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# SYNTHETIC DEBRIS AS AN ANTHROPOGENIC IMPACT ON COASTAL ENVIRONMENT: A REVIEW

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## ABSTRACT

This review paper has been focused on 4 major areas as (1) Coastal debris accumulation sources and activities (2) Debris assessment and relavent quantities in different regions over the globe (3) Effect on coastal debris with respect to ecological and commercial aspects (4) Recommendations as mitigation measures. Coastal debris accumulation is one of major man-made growing problems along the coastal ecosystems, over the world, as revealed by the current review. Coastal debris load is varied with temporal and spatial changes in a specific location. Plastic is a major component of coastal debris composition emphasizing land and ocean based activities as the main debris accumulating sources in most of regional coasts. Micro-plastic ingestion which is a process with toxic impact, has a serious threat on both coastal Vertebrate and Invertebrates. Debris accumulation directly affect on immediate vicinity of the coastal area and subsequently coastal tourism sector. Site specific issues need to be considered when planning mangemnet actions for a selected regional coast.

**Key words**: Debris, Coastal Eco-system, Micro-plastic, Ecological impact, Economic effect, Debris management

## 1. INTRODUCTION

Coastal zone acts as the transition zone between land and sea (Pehlivankucuk, 2012), is a very significant ecosystem. Coastal environment is composed of attractive subsites with several kinds of natural resources including biological resources. On the other hand coastal region is significant for ecological and commercial (industrial, tourism and recreational) activities, therefore world most large cities locate with coastal zones. This results high competition among different sectors for its limited space in those coastal regions, in all over the world (Pehlivankucuk, 2012). It has been reported that globally large parts of coastal zones are polluted and degraded by anthropogenic activities via releasing contaminants by upland sources, wetland drainage, fishing activities, overexploitation and beach ruining by recreational activities in many countries (Post and Lundin, 1996).

Among all kind of pollutants, coastal debris plays a significant role in exerting considerable stress on natural coastal and marine environment (Nualphan, 2012). Coastal debris is also called as coastal litter. Coastal and marine debris is defined as ‘‘any kind of manufactured or processed solid waste material that comes in to the marine or coastal environment from any source’’ (Coe and Rogers, 1997). According to NOAA (2007), coastal debris can be any kind of discarded, abandoned or disposed manmade object which enter into the coastal environment. Eighty nine percent of coastal and marine debris is reported as plastic, or an estimated 46,000 pieces of plastic per square mile globally every year (Central database system and data standard for marine and coastal resources, 2013).

Coastal debris can be found in all the beaches, entering by number of sources and post entry disposal methods. Sources of debris can be activities from sea, shore, or inland actions (Thiel et al., 2013). Among above sources, most common sources of marine and coastal debris are from shoreline and recreational activities, oceanic sources, smoking based activities and waste dumping at sea (Ocean Conservancy, 2010). It has been revealed that coastal and marine debris are accumulated due to several kinds of manmade commercial activities including tourism, industries, aquaculture and fisheries (Nagelkerken et al., 2001; Fujieda and Sasaki, 2005; Oigman-Pszczol and Creed, 2007). Floating debris can deposit and concentrate on beaches by alteration of natural environment (Corcoran et al. 2009). Asian region is a hot spot of marine and coastal debris accumulation due to rapid development in economy, over-population, alteration in lifestyle, weakness of management systems and concerns to properly reduce debris level (Jang et al., 2014). Marine debris has been gained attention during last 25 years (Abu-Hilal and Al-Najjar, 2004).

Globally scientists are making effort by extending research and monitoring to provide qualitative and quantitative data on this environmental issue (Abu-Hilal and Al-Najjar, 2004).

## 2. COASTAL DEBRIS QUANTITIES IN DIFFERENT COASTS

Coastal and marine debris are assessed by different methods including ocean based boat surveys (Thiel et al, 2003; Shiomoto and Kameda 2005), beach surveys (Corcorn et al., 2009) and aerial surveys (Pichel et al., 2007). Debris related studies have conducted in different parts of the world including Korea, Japan, California, Chile, England, India, Taiwan and Vietnam. Lee et al., (2006) have conducted assessment of marine litter on the sea bed of East China Sea and South sea of Korea using bottom trawl nets during 1996 - 2005 periods. They have reported that higher mean distribution of debris density was 109.8 kg $km^{-2}$ in South Sea of Korea, while East China Sea has 30.6 $kg/km^2$ of debris density. Also there are records of 70%, 57% and 41% of debris by benthic trawls in the Eastern Mediterranean Sea, the Gulf of Alaska and the Bering Sea, respectively (Jewett, 1976; Feder et al., 1978; Galil et al., 1995). They have pointed out that boat based studies can create too many inaccurate results due to variation of ship speed and wind. Also they have suggested that boat oriented studies are too expensive and depend upon clear visibility. Scott (1972) was first scientists for beach survey methods and he has revealed that most of plastic debris is deposited along shore area through ocean currents. Beach surveys, particularly on remote beaches, have been used as indicators of the amount of fragmented plastic in the marine environment (McDermid and McMullen, 2004). Hong et al (2014) have assessed the levels of beach debris in total 20 sites in Korea using 100 m long survey line. According to their findings, combination of Plastic and Styrofoam were major debris in composition with 66.7% of number and 62.3% volume respectively, while main sources of debris have become commercial fishing activities and aquaculture. Abu-Hilal and Al-Najjar (2004) has conducted litter assessment study on Jordanian shores during 1994-1995. Their findings indicated that debris has composed of plastic, wood, glass, cardboard, Styrofoam, metal, while main local sources of debris have become passenger port, cargo port and beach recreational activities. There are some of records that coastal and marine debris concentrating on beaches were variable in a spatial and temporal manner (Rees and Pond, 1995; Oigan - Pszczol and Creed, 2007). Rosevelt et al (2013) have studied types, abundance, distribution pattern to support coastal managers using 50m wide belt transect method with 4 $m^2$ quadrats and mixed model approach in 12 survey sites of Monetary Bay, California. According to them, both season and location have highest impact on debris abundance. Also they have revealed, Styrofoam as the most abundant debris type, while there were fertilizer pellets as unexpected items. Study of Kuo and Huang (2014) have recorded debris is highest on rocky shore region than sandy beaches and fishing ports in Northern Taiwan without significant difference of debris according to season and tide. Further they have found out plastics as most dominant debris, while most of debris is originated from recreational activities followed by oceanic activities. Study of Thiel et al., (2014) in northern-central Chile has conducted comparative debris assessment study for 2 different coastal environments (sandy beaches and coastal waters) using 12 seasonal ship surveys and beach surveys during 2002-2005. Their results have suggested that plastics and Styrofoam as most common debris categories in both coastal waters and shore, while there is a slight difference of debris between these 2 regions due to different environmental factors. Jang et al., (2014) indicated that selected beaches in Vietnam and Taiwan have highly polluted by debris accumulation along the beaches. Sadri et al., (2014) have found out floating plastic debris level and composition in Tamar estuary, Southwest England and has shown significant differences in size frequency distribution of debris between spring and neap tides. According to their study, highest number of fragments with macro size has been recorded during spring tide regime. Cunningham and Wilson (2003) have suggested a standard sampling protocol as covering wide region for sample collection for more accurate, reliable results for beach debris analysis study. They have sampled using 250 $m^2$ series of wide belt transects as covering all strata of coastal zones in surveyed beaches-Greater Sydney, Australia. As they reveled, most abundant debris has become hard plastic (52.3 %) among all kind of debris and have originated by storm water or recreational activities in beaches. Further results have emphasized the necessity for immediate attention to overcome the issue in beaches of Greater Sydney. Whiting (1998) has introduced likelihood method as acceptable accurate method to identify sources of debris. Results revealed that commercial fishing, merchant shipping and recreational boaters have contributed for more than 85 % of all debris in Fog Bay, Northern Australia. Further debris composition has varied between beach orientation in the same year and within beach orientation between years. ICC protocol (2006) has recommended quick and reliable data card system to identify, enumerate and collect data for further analysis. Globally top 10 debris identified by this protocol are; cigarettes, cigarette filters/caps, lids/ food wrappers, containers/bags (paper and plastic)/ cups, plates, forks, knives, spoons/ beverage bottles (plastic)/ beverage bottles (glass)/ beverage cans/ straws, stirrers and rope. According to ICC programme, it has been recorded facilitating guidelines for ongoing marine debris public awareness and prevention program, with providing and extending the network of volunteer coordinators in the United States and around the world to manage the coastal and marine debris issue. According to the United Nations Environmental Program (2011), coastal and marine debris causes vast and growing threat to both coastal and marine environment. Different socio-economical and ecological impacts on coastal and marine debris have been identified by several researchers and scientists.

## 3. IMPACTS of COASTAL DEBRIS

### 3.1 Socio-Economic Impacts of Coastal Debris

Marine and coastal debris cause negative socio-economic impacts by causing significant economic losses to commercial industries such as commercial fishing, shipping, as well as recreation and tourism (CED technical series No.67, 2012). It has been reported that coastal debris creates a severe problem in tourism centers in coastal regions, particularly in recreational beaches, since it reduces the aesthetic beauty and cleanliness of coastal amenities. Hence it is resulting a decreasing number of tourists and influence on local economic system (Ping, 2011, Central database system and data standard for marine and coastal resources, Thailand, 2013). Balance et al (2000) have found out that accumulation of debris can discourage visiting tourists to polluted sites. Coastal and marine debris also can cause health and safety hazards to coastal residents and tourists. Human injuries, particularly foot laceration can result from beach debris such as broken glasses and plastic (Dixon and Dixon, 1981). Also coastal and marine debris is transported from one place to another via wind and ocean currents. That is considered as a trans-boundary problem for countries which may be far from the point sources of the debris (CED technical series No.67, 2012). Also coastal and marine debris in coastal regions can significantly affect on coastal fishery, by causing damage to fishing gears through entanglement the floating and semi-submerged fragments like nylon ropes and nets in motors and fishing gears such as gill nets, trawling nets (Rosevelt, 2011). Further, ships and tourism boats can be damaged via fouling, striking and collision by metal drums or wooden pallets in the sea (Abu-Hilal, and Al-Najjar, 2004). On the other hand, there are records of blocking water pipes by plastic sheets and disturbance to water supply. Also Debris can cause sanitary problems and health hazards to tourists and coastal residents (Abu-Hilal and Al-Najjar, 2004). Also Brink et al (2009) has pointed out introduction of alien species by debris can affect on economic activities negatively by loss of ecosystem functions. Previous reviews indicated that there can be additional coastal cleaning cost to government and coastal communities to clean up beaches and that is difficult to bear developing countries.

## 3.2 Ecological Impacts of Coastal Debris

On the other hand, coastal debris has an impact on coastal biodiversity in a number of ways: Ingestion and entanglement, Provision of new habitat, Dispersal via rafting, including transport of invasive species and ccosystem level effects (CED technical series No.67, 2012). Entanglement and ingestion of coastal and marine debris of aquatic organisms can be lethal or sub-lethal. According to previous literatures, all known species of sea turtles, about half of all species of marine mammals, marine/coastal invertebrates and one-fifth of all species of sea birds have been affected by entanglement or ingestion of coastal and marine debris (Laist, 1997). Mainly marine vertebrates such as turtles, sea birds, otters, cetaceans and pinnipeds are affected by entanglement in nets and strapping of debris (Merrell, 1984; Wehle & Coleman, 1983; Beneditto and Ramos, 2014). Goldstein et al. (1999) have recorded the incidents of entanglements of young sea lions in abandoned fishing gear, packing straps, plastic bags, rope and rubber rings.

Sub-lethal impacts include difficulty to capture and digest food particles, inability to escape from predators, slower rate of reproduction and decreased body condition, lack of locomotion, including migration, toxicity via ingestion of harmful particles, particularly of micro-plastics (Laist, 1997).

Among different kind of debris, plastic pollution has a wide range of negative impacts on coastal and marine wildlife (Provencher et al., 2014). Plastic debris are exposed into different forces (UV radiation and wave action), when those are in coastal and marine environment (Andrady, 2011; Barnes et al., 2009, Cauwenberghe, 2015). Consequently those particles degrade into smaller fragments known as micro-plastics similar to planktons and suspended materials in size and appearance (Cauwenberghe, 2015). Low density plastic debris floats in coastal water, while high density debris sinks and accumulate with sediment. Then both vertebrates and invertebrates with different feeding strategies (filter feeders, deposit feeders and detritivores) trap and ingest these synthetic debris (Pierrepont et al., 2005, Thompson et al., 2004). Ingested plastic debris is possible in inducing adverse effects on coastal organisms such as inflammatory response. There is a potential of plastic compounds to attract micro-pollutants and trace metals, then they gradually cause toxicological impacts (Teuten et al., 2009). According to Pierrepont et al., (2005) minke whale: *Balaenoptera acutorostrata*, has ingested 720 g of plastic bags and death of whale species has recorded due to the occlusion of the stomach through ingesting plastic objects with impaired immunity (Pierrepont et al. 2005). Provencher et al., (2014) have found out the impacts on two surface plungers (great shearwaters *Puffinus gravis*; northern fulmars *Fulmarus glacialis*) with highest prevalence of ingested plastic (71% and 51%, respectively), while Great shearwaters also had the highest number of plastics pieces in their stomachs, with some individuals containing as many of 36 items. McCauly and Bjorndal (1999) have detected that ingestion of debris by sea turtles, with decreased growth rate, depleted energy reserves in their body, reduced reproduction rate and decreased survival rate as the negative impacts.

There are severe impacts on invertebrates by micro-plastic ingestion. Graham and Thompson (2009) have demonstrated the possibility to ingest micro-plastic fragments by coastal sessile invertebrates with different feeding strategies using a laboratory experiment. Further their findings have found out that deposit feeding and suspension feeding sea slugs prefer to feed nylon and PVC fragments compared to natural food parts. There are different records on uptake of micro-plastics by coastal and marine biota in different taxa (Table 1). Oehlmann et al., (2009) and Teuten et al., (2009) found out that chemical substances in ingested plastics have toxicological impact on mollusks. Kohler (2010) has reported a pronounced immune response and granuloma formation in the digestive glands of blue mussels after exposing to micro-plastics. Research findings of Cauwenberghe (2015) has shown that micro-plastic level of *M. edulis* and *A. marina* are 0.2 ± 0.3 particles/g and 1.2 ± 2.8 particles/g respectively, when tissue samples were subjected to digestion by standard method of Claessens et al. (2013). Also Browne et al., (2008) have demonstrated the ingestion of polystyrene microspheres by *Mytilus edulis* using fluorescence microscopy detection technique. Further they have found out 2 and 4 µm size micro-plastics particles ingestion by *M. edulis* through the inhalant siphon, which the gill filtered out and transported to the labial palps for digestion or rejection. Also translocation of the ingested particles have been confirmed by the identification of 3 and 9.6 µm fluorescently tagged microspheres in the mussels' haemolymph (circulatory fluid), 3 days after exposure.

Further their findings revealed that barnacles contain micro-plastics with 20-2000 µm size ranges. Von Moos et al., (2012) have pointed out smaller plastic fragments with (>0-80 µm) size range can accumulate in epithelial tissue of digestive tubules of invertebrates and cause strong inflammatory infections. Also Cauwenberghe and Janssen (2014) have conducted a study to find out micro-plastic concentration in tissue samples of *Mytilus edulis* and *Crassostrea gigas* using a microscopic visualization, in the Atlantic Ocean. Their results revealed the presence of average 0.36 ± 0.07 particles/g (wet weight) in *M. edulis*, while 0.47 ± 0.16 particles/g ww was in *C. gigas* with food safety threats. Goldstein and Goodwin (2013) have assessed the micro-plastic accumulation rate of Gooseneck barnacles (*Lepas* spp.) in their gastrointestinal tract in the North Pacific Subtropical Gyre. Results revealed that plastic level in gut of barnacles was ranging from minimum one plastic particle to a maximum of 30 particles and 33.5 % barnacles had contained plastics in their gut after dissection of their stomach and intestinal tract. Further, it was recorded that particle ingestion was positively correlated to capitulum length of barnacles. Micro-plastic concentrations have been analyzed for 5 marine invertebrate species collected from different sites at Dutch coast {Oosterschelde Neeltje Jan outside (OS); Rhine Estuary (RE), Ter Heide North Sea coast (TNS)} using a standard operating procedure by Leslie et al. (2013). They have recorded 20, 11, 87, 105, 30 and 19 total plastic particles/g d.w. for Periwinkle (OS), Amphipod (OS), Pacific oyster (OS), Blue mussel (OS), Pacific Oyster (RE) and Blue mussel (TNS) with 1-5000 µm size ranges of particle size. Also researchers emphasized that importance of food chain transfer studies to investigate whether secondary poisoning is taking place, after confirmation of new environmental contaminants in this selected biota.

Moreover, marine debris sometimes can provide new habitat and has the potential impact on the relative abundance and diversity of organisms within coastal habitat. In such locations, even though there is an increasing of overall biodiversity, but also there may be potential effects on the ecosystem equilibrium of species within the native assemblage (Pace et al., 2007). It has been revealed that both mobile and sessile species including Bivalves, Bryozoans, Cephalopods, Cnidarians, Crustaceans, Echinoderms, Fish, Gastropods, Pelagic insects, Polycheates, Poriferans, Seagrass and Algae use marine and coastal debris as their new habitat (Pace et al., 2007).

Another ecological impact is the distribution of coastal and marine communities, including dispersal of invasive species through rafting. Thus it changes the balance of native ecosystem, by alteration of species richness, abundance and diversity. Taxonomic groups that may be highly susceptible for dispersal via rafting are Cnidarians, Worms, Crustaceans, Molluscs, Bryozoans, Sea grass and Algae and it results on alteration of whole structure and function of natural ecosystems such as coral reefs, sandy beaches by marine and coastal debris (CED technical series No.67, 2012). Debris fragments including micro-plastics can alter the porosity of the sediment and its heat transfer capacity in beaches (Carson et al., 2011). According to the previous research findings, there is a high risk for the intertidal sessile coastal communities compared to mobile organisms, by debris fragments, since these organisms have not or limited locomotion ability (Chiappone et al., 2002, 2005). There are records on potential in tissue abrasion, damage, and/or mortality of sessile invertebrates by coastal debris in coastal region of Florida (Chiappone et al., 2002). Debris can also have an impact on the foraging habits of intertidal organisms such as the gastropod: *Nassarius pullus*, whose foraging efficiency was found to be negatively interrelated with the amount of plastic debris fragments (Aloy et al., 2011). Coastal debris consequently affects on coastal ecosystem service and hence there is a negative impact on ecological and then economical value of coastal regions.

Brink et al., (2009) have found out the negative impacts on coastal and marine habitat by accumulation of debris. Further their findings have been recorded that intertidal floral and faunal communities are suffocated due to habitat destruction and reducing ecosystem health by overaccumulation of coastal debris. Also coastal debris serves as transporting path for non native sessile organisms such as tunicates, diatoms (Barnes and Milner, 2005). Introduction of non-native species can disturb the ecosystem equilibrium in a specific area and potentially threaten the native species (Brink et al, 2009).

Table 1: Micro-plastic uptake by different coastal and marine taxa

| Species | Micro-plastic (µm) | Identification method | Literature record |
|---|---|---|---|
| Copepods (*Acaria tonsa*) | 7 -70 | Microscopy | Wilson (1973) |
| Echinoderm larvae | 10 - 20 | Video observation | Hart (1991) |
| Trochophore larvae (*Galeolaria caespitosa*) | 3 -10 | Microscopy | Bolton and Havenhand 1998) |
| Scallop (*Placopecten magellanicus*) | 16 - 18 | Detection of $Cr^{51}$ particles | Brillant and McDonald (2002) |
| Amphipod *Orchestia gammarellus*), Lungworm (*Arenicola marina*) & Barnacle (*Semibalanus balanoides*) | 20 - 2000 | Dissection & wormcast examination | Thompson et al. (2008) |

## 4. CONCLUSION and RECOMMENDATIONS

Current review has identified coastal debris as a growing threat along coastal ecosystems of different regions over the world. Coastal debris is a function of both spatial and temporal variability combined with environmental factors. Coastal debris accumulation causes negative impact on commercial and ecological activities along the coastal region. This review of literature is recommended to establish site specific management actions to overcome coastal debris issue with short term and long term action plans.

Interanational, regional and national level solutions need to be implemented for local land based and ocean based litter accumulation sources, as those sources are highly responsible in debris load along regional coasts. As a result of growing attention of the debris problem, different international and regional conventions, regional agreements, effective policies, cleaning programs and long term, short term action plans (e.g.: MARPOL, 1973, 1978, Oslo convention, 1972, Jeddah Convention, 1982) are already adopted currently (Abu - Hilal and Al-Najjar, 2004). All responsible stakeholders need to cooperate with each other to collect, reduce, and manage coastal debris load on the regioanal beaches, in appropriate ways such as enhancing efficiency of waste collection, providing and raising awareness and knowledge of appropriate waste management of target group (munacipilaty, tourists and fishers') (Central database system and data standard for marine and coastal resources, 2013). Pollution control activities are suggested with 5 main principal concepts (1) Participatory approach with awareness and education (2) Research and scientific knowledge (3) Recycling and Reuse (4) Reducing (5) Removal

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