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Wastewater Pollution on Coral Reefs

Supporting Science Synthesis

prepared by C_2O Consulting in cooperation with the United Nations Environment Programme

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Preface

This science synthesis has been prepared by C_2O (Coasts Climate Oceans) in collaboration with the United Nations Environment Programme through the Global Coral Reef Partnership and the Global Wastewater Initiative (GW2I, one of three global partnerships under the Global Programme of Action for the protection of the marine environment from land-based activities).

It provides a review of the science including sources of wastewater, their impacts on coral reefs including in the context of climate change, as well as management strategies, aimed at advisors, managers and other officials with technical roles in governments, regional environmental organizations, and conservation organizations. It constitutes the science-basis for "Wastewater Pollution on Coral Reefs: Science-to-Policy Brief on Managing Wastewater to Support Coral Reef Health and Resilience" (UNEP, 2017), which summarizes policy and management recommendations. The policy brief and the science-basis presented here can be read in conjunction with each other, or separately.

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Acronyms

DIN……	Dissolved inorganic nitrogen
EPA ……	Environmental Protection Agency
GBR ……	Great Barrier Reef
Gt ……..	Gross tonnage
N……	Nitrogen
N_2 ……	Nitrogen gas
N_2O …….	Dinitrogen monoxide
NH_3 ……..	Ammonia
NOx …….	Nitrogen oxide
Nr …….	Reactive nitrogen
P……...	Phosphorus
PAH ……	Polyaromatic hydrocarbon
PSII …….	Photosystem II
SS……	Suspended sediment
Tg ……	Teragram

Executive Summary

This report provides the supporting science for the UNEP Science-to-Policy brief (2017). It synthesizes the current science on wastewater pollution and coral reefs to inform decision-making and policy globally. This synthesis will support decision-making and capacity building efforts at a regional level under the Global Wastewater Initiative, initially in the Caribbean and Red Sea region, and later in the Pacific region; to strengthen monitoring of wastewater loading and impacts among key stakeholder groups; and to raise awareness through Regional Seas and other relevant mechanisms. The report also provides the foundation and key recommendations for linking wastewater monitoring explicitly to coral reef status and resilience assessments.

A wide range of wastewater compounds, including nutrients, pesticides, trace metals and petroleum hydrocarbons enter reef ecosystems through various pathways and affect reef species and/or life history stages. Many wastewater pollutants, including agricultural fertilizers, pesticides and organochlorine compounds, domestic and municipal wastes, trace metals and petroleum products are now recognized to have adverse effects on coral reefs, even when released at low levels (Haynes and Johnson 2000; Pinto et al. 2003). Understanding their impacts and the species that are sensitive to these pollutants is important for informing management and monitoring.

Key Messages

1. Coral reefs are important ecosystems that millions of people worldwide depend on for food security and livelihoods.
2. All types of wastewater pollution can impact on coral reefs, including sewage, industrial waste, agricultural nutrients, pesticides and other toxic chemicals.
3. Sources of wastewater pollution entering the marine environment are varied, ranging from urban wastewater, terrestrial river runoff, and industrial discharges. These sources can generate a range of pollutants including sediment, nutrients, pesticides, trace metals, hydrocarbons, industrial organochlorines and a range of emerging pollutants such as pharmaceuticals and microplastics.
4. The only documented examples of wastewater pollution having widespread and significant impacts on coral reefs are associated with nutrient and sediment inputs. Other pollutants may be significant at local scales.
5. Wastewater pollution exacerbates impacts on reef ecosystems already under pressure from overexploitation (mainly overfishing), climate change, ocean acidification and other anthropogenic threats.
6. In general, point source sewage or industrial discharges are easier to manage than diffuse agricultural or urban wastewater streams as technological options are available such as deep water disposal or treatment options, e.g. sewage treatment, which are not so easily applied to diffuse sources.
7. Policy solutions include: managing land-based activities that contribute to wastewater pollution, minimizing other pressures on reefs such as overfishing and habitat destruction, and establishing monitoring that can determine key sources of pollution for targeted management.
8. An integrated management approach across the catchment to reef continuum is required to address wastewater issues for coral reef ecosystems.

1. Introduction

Tropical coral reefs are located in shallow waters (< 50 m) in a zone centered along the equator between latitudes 30° N to 30° S due to their specific temperature, water clarity (and light availability) and ocean chemistry requirements (Figure 1). They occur in the Pacific, Atlantic and Indian Oceans, in over 100 countries. Coral reefs cover only 285,000 km^2 or less than 1% of the Earth's surface, yet they contain a disproportionate amount of marine biodiversity. Over 80% of the world's coral reefs are concentrated in Asia and Oceania. Their three-dimensional physical complexity provide habitat and nursery grounds that support high biodiversity and productivity. Reef structures support over 600 species of calcifying corals, 4,000 species of fish, as well as high diversity of invertebrates, macroalgae and marine megafauna (Wilkinson 2008). Coral reefs are not only biologically rich, they also have complex biogeochemical roles in producing sand and limestone substrates and protecting coastal shorelines from storms.

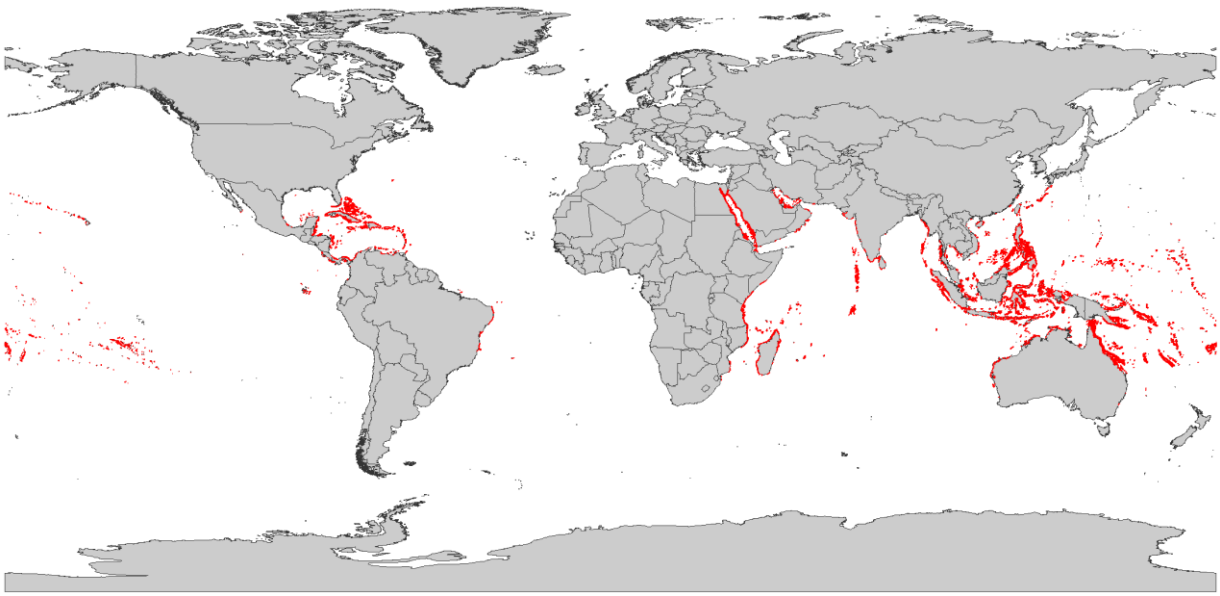

Figure 1. Map of global coral reef distribution. Coral reefs are defined in red. Source: UNEP-WCMC (http://datda.unep-wcmc.org).

More than 800 million people from 109 countries live within 100 km of coral reefs, which provide important sources of ecosystem goods and services for these communities (Donner and Potere 2007; World Resources Institute 2012). Many of these communities are in poor nations living in small islands or rural settings where they are directly dependent on reefs for livelihoods and food security. Reefs produce 10–12% of the fish caught in tropical nations and 20–25% of the fish caught by developing nations in the western Pacific, Indian Ocean, the seas of the Middle East, and the Caribbean (Garcia and Grainger 2005). Recent estimates are of 6 million reef fishers (including gleaners) in 99 nations worldwide, just over 25% of small-scale fishers fish on coral reefs, and 50% of all coral reef fishers are in Southeast Asia (Teh et al. 2013).

Approximately 500 million people depend on coral reefs for food, coastal protection, building materials and income from tourism and fisheries. This includes 30 million who are almost totally dependent on coral reefs for their livelihoods or for the land that they live on (i.e. atolls; Wilkinson 2008). For example, at least 94 nations benefit from reef-related tourism, and reef tourism

contributes more than 15% of gross domestic product (GDP) in 23 of these nations (World Resources Institute 2012). Coral reefs therefore support the socioeconomic well-being of many coastal communities, and their ecosystem goods and services are estimated at between US$100,000 and US$600,000 per km^2 per year (UNEP 2006b).

With millions of people living near coral reefs, it's not surprising that human activities are taking their toll on marine environments. Human impacts have increased along with the rapid population growth, substantial developments in technology, and significant changes in land use. Approximately 75% of reefs around the world have been rated as threatened when local stressors (e.g. overfishing, pollution, habitat degradation, introduced species) are combined with thermal stress due to climate change (Carpenter et al. 2008; World Resources Institute 2012).

Declines in coral reef condition over the past few decades have implications for ecosystem structure and function as well as dependent communities. A global semi-quantitative assessment of social and economic vulnerability to coral reef decline found that greater than 33% of very highly vulnerable countries and territories are in the Caribbean, 20% are in east Africa and the western Indian Ocean, and smaller numbers are found in the Pacific, Southeast Asia, and south Asia. Among the 27 countries and territories rated as very highly vulnerable, the majority (19) are small island states (World Resources Institute 2012). Reducing local pressures on reefs, such as pollution, particularly in small island states is the most effective way to build reef resilience and support reefs in the face of warming seas and ocean acidification.

Areas of high marine species richness are disproportionately concentrated in regions with medium to higher human impacts (Tittensor et al. 2010). For example, approximately 70% of Southeast Asia's population lives in coastal areas and intensive farming and aquaculture, rapid urbanization and industrialization, greater shipping traffic and fishing effort, as well as widespread deforestation and near-shore development, are contributing towards pollution problems. Southeast Asia also encompasses approximately 34% of the world's coral reefs and includes the global hotspot of reef biodiversity – the Coral Triangle – formed by the six nations of Malaysia, the Philippines, Indonesia, Solomon Islands, Timor Leste and Papua New Guinea. The region is also a global hotspot in terms of local threats – overfishing, pollution and coastal development – with almost 95% of reefs assessed as threatened by a combination of impacts, and watershed-based pollution a key driver (World Resources Institute 2012). The need to reduce the impacts of marine pollution in this region is therefore critical (Todd et al. 2010).

The anthropogenic disturbance of the water cycle through reservoir construction, agriculture, deforestation, and urbanization has caused considerable changes in the fluxes of freshwater,