SOLVING MARINE POLLUTION

Successful models to reduce wastewater, agricultural runoff, and marine litter

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Olha Krushelnytska, September 2018

This report presents solution models for three types of marine pollution originating on land: wastewater, agricultural runoff, and marine litter. It examines the status and impacts for each pollution type, and provides pollution management case studies with cost-benefit analysis where available. The report provides a menu of pollution abatement options to help countries and their development partners improve the health and productivity of coastal and ocean areas.

Annex 1 acknowledges contributors, and Annex 2 provides the legal and institutional context for this paper.

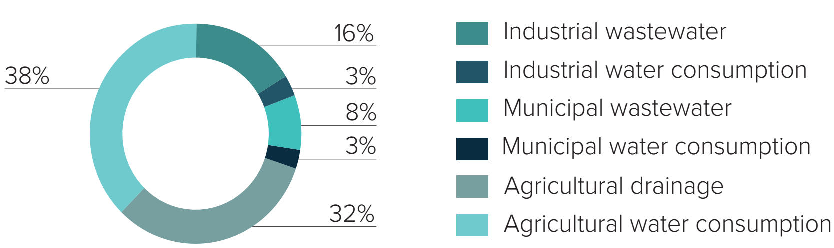
Status and Impacts

Wastewater

Wastewater, both treated and untreated, is widely recognized as a resource. As water demand is predicted to increase significantly over the coming decades, minimizing water loss, changing management approaches and enabling water reuse to become intrinsic part of long-term sustainable solutions. The Food and Agriculture Organization of the United Nations (FAO) estimates annual global freshwater withdrawals at 3,928 km3 (UN 2017). More than half of it is being released into the environment as wastewater (municipal and industrial effluent and agricultural drainage), and less than half is being consumed, mainly by agriculture through evaporation in irrigated cropland (see Figure 1). Over 80% of wastewater released to the environment is not adequately treated.

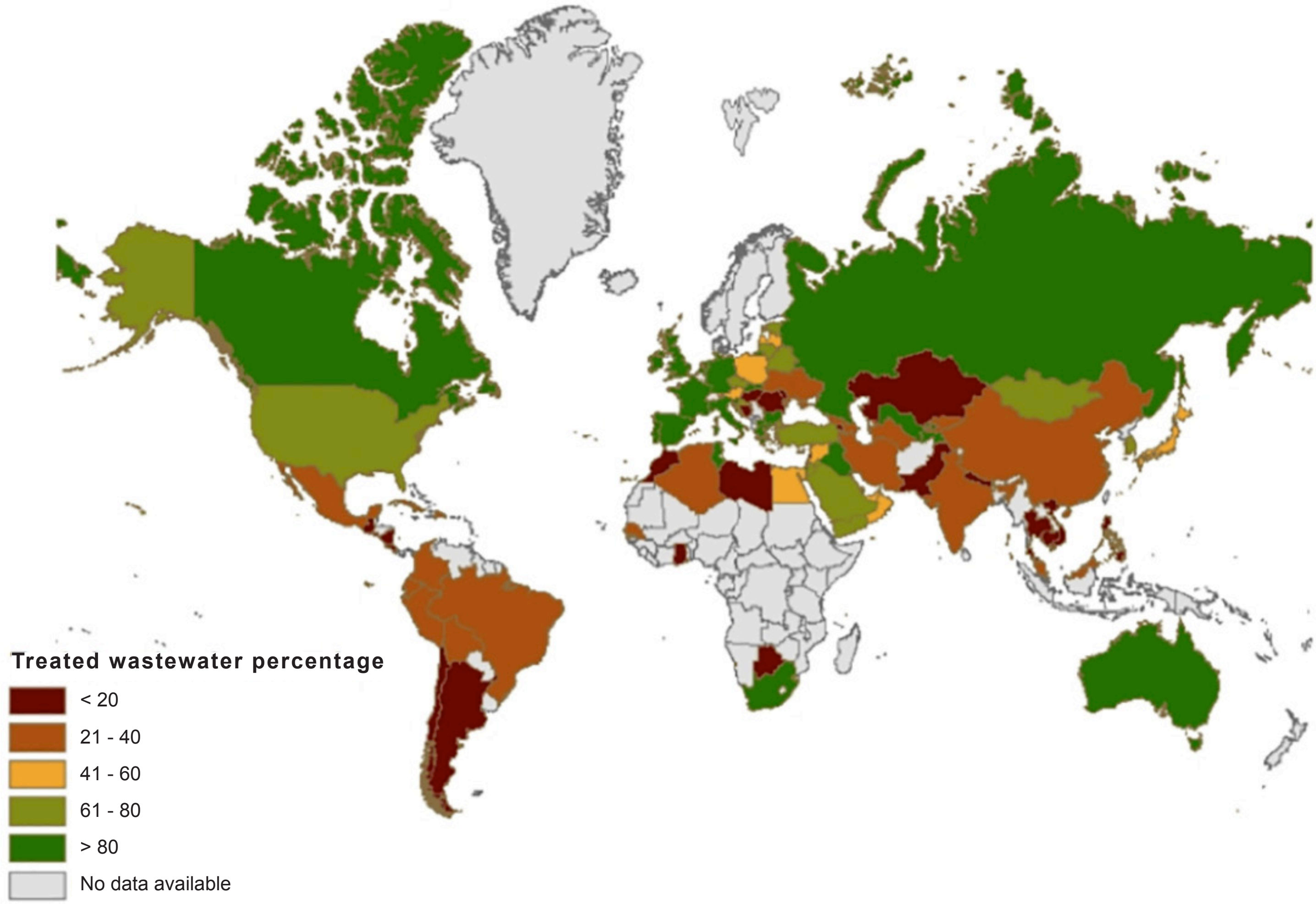
On average, high-income countries treat about 70% of the wastewater they generate. This ratio drops to 38% in upper middle-income countries and to 28% in lower middle-income countries. In low-income countries, only 8% of industrial and municipal wastewater gets any kind of treatment (Sato et al. 2013) (see Figure 2). The use of treated wastewater varies. It goes primarily to industrial and domestic sectors in the humid regions, such as the eastern part of North America, northern Europe, and Japan. And in the arid and semiarid areas, such as western North America, Australia, and southern Europe, treated wastewater is used primarily for irrigation, which is predicted to expand due to the climate change-induced changes (Sato et al. 2013).

Figure 1. Freshwater consumption and wastewater production by major sectors (circa 2010)



Source: Based on data from AQUASTAT (n.d.a.); Mateo-Sagasta et al. (2015); and Shiklomanov (1999). Contributed by Sara Marjani Zadeh (FAO).

Figure 2. Ratio of treated wastewater to total wastewater



Map prepared by the Global Partnership for Oceans (GPO) Technical Secretariat; adapted from Sato et al. 2013.

Environmental and health impacts from insufficient wastewater treatment depend on the type of pollutants:

- Decaying organic matter and debris - use up the dissolved oxygen so fish and other aquatic biota cannot survive
- Excessive nutrients, such as phosphorus and nitrogen (including ammonia) - result in eutrophication, or overfertilization of receiving waters (freshwater or marine), which can be toxic to aquatic organisms, promote excessive algae blooms, reduce available oxygen, harm spawning grounds, alter habitat (e.g. corals can be overgrown by seaweed if exposed to excesses nutrients), and lead to a decline in certain species
- Chlorine compounds and inorganic chloramines - toxic to aquatic invertebrates, algae, and fish
- Metals, such as mercury, lead, cadmium, chromium, and arsenic - have acute and chronic toxic effects on species, accumulating and increasing in concentration along the food chain
- Bacteria, viruses, and disease-causing pathogens - pollute beaches and contaminate shellfish populations
- Other substances, such as some pharmaceutical and personal care products, primarily entering the environment in wastewater effluents - pose threats to human health, aquatic life, and wildlife.

The economic impact of wastewater pollution is difficult to value. One way to do so is to establish its impact on ecosystem services and to determine the cost of replicating those services. The U.S. Environmental Protection Agency (EPA) and the Centers for Disease Control and Prevention estimated the hidden cost of unreliable water delivery and wastewater treatment to surpass $2 trillion by 2040 in USA alone (Table 1).

Table 1. Estimated costs due to unreliable water and wastewater infrastructure

Sector	Cumulative cost, 2011-2040 (billion 2010 USD)
Households	$616
Businesses	$1,634
Total	**$2,250**

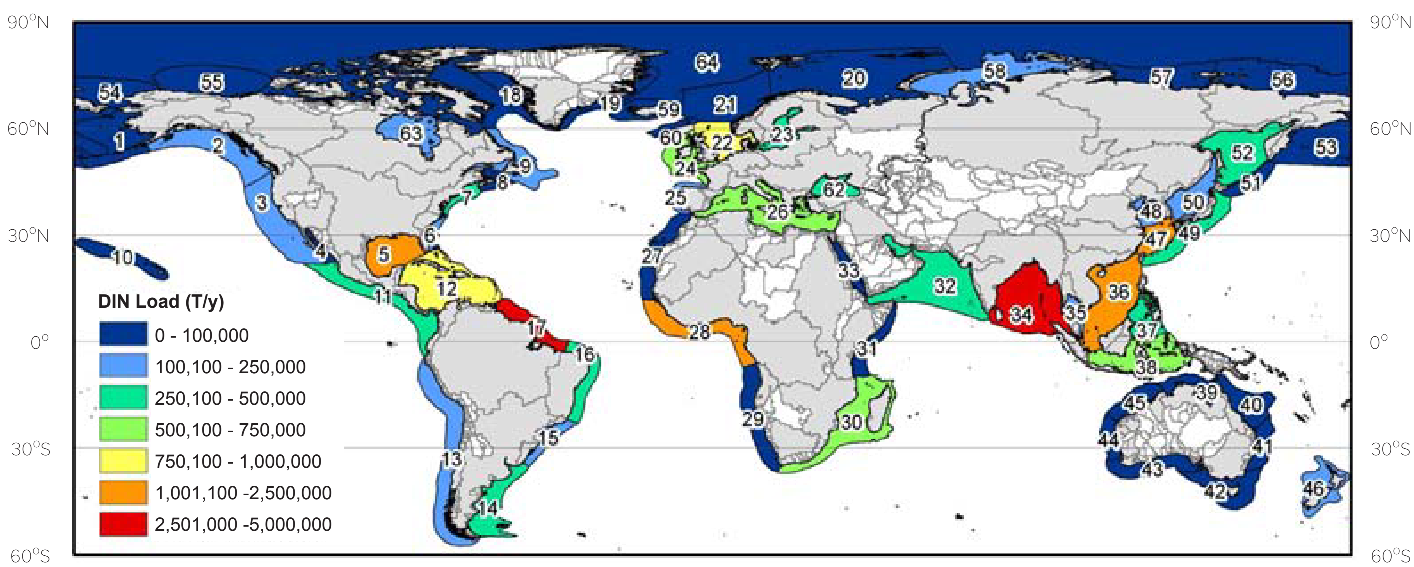
Sources: EPA

Agricultural Runoff

Agricultural activities are considered a primary contributor to an increase in pollutant delivery to marine ecosystems. Industrialized agriculture is one of the largest sources of nitrogen (N) and phosphorus (P) pollution in the form of animal manure, inefficient nutrient application, bad irrigation practices, and soil erosion. The use of N-based fertilizers is predicted to double or even triple within the next 50 years (Beman et al. 2005). Though agricultural runoff is highest among developed countries, marine nitrogen pollution is increasingly widespread because of agriculture intensification globally.

The level of land-based Dissolved Inorganic Nitrogen (DIN) export from watersheds to large marine ecosystems (LMEs) varies globally across a large range of magnitudes (Lee et al. 2016). Fertilizer was the primary source of DIN to LMEs in most of Europe and Asia, while manure was the primary source in most of Central and South America. The smallest loads are exported to many polar and Australian LMEs, while the largest loads are exported to northern tropical and subtropical LMEs. The LMEs receiving the largest loads of land-based DIN are the North Brazil Shelf, Bay of Bengal, Guinea Current, South China Sea, East China Sea and Gulf of Mexico LMEs.

Figure 3. DIN load to LMEs. Watersheds discharging to LMEs are grey, watershed with zero coastal discharge are white



Source: Lee etal. 2016

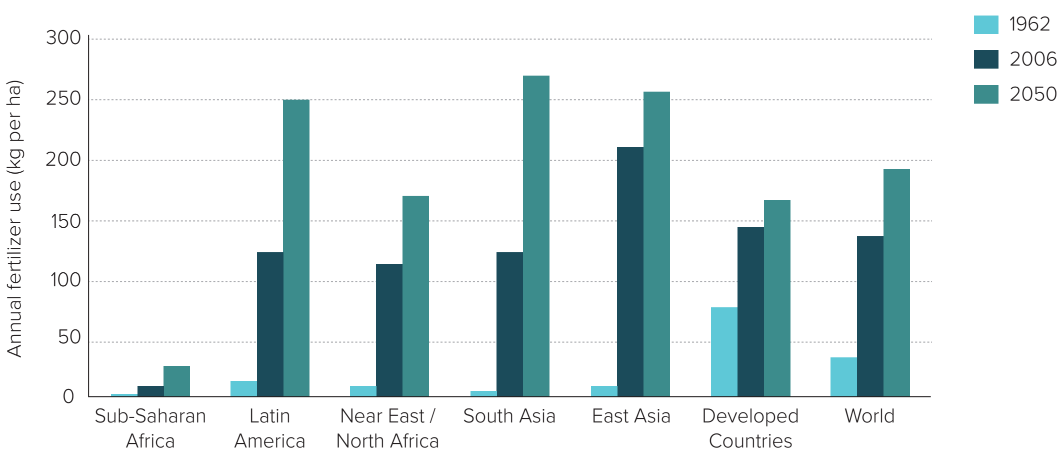
Nutrient use efficiency is a key indicator of nutrient management. Oversupply or imbalance between nutrients reduces the efficiency of nutrient use, while insufficient application of nutrients leads to depletion of organic matter, reducing soil quality and exacerbating land degradation through erosion. The efficiency of nutrient use is very low on a global scale: over 80% of nitrogen (N) and 25–75% of phosphorus (P) consumed (and not temporarily stored in agricultural soils) are lost to the environment. This wastes the energy used to prepare the fertilizers and causes pollution through emissions of the greenhouse gases nitrous oxide (N2O) and ammonia (NH3) to the atmosphere. It also results in losses of nitrate (NO3-), phosphate (PO43), and organic N and P compounds to water (Sutton et al. 2013).

Analysis of the consumption of N-based and P-based fertilizers consistently show high concentration of given chemicals in air, water, and soil in Latin America, Western Europe, the Middle East, and South-East Asia. In Africa, Latin America, and parts of Asia, there are still many regions with too few nutrients (Figure 4). In considering regional differences, it is clear there is a common need to improve nutrient use efficiency 'to produce more food and energy with less pollution'. See Annex 3 for a quick overview of the key issues and differences between regions.

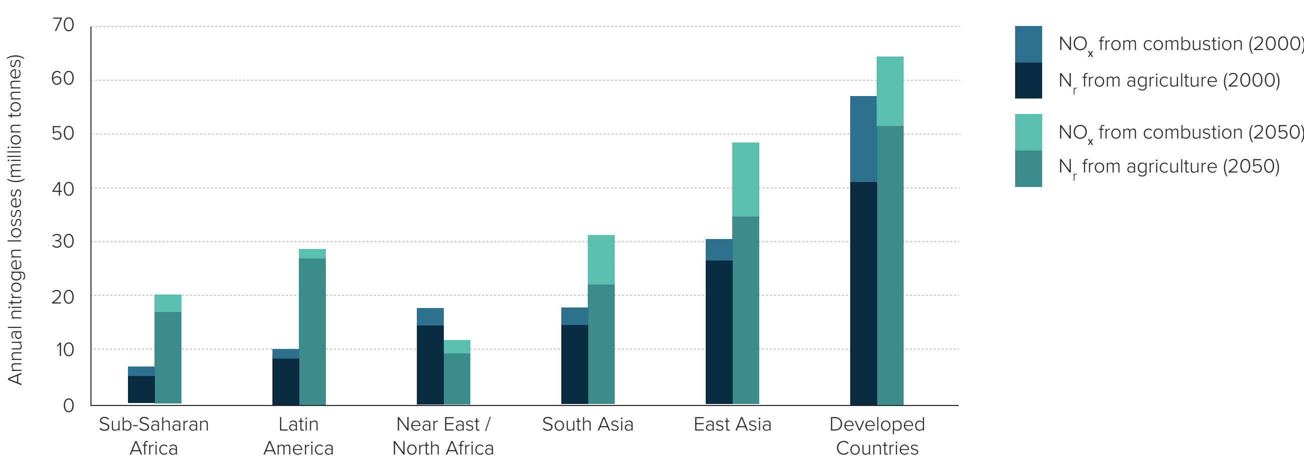
Figure 4. Fertilizer use and nitrogen losses to the environment

a. Estimated and projected use of fertilizers that contain nitrogen, phosphorus, and potassium compounds
b. Total estimated losses to the environment (air, water, and soil[1]) of nitrogen oxides (NO_X) in emissions from combustion sources and of reactive nitrogen (N_r) from agricultural activities for 2000 and 2050

a



b



Source: Sutton et al. 2013.

[1] Losses are represented mainly by ammonia (NH3) emissions from agricultural and livestock production systems, soil denitrification, and N leaching and runoff

Livestock manure is one of the major contributors to nutrient pollution. The European Nitrogen Assessment estimated that 85% of nitrogen in EU harvest was used to feed livestock, while the average EU citizen consumed 70% more protein than needed for a healthy diet (Sato et al. 2013).

China is among the world's largest producers and consumers of beef, mutton and dairy, which generate large amounts of livestock manure. China also does not have systematic nutrient management planning; most manure generated by large operations is not used as fertilizer, but instead is treated or released without treatment. In comparison, the United States has a zero-discharge system - for example, all manure and wastewater are applied to cropland, with essentially no manure nutrients or pathogens going directly to surface waters. While treating manure is expensive, its use as fertilizer can significantly benefit soil quality. If applied properly, it can result in zero nutrient emissions into surrounding freshwater systems.

Aquaculture is also a substantial contributor to nutrient pollution through the release of excess nutrients into nearby water supplies. Due to overfeeding and less than optimal feed regulation systems, and high organism density in the fish ponds, high levels of nitrate and phosphate nutrients are created that can leak out into watersheds and begin the process of eutrophication. However, not all aquaculture practices result in nutrient runoff - mollusk farms and some seaweed farms can remove excess nutrients from a watershed and thus help prevent eutrophication.

Environmental and health impacts from agricultural runoff, particularly nitrogen pollution, stem from too much or too little use of nutrients, highlighting the complexity of nutrient interactions (Sutton et al. 2013):

- **Water quality,** including coastal and freshwater dead zones, hypoxia, fish kills, harmful algal blooms, nitrate-contaminated aquifers, and impure drinking water, resulting from both N and P eutrophication
- **Ecosystems and biodiversity,** including the loss of species of high conservation value naturally adapted to few nutrients; eutrophication from atmospheric N deposition is an insidious pressure that threatens the biodiversity of many "protected" natural ecosystems
- **Soil quality**[2], including overfertilization and too much atmospheric N deposition acidify natural and agricultural soils, while a shortage of N and P nutrients leads to soil degradation, which can be exacerbated by a shortage of micronutrients, leading to loss of fertility and erosion.

In addition, poorly-managed irrigation has one of the worst impacts on water quality. It causes salt concentration and erosion; transports nutrients, pesticides, and heavy metals downstream; and decreases the amount of water that flows naturally in streams and rivers.

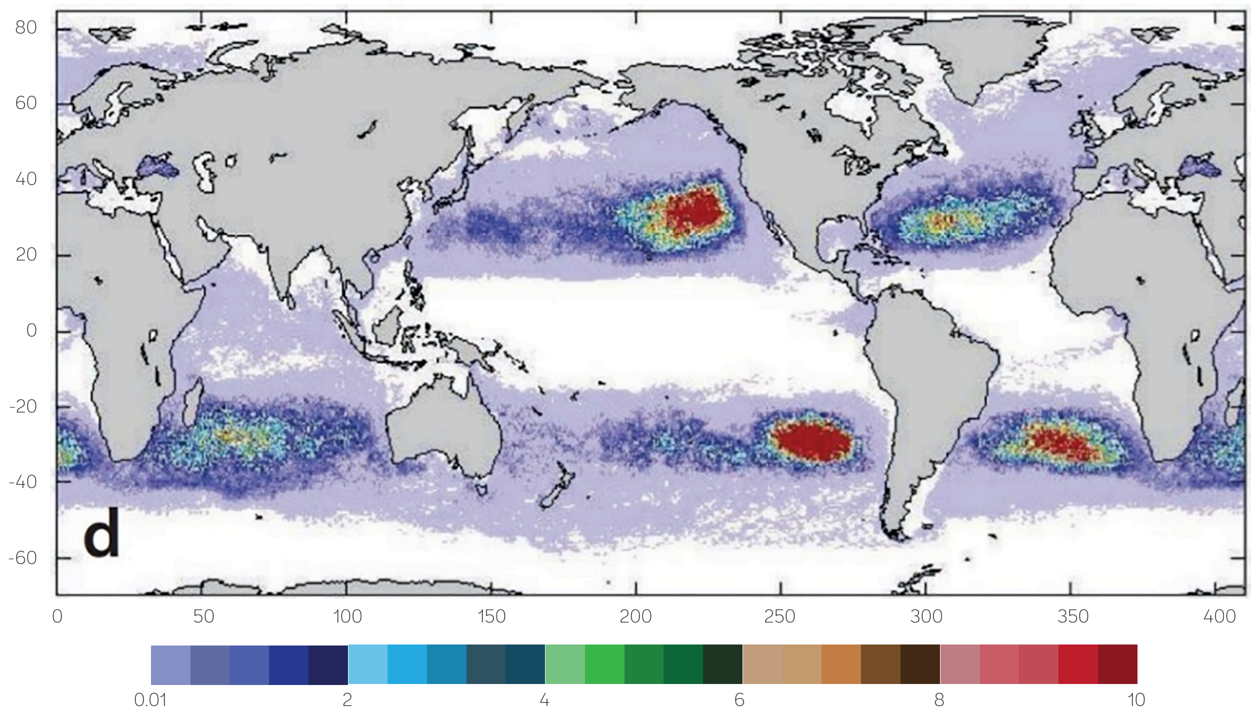
Economic cost of agricultural runoff is difficult to calculate, but it far outweighs the benefits of nitrogen application. Pollution from pesticides and fertilizers is hard to measure and the source is often diffuse, making it hard to determine. In 27 countries in the EU, the cost-benefit analysis (Van Grinsven et al. 2013) in 2008 showed the annual benefit of nitrogen application of €20-€80 billion/year with a cost of €35-230 billion/year. In China and India, the cost of agricultural pollution is set to rise as farmers race to increase food production, with some regions probably already passing the pollution level that may cause significant health issues (OECD 2012). Loss of N-P-K from an average erosion of 20 tons per hectare per year represents an annual economic loss of $242 million in nutrients, as **nutrient loss is closely associated with rainfall-runoff events, and the economics of nutrient control tend to be closely tied to the costs of controlling runoff and erosion.** The link between erosion, increasing fertilizer application, and loss of soil productivity is very direct in many countries.

[2] One of the main factors contributing to decreasing soil quality is the lack of humus, organic matter and clay. Healthy soils with adequate levels of humus and organic matter will have a higher retention capacity of N (so that leaching is minimized) and P

Marine Litter

Marine litter is one of the most insidious forms of ocean pollution, with most of it originating on land and about 80% of it being plastics. Packaging is plastics' largest use, representing 26% of the total volume (WEF, MacArthur, McKinsey 2016). Plastics drifting in the ocean are highly concentrated in five subtropical gyres: North Pacific, North Atlantic, South Pacific, South Atlantic, and Indian Ocean (Figure 5). Though the location of the gyres has been known for many years, quantification of the plastic problem - by number of pieces and weight - is an ongoing modelling effort.

Figure 5. Simulation of evolution of drifter density (or marine debris) by 2018 after 10 years of advection by currents, as determined from real drifter movements



Note: Units represent relative change in drifter concentration. Source: IPRC Climate 2008.

Box 1 - Major sources of marine litter

Land-based

- Wastes from dumpsites on the coast or river banks
- Rivers and floodwaters
- Industrial outfalls
- Discharge from stormwater drains
- Untreated municipal sewerage
- Littering of beaches and coastal recreation areas
- Tourism and recreational use of the coasts
- Fishing industry activities
- Ship-breaking yards
- Natural storm-related events

Sea-based

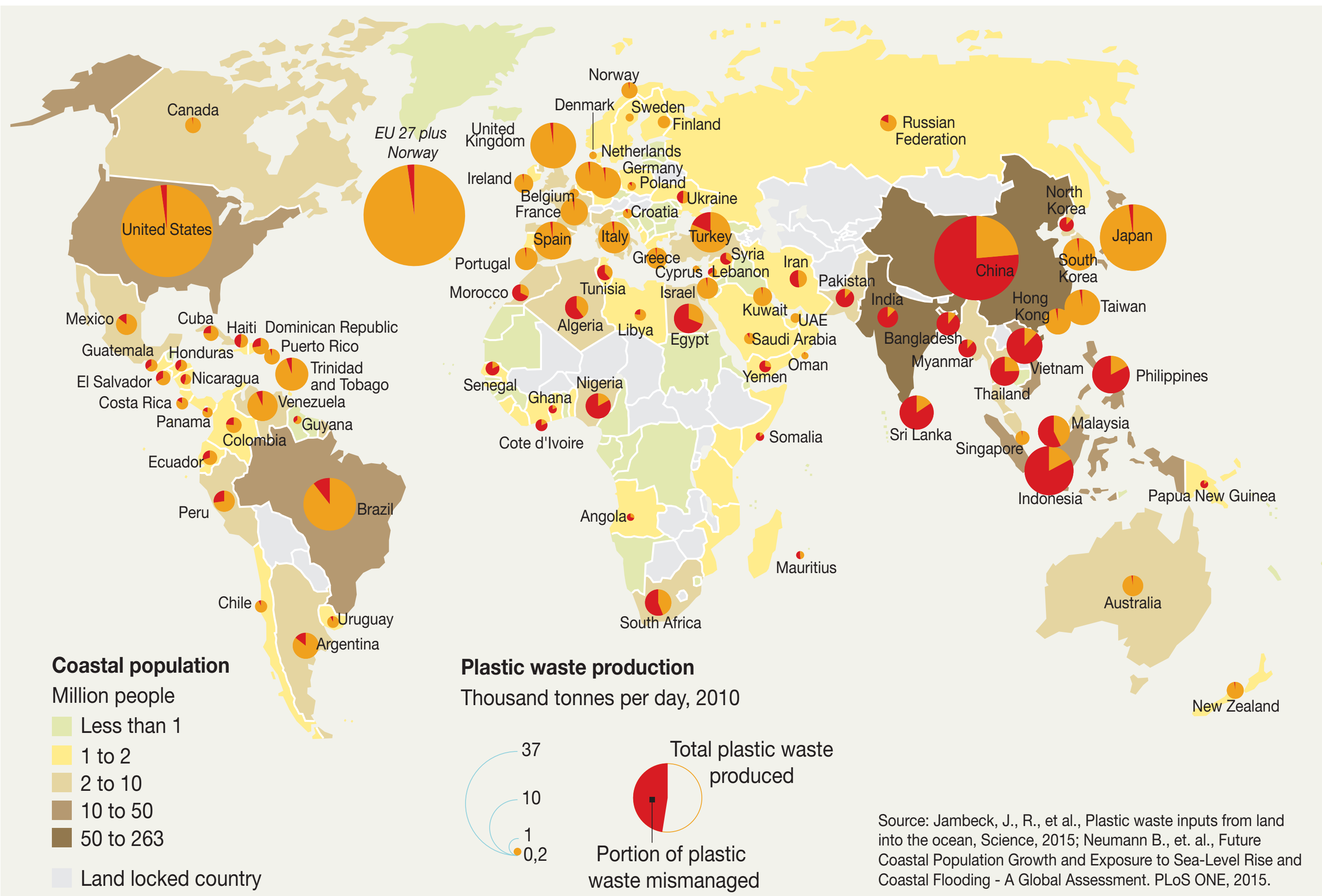
- Shipping and fishing activities
- Offshore mining and extraction
- Legal and illegal dumping at sea
- Abandoned, lost, discarded fishing gear
- Natural disasters

Recent estimate of the amount of plastics drifting at sea showed more than 5 trillion plastic particles, where smallest size is the most numerous (Eriksen et al. 2014). This includes only the plastic floating on the surface. The data collected for four size classes - small micro, large micro, meso, and macro - in all five subtropical gyres and extensive coastal regions and enclosed seas, showed that the two smallest microplastic size classes combined account for over 90% of the global particle count, while macroplastics account for around 90% of the plastic pollution weight.

The study of marine litter sources estimates 275 million metric tons (MT) of plastic waste generated in 192 coastal countries in 2010, with 4.8-12.7 million MT entering the ocean (Jambeck et al. 2015). The study linked worldwide data on solid waste, population density, and economic status to determine which countries contribute the greatest mass of plastic marine debris (Figure 6). It also pointed to the critical importance of the waste management infrastructure improvements.

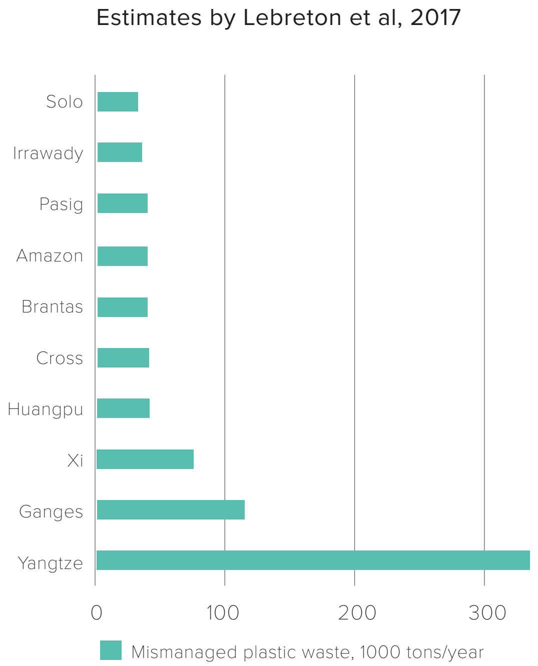
Recent studies looking at plastic pathways indicate that 10 rivers basins are responsible for 90% of land-based leakages to the ocean (Lebreton et al., 2017, and Schmidt et al., 2017). Both studies from Schmidt and Lebreton show the Yangtze river basin as the main contributor (Figure 7). The ranks for other polluted rivers differ due to the entry data used in two studies: Lebreton used the global river plastics input model for estimation whereas Schmidt's made calculations as a product of mismanaged plastic waste generated per capita and population size in the catchment.

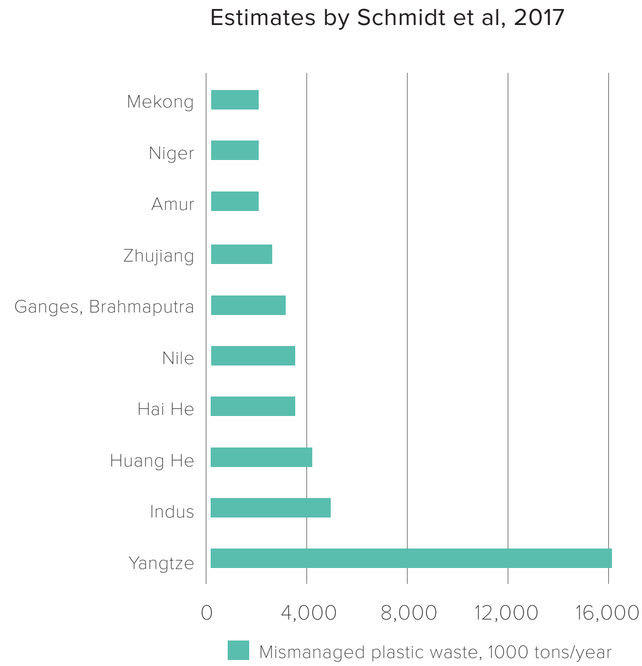
Figure 6. Plastic waste produced and mismanaged



Source: Jambeck et al. 2015.

Figure 7. Top 10 river contributing to marine litter





The level of contribution to plastic marine litter by a country or locality depends on the number of factors (ORA 2010):

- **Geography:** location of city and hydrology related to rivers, type of development, relative proximity of key polluters, topography, and water flow
- **Environment**: presence and location of native vegetative filter strips, shape of receiving water body, flow rate of receiving body, and rainfall patterns
- **Infrastructure**: type of stormwater collection system and the location of dams
- **Institutional capacity:** efficiency of waste collection and street cleaning services, extent of legislation and enforcement prohibiting littering, availability of proper waste treatment and disposal facilities, and presence and type of industry
- **Demographics**: culture and degree of environmental concern, leading to proper use of waste disposal bins; and population density
- **Economy**: income level and waste composition, with low-income communities generating larger percentages of organic wastes versus high-income communities that generate larger percentages of inorganic wastes such as plastics.

The health impact of plastic pollution is a potential disruption of key physiological processes, such as cell division and immunity. This is caused by most of the priority pollutants that are present in plastic debris. Some are ingredients of plastic are absorbed from the environment like ocean, where litter bonds with other synthetic polymers and gets accumulated in marine species, later appearing in our food. Some of these polymers are carcinogens, like polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT)[3] (Rochman et al. 2013a). Micro-plastics are particularly problematic because of their long residence times in the ocean and their ingestion by marine organisms and birds (NOAA Marine Debris Program 2015; World Ocean Review 2010), resulting in increased morbidity and mortality of marine life and infiltration of food webs. Attention should be given to abandoned, lost, or discarded fishing gear, which can continue to catch and kill marine life for decades, known as "ghost fishing". Roughly 70% (by weight) of macroplastics floating in the open ocean are fishing-related, though this also has to do with the various densities of types of plastic (Eriksen et al. 2014).

[3] Pesticides and organic pollutants such as PCBs are consistently found on plastic waste at harmful concentrations 100 times those found in sediments and 1 million times those occurring in seawater. PCBs and DDT bioaccumulate and biomagnify, with a recent EPA-funded study showing severe glycogen depletion, fatty vacuolation, cellular necrosis, and lesions in fish exposed to a mix of chemicals via plastic ingestion.

The economic cost of marine litter is most researched in the tourism sector. The estimated annual lost tourism revenues in 2011 in Asia-Pacific region were 0.3% of gross domestic product, or $622 million (Jang et al. 2014), and $29-37 million in Geoje Island in South Korea. The coastal cleanup efforts can be costly, too: recent estimates by the West Coast Governor's Alliance (California, Oregon, and Washington, with over 50 million people) have placed annual cleanup efforts of marine litter and mitigation along the U.S. West Coast at over $520 million.

Indirect costs are less known; however, tourism and fishing industries are affected by opportunity costs related to the degradation of the marine environment and forgone trips to impaired beaches. In South Africa, a survey of visitors in 2000 indicated that the degree of beach pollution could result in a loss of 52% of revenue from tourism. Marine litter has a twofold impact on fisheries: by decreasing revenues through ghost-fishing and by increasing costs due to vessels repairs. Research focusing on the Shetland fishing fleet found that marine litter could cost a vessel up to £30,000 a year (Hall 2000).

Solutions

Wastewater

Wastewater can be reused to generate different benefits, using different levels of treatment and its cost. In regions with water scarcity, investments in reclaimed water reuse and water exchange arrangements are usually profitable in the long term. Treated wastewater is used in agriculture for irrigation, in industrial activities (which account for more than one-fifth of all water used), and in urban activities such as irrigation of parks, landscaping, and street cleaning. Another use if an artificial groundwater recharge with treated wastewater. This does not only conserves groundwater resources, but helps retard eutrophication of surface waters through physical and biological processes in the soil that improve water quality. The recharge operations are not yet done on the large scale due to the lack of specific criteria and guidelines governing the artificial recharge of groundwater with recycled municipal wastewater.

Treated wastewater is still not used very frequently as drinking water, except for space missions, the Concordia Station in the Antarctic, and in some military operations, and to a lesser extent by few countries that suffer from water shortages. Several cities produce drinking water from their wastewater on a large scale: Windhoek (Namibia), Singapore, and Orange County district in California (USA), with works underway in Lima (Peru) and Kampala (Uganda).

When it comes to water purification, both the "grey" and the "green" treatment infrastructures can be used. The "grey" or conventional infrastructure is often ageing, inappropriate or insufficient, thus creating opportunities for "green", or natural-based solutions (NBS) for water. NBS embed perspectives of ecosystem services, enhanced resilience and livelihood considerations, usually offer multiple water-related benefits, and often help address water quantity, quality and risks simultaneously (UNESCO 2018). When it comes to water purification, the water treatment plant is the grey infrastructure solution, while re/afforestation, riparian buffers and wetlands restoration are green infrastructure solutions. See Annex 4 for more examples of water NBS that could be used as alternatives or in combination with the conventional water treatment systems.

One of the legal incentives for wastewater treatment is the transfer of freshwater entitlements from farmers to municipalities, allowing wastewater to be used by farmers in agriculture while freeing freshwater for municipal uses. The farmers save the cost of water pumping and fertilizing, and increase harvest yields and incomes. The transfer of freshwater entitlements depends on the farmers having secure rights to the water that they can transfer - either in water markets (see example in the Solution Examples subsection) or in return for compensation. This makes legal rights and compensation for wastewater use central to the water exchange solution, where the national legal system must permit transfer of these rights.

One of the financial solutions is to recover the operational costs of the wastewater treatment from the final beneficiaries. This will make wastewater treatment process self-sustaining and efficient in the long run. In irrigation, the economic drivers for the use of reclaimed water are unclear: the pricing mechanisms are not transparent(Radcliffe 2003), with the high cost of distribution, lack of awareness of end users, and the inefficiencies of sewage collection and treatment operations adding to the problem.

Another financial incentive for wastewater treatment it a biogas capture from the treatment process. While most sewage treatment facilities still simply flare the gas, technologies in developed countries usually include biogas capture, providing a variety of benefits. Many plants in the United States have offset capital costs completely through income and savings from using the captured biogas to generate heat and electricity. During a biogas and energy efficiency project, a sewage treatment plant in Washington State captured methane gas from the treatment process and recycled it as fuel to run equipment at the plant, saving more than $228,000 yearly in utility costs. And the largest wastewater treatment facility, DC Water's Blue Plains Advanced Wastewater Treatment Plant, extracts and reuses useful products like biosolids (recycling nitrogen and phosphorous back into local soils) and energy (generating about 10 megawatts of electricity that is consumed by the plant).

Some economic solutions are selective sales taxes on "polluting items" such as agricultural chemicals or fuels, or a pay-as-you-pollute plan. The pay-as-you-pollute method proved to be effective in Colombia, where companies had to pay for each unit of pollution (Blackman 2010). To make such a plan effective, however, the government must devote resources to collect data on nutrient runoff and fees from the companies.

Solution Examples

Thailand hotels: Attractive loans for green investments

World Wildlife Fund (WWF) Conservation Finance and its partners designed a $40 million subsidized credit facility to reduce biodiversity impacts of hotels operating on the Thai coastline. This credit facility was launched by Kasikorn Bank, the second largest commercial bank in Thailand. It offers discounted interest rates of up to –1.5% of the minimum lending rate for hotels committed to reducing their impacts on marine biodiversity and improving their environmental management. The facility offers long-term loans to finance investments mainly in wastewater treatment, solid waste management, and water consumption management. To participate, the hotels must adopt an Environmental Management System and green certification.

Manila, Philippines, sewage treatment: financial incentives and private sector participation

The GEF[4]/IBRD[5] Manila Third Sewerage project provided sewerage services to 20% of the 12 million residents of the Metropolitan Manila Area (640 km), sanitation services to 57% of the population, reduced the biochemical oxygen demand (BOD) load in Manila bay by 9,000 tonnes per year, and estimated reduction of 2,200t/year of N and 340 t/year of P (figures as of 2014). To increase private sector investment, two key policy areas were identified through extensive consultation - making septage manage compulsory and increasing minimum standards for industrial pre-treatment - with policy drafted and adopted, and serving as a model for adoption by other local governments. Use of market-based incentives for pollution reduction was achieved through expanding the pollutants covered under the Environmental User Fee, institutional strengthening, community participation, and the awareness raising.

Colombia and India: Cost recovery through tariffs and differential sewage pricing

In Hyderabad, India, wastewater treatment cost recovery is restricted to water supply, and the Hyderabad Metropolitan Water Supply & Sewerage Board has not yet been successful in full cost recovery. During one of the studies, only 30% of respondents were willing to pay for wastewater to be treated to potable quality. This indicates that the full cost recovery of sewerage services and wastewater treatment is not possible. However, a phased increase in the water tariffs accompanied by simultaneous improvements in service delivery mechanisms may be successful in the future. Also, like water supply charges, the sewerage fees could be levied according to consumer income levels. Such a system exists in parts of Colombia, where urban areas are divided into zones based on socioeconomic criteria and water rates are adjusted according to the zone (Mekala et al. 2009).

Caribbean Region: innovative solutions and financing mechanisms for water treatment

13 countries in the Wider Caribbean region benefitted from the Caribbean Regional Fund for Wastewater Management (CREW) project, funded by the GEF and co-implemented by IDB and UN Environment in 2011-2016. Some of the achievements included Land-Based Sources of Marine Pollution Protocol (LBS protocol) ratified by Jamaica and Costa Rica, over 37,000 people (8,400 households) getting access to improved wastewater treatment, and 12 new wastewater treatment plants to be completed. The following financial mechanisms were established:

- In Belize and Guyana, National Wastewater Revolving Funds worth $5m and $3m respectively will provide below-market interest rate loans for wastewater treatment projects.
- In Jamaica, Credit Enhancement Facility worth $3m will provide credit enhancement for local commercial bank financing of wastewater projects. The government of Jamaica pledged an additional $12M, with total financing expected to grow substantially. 13 projects are planned involving either rehabilitation or construction of wastewater facilities.

A second phase of CReW project was approved in 2017 with $14 million of financing, covering 18 countries in the

[4] The Global Environment Facility
[5] The International Bank for Reconstruction and Development

region. Additional information can be found in Cost-Benefit Analysis section and Annex 4.

Cartagena, Colombia: Private ownership and legal framework

Cartagena underwent an environmental and public health crisis in the mid-1990s, caused by rapid population growth, unplanned urban development, and poor wastewater management. In response, the government adopted a new National Environmental Law in 1993, which created a framework for environmental management and autonomous regional environmental authorities. The key to the solution was liquidation of the municipal wastewater utility and creation of a mixed-capital company ACUCAR, owned by a Spanish private company 46%, the Colombian state 50%, and the public 4%. ACUCAR implemented the infrastructure development program, which covered improving the water supply service; improving drainage in high-value economic areas; improving water circulation in the lagoon; and collecting, treating, and disposing Cartagena wastewater (Table 2). Now Cartagena's Caribbean beaches are essentially free of contamination from sewage, and Cartagena Bay water quality is significantly improved.

Water quality trading in developed countries

Water quality trading is a market-based instrument that is gaining popularity as a mechanism to meet water quality goals cost-effectively. It is premised on the fact that the costs of reducing pollution differ among individual entities, depending on their size, location, scale, management, and overall efficiency. Trading allows sources with high abatement costs to purchase pollution discharge reductions from sources with lower abatement costs. Entities with lower abatement costs can economically lower their pollution discharges beyond regulated or permitted levels, enabling them to sell their excess reductions to entities with higher costs. Water quality trading is most commonly applied to nutrients (such as N and P), but it has also been applied to temperature, selenium, and sediment. In 2009, there were 26 active water quality trading programs worldwide (WRI 2009), 21 located in the United States, and the rest in Australia, New Zealand, and Canada.

US: Low-cost financing and reinvestments through the Revolving Fund

The Clean Water State Revolving Fund (CWSRF) program in the United States is an independent and permanent source of low-cost financing to fund a wide variety of water quality infrastructure projects. Funds can be used for nonpoint-source pollution management, watershed protection and restoration, estuary management projects, and traditional municipal wastewater treatment projects. Funds for the CWSRF programs are provided through federal government grants and state matching funds (20% of federal). As the loans are repaid, money becomes available to be used again for new financing - a true revolving fund. Building on a federal investment of over $39 billion, the state CWSRFs have provided more than $111 billion to communities through 2015.

Table 2. Cartagena Water Infrastructure Development Program

Year	Water supply coverage	Water supply customer	Sewerage coverage	Sewerage customers	Wastewater treated	Revenues COP-milliion
1995	73%	92,573	61%	77,553	0%	25,592
2013	99.9%	233,412	90.3%	211,022	>90%	165,889

Agricultural Runoff

As the vulnerability to agricultural runoff and the cost of prevention vary, it is important to identify runoff hotspots and set policies on both local and regional levels. Nitrogen and phosphorus input-output cycle can be localized in the single field or have a transboundary nature due to air and water movement and the global increase in N2O concentrations. This requires solutions that consider local and regional conditions while addressing the necessary improvement in nutrient use efficiency at the global scale.

Determining and reducing the amount of nutrients in animal feed and crop fertilizers maximizes the efficiency of their use and brings economic benefits. The Millennium Ecosystem Assessment estimated that the United States alone applies 20-30% more fertilizer to crops than is necessary (Howarth and Ramakrishna 2005). Animals are also often given far more nutrients than their bodies can absorb, leaving the rest to be expelled out as manure. Reduction in phosphorus in cow diets from 0.31% to 0.47% led to increased milk production (42.4 g/da to 79 g/day) and reduction in phosphorus dissolved in runoff (from 79 g/ha to 7 g/ha). Strategies to reduce the surplus nitrogen in animal production include selecting and optimizing the feeds with appropriate N concentration and an ideal protein composition.

Good agricultural practices that reduce N and P runoff include planting perennial and winter crops, applying fertilizers at the right time, conducting tillage, reducing sedimentation, rational irrigation, and pesticides management:

- Planting perennial crops instead of annual ones in highly sensitive areas would retain nitrogen in the soil and greatly reduce the loss of groundwater. Planting winter crops would reduce the rate of nitrates leaching into the ground, which generally occurs in the winter and spring due to heavier rainfall. It can also provide an economic benefit from increased agricultural production and the added benefit of nitrogen fixation provided by the winter crop.
- Fields with winter cover plowed under in the spring have 55% less water runoff and 50% less soil loss annually than do fields with no winter cover. And soil losses from corn or soybeans no-tilled into a vigorous growth of rye or wheat can be 90-95% less than soil losses from corn and soybeans conventionally tilled (Howarth and Ramakrishna 2005).
- Practices to control nutrients runoff from sedimentation include maintaining natural vegetation along canals, rivers, and coastal wetlands to lessen soil erosion into coastal or riparian areas.
- Reducing agricultural runoff (nonpoint source pollution) from irrigation includes measuring actual crop needs, applying only the amount of water required, and using higher efficiency irrigation equipment.
- And, to reduce contamination from pesticides, farmers can use integrated pest management techniques - based on the specific soils, climate, pest history, and crop conditions of a field - which include using natural pest barriers, reducing pesticide use, and minimizing pesticide movement from the field.

Methods to reduce phosphorus runoff - which does not spread nearly as far as nitrogen and thus affects immediate ecosystems of freshwater and coastal lagoons - include tillage, planting along contours, and creating buffer zones. Constructed wetlands that "soak up" all types of nutrient runoff, and provide a complementary nature-based solution to conventional wastewater treatments, are estimated to reduce between 11-49% of phosphorous and 26-78% of nitrogen, and 5-90% of different pharmaceuticals (WWDR 2018; Zhen et al. 2011).

Technologies exist that can remove up to 95% of phosphorus and up to 90% of nitrogen from sewage, but they are quite expensive. The cost can be reduced if the treatment plant is built to treat sewage for nitrogen and phosphorus from the start. Furthermore, current sewage plants can be adjusted and new ones built in areas with a high population density, spreading the cost of the new technology over a large amount of people.

Financial mechanisms, similarly to those found in wastewater management, include taxes and water quality trading. Selective sales taxes on "polluting items" raise revenue and can shift behavior away from polluting products. Nutrient trading is an environmental market for a voluntary exchange between a buyer and a seller. What is being exchanged is a unit of environmental improvement, or nutrient credits. This market is driven by regulatory compliance of a set volume of nutrients allowable within water quality regulations for a given water body.

Solution Examples

Danube/Black Sea partnership: nitrogen and phosphorus reduction in Romania

Danube/Black Sea Strategic Partnership on Nutrient Reduction was launched in 2001 with almost $100 million in combined funding from the GEF, The World Bank, UNDP, UNEP, and other sources. The Investment Fund for Nutrient Reduction was established with $70 million of GEF financing and $260 million of co-financing. It provided country-level investments during 2001-2013 for reducing nutrient pollution in the Black Sea and accelerating investments in sectors such as municipal wastewater, agricultural run-off, and industrial pollution.

The funds for Calarasi region in the Southeast of Romania were used for technology innovation, capacity building, and public awareness campaigns. These interventions achieved results on multiple scales: improved local water quality, leading to improved health and agricultural practices, and reduced nutrient run-off on the radiational scale, thereby improving health of the Danube and the Black Sea. At the end of the project, the area of the region under improved nutrient management increased from zero to nearly 34%. Importantly, the Romanian government in 2007 introduced nation-wide policies that replicated the best practices demonstrated in the Calarasi region. The success of the project, coupled Romania's commitments to meet the EU Nitrates Directive requirements, resulted in the loan support from the World Bank, as well as $5.5 million GEF grant for Integrated Nutrient Pollution Control project for 2008-2017. In 2017, the Romanian government collaborated with the World Bank to initiate another Nutrient Pollution Control project for 2017-2022 to support the baseline created under the original GEF initiative.

EU policy for improving nitrogen use efficiency

A cost-benefit analysis (CBA) of nitrogen use efficiency, conducted for 29 EU countries (Van Grinsven et al. 2013), showed large potential to increase nitrogen efficiencies and reduce runoff from manure and fertilizer use with limited effects on agricultural production. Implementation of a policy targeting optimum N rates would initially reduce the total cereal production. This, in turn, could increase market prices of cereal and lead to a decrease in demand or an increase of production in areas where N input rates are lower. The EU Common Agricultural Policy, with an annual budget of €70 billion, along with environmental directives, could provide the means, conditions, and instruments for a spatial optimization of agricultural production in the EU. Using the CBA results, a translocation of agricultural production in the EU from northwest to east would create net social benefits in both regions. The CBA analysis for the EU could be a good model for other regions.

EU fertilizer controls: Voluntary and mandatory planning and monitoring

Voluntary and mandated controls in the EU for fertilizers (FAO/ECE 1991), established in 1991, are still relevant and can be used for nutrient management:

Mineral fertilizers

- Taxes on fertilizer
- Fertilizer plans
- Preventing the leaching of nutrients after the growing season by increasing the area under autumn/winter green cover and by sowing crops with elevated nitrogen
- Promoting and subsidizing better application methods, developing new, environmentally sound fertilizers, and promoting soil testing
- Limiting the use of fertilizers in water extraction areas and nature protection areas

Organic fertilizers

- Maximum number of animals per hectare based on the amount of manure that can be safely applied per hectare of land
- Maximum quantities of manure that can be applied on the land is fixed, based on the N and P content of the manure
- Holdings wishing to keep more than a given number of animals must obtain a license
- The periods during which manure can be applied to the land have been limited, and it must be worked into the ground immediately afterwards
- Establishment of regulations on minimum capacity for manure storage facilities
- Fertilizer plans
- Taxes on surplus manure
- Areas under autumn/winter green cover extended, and green fallowing (uncultivated land) is being promoted
- Maximum amounts established for spreading of sewage sludge on land based on heavy metal content
- Change in composition of feed to reduce amount of nutrients and heavy metals
- Research and implementation of means of reducing ammonia loss

Costa Rica, Colombia, and Nicaragua: pesticide reductions through best agricultural practices for pineapple and banana cultivation

Three GEF/UNEP RepCar[6] projects in the Caribbean (UNEP 2011a) towards applying best agricultural practices in pineapple and banana farms gained the following lessons in reducing the pesticide use:

- In banana cultivation, the achieved pesticides reduction was 33% of nematicides and 100% of herbicides, corresponding to 7.6% of all pesticides applied in bananas compared with conventional management practices. Although the cost-benefit analysis showed negative balance in the short term due to the initial cost of establishing the system, it is predicted to reverse once the system becomes more stable over the years.
- To mitigate the runoff of pesticides to water bodies, vegetation cover was established in the drainage channels and buffer areas. To complement the full recovery of the plantation, work was done toward improving soil and root health by reducing the use of synthetic fertilizers and applying calcium, non-acidifying nitrogen sources, organic matter, and organic substrates highly colonized by beneficial microorganisms.
- In pineapple cultivation, the achieved pesticides reduction was 70% of nematicides and 100% of herbicides in the control group (35% on average over the entire cycle), 70% of fungicides, and 55% of insecticides. This represented 40% of all pesticides applied in pineapples. The cost-benefit analysis showed a reduction in the costs of alternative pest treatments due to the decrease in applications (both supplies and labor costs); these represented 66% and 45% respectively of the costs of the conventional treatments.

Thailand, China, Vietnam: livestock waste management technological solutions

The GEF/IBRD Livestock Waste Management (LWM) in East Asia project helped develop pollution mitigation technologies in China, Thailand, and Vietnam. It improved pollution control practices and regulations; altered the spatial distribution of livestock production facilities; raised awareness and promoted information exchange on pollution threats and health problems from livestock waste. A total of 58 LWM systems supported by 10 proven LWM technological packages were constructed - covering composting, aeration processes and anaerobic digestion technologies - with 92 training courses and workshops held at national, provincial, district to commune levels for about 9,000 participants. The project developed country-specific replication strategies to guide the process into the future. The project reduced impacts of livestock-induced pollution in fresh and marine surface waters and risks to human health through an estimate reduction of 3,600 ton of P, 6,200 ton of N, 41,100 ton of BOD was avoided from discharges into the South China Sea.

Australia: reducing nutrient runoff through improved sugarcane cultivation practices

As part of a global partnership between the Coca-Cola Company and the WWF to conserve freshwater resources, Project Catalyst in Australia engages farmers to improve sugarcane cultivation practices, while measuring impacts on freshwater and reef ecosystems. The goal was to halve nutrient runoff to freshwater catchments in five years, and to use acquired knowledge of sustainable farming for replication and scaling globally. Project commenced in 2009 with 19 cane farmers and 4,800 ha of land and expanded more than four times. It has improved the water quality of 101,725 megaliters (26 billion gallons) of runoff and provided the following annual load reductions to the Great Barrier Reef: particulate nitrogen - 72 tons; particulate phosphorous - 34 tons; dissolved inorganic nitrogen - 64 tons; filterable reactive phosphorus - 13 tons; pesticide - 551 kg.

Chesapeake Bay, US: nutrient trading and nutrient runoff reduction

During 2001-11, four Chesapeake Bay states - Maryland, Pennsylvania, Virginia, and West Virginia - introduced nutrient trading programs to provide wastewater treatment plants with flexible options for meeting and maintaining permitted nutrient load limits. Through these programs, wastewater treatment plants may purchase credits or offsets generated by other wastewater treatment plants or farms that reduce the nutrients they release to impaired water bodies. States are also exploring options for construction and urban stormwater programs to buy and sell credits and offsets.

[6] REPCar = Reduciendo el Escurrimiento de Plaguicidas al Mar Caribe, or Reducing Pesticide Runoff to the Caribbean Sea

Marine Litter

Arguably, solid waste reduction (particularly plastics) is mainly a regulatory and policy issue.[7] Meaning the solution lies in providing an enabling environment for a new technology, investing in waste management infrastructure, and changing consumer behavior. An example of such regulatory plastic reduction attempt is the adoption of first-ever Europe-wide strategy on plastics in 2018.[8] The strategy envisages recycling of all plastic packaging by 2030, reducing consumption of single-use plastics and restriction of the intentional use of microplastics. Another example is the G20 action plan on marine litter as of 2017, which aims to prevent and substantially reduce marine litter by 2025. Reducing the use of substances of concern and substituting them with less harmful alternatives is the first step of the waste hierarchy: prevention, which includes production and consumption. Marine litter solutions presented below are built into the plastics value chain: (1) production and consumption of plastics (upstream measures) and (2) collection, recycling, conversion and disposal (downstream measures).[9]

(1) Production and consumption

Promoting better materials for packaging and single-use applications, as well as innovative products for multiple reuse and recycle can reduce about 30% of plastic packaging that would otherwise never be reused or recycled (World Economic Forum and Ellen MacArthur Foundation 2017). Policy mechanisms for packaging solutions include packaging directives, product bans and taxes, and extended producer responsibility, EPR (SAIC 2012). The latter aims to decrease a total environmental impact of a product by making the manufacturer responsible for the entire life cycle of the product and especially for the take-back, recycling, and final disposal.

Preventing waste can be also addressed via discouraging unnecessary consumption through the classification measures, public awareness and economic incentives. Classifying the most harmful plastics as hazardous would empower regulatory agencies to prevent accumulation of marine debris (Rochman et al. 2013). The United States, Europe, Australia, and Japan classify plastics as solid waste, treating them like food scraps or grass clippings – despite their harmful effects, toxicity, and ability to absorb other pollutants. Heightened public awareness can change behavior through increased public access to rivers, streams, and beaches. Additionally, through public land and use management programs, governments can buy conservation easements along the river/coast that prohibit development and require new developments to control pollution stringently.

Economic incentives include: product take-back/buy-back programs[10] for items such as electronics, tires, plastics bags, and packaging waste, providing access to low-cost, recyclable inputs for future operations for the manufacturer; environmentally preferred purchasing programs - voluntary or mandatory for government agencies and corporations, effectively stimulating demand for recycled content products; and product bans and taxes. Funds generated can support environmental programs, including recycling or other waste activities. Plastic bags (LDPE) and styrofoam (polystyrene-PS) are the most common plastic products subjected to bans and taxes.

Solution Examples

Extended producer responsibility (EPR), packaging directives, and product redesign

- More than 35 countries worldwide and several Canadian provinces have adopted EPR policies on packaging waste and printed paper (SAIC 2012).[11]
- The State of California began implementing the Rigid Plastic Packaging Container Law in 1991. Manufacturers must meet one of five product requirements: (i) min of 25% post-consumer material generated in California; (ii) weight reduced by 10%; (iii) refillable five times; (iv) reusable five times; (v) 45% recycling rate.
- In 2018, the number of companies working toward 100% reusable, reusable, recyclable or compostable packaging by 2025 or earlier has grown to 11 – Amcor, Ecover, Evian, L'Oréal, Mars, M&S, PepsiCo, The Coca-Cola Company, Unilever, Walmart, and Werner & Mertz - together representing more than 6 million tonnes of plastic packaging per year.

[7] Many policy solutions in this section are drawn from Plastic Marine Litter and the Mitigation of Land-Based Sources report prepared by Ocean Recovery Alliance under the GPO partnership and the PMEH program

[8] European Commission press-release on the first-ever Europe-wide strategy on plastics, http://europa.eu/rapid/press-release_IP-18-5_en.htm

[9] Private and investments solutions are largely drawn from the Sea of Opportunity report, 2017

[10] Product Takeback presentation, at http://www.ce.berkeley.edu/~horvath/NATO_ARW/FILES/Klausner.pdf

[11] EPR is a policy mechanism that shifts financial and/or physical responsibility of managing products at the end of their useful life away from local government and onto product manufacturers.

- WalMart introduced a scorecard in 2006 for suppliers to self-evaluate against their peers based on packaging innovation, recycled content, product-to-package ratio, and recovery value. WalMart has reduced waste in its US operations by 80%+ and returned more than $231 million to its business in 2011.
- Aveda committed to use post-consumer recycled content in all packaging.
- LEGO committed in 2015 for the next 15 years to find more sustainable plastics both for packaging and to replace ABS as the single material used to make LEGO bricks.[12]
- Several organizations won the 2018 Ellen MacArthur Foundation competition for new recyclable and compostable packaging solutions: (i) the University of Pittsburgh and Aronax Technologies Spain used nano-engineering to mimic the way nature uses molecular building blocks to create a large variety of materials; (ii) the VTT Technical Research Centre of Finland created a compostable multi-layer material from agricultural and forestry by-products, while the Fraunhofer Institute for Silicate Research developed a fully compostable silicate and biopolymer coating for a range of food packaging; (iii) Full Cycle Bioplastics, Elk Packaging and Associated Labels and Packaging created a compostable, high-performance material from agricultural by-products and food waste to pack products varying from granola bars to laundry detergent.

Plastic bag bans

Governments all over the world have acted to ban the sale of lightweight bags, charge customers for lightweight bags and/or generate taxes from the stores who sell them. The Bangladesh government was the first to do so in 2002, imposing a total ban on the bag. The trend is growing and currently plastic bags are banned in Rwanda, China, Taiwan, Macedonia Mexico City, Rwanda, UK (Modbury), Yangon (Myanmar), China (restricted use), Bangladesh, Australia (12 towns, including Sydney)[13] and most recently (August 2017) Kenya. Other places have discouraged use of plastic bags through financial means rather than a ban. Italy, Belgium, and Ireland have taxed plastic bags since before 2008. In Ireland, plastic bag use dropped by 94% within weeks of the 2002 ban. In Switzerland, Germany, and Holland, plastic bags come with a fee. In US, the bans were adopted in California, coastal North Carolina, and the cities of Portland, Austin, Seattle and Chicago; while Michigan, Arizona and Missouri states prohibit local governments from banning plastics bags, justifying it as protecting businesses from additional regulations.

Reusable coffee cups

- In 2014, Hamburg, Germany, introduced refillable cups from biodegradable material that can be returned to any shop in the network for a refund. Customers can also buy the cup with their own fitted lid. In New York, in 2014, students came up with a cup-sharing program that allows members to drop off their empty mug in a collection bin near the subway or at another cafe. The cup's lid acts as a membership card.
- The UK opened two specialist plants for recycling coffee cups in 2013, followed by the establishment of Simply Cups to help businesses segregate and transport their cups to these plants. As a trial, Simply Cups has been collecting cups from a few working Costa, Pret A Manger and McDonald's stores, with expansion planned into 2,000 stores. Having coffee cup recycling points in town centers is another possible solution, piloted in Manchester with large bins for the collection of cups. Waitrose, Greggs, KFC and other coffee retailers have financially supported the campaign. Yet there still needs to be greater cooperation and investment from businesses to solve this problem, especially bigger businesses.

(2) Collection, recycling, conversion, and disposal

There are three main issues around collection. First, **optimizing collection and street sweeping** includes vehicle routing, frequency of collection and street sweeping (based on litter loading and climate patterns), use of appropriate technologies (vehicles, hand carts), and properly sized bins/bags. Second, **supporting the informal waste sector** involves offering training and micro-loans to help waste pickers, who are mostly women, to establish SMEs. Enhancing recycling, repurposing ("upcycling"), and composting to better capture waste at each stage of the value chain provides income for vulnerable populations in lower-income countries. Third, **clean-up campaigns and litter collection education can combine with increased convenience**, such as bin placement in strategic public places, single stream recycling and drop-off centers. Clean-up campaigns, whose benefits are temporary, should occur in parallel to waste prevention strategies.

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[12] Fisher, G., Lego says its plastic pieces will be made with sustainable material by 2030, in Quartz. 2015, http://qz.com/437264/lego-says-its-plastic-pieces-will-be-madewith-sustainable-material-by-2030/

[13] How Many Cities Have a Ban on Plastic Bags? Rachel Cemansky, http://people.howstuffworks.com/how-many-cities-have-a-ban-on-plastic-bags.htm roduct Takeback presentation, at http://www.ce.berkeley.edu/~horvath/NATO_ARW/FILES/Klausner.pdf

Incentives and methods for reduction, reuse and recycle:

- **Bottle bills**[14] or container deposits, promote recycling or reuse by incentivizing the voluntary return of beverage containers to retail centers, redemption centers, or depositories
- **Advanced disposal fees** put a surcharge on consumer goods to subsidize the otherwise cost-prohibitive action of recycling the product at its end of life.
- **Variable pricing for waste generated, also known as pay-as-you-throw, and unit-based pricing** - including resident's property taxes or a fixed monthly bill - drives customers to reduce the amount of waste they generate through billing structures that increase as the amount of solid waste thrown away increases.[15]
- **Variable rate pricing for waste reduced, also known as pay-for-success model** - mean the borrower (municipality or NGO) repays a debt with (lower) rates based on the (higher) project's success. For example, a municipality could issue an impact bond to fund the growth of zero waste-based informal waste collection. With funds from an impact bond, the municipality could pay for training and infrastructure upgrades. It would repay the loan based on the program's ability to save money in the long run from reducing waste generated.
- **Recycling penalties, rewards, rebates, and waste collection cessation** can increase compliance with mandatory or voluntary source separation programs. Penalties, rewards, and rebates are applied to a generator's waste bill, depending on whether the generator meets minimum recycling requirements. Rewards often are in the form of coupons to local business. Waste collection cession programs discontinue service to generators that fail to comply until they change their behavior.
- **Tax abatements** for recycling and waste processing facilities that generate renewable energy can incentivize developers to construct new sites.
- **Environmentally preferred purchasing programs - voluntary or mandatory** - can be applied to the large purchasers of goods, such as government agencies and corporations, effectively stimulating demand for recycled content products.
- **Disposal bans** - prohibit the landfill disposal of certain types of materials, but require that recycling infrastructure and markets are in place. In the absence of markets for banned materials, and stringently enforced laws on dumping, waste can be hauled outside of the ban's boundaries or be illegally dumped, creating even larger problems for a community.
- **Disposal limits** incentivize recycling and can limit the number of bags per week collected or on the capacity of bins used. While this policy can drive generators to recycle more waste, it must be supported by effective recyclables collection. Otherwise, generators that produce excess waste may seek alternative disposal methods.

In collection, litter traps can collect litter not captured through street sweeping, waste collection, or storm drain grate systems. Grates on storm drain inlets in high litter-loading areas may require retrofits, installation, and regular cleaning, but are often less expensive than downstream interventions. Improving port reception, which lack proper facilities and treatment in many low- and middle-income countries, would also be beneficial. Developing organics management programs that separate dry and wet wastes at the source improves the quality of both organic waste (wet) sent to aerobic or anaerobic processing and recyclables (dry waste).

Integrated waste management solutions- combining various methods of Collection, recycling, conversion, and disposal - are especially important for countries with low rates of waste capture and high leakage in areas of Southeast Asia, Africa, and Latin America. Integrated solutions comprise collection, recycling and repurposing, and conversion and disposal.

Solution Examples

Separation of organic materials during collection

In 2009, San Francisco became the first US municipality to universally require separation of organic material for composting. This was part of its ambitious goals to reduce greenhouse gas generation and achieve zero waste by 2020. By 2014, San Francisco was diverting 80% of waste from landfills through recycling and composting.

Trainings and micro-loans for women waste pickers

- **In Pune, India**, Solid Waste Collection and Handling (SWaCH) is the first wholly-owned cooperative of self-employed waste pickers. Pune's waste pickers are more than 90% women from the lowest caste (Dalit or "untouchables"), and most are the sole breadwinners for their families. In 2008, SWaCH partnered with the Pune Municipal Corporation for door-to-door garbage

[14] Bottle Bill Resource Guide at http://www.bottlebill.org/about/benefits/litter/bbstates.htm
[15] Skumatz 2002.

and recycling services for the city. This arrangement provides better working conditions (protective gear, rolling bins, and even some motorized carts or trucks) and workers can make the same or more money in fewer hours compared to other jobs.[16]

- **In the Philippines,** the Payatas Environmental Development Programme and Vincentian Missionaries Foundation provided the women with micro-loans and waste-specific business consultancy and extension services, which resulted in several successful SMEs.

Cleanup and recycle banks

Plastic Bank, the Vancouver-based for-profit social enterprise pays poor people to pick up plastic from waterways, canals, beaches, and other access points to oceans. They redeem the items at collection centers for money, and goods and services like cooking fuel and phone charging. After testing a small project in Lima, Peru, Plastic Bank is rolling out a larger project in Haiti with plans for Brazil and Indonesia as well.

Repurposing waste for social impact or new products

- **In Ghana**, the Recycle Not A Waste Initiative, "Recnowa," trains street youth, people with disabilities, and women from urban slums to use waste plastic to create hand-crafted eco-friendly products, sold in international markets.[17] Similar programs exist in other **African, Asian, and Latin American countries.**
- **Adidas and Parley for the Oceans** created a running shoe made from plastic reclaimed from the ocean around the Maldives.
- **Method** combined reclaimed ocean plastic and post-consumer recycled plastic to create bottles for its two-in-one dish and hand soap.
- **Italian firm Aquafil** is using reclaimed discarded nylon fishing nets as feedstock for carpeting and to make clothing, including swimsuits.
- **Bureo** makes skateboards and sunglasses from fishing nets dropped off at its collection sites in coastal Chile.

Recycling of fishing gear

Recycling and repurposing is part of the complex fishing gear solution, which has three parts: (i) Losing less gear through marking to identify ownership and using new technology to avoid unwanted gear contact with seabed and to track gear position; (ii) using gear products that biodegrade; and (iii) marinas or others providing incentives for fishermen to collect gear they find. For example, **the Global Ghost Gear Initiative** addresses lost and abandoned fishing gear worldwide, and **the Net Works program in the Philippines** aggregates fishing nets collected by local people for an income to make carpet at Interface. Likewise, the **Steveston Harbor Net Recycling Initiative** collects nets and ships them to an **ECONYL plant in Slovenia** to be made into carpeting and clothing. In the US, NOAA MDP sponsors Fishing for Energy where nets are collected from marinas and then combusted for energy recovery in Hawaii and on mainland United States.

Microfiber capture in washing machines

Synthetic fabrics such as polyester may shed microfibers at any time, however, the wash cycle has been identified as both a moment when fibers are more readily shed and more readily collected. This is especially important as wastewater treatment does not clean all microplastics out of the water before discharge back into the environment. The Rozalia Project is bringing a microfiber catcher device to market to address this issue. The device can capture microfibers in the washing machine prior to the rinse cycle and prevent them from washing into the sea.

Plastics waste management in Bogota, Colombia

In 2012, Bogota launched the Basura Cero (Pollution Zero) program to achieve zero waste within 15 years. It has already achieved visible results, including new treatment facilities and incorporation of informal recycles, but it faces challenges. See Annex 5 for details and next steps.

The following plastic reduction recommendations from the GPO Colombia Magdalena-Basin Plastic Waste Management Pilot Program in Colombia would be useful for other geographies:

- Enhance coordination with relevant policy making and regulatory departments.
- Measure and classify solid waste streams, including by conducting formal litter studies[18] that measure the

[16] Carr, C. Untouchable to indispensable: the Dalit women revolutionizing waste in India. 2014 November 18, 2016]; Available from: https://www.theguardian.com/global-development-professionals-network/2014/jul/01/india-waste-picking-women-waste-cities-urban
[17] Recnowa. [cited 2017 January 23]; Available from: http://recnowa.org/
[18] A formal litter study identifies critical sources of litter (direct dumping, storm drains, landfills, etc.); identifies key polluters (specific communities, industries, etc.); quantifies litter (by weight, volume, and number of pieces) flowing at certain points of and from the river basin; quantifies plastic litter (by weight, volume, and number of pieces) flowing at certain points of and from the river basin; classifies litter (percentage by weight) by material type (paper, plastic, metal, garden, etc.) and resin type (PP, PET, PVC, etc.) flowing into and from the river basins; accounts for seasonal variation in litter flows; and establishes a model for projecting litter loading rates from other riparian or coastal cities.

composition of waste streams and determine their points-of-inflow to river basins.
- Stimulate demand for recyclable post-consumer plastics by helping recycling cooperatives capture and deliver more consistent and larger volumes of clean, plastic feedstock.
- Enhance regulations and their effectiveness.
- Increase public awareness.
- Improve collection and street sweeping services.
- Increase nationwide processing capacity for post-consumer plastics.
- Expand collection of post-consumer plastics in rural communities.
- Evaluate EPR policies and financial incentives that divert plastics from landfills and increase recycling (packaging directives, advanced disposal fees, bottle bills, recycling rebates, etc.).
- Install secondary control measures along main rivers and their tributaries.

Zero Waste in the Philippines

Several municipalities in the Philippines are investing in comprehensive zero waste systems:

- The City of Fort Bonifacio in Taguig established effective systems, built necessary infrastructure, created supportive policies, and inspired constituents to cooperate. All households are now covered by door-to-door collection.
- The City of San Fernando in Pampanga has a city-wide separate collection, recycling, and composting system, and has achieved high participation and a 73% diversion rate. San Fernando has saved almost 80% of the costs of its “collect and dump” model.
- In the City of Malabon, Mother Earth Foundation (MEF) has worked in the low-income, industrial Barangay Potrero, which was rife with illegal waste dumping, to establish Material Recovery Facilities (MRFs). It has reached 89% compliance with 65% waste diversion in less than a year. Building on this success, MEF is pursuing scale-up work in other cities in Metro Manila.

Responsible waste-to-energy (WTE) conversion solutions[19] has many methods, with the incineration being the most common. However, this category also includes other forms of thermal conversion of waste, such as gasification, pyrolysis, and plasma arc technologies. Although not directly WTE, byproduct gases generated from waste (e.g. through anaerobic digestion and landfill gas), can be used as a source of energy as well.

There are divergent views on the economic and environmental viability of WTE technologies, including on their impact on human health. In some contexts, WTE facilities may be able to use waste to generate energy in a ‘double win’ for municipalities. In other cases, problems with energy generation, environmental outcomes, or financial weakness have led to the failure of some WTE facilities, often with serious consequences for the municipalities that supported them. There are also concerns that WTE discourages waste reduction as waste becomes seen as a needed feedstock. There is a need for more advanced technologies for cleaner, safer, and more economically sound WTE, though they will require time and funding to be tested and scaled.

Waste to Worth project by Procter & Gamble

Waste to Worth (W2W) seeks to end consumer and manufacturing waste from landfill in low- and lower-middle-income regions. It leverages multiple technologies to extract the value from waste - energy, fuels, gas and recyclables - for the local economy, while developing sustainable and economically viable waste infrastructure. It has four major projects in planning and development in the Philippines, expected to mitigate over 1,200 tons per day of municipal solid waste. Additional projects are expected to mitigate 1,600 tons per day in the Philippines and Indonesia.

[19] Section taken from the Sea of Opportunity report. *Please note: waste-to-energy investments require extensive due diligence to assure their economic and environmental viability. There is much debate on the role of WTE in waste management and it is outside the scope of this report to determine exactly where, how, and with what existing or new technologies WTE may make sense, but they are considered a potential solution.

Cost-Benefit Analysis

Cost-benefit (or cost-effectiveness) analysis (CBA) covers a wide range of criteria from financing to level of skills and resources, environmental friendliness, regional applicability, cultural acceptability, and barriers to entry. This section compiles CBAs to date, focusing on several of these criteria.

Wastewater

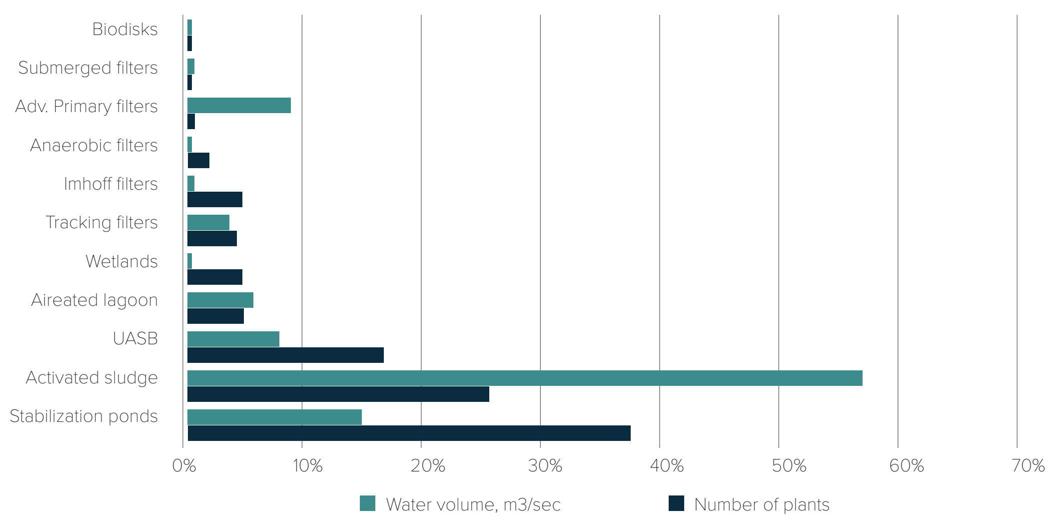
Prevention is the highest priority on the cost-benefit scale among wastewater pollution management strategies, which includes reducing production and flow of wastewater. The second priority is the treatment itself, either off-site or on-site (Table 3).

The assessment in Mexico, Colombia, Guatemala, Dominican Republic, Brazil, and Chile (Noyola et al. 2013) of wastewater technologies most frequently used among the installed treatment plants showed **stabilization ponds as dominant technologies, followed by activated sludge**. These two also dominated when technologies were compared in terms of cumulative volume of treatment (with total treated flow at 181 m3/s, or approximately 20% of the total wastewater discharge) (Figure 8). Most treatment plants in the countries analyzed were small; medium-sized plants were the majority only in the Dominican Republic.

Table 3. Wastewater treatment systems

Priority	Main System Approach	Examples
Highest	Flow reduction (prevention)	Elimination of extraneous flows; reduction of wastewater flows; wastewater recycle/reuse system[20]
Lowest	Off-site systems (centralized or de-centralized)	Primary (mechanical), secondary (chemical), and tertiary (biological) treatment
		Aquatic systems: facultative lagoons, constructed wetlands, sand filters
		Terrestrial systems ("zero discharge" systems)
	On-site systems (several smaller units serving individual houses, clusters of houses, or small communities)	Pit latrine, pour-flush latrine, composting toilet, septic tank, evapo-transpiration bed, tile field, soakway pit

Figure 8. Number of wastewater treatment plants and flow volume by plant type, m3/sec (in Mexico, Colombia, Guatemala, Dominican Republic, Brazil, and Chile)



Source: Noyola, Morgan-Sagastume, and Güereca (2013).
Note: Technologies are ordered according to the number of installed plants. UASB = Upflow Anaerobic Sludge Blanket.

[20] For specific examples, see e.g. US Environmental Protection Agency (EPA) Onsite Wastewater Treatment Manual 2002, http://water.epa.gov/aboutow/owm/upload/2004_07_07_septics_septic_2002_osdm_all.pdf

In the Wider Caribbean region (WCR), a study conducted by the GEF-CReW Project of several **wastewater treatment systems for the region, provided qualitative assessment of their costs**, environmental effects, and other factors for selecting wastewater treatment systems presented below (Table 4, with additional details in Annex 6).

Table 4. Wastewater treatment systems comparison in the Wider Caribbean region

Appropriate technology	Relative cost	Environmentally friendly
Activated sludge process	High	High
Anaerobic ponds	**Low**	**High**
Biodigester	**Low**	**High**
Biodigester septic tank	**Low**	**High**
Cistern-flush toilet	Low	
Cluster systems	Moderate	Moderate
Composting toilet	Low	Yes
Constructed wetland	**Low**	**High**
Conventional sewerage	High	Moderate
Dual distribution (reticulation) systems	High	Moderate
Ecological sanitation	Low	
Facultative ponds	Low	Moderate
Imhoff tanks	Low	Moderate
Maturation ponds	**Low**	**High**
Membrane reactor	Moderate	High
Mound systems (raised bed)	Low	
Pit latrine	Low	Low
Pour-flush latrine	Low	Moderate
Pour-flush toilet	Low	
Rotating biological contractors	High	Yes
Sanitary bio-latrine unit		Moderate
Septic tank	Low	
Septic tank with evapo-transpiration bed	**Low**	**High**
Sequential batch reactors	High	High
Small bore (settled) sewerage	Low	Moderate
Soakaway (seepage) pit	Low	Low to Moderate
Tile field (with septic tank)	Low to Moderate	Moderate
Upflow Anaerobic Sludge Blanket (USAB) reactor	**Low**	**High**
Ventilated Improved Pit (VIP) latrine	Low	Moderate

Source: GEF-CReW Report 64/2919[21]

[21] Ibid.

The best choice, at first glance, would be environmentally friendly options with low costs. However, this option is not always feasible. As an example, the conventional sewage treatment systems appear expensive to establish and operate, but may be the only feasible option, particularly in big cities along the coast. Moreover, the cost of land is not included in the options that require large space, but is a potential barrier. This underlines the need for analysis that considers local conditions to find the best option.

Construction of a plant for secondary treatment serving 1 million people costs around $100 million in 2009, excluding substantial operation and management (O&M) costs (The World Bank and Scheierling et al. 2010). When compared with the costs of a disease outbreak and loss of crucial ecosystms services due to ecosystem degradation, they are small: in the cholera outbreak of 1991 in Peru, wastewater impact costs (health service, prevention, tourism decline, and exports restrictions) were in the range of $180-500 million in the first year.

Stabilization ponds and tracking filters are widely recognized as the most cost-effective options that comply with World Health Organization standards (Reynolds 2002; Oakley and Salguero 2011). Underground wetlands and the activated sludge are considered the most expensive solutions (Quintero et al. 2007). The favor for stabilization ponds is also based on the fact that inputs can be locally supplied and energy consumption is minimal: an activated sludge plant for 10,000 people would require 1 million kilowatt-hours/year, whereas a stabilization pond would require zero electricity.

Agricultural Runoff

This section provides examples of experiences in best agricultural practices (BAPs) and their costs compared to traditional practices. Agricultural practices vary considerably between regions according to the type of crop, topographic and environmental conditions, rainy vs dry seasons, cultural traditions, etc. Adoption of BAPs is limited by farmers' (poor) knowledge, participation of their harvest in export markets, and lack of consumer interest for agricultural products obtained with BAP (González and Rodríguez 2010).

BAPs benefits:

- Increase and stabilization of profits (higher prices, access to sophisticated markets)
- Cost reduction (lower inventory costs, lower waste, higher efficiency on use of labor and other inputs)
- Legal and behavioral incentives (avoid penalties for environmentally harmful practices)
- Enhancement of human capital (capacity building).

BAPs costs:

- New production techniques that could raise variable costs, reduce yields (less intensive use of agrochemicals), and require capital investments
- The lack of an institutional setting to support adoption
- Human capital not adequate; capacity building required
- High certification costs

In the short term, adoption of BAPs to reduce pesticides could cost more than conventional practices (CORBANA 2011). Production costs decreased when using BAPs for medium-scale pineapple crops in the Caribbean, but not for large-scale production. Costs of applying BAPs to banana plantation increased in the initial investment phase, but are expected to decrease over time. In other studies, the larger the scale, the lower the additional initial investment costs for implementing BAPs.

Whether BAPs produce better results in the short term can depend on parcel-specific conditions, including skilled labor, climate, and other. This is shown during BAPs adaption in banana production in the Caribbean region of Costa Rica (Table 5), which resulted in a short-term loss of $1,860 in Balatana, while in San Pablo the balance was close to zero (-$3.90) (Table 5).

As the balance is computed immediately after adopting BAPs, it includes higher labor costs and capital costs due to adoption of new activities. In the medium term, savings will increase due to even less intensive use, while adoption costs are usually incurred once. Thus, the medium-term balance will favor BAPs, especially when social and environmental benefits are included.

Table 5. BAPs and conventional practices in Costa Rica, May 2010 – March 2011

PRODUCTION	Balatana, Costa Rica		San Pablo, Costa Rica	
	BAPs	Conventional	BAPs	Conventional
Boxes/Ha/Year	2,752	2,763	2,793	2,554
Value/Ha ($7.00/Box)	**19,263**	**19,342**	**19,550**	**17,874**
Difference	-79		1,675	
Additional Expense	2,382		2,279	
BALANCE	**-2,461**		**-604**	
Savings:				
Fertilization Program	450		450	
Weeds Control Program	150		150	
Total Savings	600		600	
GENERAL BALANCE/HA	**-1,861**		**-1**	

Marine Litter

This section compares the economic costs of litter-reducing strategies (see Table 6), and discusses some considerations for pollution abatement. Some strategies need to be combined for the management strategy to be effective. For instance, waste collection may be accompanied by landfill disposal, recycling, or conversion of plastics to fuel. While this information is valuable, more technical detail is needed to estimate costs for a stand-alone strategy. For instance, educational programs seem to have low outreach costs, but more analysis is needed to discover how well they reduce litter.

Table 6. Economic cost of select litter-reducing and plastic waste management strategies

Strategy	Cost (lowest to highest)
Education and public outreach	10-18¢/year
Street sweeping	$101/ton
Waste collection and transportation	$26/ton
Landfill disposal	$27/ton
Plastics to fuel	$127-152/ton
Recycling	$594/ton
Storm drain grates (coupled with street sweeping)	$754/ton
SCS or UWEM type litter traps	$261-783/ton
Other litter traps	$2,611-6,526/ton
Removal of litter by hand from the riverbanks	$2,611-3,916/ton

Source: GPO (2013).

Maximum impact comes from integration of different pollution management techniques, which are spread across collection, mitigation, and conversion (McKinsey and Ocean Conservancy 2015). This integration depends largely on a country's starting point. For instance, the Philippines, with high collection rates, would benefit the most from improving open dump sites or finding alternative treatment options such as gasification facilities. Conversely, Indonesia, which lacks proper collection facilities, would be most affected by improved collection services. The best pollution management strategy targets sources of pollution. For example, educational campaigns and beach cleanups would be the most appropriate solution for pollution caused mainly by visitors during weekends and holidays.

A recent McKinsey study illustrates how integrated measures could reduce plastic leakage to the ocean by around 65% in five countries and by approximately 45% worldwide by 2025 (McKinsey and Ocean Conservancy 2015) (Figure 9).

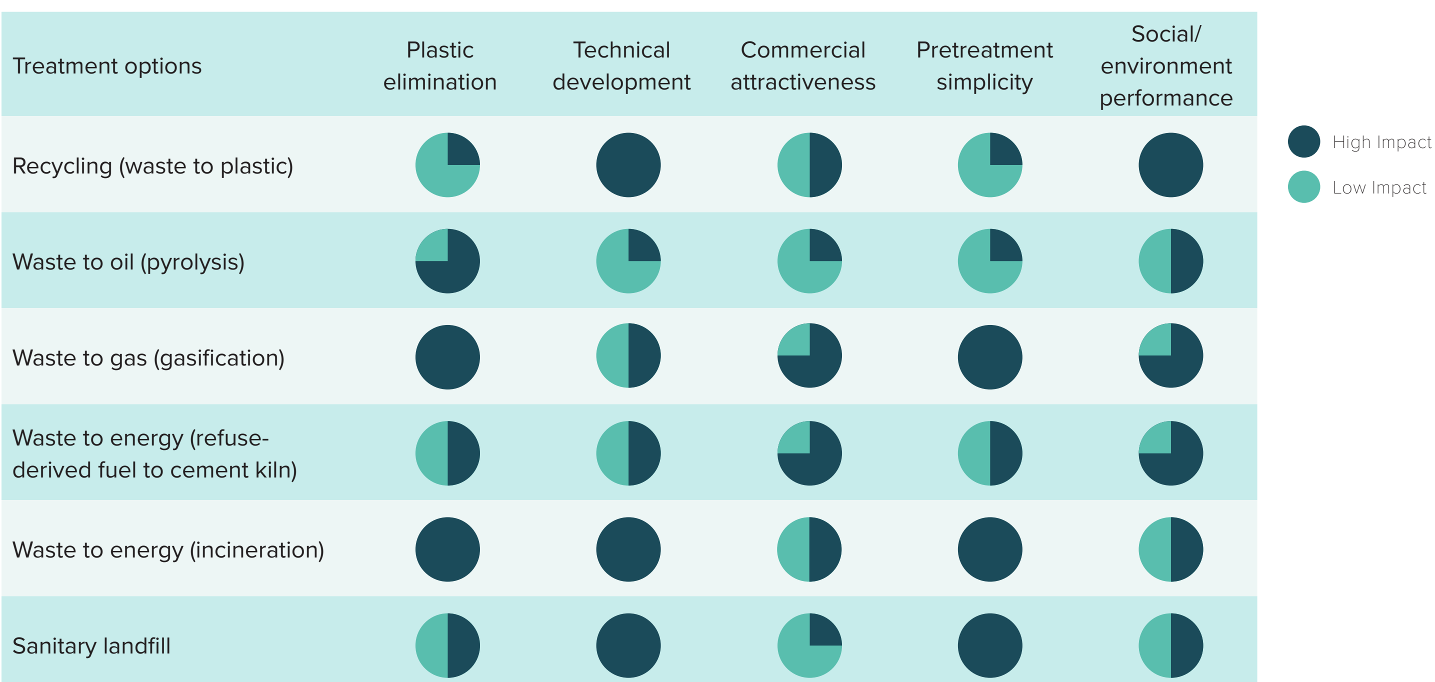
The options for waste conversion are particularly complex, as there are many methods, which are in various stages of development and application. McKinsey evaluated six options against five criteria (Figure 10).

Figure 9. Five measures that could yield the greatest impact across five countries to reduce total plastic leakage by approximately 45%

	China	Indonesia	Philippines	Vietnam	Thailand
Collection services	✓	✓		✓	
Close Leakage points within the collection system	✓	✓	✓	✓	✓
Gasification		✓	✓		
Incineration	✓			✓	✓
MRF- based recycling	✓	✓	✓	✓	✓

Source: McKinsey analysis from McKinsey and Ocean Conservancy 2015.

Figure 10. Comparison of waste-treatment options



Note: Other chemical recycling methods are out of scope as they are not economical. Source: McKinsey & Company and Ocean Conservancy. 2015. Stemming the Tide.

Investors interested in WTE solutions should carefully consider all possible benefits, costs, and risks. In individual cases, WTE has been shown to have life-cycle assessment (LCA) benefits (e.g. energy production and offsets). However, results depend on the definition of system boundaries, functional units, and waste composition, as well as local environmental and regulatory conditions. The costs and environmental burdens associated with air pollution control (APC) or residual (e.g. ash) management are not yet addressed. In most cases, however, WTE facilities are expected to meet all national and local regulations, although these differ and may not exist everywhere. These facilities can cost anywhere from $20 million to over $500 million, depending on their size and technology. Municipalities with inadequate collection systems to accommodate WTE facilities should budget another $5–$50 million.

Recommendations

There is no systematic tracking of a specific ocean pollution indicator, and the geographic sources of marine pollution vary with pollution type. While insufficient wastewater treatment is mainly a problem in developing countries, agriculture is the major focus to reduce nutrient runoff in developed countries. Marine litter (plastics, for this paper) affects everyone.

Addressing the issue effectively requires customized approaches, with a strong deference to local context and regional heterogeneity. The report recommends that countries and their development partners consider the following solutions to improve the health and productivity of coastal and ocean areas.

Wastewater

- **Reduce water usage and recognize the reuse of treated wastewater and wastes from treatment processes as a renewable resource.**
  - Improve wastewater treatment through enhanced sewage technologies, focusing on improving systems that do not operate at maximum capacity, groundwater recharge with treated wastewater, and community control solutions.
  - Promote treated water usage through legal incentives (creation of and transfer of entitlements to the freshwater being released) and economic incentives (compensation for releasing freshwater).
- **In urban areas, adapt different treatment systems to local conditions.** Centralized wastewater systems may be more cost-effective due to restricted land availability (high costs of land). In places with sewage collection infrastructure but no treatment of collected wastewater, the incremental cost of an operating system with both collection and treatment is relatively low.
- **In less densely populated areas with low-cost land available** – that is, without a high alternative value in use for agriculture, forest, development, etc. – consider decentralized treatment systems, which may be more cost-effective than the usual centralized ones.

Agricultural Runoff

Target interventions to regional pollution and agricultural practice (subsistence farming, large-scale intensive monoculture, and cattle grazing) as each gives rise to different problems. Move toward best practices through the following interventions:

- Improve efficiency of fertilizer, manure, and pesticides (amount, time, weather-dependent, etc.
- Adopt improved agricultural growing techniques (planting perennial crops, applying fertilizer/manure/pesticide at correct times to prevent runoff and erosion, and where relevant, grow winter crops.
- Conduct tillages and planting along contours and create buffer zones (to reduce P runoff).
- Consider nutrient trading as a financial incentive to reduce use of polluting products and to provide wastewater treatment plants with flexible options for meeting and maintaining permitted nutrient load limits.

Marine Litter

Adopt existing techniques to reduce plastic waste from polluting the ocean in three areas:

- **Reduction**: packaging directives; product ban/tax; extended producer responsibility; structural controls, and other policies.
- **Collection**: increased convenience mechanisms; collection and street sweeping optimization; litter education programs; cleanup campaigns; litter laws; litter abatement grants; environmental courts; port reception facilities; ocean-based waste collection.
- **Recycling and disposal:** mandatory recycling; recycling or diversion goals; recycling grants; advanced disposal fees; disposal bans; disposal limits; variable rate pricing; bottle bills; product take back/buy back; penalties, rewards, rebates, and waste collection cessation; recycling education; environmentally preferred purchasing; organics management programs; tax abatements; regulatory and financial solutions.

Prevention of solid waste arguably is mainly a policy/regulatory issue. Treatment is both a regulatory and private issue with opportunities for investments across the plastics value chain, across asset classes, and with different time horizons. These opportunities hold tremendous potential for impact on a problem with global implications for the environment and for people.

We hope the review of the status of marine pollution issues along with solution options in this report will help design strategies to improve the health of coastal and ocean areas.

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Annexes

Annex 1 - Acknowledgments

The report was prepared by Olha Krushelnytska (the main author), with great help from Jostein Nygard, who helped design the document.

This report benefited greatly from the technical inputs from the Global Partnership for Oceans (GPO) Pollution Working Group (PWG). The GPO Pollution Working Group was active from October 2013 to January 2015 and represented the following organizations: UN Environment Programme, UN Development Programme, International Maritime Organization, Netherlands Ministry of Infrastructure and the Environment, US Environmental Protection Agency, Global Garbage, State Oceanic Administration of China, Ministry of Climate and Environment of Norway, Ministry of Environment and Sustainable Development of Colombia, Centre for Ecology and Hydrology (UK), Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, Secretariat of the Pacific Regional Environment Programme, Plastics SA (a South African NGO), and the World Bank.

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Annex 2 - Legal and Institutional Content

International law, as reflected in the provisions of the United Nations Convention on the Law of the Sea (UNCLOS) and elsewhere, sets forth rights and obligations of states and provides the international basis upon which to pursue the protection and sustainable development of the marine and coastal environment and its resources.

In accordance with general international law, while states have the sovereign right to exploit their natural resources pursuant to their environmental policies, the enjoyment of such right shall be in accordance with the duty to protect and preserve the marine environment from all sources of pollution, including land-based activities. The provisions contained in Article 207 of UNCLOS, "Pollution from land-based sources," and Article 213, "Enforcement with respect to pollution from land-based sources" were of significance for this paper.

The duty of states to preserve and protect the marine environment has been reflected and elaborated upon in numerous global conventions and regional instruments, including the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change, Regional Seas Conventions, and the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). Innovative new principles and approaches applicable to the prevention of the degradation of the marine environment from land-based activities have been included in several such agreements.

In 1982, the United Nations Environment Programme (UNEP) took the initiative to develop advice to governments on addressing impacts on the marine environment from land-based activities. This initiative resulted in the preparation of the Montreal Guidelines for the Protection of the Marine Environment against Pollution from Land-based Sources in 1985.

The duty to protect the marine environment from land-based activities was placed squarely in the context of sustainable development by the United Nations Conference on Environment and Development in 1992. Paragraph 17.23 of Agenda 21, a voluntary non-binding action plan produced at this conference in Rio, says that states agree that access to cleaner technologies and relevant research, as well as provision of additional financial resources, would be necessary to support action by developing countries to implement this commitment.

International commitments have been made to prevent, reduce, and control marine pollution to levels that are not detrimental to ecosystem function, services, and biodiversity (though specific global reduction targets are still lacking). Since the Rio Conference in 1992, progress has been made in leveling off and even reducing marine pollutants from several sources. However, pollution from nutrients, marine litter, and wastewater continuously worsened from 1995 to 2012, according to the Global Program of Action for the Protection of the Marine Environment from Land-Based Activities (GPA).

The problem of pollution is incorporated in the UN-Habitat mandate and its 2014–19 strategic plan, as well as in the strategic objectives of the Food and Agriculture Organization of the United Nations (FAO). Its Strategic Objective 2 aims to increase and improve provision of goods and services from agriculture, where the key challenges are high levels of pollution that lead to natural resource depletion and degradation and associated cost increases.

In early 2011, in response to growing calls for increased investment and cooperation in healthier oceans, the World Bank reviewed its support for this effort. In September 2011, several governments and organizations convened a side event at the Annual Meeting of shareholders to discuss the possibility of establishing a global support mechanism for healthier oceans. For this reason, in February 2012 at the World Oceans Summit in Singapore, the World Bank announced the interest of several governments, international organizations, civil society groups, and private sector interests to form a Global Partnership for Oceans (GPO), with the objective of promoting healthier oceans that could make a greater and more sustainable contribution to the global economy. The GPO was launched at the Rio+20 Summit in 2012 and stayed active until January 2015. The GPO pollution team, including the international Pollution Working Group, worked during 2012-2015 to meet international commitments and proposals made within, for example, the GPA, including the January 2012 Manila Declaration during the Third Intergovernmental Review of the GPA.

In April 2015, the World Bank established the Pollution Management and Environmental Health (PMEH) program to help client countries significantly reduce air, land, and water pollution levels. The component that focuses on water pollution – Land-Based Pollution Management to Protect Marine Environments – builds on the success of the pollution component of the Global Partnership for Oceans (GPO) and the work of the GPO Pollution Working Group.

Annex 3 - Nutrient Threats and Policy Solutions

	Main nutrient threats	Status of key drivers: Agricultural sources	Status of key drivers: Sewage sources	Key needs for future policies
Sub-Saharan Africa	• Lack of access by farmers to N and P limits food production and exacerbates land degradation • Little investment in fertilizer production, with existing facilities focused on export	Very low per capita consumption of animal products, with low fertilizer and feed inputs; high level of recycling practices, but recycled inputs limited in quantity and quality; available P-rock deposits lack investment to support production	Very low per capita consumption, but lack of policies and implementation of basic water treatment	Commitment to improve infrastructure for adequate N and P supply to farmers, while developing existing recycling best practices and improving NUE
Latin America	• Lack of access by small land- holders to both N and P limits food production, especially exacerbating the degradation of extensive pastureland • Nutrient pollution from intensive farming, urban areas, and sewage affects ecosystem and human health	Social dynamics contrast traditional small landholders with modern agribusiness, leading to uneven fertilizer use; increasing bioenergy production and consumption of animal products, with low fertilizer and feed inputs (grass-fed beef); little focus on low-emission methods	Basic sewage treatment is increasing, as well as per capita consumption, but basic water treatment is not equally distributed in the region	Commitments to improve infrastructure for adequate N and P supply to small landholders, to reduce surpluses, and to increase full-chain NUE (given increasing per capita consumption), including recycling of nutrients from wastes and stabilizing consumption of animal products
Europe and North America	• High pollution impacts on health and environment from N and P losses from combustion, agriculture, and sewage • High exposure to potential risk of future P shortage	Very high per capita consumption of animal products, requiring large fertilizer input and net feed import in many countries; wide range of practices, including adoption of low-emission methods in a few countries	Very high per capita consumption, with basic sewage treatment, but little recycling of sewage N, P and little tertiary N treatment in United States	Commitment to reduce nutrient surpluses and increase NUE in agriculture; recycling of N and P in wastewater; reducing per capita overconsumption of animal products toward environmental and health guidelines
South and Central Asia	• Deterioration of agricultural soils due to underuse, imbalanced use (excess N relative to other nutrients), and overuse • Pollution impacts from N and P on environment and health	Uneven fertilizer use, food consumption shifting from coarse grains to fine grains and from vegetarianism to meat; high level of recycling practices adaptable for emission reduction	Increasing sewage loading due to rising per capita consumption, uneven treatment policies/ strategies, and their poor implementation	Commitment to reduce surpluses and increase full-chain NUE for plant and animal foods, assuming increased per capita consumption, including recycling of nutrients from wastes and stabilizing consumption of animal products
South-East Asia	• Very high pollution impacts on human health and environment from high N and P releases to air, soil, and wate • Varying exposure to potential risk of future P shortage	Rapidly increasing per capita consumption of animal products, with increasing fertilizer and feed inputs; low attention to recycling and low emission opportunities	Increasing per capita consumption, decreasing focus on recycling, and lack of wastewater treatment policies	Commitment to reduce surpluses and increase full-chain NUE for plant and animal foods under the anticipation of increasing per capita consumption

Source: Sutton, M.A. et al. (2013)

Annex 4 - Green Infrastructure Solutions for Water Resources Management

Water management issue (primary service to be provided)		Green Infrastructure Solution	Location: Watershed	Location: Floodplain	Location: Urban	Location: Coastal	Corresponding Grey Infrastructure solution (at the primary service level)
Water supply regulation (incl. drought mitigation)		Re/afforestation and forest conservation	X				Dams and groundwater pumping Water distribution systems
		Reconnecting rivers to floodplains		X			
		Wetlands restoration/conservation	X	X	X		
		Constructing wetlands	X	X	X		
		Water harvesting*	X	X	X		
		Green spaces (bioretention and infiltration)			X		
		Permeable pavements*			X		
Water quality regulation	Water purification	Re/afforestation and forest conservation	X				Water treatment plant
		Riparian buffers		X			
		Reconnecting rivers to floodplains		X			
		Wetlands restoration/conservation	X	X	X		
		Constructing wetlands	X	X	X		
		Green spaces (bioretention and infiltration)			X		
		Permeable pavements*			X		
	Erosion control	Re/afforestation and forest conservation	X				Reinforcement of slopes
		Riparian buffers		X			
		Reconnecting rivers to floodplains		X			
	Biological control	Re/afforestation and forest conservation	X				Water treatment plant
		Riparian buffers		X			
		Reconnecting rivers to floodplains		X			
		Wetlands restoration/conservation	X	X	X		
		Constructing wetlands	X	X	X		
	Water temperature control	Re/afforestation and forest conservation	X				Dams
		Riparian buffers		X			
		Reconnecting rivers to floodplains		X			
		Wetlands restoration/conservation	X	X	X		
		Constructing wetlands	X	X	X		
		Green spaces (shading of water ways)			X		
Moderation of extreme events (floods)	Riverine flood control	Re/afforestation and forest conservation	X				Dams and levees
		Riparian buffers		X			
		Reconnecting rivers to floodplains		X			
		Wetlands restoration/conservation	X	X	X		
		Constructing wetlands	X	X	X		
		Establishing flood bypasses		X			
	Urban stormwater runoff	Green roofs			X		Urban stormwater infrastructure
		Green spaces (bioretention and infiltration)			X		
		Water harvesting*	X	X	X		
		Permeable pavements*			X		
	Coastal flood (storm) control	Protecting/restoring mangroves, coastal marshes and dunes				X	Sea walls
		Protecting/restoring reefs (coral/oyster)				X	

*Built elements that interact with natural features to enhance water-related ecosystem services.
Source: UNEP-DHI/IUCN/TNC (2014, table 1, p. 6).

Annex 5 - Plastics Waste Management in Bogota, Colombia

In 2012, Bogota launched the Basura Cero program to achieve zero waste within 15 years. Priorities included:

- Construction of new treatment facilities and waste collection centers, including a sorting facility and a 40 TPD plastic processing facility, with discussion on the inclusion of plastics to fuel technology, bioreactors, biomass use, composting, and construction and demolition reuse.
- Public education campaigns on source separation.
- Introduction of waste disposal tariffs.
- Formation of strategic alliances with recycling organizations.
- Incorporation of informal recyclers through the establishment of a public recycling company owned and operated by the workers.
- Acquisition of new collection vehicles.

The program has faced some challenges:

- Recyclers break open bags at the curb and select the highest-value materials, leaving behind less valuable recyclables and litter in the streets.
- Cleanup is time-consuming for mixed waste collection crews, reduces collection efficiency, and increases the overall cost of service. Additionally, if street sweeping schedules are not aligned with set-out practices, or if rains arrive before street sweeping occurs, plastics can be washed into local stormwater drains.

By developing **processing facilities and markets for plastics that are not being selected**, Bogota could decrease its amount of street litter and increase the efficiency of its collection fleet. Incentive structures that reward the collection and delivery of non-value plastics should be seriously explored.

Opportunities to c**onvert waste to energy** should be further explored. Cemex operates a cement kiln in Bogota, which could be a potential end-user of post-recycling refuse-derived fuel. Additionally, given the high quantity of plastic film (low-density polyethylene, LDPE) in Bogota's waste stream, polymer-thick film (PTF) technology should continue to be monitored for commercial viability and evaluated for local application. While plastic film is an ideal feedstock for PTF, existing facilities are small (<50 TPD), and therefore PTF will likely be unable to absorb the entire LDPE or other non-value plastic streams.

Based on conversations with plastics reclaimers, the primary constraint to expanding business is access to high-quality feedstock. This will be improved through the **enhancement of source separation programs.** Additional challenges to waste collection are **lack of education, unreliable collection infrastructure (vehicles), enforcement of laws, and the presence of illegal settlements along the river.** Bogota should explore establishing drop-off centers in hot spots along the Bogota River in conjunction with localized education campaigns in illegal settlements.

Annex 6 - Selection of Wastewater Treatment Technology

A study conducted by the GEF-CReW Project evaluated several wastewater treatment systems for the wider Caribbean region, providing qualitative assessment of their costs, effects, and other relevant factors for selecting the appropriate technology.

Appropriate technology	Relative cost (high, medium, low)	Level of operation and maintenance (O&M)	Environmentally friendly	Cultural acceptability	Use in WCR	Potential barriers to implementation
Rotating biological contractors	High	Skilled labor required	Yes	Yes	Not widely used. Used successfully in St. Kitts and St. Lucia	High energy requirement Energy required on a 24/7 basis for bacterial activity
Sequential batch reactors	High	High O&M Requires skilled installation	High	Yes	Limited use. Growing use in Antigua, St. Kitts, T&T, Barbados and St. Lucia	Requires electricity Only receives liquid waste Requires reliable water supply
Membrane reactor	Moderate		High	Yes	Increasing use within the region	Requires electricity Requires reliable water supply
Imhoff tanks	Low	Requires removal of scum and sludge at regular intervals	Moderate	Yes	Limited use in the Caribbean	Effluent requires tertiary treatment
Activated sludge process	High	Skilled labor required	High	Yes	Widely used	High energy requirement for bacterial activity
Constructed wetland	Low	Low. Plants require maintenance/ manual harvesting	High	Yes. Growing	Moderate use (St. Lucia, Grenada, Jamaica)	Large land area Pest/insect control
Anaerobic ponds	Low	Low	High	Yes	Increasing use in the region	Land space Pest and odor control
Facultative ponds	Low	High	Moderate	Yes	Increasing use in the region	Land space High energy use if mechanical aerators are used
Maturation Ponds	Low	Low	High	Yes	Increasing use in the region	Land space
Upflow anaerobic sludge blanket (USAB) Reactor	Low	Low	High	Limited	In Jamaica for agro-industrial wastewater and centralized sewerage systems	Start up time not immediate
Conventional sewerage	High	High	Moderate	Yes	Widely used in major cities	Technology requiring skilled engineers High, reliable water supply
Small bore (settled) Sewerage	Low	High. Skilled Personnel required. Maintenance and cleaning of septic tanks	Moderate	Yes	Increasing use e.g. Grenada	Technology requiring skills Engineers. High, reliable piped water supply
Cluster systems	Moderate	Low	Moderate	Yes	Used in the region	More than one collection and disposal system

Appropriate technology	Relative cost (high, medium, low)	Level of operation and maintenance (O&M)	Environmentally friendly	Cultural acceptability	Use in WCR	Potential barriers to implementation
Dual distribution Systems	High	High	Moderate	Yes	Used in US Virgin Islands, Turks and Caicos, the Bahamas, Cayman Islands	Technology requiring skilled expertise
Cistern-flush Toilet	Low	Moderate		Yes	Used extensively	High, reliable water supply
Pour-flush toilet	Low	Low			Limited use in the region	Requires storage and handling of water
Ecological Sanitation	Low	Moderate			Not widely used	
Pit latrine	Low	Low	Low	Yes	Widely used especially in rural areas	
Ventilated improved Pit (VIP) Latrine	Low	Low	Moderate		Actively promoted	
Pour-flush Latrines	Low	Low	Moderate	Yes	Not commonly used	
Septic tank	Low			Yes	Used extensively	Effluent requires further treatment
Septic tank with evapo-transpiration Bed	Low	Low	High	Yes	Widely used	Large land area required
Biodigester	Low	Low	High	Yes	Widely used (e.g. Jamaica, Guyana, Barbados, T&T, Grenada)	Skilled labor required for construction
Sanitary bio-latrine unit		Low	Moderate	Yes	Limited use in Jamaica in camping sites and inner city and rural communities	Effluent requires tertiary treatment
Biodigester septic tank	Low	Low. Relatively skilled personnel required	High	Yes	Used in Jamaica in single households, apartments and townhouse complexes	Effluent requires tertiary treatment
Tile field (with septic tank)	Low to moderate	Low if constructed properly	Moderate	Yes	Low usage	Large space requirements
Soakaway (seepage) Pit	Low	Low	Low to Moderate	Yes	Used extensively	
Mound systems (Raised bed)	Low	Low		Yes	Low usage in the Caribbean	Large space requirement
Composting toilet	Low	Requires occasional manual removal of finished composting material	Yes	No	Used to a limited extent in Dominica	Time for maturation of compost

Source: GEF-CReW Report 64/2919[22]

[22] Ibid.

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