INTRODUCTION
The Marine Water Quality Monitoring Programme (MWQMP) of the Environmental Agency – Abu Dhabi (EAD) initiated with the goal of identifying the potential MWQ threats in order to develop measures to ensure the coastal waters of Abu Dhabi Emirate are safe and healthy for people, plants and animals. Abu Dhabi’s marine waters face potential environmental challenges due to factors associated with urbanisation, industrialisation and tourism. The coastal waters have been exposed to pollutants, including nutrients, organic matter, heavy metals, and microorganisms.

EAD’s MWQMP has collected ambient marine water quality data to monitor its status since 2006. During 2019, 22 sites in Abu Dhabi coastal waters were monitored under the MWQ sampling programme. The data obtained through this programme elucidate the status of various water quality parameters including microbial pollutants and its trend. Long-term monitoring is important for not only assessing the quality of Abu Dhabi’s waters but also allows to develop regulations, policies and implementing strategies to protect marine resources and public health. Present summary report provides insight into the status of the marine environment by highlighting key findings from the 2019 MWQMP.

Responses to these changes in the state of the environment could involve promulgating rules and regulations for activities that cause environmental pressure, expanding the marine monitoring programme, and taking steps to minimise discharge into marine waters.

Impacts in Abu Dhabi include a decline in biotic communities and increases in eutrophication, harmful algal blooms (HABs), bacterial contamination, and contaminated sediments as well as increased costs to desalinate or clean water. EAD and other agencies respond by monitoring and enacting regulations to protect water quality.

The two major driving forces that apply pressures on Abu Dhabi’s marine environment are human population growth and the associated rapid economic development. These drivers create pressures such as discharges into marine waters, atmospheric deposition of pollutants, sediment dredge and fill operations. These pressures can introduce excess nutrients, sediments, and chemical contaminants into marine waters, leading to the decline of water quality and to the loss and deterioration of habitats.

Development and population growth also spur demands for more fresh water from desalination plants and an increased need for wastewater treatment facilities.

EAD employs the drivers, pressures, states, impacts, and responses (DPSIR) model to assess how human activities may affect the environment. Figure 1 illustrates the causal chain that links human activities and environmental pressures to environmental impacts and policy responses.
HARMFUL ALGAL BLOOMS

- When the environment is suitable, the phytoplankton proliferate and produce harmful algal blooms (HAB).
- Some algal species produce toxins, which is harmful to human health and animals.
- HABs are responsible for mass mortalities of marine organisms and closure of public beaches and desalination plants in Abu Dhabi.

MICROBIAL CONTAMINATION

- Results from the discharge of inadequately treated municipal wastewater into the marine environment.
- Contaminated water or seafood can cause gastrointestinal illnesses, respiratory illnesses, and skin infections in people.
- Microbial contamination of beach water affects recreational activities and tourism.

CONTAMINATED SEDIMENTS

- In general, marine sediments act as a sink for heavy metal pollutants and play a vital role in the monitoring and assessment.
- They can accumulate and assimilate heavy metals even from low concentration in the overlying water column.
- Human health is threatened when contaminants bio-accumulate in fish eaten by humans.
- It affects biological activities of the marine organisms, including reproductive functions and possible production of tumours.
2.1 // SAMPLING STATIONS

Marine water quality sampling stations cover the entire emirate, from ecologically important areas to more heavily used areas, important natural habitats and from Abu Dhabi City to the Al Dhafra Region of Abu Dhabi Emirate Figure 2.

- Confined areas
- Public beaches
- Ports and marinas
- Point source
- Desalination plants
- Marine protected areas (MPAs) and natural habitats
- Newly developed and developing areas
- Nuclear power plant
- Reference station
**Figure 2. Sampling site details**

- **Confinned Areas**
  - Stn1- Al Salamiyah Channel
  - Stn2- Mussafah South Channel
  - Stn3- Mussafah Industrial Area
  - Stn4- Mangrove Area - Eastern Corniche

- **Public Beaches**
  - Stn7- Bateen Beach
  - Stn9- Corniche Beach
  - Stn10- Fairmont Beach

- **Ports & Marinas**
  - Stn10- Intercontinental Jetty
  - Stn11- Port Mina Zayed
  - Stn12- Ruwais

- **Desalination Plants**
  - Stn13- Um Al Nar
  - Stn14- Taweelah
  - Stn15- Mirfa

- **MPAs**
  - Stn16- Marawah
  - Stn18- Butina
  - Stn19- Al Yasat
  - Stn1-23- Ras Ghanada

- **Newly Developed and Developing Areas**
  - Stn117- Al Reem Island
  - Stn119- Al Hudayriat Island

- **Nuclear Power Plant**
  - Stn125- Barakah

- **Reference**
  - Stn126- Reference

Note: Mussafah South Channel (Station 104) is a point source and is not included in the indices that capture ambient water quality.
2.3 MATERIALS AND METHODS

Water samples were collected and analysed in Abu Dhabi Quality and Conformity Council’s Central Testing Laboratory using standard methods for nutrients, organic compounds, biochemical oxygen demand (BOD), total suspended solids (TSS), heavy metals, and faecal indicator bacteria (enterococci and faecal coliforms). Concurrently, sediment samples were collected and analysed for heavy metals. Along with the MWQ samples, observations of weather, wind, and water appearance (e.g., colour, odour, tide) were recorded.

2.2 SAMPLING FREQUENCY

The sampling strategy incorporates two types of sampling frequencies. The stations around Abu Dhabi City (i.e., Stations 1–11, 13–14, 107, 117, 119, 123, and 126) were monitored monthly. The stations outside of the city and in Al Dhafra Region (i.e., Stations 12, 15–19, and 125) were monitored less frequently.
Water Quality Indices

Three water quality indices provide summary analytics through a generic Water Quality Index (WQI) method (developed by the Canadian Council of Ministers of the Environment in 2001). The indices are based on three groupings of parameters that represent different aspects of MWQ:

Eutrophication Index
Indicates the level of nutrient over-enrichment of the coastal waters and is based on parameters associated with eutrophication, including nutrients (i.e., nitrate, phosphate, and ammonia), dissolved oxygen, and chlorophyll a.

Microbial Index
Indicates the level of bacterial contamination in marine waters that can pose a threat to public health and is based on the faecal indicator bacteria, enterococci, and faecal coliforms.

Heavy Metals Index
Indicates the extent of metal contamination in marine sediments and is based on parameters that are heavy metal contaminants (i.e., cadmium, copper, lead, nickel, mercury, and zinc) in sediments.

A yearly value for the 3 indices is calculated for each station and a yearly average (presented in this report) is calculated for each of the indices for all of Abu Dhabi coastal waters.

The WQI produces a score between 0 and 100 for each monitoring station for the year. Scores are grouped into condition-rating categories of “Good” (a score of 75 and higher), “Fair” (a score of 50 to 74), or “Poor” (a score of 0 to 49).
EAD monitored 22 stations for 28 water quality parameters and 11 sediment quality parameters. Results from the 2019 sampling programme indicate that the mean concentrations of nutrients were reduced, and the eutrophic nature of the marine water quality was improved than previous years.

The basic water quality parameters such as temperature, salinity, pH, and dissolved oxygen were monitored through in-situ instrument and indicated that the variation between the stations were minimum; except confined areas and point sources. The temperature values fluctuated along with the atmospheric temperature and ranged between 19.22 and 35.78 °C. Since the precipitation was less in Abu Dhabi, the fluctuation of salinity values was insignificant, and it varied between 36 and 46.76 ppt. The pH values were normal (7.9- 8.48). The dissolved oxygen concentration was very low (hypoxic) at bottom waters of confined areas (0.86 mg/L) and high in surface waters of confined areas (9.96 mg/L) due to algal blooms. The chlorophyll values were normal in all stations except the confined areas where the values were fluctuated between 0.29 µg/L (bottom waters) and 45.9 µg/L (surface waters). Water clarity was highest in reference and offshore western region stations.

Results from the 2019 sampling programme indicated that mean heavy metal concentrations in sediment appear relatively stable and elevated concentrations were recorded only in confined areas. Mercury was not detected in water or sediments.

Microbial pollutants were not detected in most of the collected samples in 2019, particularly at the stations outside of Abu Dhabi city. The stations in the confined areas and the ports and marinas had elevated bacterial values.
Eutrophication Index

- In 2019, the eutrophication index annual mean score reached 73 for the first time throughout the years, it is almost touched the index score 75 (100) (Figure 3).
- Overall a significant improvement in the average annual score and increasing 23 points from 50 (Poor) in 2018 to 73 (Fair) in 2019.
- Three stations (Butinah, Barakah and Al Yasat) achieved perfect eutrophication scores of 100, (Table 2).
- The annual average eutrophication score for Taweels (Desalination Plant) Al Reem island (newly developed area), Intercontinental Jetty (Port and Marina) and Ras Chandalah (coral reef) went from Fair to Good.
- For the seventh consecutive year, the Mussafah South Channel showed the lowest score. However, the score was improved substantially, from 13 in 2018 to 33 in 2019.
- All the MPA stations achieved Good eutrophication scores.

Microbial Index

- 19 sites showed microbial index score of 100 in 2019 (Figure 4), (Table 2).
- The stations in confined areas including Mussafah South Channel showed perfect microbial index score of 100.
- Station categories further away from the city (Desalination Plants, Marine Protected Areas, Newly Developed and Developing Areas, Nuclear Power Plant, and Reference) achieved perfect microbial Index scores.
- Scores improved and maintained in all sites except the port and marinas categories, where the scores were fluctuating and decreased from 2018 and categorised as Fair.

Heavy Metal Index

- The heavy metals scores were improved, and records ameliorate trend in confined areas (Figure 5), (Table 2).
- All the sites except Mussafah South Channel (Confined area), Industrial area and Port Mina Zayed (Port and Marinas) displayed high index scores (Good).
- Nuclear Power Plant index score were in decreasing trend. However, the scores were in good category.
- No stations achieved heavy metals scores of 100, compared with previous years (2-7 sites achieved score 100).
Since 2005, EAD has been running the marine water quality monitoring programme in Abu Dhabi coastal waters. The programme supports in meeting EAD's goals for protecting public health and the environment. In 2014, EAD initiated the automated marine water monitoring programme through the deployment of three automated buoys and the network was expanded by eight additional buoys in 2016. Currently, the network consists of 10 stations that continuously monitors MWQ on real-time basis in ecologically important and sensitive sites such as confined areas, beaches, critical marine habitats (coral reef, seagrass and mangroves), newly developed areas and nuclear powerplant area (Figure 6). These buoys measure seven key marine water quality parameters (salinity, conductivity, temperature, pH, dissolved oxygen, chlorophyll and cyanobacteria) every 15 minutes and transmit the data to EAD’s central database every hour. In addition, these buoys allow the MWQP to detect immediate changes and acts as an early warning system for harmful algal blooms (HAB) and marine water quality.
Hydrodynamics and Water Quality Modelling (HWQM) project was initiated early 2019 that aims to build internal capacity and expertise and establish a fully validated HWQ model of Abu Dhabi territorial waters. Building this modelling capacity will support our system holistically to understand the water dynamics and pollutants concentrations as they move through the environment. Especially in a rapidly developing waterfront of Abu Dhabi that includes the commercial, strategic and industrial type of activities, this tool will help determine the source of pollutants and forecast the impacts of any coastal activities. In addition, through a series of long-term trainings, in-house capacity/experts will be confidently able to understand, run, and modify the model as needed by the end of 2020.

The project was launched with a start-up workshop in April where the EAD Modelling Team was given an introductory course in HWQMs. Over the following months the team have been working through a series of task assignments setting the background, objectives and conceptual models for case studies designed to integrate HWQMs into proactive environmental management planning. A review of the literature of HWQMs applied to the Arabian Gulf and Abu Dhabi coastal waters was presented in a follow up workshop in July. A series of workshops took place in October to train in data requirements for HWQMs. Meanwhile, data is being collated and processed into a model ready for calibration of the Abu Dhabi coastal waters.
MARINE WATER QUALITY PORTAL ENHANCEMENT

In response to the need of a common tool to store and access standardised Marine Water Quality data, EAD developed Marine Water Quality Portal (MWQP) in 2014. The goal of the MWQP is to have a single point of data access for internal and external stakeholders. The MWQP is a web-based GIS application which provides various input parameters including location, site, sampling date and other physical, chemical, and biological parameters.

At present, EAD enhanced the capability of the portal to achieve the utmost benefit according to the stakeholders’ needs. The stakeholders are now able to access features of navigation from one location view to another, mark locations of interest by different drawing tools to create a sketch of their work, export map images to files and share them by e-mail. They could also measure distances and areas on the map and viewpoint coordinates, as well as print images of displayed map areas. In addition, it includes data analysis module along with the integration of marine water quality automated buoys to display real time content. EAD conveys the marine water quality indicators derived from long-term monitoring data along with real time information from buoys to the stakeholders for effective decision making.

COMPREHENSIVE ANALYSIS OF MULTIPLE FISH KILLS IN ABU DHABI WATERS

Fish kills are a global phenomenon and can be related to natural and anthropogenic activities. Human activities and coastal development driven by economic growth in countries bordering the Arabian Gulf have increased marine pollution and concurrently the marine ecosystem health is deteriorated, and number of fish kill incidents are increasing. EAD has been investigating fish kills since 2002 and reported the hot spots.

In response to the growing concern on the marine ecosystem management, EAD compiled the results of the fish kill incidents probed for the past 18 years (2002-2019) and analysed the results comprehensively to find out the common causes and consequences in order to develop measures to protect public health and biodiversity. For the past 18 years, EAD investigated 51 fish kill incidents, among them 26 incidents were reported in confined areas, followed by eight incidents in desalination plant areas, five incidents in public beaches and the other four reported were in other areas. Most of the fish kills reported were in confined areas which are heavily impacted by high-density industrialisation and urbanisation including eutrophication, algal blooms, and hypoxia. Major species involved in the fish kills was Nematalosa nasus (99.78 %). The largest number of fish kill events and the highest number of fish killed occurred during the post summer periods months. The main cause of fish kills was found to be low dissolved oxygen concentrations caused by both physical and biological factors. Since the population increase is the main drive for these marine environmental problems, natural resources require additional protection.
In 2019, EAD presented two studies at international conferences. EAD is the first organisation to have studied the HAB cyst distribution in UAE waters. The study included multiple dimensions such as cyst distribution in UAE waters in relation to catastrophic incident in 2008 and 2009 (Cochlodinium Spp. bloom), cyst distribution in relation to eutrophication and cyst distribution in Abu Dhabi territorial waters.

The first paper entitled “Influence of eutrophication on dinoflagellate cyst distribution in Abu Dhabi coastal waters and future aspects” was presented in North Pacific Marine Science Organization (PICES), annual meeting held at Victoria, Canada, from 16-27 October 2019. The conference brought together experts in marine water quality management from the US and abroad, marine water quality researchers, federal-level policy makers, and many others.

The second paper entitled “Dinoflagellate cyst surveys used in management of harmful algal blooms in territorial waters of Abu Dhabi” was presented in 10th US Symposium on Harmful Algae, held at Orange Beach, Alabama, USA, from 2-8 November 2019. The conference brought together experts in HAB management from the US and abroad, federal-level policy makers, HAB researchers, and many others.
This year, EAD’s board approved the marine water quality regulations aimed at maintaining ambient marine water and sediments quality through regulating land-based discharges and implementing anti-degradation requirements through environmental impact assessment studies and permitting processes. This is consistent with Abu Dhabi Plan and EAD strategy. EAD developed the implementation plan as and the communication and outreach plan for the regulations.

The regulations include scientifically based quality specifications for ambient marine water as well as liquid discharges to marine from land-based activities. The incorporated specifications establish goals for marine waters and sediment to ensure the protection of marine environment including its wildlife and biodiversity along the coastline of the emirate.

**PROTECTING AND SUSTAINING MARINE WATER QUALITY IN ABU DHABI EMIRATE (2012 – 2018)**

A book that tells a success story achieved by the Higher Committee for Enhancing Marine Water Quality and the technical team led by EAD was launched during Blue Week in March 2019. It documents the main achievements during the period from 2012 to 2018 in the field of protection and sustainability of marine environment and describes the most important projects and programmes implemented in the last few years.

The legislative and regulatory frameworks in the emirate has been strengthened through the promulgation of policies, regulatory instruments, guidance documents and technical standards.
CONCLUSION

The result of the 2019 MWQ monitoring programme reveals that the marine water quality in Abu Dhabi is generally good. The recreational waters meet public health criteria for swimming and other recreational activities. It is noteworthy to mention that the eutrophication index of the confined areas showed significant progress and that the annual mean value is categorised as Fair (73) but is very close to the Good range (>75). Result of this reduction in eutrophic condition, the harmful algal bloom (HAB) incidents are on a decreasing trend. The water quality of the confined areas shows significant improvement.

WAY FORWARD

• In 2020, EAD will:
  o Study the impacts of two desalination plants on the marine environment with the collaboration of terrestrial and marine biodiversity sector.
  o Pilot a study of micro-plastics in marine environment.
  o Study the influence of MWQ on the bioaccumulation of heavy metals in the flora and fauna of Abu Dhabi waters.
  o Review the marine water quality network.
  o Update the Harmful Algae Identification Manual with distribution maps.