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Plastic Pollution in the Mediterranean and Public-Private Partnerships to Manage It - A Case Study in Lebanon

Michel Soto Chalhoub

Abstract

Hazards of plastic pollution in the oceans threaten human, animal, and vegetation life. Sources of plastic pollutants include marine transport activity, shore-to-shore movement by waves and currents, and waste transported from land to sea by rivers. Industries in several countries in the Mediterranean region, which generate waste dispose it in rivers or into municipal networks. They justify their activities as drivers of local economies, while a closer look shows the opposite. A case study is presented about Lebanon, a country on the Mediterranean easternmost boundary serving as a maritime transit gate to the rest of the Middle East. Private sector companies could play a major role in curbing plastic pollution through innovation to migrate toward green products and substitutes to plastics. Both remedial and preventive strategies in the private sector would be better realized through support from public sector entities. Therefore, public-private partnerships are recommended to alleviate current pressures exerted on local communities willing to fight plastic pollution and help them operate within known and supported norms. As such, we recommend incentive-based public policies.

Keywords: plastic pollution, ocean life, river load, public-private partnership, incentive-based policies

1. Introduction

Plastic litter transport in the oceans is a complex phenomenon. In particular, the accumulation of floating debris is a serious problem in the Mediterranean whose hydrodynamics comprise an inflow of surface water from the Atlantic. Several researchers argue that plastic litter is owed in large quantities to traveling vessels [1, 2]. It was argued that about 90% of consumer goods worldwide are moved through an international fleet of cargo ships and most of these goods are contained or wrapped in plastic. Hundreds of containers tip over in rough seas every year and eventually sink and break open, releasing their contents in the ocean. There are several cases of tipped containers that were abandoned on the seafloor. Off the coast of Monterrey Bay, California, over twenty-four containers were lost in a February 2004 storm, one of which is still resting on the seafloor at a depth of about 1500 meters [3].

Figure 1.

Drifter starting and ending points in total; starting and ending points in summer and winter. Source: Zambianchi et al. [5].

Significant plastic loads originate from the shore from various sources such as solid waste dumps, trash conveyed from dry land to shore through rivers, and ocean currents carrying plastic debris from shore to shore. There have been several documentaries by environmental activists showing that rivers are a significant source of solid waste, in particular plastic, that make it into the marine environment [4]. There is no evidence yet that the Mediterranean contains a permanent trash island, but there are signs of litter accumulation. Possible retention areas can be identified by analyzing historical data to compute the probability of debris particles circulating into subbasins. The prediction of the location of floating trash islands becomes feasible once accumulation rates are quantified. Climatological reconstructions were performed using empirical data to study the evolution of litter concentration. Floating litter has a general tendency to concentrate in the southern portion of the Mediterranean [5]. A long-term accumulation of litter seems to be forming in the southern and southeastern Levantine basin.

Based on data collected and processed by Zambianchi et al., note how the near-surface drifters were used to track currents starting from a dispersed status (red dots) and ending along coasts on the East Mediterranean including Lebanon and North African countries [5]. Besides the Adriatic Sea portion, and focusing on the Mediterranean, a large percentage of the ending-points concentrate on the East Mediterranean coast, including Lebanon for both summer and winter seasons (**Figure 1**). As such, the author recommends that special attention be placed on the Levantine area to estimate existing, and forecast potential, plastic debris accumulation.

2. Rivers and challenges related to Land-To-Ocean data

Several sources of secondary data in the literature provide quantitative estimates about plastic pollution at large. In Europe and the United States, significant progress was made in data collection and availability in relation to weight, volume, and movement of plastics from their original points on dry land to the oceans. However, such data is not as available or reliable in Lebanon and several countries around the Mediterranean. In subsequent parts of this chapter, it is recommended that

fieldwork, surveys, and quantification techniques be developed over the next few years to build a database in support of decision-making and policy design.

It is estimated from various studies that about 8 million metric tons of plastic waste per year travels to oceans worldwide and this figure is expected to increase. Studies in the U.S. and Australia present computational models that analyze data from 192 countries with coastlines. Starting from a total amount of solid waste generated as household refuse per capita, an assumption is made about its percentage of plastics. Another assumption is made about the proportion that will reach the oceans to estimate these amounts over the next decade on the basis of census data and population growth [6].

Results from different sources show corroboration that marine plastic debris, which originates inland and travel the most through rivers. A simplified infographic in **Figure 2** shows residential, commercial, and industrial conglomerates mismanaging plastic waste and discarding it in rivers, which in turn carry it to the oceans, terming the process as “plastic load.” A study of 57 rivers investigated the concentration of plastic bags, bottles, fibers, and beads, and used the river flow to compute the total weight of plastic transported by the river to the ocean. Plastic litter per day per person was computed for each river and compared with littering onshore. Rivers were proven to be substantial conveyors of plastic debris into the marine environment. Schmidt et al., compiled global data on plastics in the water in rivers of a wide range of flows, including macroplastics (particles >5 mm) and microplastics (particles <5 mm). They identified mismanaged plastic waste (MMPW) discharged over river catchments basins, transported along the main river artery and into the sea [7]. They concluded that the mathematical relationship is not linear. Major rivers surrounded by densely populated areas generate a higher fraction of MMPW. Further, they concluded that 88–95% of the global plastic river load is conveyed through the ten top-ranked rivers, with an estimated range between 410 tons and 4 million tons per year [7]. This large disparity is owed to uncertainty in data. In fact, such a model requires additional parameters related to seasonality, climate change, hydrological factors, and local or regional precipitation [8]. There has been a misconception related to river loads in the articles attributed to ten rivers that these

Figure 2. Rivers exert “plastic loads” from common use and mismanaged plastic waste that make their way to the oceans Schmidt et al. [7].

ten rivers take 90% of total plastic pollution in the oceans. It should be clarified that the 90% estimate of the top ten river load is a percentage of total river load and not total ocean pollution.

3. River plastic load: a global problem and a Mediterranean concern

Most studies on river plastic loads address the largest ones across continents, while little attention was given to smaller rivers in countries around the Mediterranean. Nevertheless, it is useful to provide some context by comparing the Nile, which is the largest river with an estuary on the Mediterranean, with other major rivers worldwide. The top 10 rivers worldwide that were listed among polluters include the Nile and Niger, both of which are African rivers, and the others are Asian rivers. Note that the Yangtze alone was estimated to carry about 2.75 tons of plastic yearly into the sea [9]. Alarming documentaries have been shared on social media showing the Yangtze, among other rivers exhibiting the same problem, covered in opaque blotches of plastic waste (**Figure 3**).

The Nile River flows over 6600 kilometers and runs through (or along the border of) South Sudan, Sudan, Ethiopia, Uganda, Kenya, Congo, Rwanda, Tanzania, Burundi, and Egypt into the Mediterranean Sea making it the longest river in the world. The river has been critical in the development of ancient Egypt as it provided for irrigation, transportation, and fishing among other features. In recent years, over 90% of the Egyptian population lives only within a few kilometers of the Nile riverbanks using ferries, water taxis, and private boats for commute, leisure, or tourism. Today, the Nile is ranked among the top ten polluting rivers (**Figure 4**).

Research in the literature shows that the Mediterranean Sea suffers from high concentrations of floating plastic. This is an indicator that a trend is developing akin to the accumulation zones in the five subtropical ocean gyres. According to a study in the year 2015, an average density of plastic was found to be about 1 item per 4 m^2 . It also showed that the frequency of occurrence is 100%, in the sense that all sampled sites showed an occurrence (presence) of plastic debris in the water. Plastic items found were in the range of millimeters. Large plastic items were also found to be in higher proportions than those documented in the oceanic gyres [10]. Most likely, this is due to the fact that sources of pollution around the Mediterranean are closer. Floating plastic in the Mediterranean Sea was estimated to be between

Figure 3.
The Yangtze River with workers collecting floating garbage (source: www.news.cn, 2019).

Figure 4.
Top 10 river polluters, among them the Nile flowing into the Mediterranean. Source: “Export of Plastic Debris by Rivers into the Sea,” by Christian Schmidt et al. [7] (Artwork credit Amanda Montanez 2018).

1000 and 3000 tons. Schmidt et al. found the Nile to be the fifth river among the top ten polluting rivers worldwide [7]. **Figure 4** shows the contributions of the top ten polluting rivers with the estimated quantities of plastic transport in hundred thousands of metric tons. Ten countries sharing the benefits of the Nile bordering or running through them have a moral obligation toward each other to curb plastic waste at the source. They also have an obligation toward countries around the Mediterranean that are recipients, as well as contributors, of plastic waste on their shores. Therefore, the problem requires collaboration at a regional level.

4. Environmental and social challenges - case of Lebanon

4.1 Challenges pertaining to river loads

In terms of solid and plastic waste, the case of Lebanon carries even more uncertainty due to challenges in data availability, collection, analysis, and estimation. Lebanese rivers convey large amounts of solid waste and plastic debris into the Mediterranean, but disproportionately large amounts are due to direct dumps of solid waste and landfills on its coast. Landfills along the Lebanese shore are the source of sea pollution in the direct vicinity of the beaches. This makes the estimation of river plastic load even more complicated to relate to the river’s water discharge rate. A previous estimate by the author used a model that combined population density around major Lebanese rivers, industrial activity, and average yearly discharge. The estimation model at the time focused on percentages rather than absolute numerical values with the objective of directing efforts for awareness and advocacy within the context of general solid waste inclusive of, but not limited to, plastics [8].

It would be necessary to pursue these estimates by collecting primary data from landfills, rivers, and direct dumps to update a geographic mapping focused on plastics transported through rivers into the sea. If we consider river flows exclusively, then we would find that Nahr el Kabir, Ostuene, Araqa, El Bared, Abou Ali, and

Al Jaouz would constitute about 24% of total Lebanese river discharge. Nahr Ibrahim would constitute about 13% and Nahr el Kalb 6% of total Lebanese river discharge. However, the presence of landfills and industrial activity yield different numerical values. For example, even though Nahr Beirut contributes about 3% of Lebanese river discharge, the presence of landfills, population density, and industrial activity tripled the percentage in that particular zone yielding 10% and 11% between Narh el Kalb and Nahr Beirut (**Figure 5**).

The question remains: Is solid waste at large a good indicator or proxy for plastic waste? By most standards, the proxy between the two indicators is close enough to proceed with a subsequent phase of primary data collection, documentation, analysis, and awareness building.

4.2 Challenges related to MSW and demographics

Several studies were performed about solid waste in Lebanon but there is a need to develop detailed observations and recommendations specific to plastics. According to a Country Report on Solid Waste Management in Lebanon, 1.57 million tons of municipal solid waste (MSW) was generated in Lebanon in 2009 [11]. Knowing the challenge of reaching an accurate census with the refugee situation in Lebanon, and using a simplified estimated population, the average waste generation per day per capita is estimated at 1.1 kg/day/capita in urban areas and 0.7 kg/day/capita in rural areas, with about 50% of the waste being organic. Nevertheless, plastics constitute 13% while paper, pulp products, and cardboard constitute 17%. It is expected that, in absence of focused public policies, waste generation will continue to rise annually by 1.65% [11]. The same study in 2010 reports that 30% of MSW is dumped in the

Figure 5. Percentage estimates of solid waste distribution along the Lebanese coast. (Source: Chalhoub [8]).

open, 53% is land-filled, while only 9% is composted and 8% recycled. In Lebanon, the largest landfill is in Naameh, south of Beirut, which was closed following a public uproar [12]. Beirut generates the highest proportions of MSW in the country due to the fact that about 50% of the population lives in the capital and its direct suburbs, in addition to being a tourist attraction with a concentration of hotels and restaurants.

The Syrian refugee crisis affected demographics in Lebanon. By May 2014, Lebanon received over 35% of the region's Syrian refugees with an estimate of an additional 1000 tons/day of solid waste. Under such considerations, there are projections that by 2025, MSW would surpass 2.4 million tons [11, 13]. Studies showed that 37% of MSW in Lebanon could be recycled or reused, except for organic waste which can be composted into other products such as fertilizers [14]. Since there has not been a clear national strategy for solid waste management, MSW remains a critical problem with several environmental, economic, and public health impacts. Even though MSW in large Lebanese cities such as Tripoli, Beirut, Zahle, and Sidon is collected through private companies, the Lebanese end-user should adopt a preventive approach by reducing waste generation including plastics, and by looking for alternatives [8].

4.3 Challenges related to the private sector

Lebanese plastic companies serve local buyers but have well-established export markets. In 2014, Lebanon imported raw materials for the manufacturing of plastic semifinished and finished products in the value of \$695 Mn, while it exported a total value of \$131 Mn in raw materials and finished products [15]. Among the top seven Lebanese plastics manufacturers, there are those who produce food packaging, followed by containers, bottles, then piping products, furniture, agricultural materials, hospital consumables, bags, and other industrial materials. While only 10% of discarded plastics are recycled, the remaining quantities go to landfills and the sea. Three sectors, shipping, fishing, and tourism are briefly addressed to illustrate their socio-economic impact and highlight the role that they could fulfill in curbing marine plastic pollution.

4.3.1 Shipping

Historically, Lebanon is known for its shipping and transit activities. Despite the civil war in the 1970s and the current economic meltdown, maritime transport still plays an important role in the Lebanese economy. There are dozens of small ports all along Lebanon's coast used for limited activities and primarily fishing, in addition to twelve marine centers for leisure. But the main commercial ports in Lebanon where the bulk of maritime activities reside are located in Beirut, Tripoli, and Saida [16, 17].

Stretched on a 1.18 km² plot at the foothill of Ashrafieh, the Port of Beirut constitutes the main port of trade in Lebanon transiting products to Iraq, Jordan, the Gulf States, Syria, among other countries. The recent August 4, 2020 explosion crippled its activities but despite the extensive damage that it has endured, it started to limp back into a running operation in the following few months [18]. The port of Tripoli is ranked as the second commercial port in Lebanon. It covers a larger plot of about 2.9 km², but it is still less technically developed than the one in Beirut.

Secondary data indicates that, over the time span between 2014 and 2018, Tripoli docked between 500 and 870 ships per year while Beirut docked between 1600 and 2000 ships. Over the same time period, Beirut Port processed an average of 8 million tons of merchandise per year tonnage while Tripoli processed between

1.3 and 1.9 tons. As for Sidon Port (Saida), it is of a different character; more of a celebrated historic site, of lesser commercial stature, used mainly for small boats and about 190 ships per year [18]. Shipping is both a contributor to plastic pollution as well as a sector that suffers from plastics at docking facilities and potential hindrance at sea.

4.3.2 Fishing

Fishing in Lebanon has primarily three segments; sea fishing, fish farms, and imports. We focus on sea fishing as it is the one relevant to plastic pollution in Lebanese waters and on its shores. Lebanese fishing activities are considered as small businesses consisting of a single person each, with a crew of two or three helpers, hence closer to artisanal than industrial. With Mediterranean waters housing off the coast of Lebanon over 1700 marine fauna species, with over 82 fish species sold on the local market. Commonly used tools include small mesh nets used to fish near the seafloor. “Ghost fishing” is a term used to indicate lost nets. These nets are made of plastic wire mesh and cause various sorts of hindrance and death of untargeted marine organisms. Most fishing is performed at depths between 40 m and 65 m, and about 92% of fishermen operate at about a nine-kilometer radius from their base harbors. Ghost fishing is one of the concerns related to plastic pollution in marine waters.

The Ministry of Agriculture comprises a Fisheries and Wildlife Department that publishes data sporadically. There has been an increase in sea fishing activity between 1995 and 2005. In 1994, small-operation fishermen totaled about 4100 with a fleet of approximately 2050, while in 2005, the number was between 4500 and 9600 commensurate with the active seasons most of whom were Lebanese (89%).

Fishermen are considered among the poor population segment because their annual income is less than the minimum wage annual income population. Secondary data indicates that the annual average range between \$800 and \$2100 while the minimum wage corresponded (in 1999) to \$5400 per year [18, 19]. Research by Kanbar shows a distinctive difference in income between those who own their boats, averaging \$7400 per year, and those who lease or are loosely employed by boat owners, averaging \$3000 [17]. Fishing contributes to plastic pollution and simultaneously suffers from plastic litter, which reduces productivity, fish reproduction (quantity), and fish quality. Further, fishing boats are also hindered at sea.

4.3.3 Tourism

Lebanon has always depended on tourism in its economy. There are various dimensions through which tourism contributes to economic growth. Earnings from tourism provide foreign currencies, which in turn support imports. Further, destination marketing enhances healthy competition among local service providers and hospitality establishments [20–22]. Another indirect effect of tourism is that it creates demand for skilled human resources and new infrastructure, which requires investment. Tourism increases demand for products and services in construction, manufacturing, transportation and rental vehicles, and financial services such as insurance and banking [23, 24].

Tourism in Lebanon showed an overall upward trend between 1961 and 2011. Between 1996 and 2010, arrivals of tourists in Lebanon increased by a factor of 2.5. The tourism sector is sensitive to security and political developments, which explains fluctuations including a drop down from 7.8 million arrivals in 2004 to 5.9 million in 2005. In 2011, when the civil war broke out in Syria, Lebanon saw another drop in total arrivals from 9 million in early 2011 to 5.8 in 2016 [25].

In 2018, the total contribution of tourism and travel to Lebanon's GDP was 19%, down from 27% in 2010 and 18% in 2017 [26]. That was the result of several events including travel bans, the refugee situation, regional and internal political tensions, and most of all local mismanagement in the public sector. Most of the inbound tourists are Lebanese living overseas or Arabs, with the percentage of Arab tourists decreasing from 59% in 2013 to around 41% in 2018. The tourism sector is affected by solid waste crises, among others, as was seen in the last two decades [18, 26, 27].

Tourism contributes directly and indirectly to job creation. Despite the drop in arrivals, there were about 395 thousand jobs in 2018, up from 365 thousand in 2017, while overall, the percentage of total employment decreased to 18% in 2017, down from 24% in 2010 [26]. Besides hotel services, travel agents, leisure, and such jobs are directly related to tourism, there are indirect jobs such as cleaning, food and beverage, suppliers to companies providing hospitality services, local tours activities, and the like. Therefore, the percentage affected by the tourism sector would be in the range of 33%, which is significant.

Plastic pollution in rivers, on the beaches, and in the streets have a drastic effect on touristic, hence economic activity. For instance, in 2017, hotels officially registered in the Syndicate of Hotel Owners reached 408 with a total of 21,804 rooms most of which are located on the coast. Secondary data from 2008 indicate that 68 beach resorts occupy 7.5% of the coastal square footage. By 2017, their number increased to 200, of which 65% are located between Byblos and Beirut, over a 38-kilometer distance along the Mediterranean coast [28]. Therefore, the way solid and plastic waste are managed by those resorts has a large impact on marine pollution.

The rush in the mushrooming of beach resorts caused an overdevelopment on the shore including several environmental breaches bypassing environmental impact assessments and permitting processes. This phenomenon has a double effect; excessive waste generation as well an effect on environmental quality. While plastic pollution has an obviously negative visual effect for tourists, microplastics have a health effect as it is transmitted to humans from fish and seafood. A study by the author on tourism entities operating on the coast between Adonis City and Tabarja shows that those establishments generate six-fold the waste in summer compared to winter. Tourism contributes to plastic waste but it is also negatively impacted by plastic pollution which spoils the beauty of the shores, the attractiveness of leisure sea trips, and increases risks of digestive diseases in hospitality establishments due to microplastics in fish and seafood.

The above sections show that the economic impacts of marine plastic pollution on shipping, fishing, and tourism are disconcerting. Cleanup costs, losses in fishing, ghost fishing, boat damage, economic losses in tourism, and ship hindrance are all effects that require prevention of plastic litter rather than remediation. There should be a joint effort between the private and public sectors to collect reliable data, on a continuous basis, and categorize plastic waste by description (type) and quantities. Such data would help develop a more accurate evaluation of how marine litter impacts these three areas in the private sector. Additionally, the more challenging quantification pertains to marine ecosystems and the reduction in marine life reproduction and mobility.

5. Public-private partnership - a roadmap and recommendations

We continue our illustration with the case of Lebanon as it represents a less developed country, located on the Mediterranean, subject to plastic pollution, and faced with public policies and management challenges. Local authorities such as

municipalities at a town or city level have been traditionally entrusted with solid waste collection and disposal. In recent decades, nongovernmental organizations intervened and started to provide services, some funded by international agencies and some based on volunteerism. Either way, a significant social cost is incurred to remove marine litter. For beach cleanup projects, which became in vogue in the last ten years, there is a cost of mobilization, time away from the job (for volunteers), and cost of labor when done as paid professional services. Cleanup cost includes collection, loading, transportation, disposal, and when applicable, recycling. Therefore, the economic opportunity cost of cleaning depends on the line of business that is being forfeited within the local economy.

There have been attempts to quantify such activities in highly developed countries, whereby such studies were performed by the public sector. In the United Kingdom, port authorities spent Euros 2.3 million on debris removal from harbors, while the cost of removing plastic bags on beaches was estimated Euros 340,000/year. Other examples from Belgium and the Netherlands show that about Euros 10 million/year were spent to remove solid waste off beaches [29, 30].

Various studies showed that beach cleanliness ranks as a top priority for tourists and visitors [31]. An analysis of litter impact on beach visitors in the Cape Peninsula in South Africa found that 97% of visitors would not be allowed to a beach with 10/m² or more of large litter items. This indicates that marine litter threatens the image of a country like Lebanon and ultimately leads to a decline in its tourism, which corresponds to 20% of its GDP as seen in previous sections. Another area of public-private cooperation is that, according to UNEP, tourism not only drops from the marine litter but also contributes to it [32].

5.1 Public-private partnerships for remedial actions

Several activities led by NGOs and advocacy groups, while noteworthy in terms of community service in fighting plastic pollution, are considered by the author as merely reactive. Granted that beach cleaning campaigns, distribution of trash containers for plastic collection, and offering trucking services from trash collection points to recycling plants are all necessary remedial activities, they fall short of offering a long-term solution to plastic pollution. The circle of manufacturing, consuming, dumping, collecting, and recycling plastics has its own carbon footprint problems that should be thoroughly evaluated and gradually replaced by preventive strategies.

Private sector establishments in Lebanon, namely the ones that are active in plastics trading and manufacturing have an opportunity to play a critical role in partnering with the public sector in a national and regional effort. New process innovations, manufacturing techniques, and new product development must be implemented in the Lebanese manufacturing sector. To reach such operational achievements, concepts of corporate social responsibility must become an integral part of the companies' vision and strategy.

There has been a flawed argument that there is tension between industrial activity and job creation on one side, and environmental preservation on the other side. Numerous examples confirm the opposite in that sustainability in strategic planning and environmental consciousness are aligned with long-term results in business development. Private sector entities, plastic traders, producers, and corporate users are increasingly subjected to changes in consumer awareness about plastics as hazardous waste. Therefore, they need to embrace corporate social responsibility to align and anticipate market needs.

Figure 6 summarizes the relationships among various stakeholders and how actions among private sector establishments, public sector entities, and the citizen

Figure 6.
A citizen- and consumer-centered view to a proposed interaction and public-private partnership in fighting plastic pollution.

are interrelated. The local population must be engaged in awareness campaigns, and the manufacturing sector is to be part of advocacy campaigns. Radical changes are required through preventive strategies. Since the Lebanese coast is not only a source of plastic litter but is also a destination, a collaboration at a regional level would serve best the common interest to protect this shared sea [33].

6. Conclusions

Among multiple sources of plastic pollution, rivers carry solid waste from inland to the ocean from residential, industrial, and agricultural areas. There has been an increased awareness about the hazards of plastic pollution and threat to human, animal, and vegetation life. While the maritime transport industry was blamed for many decades as the main source of marine plastic pollution, it is found that river load and dumps on the shores are major contributors. The problem is exacerbated by movements from shore to shore by waves and currents. Our overview about river solid waste loads calls for urgent actions to be taken by the private sector by embracing corporate social responsibility. The Mediterranean, which is particularly fragile because of its enclosed geography, suffers from industries in several countries around the basin that generate toxic or solid waste disposed of in rivers and municipal sewage networks. A practical application was presented using data from Lebanon, located on the easternmost shore of the Mediterranean, and whose economy depends by and large on service sectors including transit from its harbors to inland countries in the region. The private sector is expected and recommended to play a leading role in curbing plastic pollution by partnering with the public sector. Companies are encouraged to be proactive in the process and product innovation, and the public sector is recommended to stimulate such preventive corporate strategies through the enactment of thoughtful and forward-looking public policies. While remedial actions such as cleanup and recycling are necessary, the solution resides in migration toward green products and the development of

bio-substitutes to plastics. A concerted effort to fight plastic pollution onshore and in the marine environment is required through partnerships between companies and local governments.

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