencing the Pacific islands coastal ecosystems as waste is transported by wind and surface currents (Lebreton et al., 2018). The highest amount of plastic litter contributes from domestic, industrial and fishing activities (Li, Tse, & Fok, 2016). As such, plastic pollution poses a significant threat to the coastal ecosystems of the Pacific Island States, directly and indirectly affecting marine and terrestrial environments, life on land and life below water.

The following questions are addressed in this paper: What is the extent and significance of the problem of plastic debris on the Pacific Islands? And : What are their ecological and health impacts? The subsequent parts of this paper will address these issues.

Plastic debris in the Pacific: the extent of the problem

There are two main historical sources of plastic debris in the Pacific region: land-based and ocean-based. About 80% of this plastic debris is attributed to land-based sources, with the remaining 18% from the fishing industry including aquaculture (Hinojosa and Thiel, 2009) and an estimated 2% from land-ocean-based sources, such as shore-based plastic debris and incidental losses (e.g. via ocean transportation and run-off from processing facilities) (Andrady, 2011; Norrman and Soori, 2014; Le Guern, 2018). The impacts of plastic debris include harm to the environment, marine life, economy and human health (Timmers et al., 2005; Watson et al., 2006; O'Hanlon et al., 2017).

Using a mapping analysis, a literature review, and document analysis and survey, the authors can present herewith a set of historical data and evidence of plastic debris from 2008.



examined separately below.

Land-based plastic debris

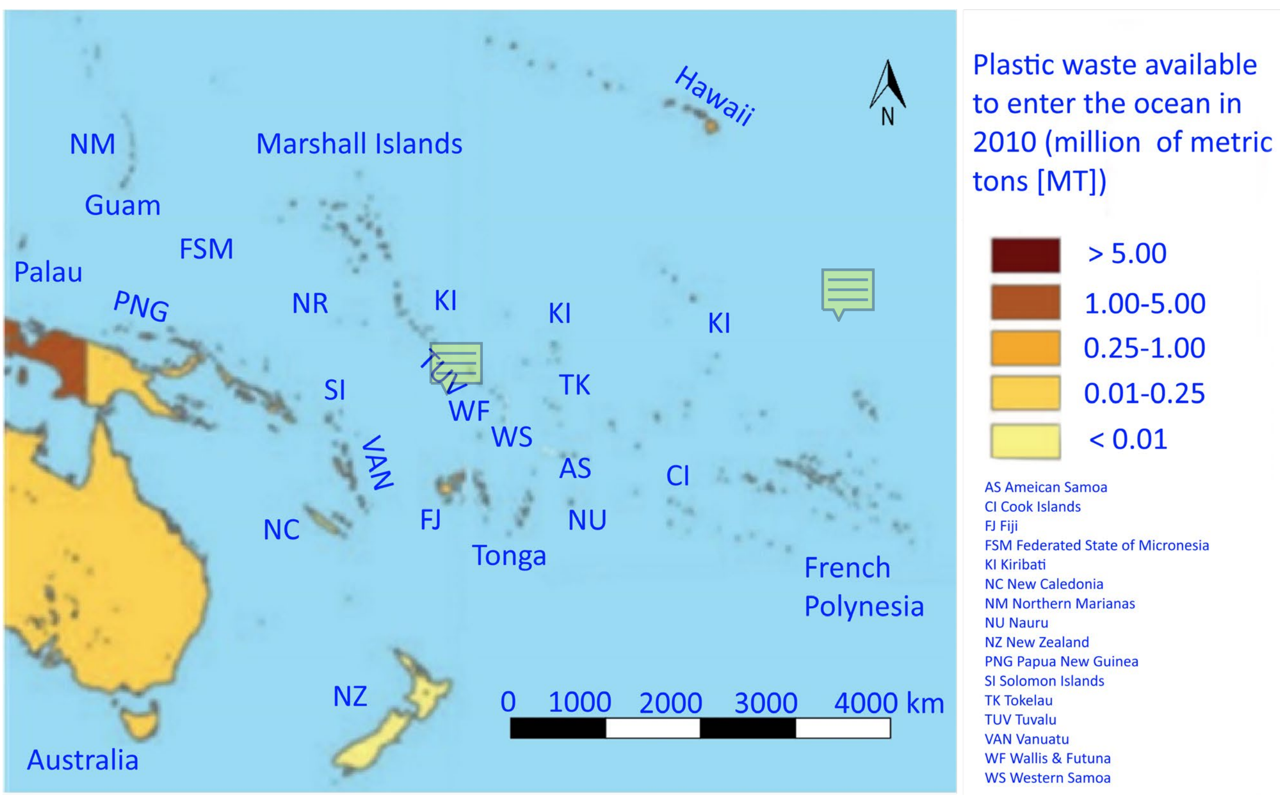
Evidence in the Pacific suggest that the plastic debris from land-based sources can be attributed to four factors: (1) littering, (2) solid waste disposal around coastal and undervalue areas, (3) plastic debris induced by climate change and disasters caused by natural hazards (4) plastic debris from discarded plastic bags (Table 1, Figure 2, Table 2), (Chowra, 2013; Norrman and Soori, 2014; Gee, 2018).

Table 1: Record of land-based plastic debris in the Pacific island countries

Source	Country	Year	Amount	Types
Litter Clean-up	American Samoa	2012-2013	1,960 kg	Fast food, beachgoers, sports/games, festivals, and litter from streets/storm drains
	Henderson Island	2017	37.7 million	Plastic debris
	Fiji	2018	788.20 kg	Plastic bag & bottle, plastic wraps, diapers, cigarette butts, plastic pipes
Solid waste disposal	Fiji, Kiribati, Marshall Islands, Palau, Solomon Islands, Tokelau, Tonga	Throughout	Varies	Dumpsites – coastlines, undervalued areas (swamps and mangroves forests). High tide events, storm surges, and other extreme weather events can release and transport light plastic debris.
	Tuvalu	Annual average for household and office waste 2003-2015	1,000-1,400 tonnes per year total (50-70 tonnes per	By weight, household waste is 65-70% of total solid waste, and office waste from commercial and Government of Tuvalu offices is 30%. Solid waste is composed of 70% organic materials (12% of organic waste is paper and cardboard); 5% plastic; 20% glass and metal; 5% other.

			year of plastic)	
Climate change and natural hazard	Affected islanders	Dry-wet seasons	Varies	Provide avenues for plastic debris to enter the marine environment from the land.
Plastic bags	Affected islanders	Throughout	Varies	Plastic bags are lightweight and sturdy, so winds and currents can easily carry them. Its buoyant and durable making them get caught in trees, bushes and to block storm pipes, causing flooding or breeding grounds for mosquitoes. They can easily litter and be carelessly discarded if waste litter bins are not available.

Source: Authors; Hemstock et al. (2006) Chowra (2013); Lavers and Bond (2017); Captain Cook Cruises (2018)



Map created by Peni Hausia Havea using QGIS (2018)

Figure 2: Pacific islands map with each country shaded according to the estimated mass of mismanaged plastic waste [millions of metric tons (MT)] generated in 2010 by populations living within 50 km of the coast.

Source: Authors; Jambeck et al. (2015)

Table 2: Types of land-based plastic debris, time of degradation, entering pathways and health effects

Plastic debris	Degradation time (Years)	3 pathways plastic pollutants entering the human body	Health effects due to foodborne chemicals
Cigarette butt Disposable diaper Fishing line Food wrapper PET-bottle Plastic bag	10 450 600 20-30 300-500 30-60	1) Chemical toxicity: Plastic pollutants may enter the human daily diet through ingestion of contaminated fish, mammals and other edible sea creatures who consume plastic polluted food; inhalation; and air- and -waterborne hydrophobic contaminants. 2) Pathogen and parasite vectors. 3) Particle exposure toxicity.	Cancer, birth defects, immune system problems, childhood developmental issues, lung & gut injury, oxidative effects (oxidative stress, cell damage, inflammation, and impairment of energy allocation functions), male infertility

Source: Norrman and Soori (2014); NJDEP Science Advisory Board (2015); Vethaak and Leslie (2016); Forrest and Hindell (2018); Ecology Center (2018); Metz 2016

Ocean-based plastic debris

In the region, commercial fishing and shipping are the main causes of ocean-based plastic debris. The commercial fishing debris includes nets, ropes, strapping bands, bait boxes, plastic bags, and gillnets (Sheavly, 2010). The commercial-based shipping debris is the illegally dumped waste or littering from shipping activities (Figure 3) (Chowra, 2013; Thevenon et al., 2014; Le Guern, 2018). A study on Sand Island on Midway Atoll between 2008 and 2010 found a total of 740.4 kg of beached marine-based litter made up of 32,696 objects, of which 91% were mainly plastic debris (polyethylene and polypropylene), (Ribic et al., 2012).

Based on this historical data and evidences of plastic debris in the Pacific between 2008-2018, the authors estimate that over 30 million tonnes of plastic debris can be found in the region.

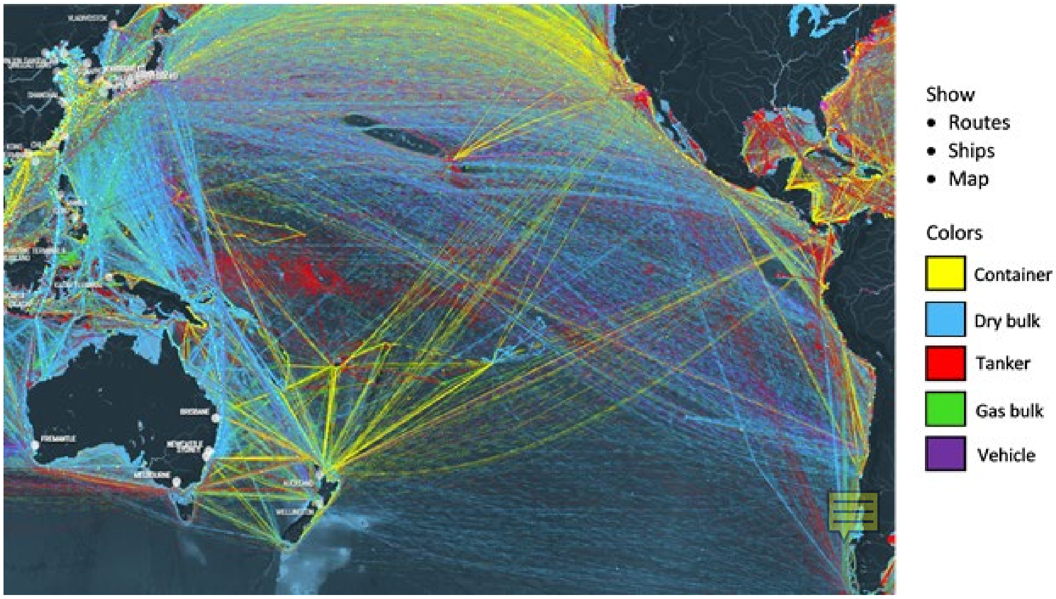


Figure 3: Shipping routes and areas for illegal ocean-based littering in the Pacific Ocean
Source: (Klin et al., 2012)

In order to provide some context to the currently insummountable problem of land based and ocean based plastic waste in the Pacific islands region, it is necessary to look at island waste management. Taking Tuvalu as an example, it is clear that Pacific island nations cannot look at plastic waste management in isolation. The first national strategy-related document on waste management for Tuvalu was the 1993 Tuvalu State of the Environment Report (Lane, 1993). This report lists solid waste management as "perhaps the most obvious environmental issue in Funafuti" it also states that: "Tuvalu at present does not have a significant or insoluble pollution problem, despite the volume and variety of solid waste dumped indiscriminately around Funafuti." Lead contamination from discarded batteries was identified as a major waste management issue and plastics are conspicuous by there absence in that plastics were not identified as a land or marine pollutant.
From table 1 Tuvaluan households contribute a maximum of 70 tonnes per year of plastic waste to the environment – this is an insignificant amount in global terms. For Tuvalu, population pressures and the impacts of external pollution have lead to increasing waste management issues. For Tuvalu, over a decade ago (Hemstock et al., 2006; UNDP, 2006), the major waste management gaps were identified as:

- A lack of an agreed national set of waste sector objectives that are applicable at a "country level", as well as possible additional legislation to ensure their effectiveness, either nationally or at a Kaupule (By-Law level). International agreements and frameworks have not improved waste management in the Pacific least developed states.
- The need to achieve consistency in the standards of operation, scope of activities, and waste management service provision with a management and finance structure that ensures fair and equitable payments for services.
- A severe (critical) shortage of labour and equipment for waste service provision, even at a basic level.

- A worsening situation in respect of waste disposal.
- The need to provide support and capacity building to Tuvalu waste organisation(s)
- A general lack of community interest and awareness in relation to waste issues.

Despite a mention of waste management in the current National Environmental Management Stategy, there is still no cohearant waste management plan for Tuvalu. The situation for waste management in Tuvalu is now critical, despite a plethora of technical assistance and feasibility studies costing US$600,000, (Hemstock & Smith, 2011), as well as efforts under the EDF 10 and EDF 11. SPREP, known as the South Pacific Regional Environment Programme, is the regional intergovernmental environment organisationand has the lead responsibility for regional coordination and delivery of waste management and pollution control action. SPREP is guided by the strategic management framework, Cleaner Pacific 2025, in facilitating regional cooperation and collaboration. For Tuvalu, depite over a decade of strategy development nad fesibilty studies, waste management in Funafuti – the most populous atoll - is in crisis.

2. Ecological impacts of plastic debris

Plastics are the most widely used disposable material globally (Scisciolo et al., 2016). They are nondegradable petroleum-based products that lack the ability to decompose or mineralize at measurable rates (Leslie, 2015). Their diversity, versatility, relatively inexpensive manufacture processes, durability and practical applications are some of the reasons for their indispensability in several aspects of modern life (Monteiro, Ivar do Sul, and Costa, 2018; APME 2014). Unfortunately, the present unsustainable usage of many plastic items, coupled with its highly durable nature, generates substantial quantities of waste with environmental and socio-economic implications (Debrot et al., 2013; Ryan et al., 2009). 80% of anthropogenic debris littering the oceans are plastics (Landon-lane, 2018), threatening the safety, integrity, and sustainability of oceans. The ubiquity of plastics in oceans has resulted in a critical situation for ocean ecosystems (Vince, 2015). In 2015, approximately 322 million tonnes of plastic were generated with over 10 million tonnes being deposited in the oceans (Landon-lane, 2018). Oceans are highly susceptible to diverse sources of plastic pollution due to long-distance movement of debris by wind, water bodies, superficial ocean current etc. (Eriksen et al., 2013, Cózar et al., 2014). Land-based debris originates from the activities of local populations such as the improper disposal of wastes by manufacturing companies and tourists' activities while ocean-based debris consists of debris originating from anthropogenic ocean activities and pelagic sources such as shipping, fisheries etc. (Scisciolo et al., 2016). From 1950, 8.3 billion metric tons of plastic has been produced globally and half of that has been produced in the last 13 years (Geyer, Jambeck, and law, 2017; Jambeck, 2017). According to (UNEP, 2014), a 5% increase in global plastic production is documented annually and this figure is projected to increase significantly in the near future. This underlies recent projections of an increase in marine plastic debris (van Sebille et al., 2015) since over 80% of plastic debris are produced terrestrially. If the current pollution rates are sustained, the volume of plastic in the oceans will surpass that of fish by 2050 (Simon and Schulte, 2017) .

The unabated accumulation of wastes in the ocean constitutes a global pollution issue affecting several coastal countries, cities, and islands (van Sebille et al., 2015). The proximity of Coastal environments to terrestrial plastic sources makes them highly vulnerable to the impacts of plastic debris pollution (Jambeck et al., 2015). Oceanic insular environments are equally vulnerable to plastic pollution because populated islands are also potential sources of plastics. Moreover, various meteoceanographic mechanisms support the retention of plastics from the surrounding sea on islands (Monteiro, 2018).

Although plastic pollution affects both terrestrial and marine habitats, most of the work assessing the environmental impacts of plastic debris focuses on marine environments (Thompson et al., 2009). According to the UNEP (2014) as reported in Landon-lane (2018), marine ecosystems are devalued to the tune of $13 billion/annum globally. Marine organisms encounter more plastic debris than any other form of pollutant in the marine environment, causing wide spread entanglement and ingestion (Gall and Thompson, 2015). Apart from ingestion, organisms also consume contaminants through inhalation and dermal sorption (Teuten et al., 2009). Records show that over 180 species of animals have ingested plastic debris, including birds, fish, turtles and marine mammals and over 250 species have been affected by ingestion and entanglement as reported by (Laist, 1997) in Gregory (2009), and more recently by Werner et al., 2016. Large animals are particularly susceptible to accidental ingestion of plastic debris and entanglement in floating plastic (Chiba et al., 2018).

These frequent interactions have severe impacts on wildlife, with nearly 700 species known to be affected directly or indirectly (Gall and Thompson, 2015). Entanglement and Ingestion of plastics poses several dangers, including gastrointestinal blockages (Baird & Hooker 2000), ulceration (Fry, Fefer, and Sileo, 1987), internal perforation and death due to starvation and debilitation (Grogory, 2009; Mascarenhas, Santos, & Zeppelini, 2004). In Gregory (2009), it was reported that 95 per cent of dead fulmars in the North Sea have plastic in their guts, and large quantities of plastic were present in the guts of other birds. Exposed surviving organisms are afflicted with a reduced quality of life and impaired reproductive performance (Gregory, 2009). Apart from marine animals, terrestrial vertebrates are also at risk of entrapment in plastic wrack debris. Plastic debris also have the potential to penetrate the marine food chain and cause human sickness through consumption of seafood poisoned by organic and organometallic contaminants inherent in plastic debris (Chiba et al., 2018; Teuten et al., 2009). For instance, tropical animals, including different species of fish in the food web are potential consumers of micro-plastics passed on by zooplankton (Cole et al., 2013), with likely medical consequences for humans (Chiba et al., 2018). Plankton-eating animals like mysticetes (baleen whales) are therefore vulnerable to plastic ingestion (Gregory 2009). Consumption of fish that have eaten plastic is a common form of plastic ingestion by human beings and marine mammals (Eriksson & Burton 2003).

Plastic wastes also affects the surrounding environment. The leaching of toxic pollutants from fragmented plastic negatively impacts the environment and affects the biological function of organisms. This is because plastics can transport contaminants as well as increase their environmental persistence (Teuten et al., 2009). Several contaminants leach out of plastics in the landfill environment, thereby contaminating surrounding areas. For example, in the case of Tuvalu, a coral atoll, due to the porous nature of the coral bedrock tidal surges wash leachates from the municipal landfill into the lagoon. The environmental problems caused by plastic debris are chronic in nature rather than acute (Gregory, 2009). The pollution of soil and terrestrial ecosystems by plastics and microplastics is another environmental problem (Chae and An, 2018), and there are growing concerns on the possibility of microplastics penetrating the soil profile and polluting the groundwater (Scheurer and Bigalke, 2018); Rillig et al.,2017). Presently, the leaching of chemicals from plastic products and the potential for plastics to transfer chemicals to wildlife and humans is one of the major concerns arising from plastic usage and disposal (Thompson et al., 2009). According to (Talsness et al. 2009), chemicals from plastics production such as phthalates and BPA exist in the human population, with potential adverse effects, including reproductive anomalies. However, the extent of chemical transfer and toxicological impacts of exposures to these chemicals are fuzzy and require further investigation (Thompson et al., 2009).

Also, floating plastic debris facilitate the spread and transportation of exotic invasive species (Schuyler et al., 2015, Lachmann et al., 2017). Furthermore, plastic debris cover the flora and fauna, and cause hypoxia induced by limitation of gas exchange between pore waters and overlying sea water (Gregory & Andrady 2003; Gregory, 2009). Plastic debris equally devalue recreational spaces by diminishing their aesthetic appeal thereby resulting in significant drop in revenue from tourism; disrupt ecosystem services and are hazardous to maritime activities such as shipping and fishing (Moore 2008).

A high occurrence rate of plastic debris in the deep sea has more recently been documented. Areas with proximity to densely populated regions, such as the Mediterranean Sea, are particularly vulnerable (Chiba et al., 2018). The biodiversity of deep-sea ecosystems and other marine ecosystems is thus threatened by plastic debris. Previously, many islands were thought to be insulated from ocean-based sources of plastic marine debris, but recent studies have discovered millions of stranded plastic items on island beaches in relatively short time ranges (Lavers and Bond, 2017). Even the most remote of localities of both Northern and Southern hemispheres are no longer immune from littering by marine debris, including the Pacific islands (Gregory, 2009). Despite the impacts of plastic debris on tropical and sub-tropical islands due to their vulnerable ecosystems (Scisciolo et al., 2016), the number of studies that have assessed the impacts of plastic debris in insular environments are relatively few (Monteiro, Ivar do Sul, and Costa, 2018). This is despite the tendency to accumulate stranded plastics on depositional habitats such as island beaches. It is noteworthy that different studies on selected Caribbean and Pacific islands observed significant differences in both volume and content of debris found in these locations. Therefore, the impact of different island's exposure to debris vary spatially and temporally (Scisciolo et al., 2016). This gives credence to the claim that environmental pressure exerted by debris are not the same on all islands. It is thus plausible that the ecological and health impacts of plastic debris also vary between islands. Although plastic pollution has been established as a source of transboundary environmental harm, there is limited knowledge on the specific damage and impacts of plastic pollution due to its relative newness (Landon-Lane, 2018).

3. Health impacts of plastic debris

There is a paucity of studies on the health impacts of plastic debris. This limited knowledge on the impacts of plastic chemicals on human health is also highlighted by Keswani et al. (2016). Although plastics are potential unknown reservoir of Faecal indicator organisms (FIOs) such as E. coli and pathogens, further critical investigation is required to establish a correlation between plastics and public health risks. Links between plastic debris with human pathogens and FIOs on the one hand, and the ingestion of microplastics on the other hand, and the impacts of these on human health, remain unestablished (Keswani et al., 2016; Barboza et al., 2018). Globally, the adverse effects of plastic debris on human health remain controversial and hazy however emerging evidences suggest the possibility of micro- and nanoplastic penetrating secondary tissues, such as liver, muscle, and brain, and attacking the immune system causing immunotoxicity and triggering adverse effects like immunosuppression and abnormal inflammatory responses (Lusher et al., 2017; Wright and Kelly, 2017).

Plastic debris may leach out and absorb toxic contaminants, which can then enter the food chain when consumed by marine and sea-based life, ultimately affecting human health as well. Recent research shows that microplastics have been found in economically important marine species such as lobster, mussels, and several fish species, and could also be detected in table salt and tap water. (Kontrick, 2018; Lachmann et al., 2017) Since plastic pollutants are known to cause lasting damage to the nervous, metabolic and endocrine system, especially pregnant women and children are among the most susceptible groups (Halden, 2010). The adverse health impacts resulting from exposure to microplastics are yet not well understood, but it is clear that both macroplastics and microplastics have the potential to compromise the balance of coastal and marine ecosystems, and to cause hazardous effects on human and wildlife health in several different ways (Kontrick, 2018; Moy et al., 2017).

From a One Health perspective, human health is closely linked to the health of the environment and animals (CDC, 2018), which is especially true for the impacts of plastic debris on human health and well-being. Because Pacific islands' coastal environment, as well as marine and land-based animals share our exposure to plastic pollution, we need to pay particular attention to the relationship between human, environmental, and animal health to fully understand the public health consequences of plastic pollution.

Plastic debris influences not only marine and terrestrial habitat and, hence, land and sea-based wildlife, but also our living environment, agricultural land, and freshwaters. In this respect, changes in marine and coastal ecological systems may affect the biodiversity of animals and plants in the Pacific region which primarily contribute to the human living environment as well as local food web and economy, including tourism and fishing industry. In turn, how we deal with marine plastic litter and waste management on land is directly impacting the health of the human population, animals, and the environment. In addition to discarding plastic waste in landfills, burning domestic plastic waste in the backyard is a common practice of land-based waste management in developing countries including Pacific Island States with hazardous effects to human health (Baker et al., 2015; Halden, 2010). Table 1 summarizes the significant ecological and health impacts of plastic debris on human health and well-being in relation to environmental and animal health consequences, with attention to the Pacific region.

Table 1. Ecological and health impacts of plastic pollutants from a One Health perspective

Exposure	Environment	Animal health	Human health
Persistence in the environment for up to a century (primarily macroplastics)	Contamination of surface and deep waters, beaches, sediments, and shorelines, marine and terrestrial organisms [8, 10]	Entanglement in floating litter and plastic materials at shorelines, beaches, and seabed with harmful and lethal effects [3, 11]	Contamination of marine and sea-based food as well as living environment causing adverse health effects [2,8]
		Ingestion of plastic with harmful effects on food intake, digestion, reproduction, and survival [3,11]	Contamination of marine and sea-based food causing adverse health effects [8,10]
	Surface abrasion, shading, suffocation, loss of marine biodiversity including seagrass, mangroves, and coral reefs [5, 11]	Loss of biodiversity, nutritional base and living habitat; higher vulnerability to environmental hazards [6, 11]	Loss of ecological balance and variability in marine/sea-based food; Higher vulnerability to environmental hazards [8, 10]
Transfer of pollutants and chemicals	Introduction of alien invasive species, pathogenic micro-organisms and parasites [4]	Altering of marine and terrestrial habitat; Exposure to harmful pathogens and parasites causing sub-lethal and lethal health effects [3, 4]	Loss of variability in marine/sea-based food; Exposure to harmful pathogens and parasites causing sub-lethal and lethal health effects [4, 8, 10]
Exposure to microplastics due to fragmentation of macroplastic or as part of certain products	Spreading of harmful pathogens and toxins; harassment of natural resources, including agriculture and fresh water/tap water [5, 6, 8]	Ingestion of microplastic particles and toxins may lead to physical damage and death due to starvation and disrupted metabolism, loss of mobility, loss of reproductive and development function, and damage of the nervous system [7]	Ingestion (including marine food) and inhalation of microplastic particles and toxins may lead to cell damage, endocrine and metabolic disruption, which can cause inflammation, cancer, birth defects, immune system suppression, damage of metabolic, reproduction and developing system, and increased risk of severe infection [1, 5, 8, 10]
Burning of plastic waste	Release of dioxins, toxins and microparticles in the environment, including	Inhalation and absorption of toxins (including contaminated food) affecting the metabolic and endocrine system; may lead to cancer	Inhalation and absorption of toxins (including contaminated food) that may act as carcinogens, endocrine disruptor, and hazardous

	waterways, crops and air [9]	and loss of reproductive and development function (health effects expected to be similar to those described in humans) [9]	pollutants, which may cause rash, nausea and headache, and may lead to an increased risk of heart diseases, respiratory illness such as asthma and emphysema, cancer, endocrine disruption, and damage of nervous system, reproductive and developing system [9]

References: [1] Halden, 2010; [2] Jupiter, Mangubhai, & Kingsford, 2014; [3] Kühn, Bravo Rebolledo, & van Franeker, 2015; [4] Lachmann et al., 2017; [5] Li et al., 2016; [6] Moy et al., 2017; [7] Sharma & Chatterjee, 2017; [8] Thompson, Moore, vom Saal, & Swan, 2009; [9] Verma, Vinoda, Papireddy, & Gowda, 2016; [10] Vethaak & Leslie, 2016; [11] Werner et al., 2016

Coping with the problem

Sources and pathways of marine litter are diverse and exact quantities and routes are not fully known (Löhr et al 2017). However, the amount of scientific data and practical knowledge on plastic wastes as a whole, and on plastic debris in the Pacific region in particular, means that a sound basis for action is available. Marine litter is a problem which can be avoided, provided proper policies are in place and are implemented to address it.

Overall, three main categories of measures are needed to address the problem:

1. Political action to restrict the use of conventional plastic
2. Economical sanctions to discourage the use of conventional plastic, coupled with incentives to use more bioplastic based materials;
3. More research on the generation and use of bioplastic

Table 2 outlines some of the measures which can be deployed to address the problem in the Pacific region, some of which may also be implemented elsewhere.

Table 2- Some measures to mitigate the problem of plastic debris in the Pacific region

Measure	Impacts
Impose a ban on plastic bags	Reduced waste generation and drive for more environmentally-friendly means to carry good (e.g. bags made of natural fibres)
Avoid plastic packaging when possible	Reduced plastic debris generation
More efficient waste management systems	Better collection and processing of plastic and prevention of plastic debris
Engage the tourism sector in using recyclable or re-usable materials (e.g plates, cutterly)	Reduced plastic debris generation in a substantial manner
Use education, outreach and regular clean-up campaigns	Foster the awareness and prevention of plastic use, and reduce the amonunts of plastic debris produced
Encourage the use of bio-plastic	Prevention of plastic debris generation due to the biodegradation of the materials

Source: authors

These measures, when combined, can make a real difference in providing a basis upon which the problem of plastic debris can be kept under control. The potential can be especially conspicuous in respect of restricting the production and use of throwaway plastic products (e.g. cotton buds, cutlery, plates, straws, drink stirrers, sticks for baloons), plastic bags, plastic packaging (including packaging of cosmetics), plastic toys, shipping, fishing, and aquaculture equipment.

Conclusions

Although substantial advances in dustry and in many sectors of society result from the use of plastics, there is an urgent need to balance the achievements of plastic materials, which are widely used through our daily activity, and the potentially hazardous exposures to human health. This study revealed that sustainable management of plastic debris is one of the major environmental issues in the Pacific Islands. Land and ocean-based plastic debris account for a substantial amount of the solid wastes found in the region and only minimial success has been achieved in attempts to manage the plastic waste problem. The persistence of plastics in the environment for up to a century (primarily macroplastics), transfer of pollutants and chemicals, exposure to microplastics due to fragmentation of macroplastic or as part of certain products, and burning of plastic waste, all negatively impact the Pacific Island's ecosystem.

However, profound knowledge to provide detailed information on the extent of effects of both macro- and microplastics remain limited, and designing robust studies remain challenging (Lachmann et al., 2017; The Lancet Planetary Health, 2017). Consequently, when monitoring at a public health level, pollution databases and environmental observations, including wildlife studies, prove useful to assess the complex health burden caused by the adverse effects of plastic debris from a One Health perspective (The Lancet Planetary Health, 2017). Therefore, with the growing plastic consumption worldwide and Pacific Island States disproportionately affected, further studies and integrated strategies are needed, involving public education and empowerment, governmental action, as well as ecologically sustainable industry leadership.

It is also clear that more research is needed in respect of developing alternatives to conventional plastic, by the production of bio-plastic, i.e. plastic which is produced from natural (e.g. non-fossil fuel-based sources) materials, and which can be fully biodegradable.

Finally, more substantial efforts are needed in the Pacific islands in respct of awareness-raising, so that public support to the prevention of plastic debris can be provided.

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