Oxygen-dead zone sites' characteristics analysis and corresponding modified solutions

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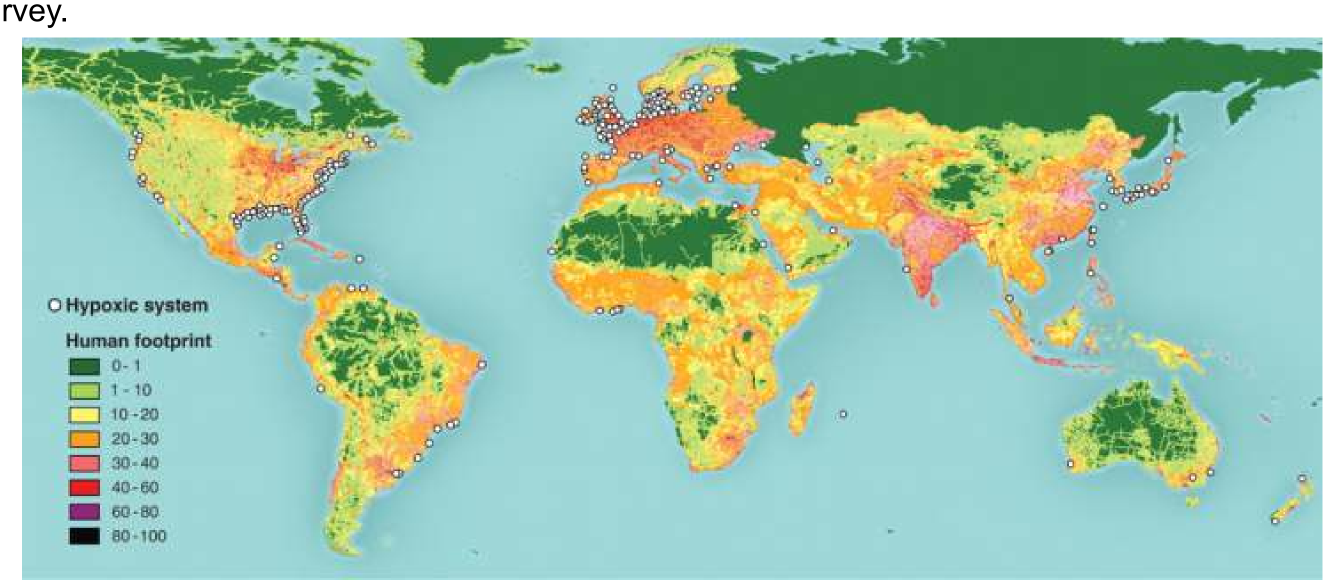
Before reading this article, I want you to ask yourself: Do you know what an "oxygen-dead zone" is?

I randomly asked thirteen 17-year-old teenagers, three teachers in our school, and three adult relatives, who are all Chinese from Shanghai, China, and the answers were all "NO."

I wasn't familiar with the term "oxygen-dead zone" at first either. The first time I saw it was when I was working on a research project regarding ocean protection, and the webpage presented a list of disasters that the ocean is facing, including the oxygen-dead zone. This term seemed fascinating to me due to its wording as it might be something related to… death?; however, I had never seen it before. I then started to briefly google it and found out that the oxygen-dead zone should indeed be taken into account seriously.

An oxygen-dead zone, also called hypoxia, is an area where oxygen levels are depleted (dissolved oxygen < 2 mg/L), and it is mainly called a "dead zone" because most animals either die or leave due to the deficiency of oxygen [1]. There are about 405 oxygen-dead zones recorded worldwide, affecting an area of about 95,000 square miles, which is as big as the area of 316 New York cities [2]. Most of them were formed in the past 50 years. The cause of oxygen-dead zones is called "eutrophication," which is "a process that results from the accumulation of nutrients in lakes or other bodies of water," according to the U.S. Geological Survey.



Eutrophication occurs when nutrients beyond natural levels flow into the water, stimulating significant increases in the growth of algae by fertilizing them with nitrogen and phosphorus. Algae can grow on the surface of the water and deprive the entire body of water below of light, which limits photosynthesis deeper down. The algae produce oxygen primarily on the surface of the water. So even before the algae die off, there is an impact on the plants that need to produce oxygen and the potential to suffocate the fish. And, even though the algae produce oxygen during photosynthesis, the algae have a short life span and eventually die, sink, and decompose at the bottom. This consumes oxygen in the bottom waters as they are decomposed by bacteria, which take oxygen from the water during decomposition. This continuous consumption of oxygen will finally lead to the depletion of oxygen, a phenomenon called the oxygen-dead zone, in the bottom water.

Oxygen-dead zone, however, will cause a huge negative impact on the planet. For effects on humans, oxygen-dead zones will result in a higher cancer rate, a greater chance of getting stomach or liver illness, more respiratory problems, or neurological effects due to the contaminated drinking water [3] [4]. It will also cause unnecessary and tremendous financial costs in dealing with clean water, tourism, surrounding real estate, and fishing [5]. Furthermore, for the effects on the environment, oxygen-dead zones will result in lower fertility rates for certain creatures, greater mortality rates, pollution in the entire food chain of certain areas, increasing amounts of acid rain and air pollution, etc [6]. Therefore, people should raise awareness about oxygen-dead zones and start working on solutions for them as soon as possible.

In this review, I will first present two global sites harmed by oxygen-dead zones. The reason I selected these sites is that they are, or were, the sites that had the biggest overall oxygen-dead zone on the globe and have typical traits. I analyzed the characteristics of these sites by identifying their location, the causation of oxygen-dead zones, recent data on nutrient inputs, the effect on economics and animals, and the ongoing solutions. The literature review will be ended with the collected characteristics of the previous remedies and proposed recommendations of remedy, in light of the many possible solutions already globally recognized.

The first site: New Jersey-size dead zone in the Gulf of Mexico

Location and Size

The oxygen-dead zone in the Gulf of Mexico is located along the Louisiana and Texas coasts, adjacent to the Mississippi River. A research cruise by NOAA found that the Gulf of Mexico oxygen-dead zone was approximately 3,275 square miles on August 3, 2022, which is about 1,187,955 standard soccer fields. It is as large as the state of New Jersey in 2017 when it was measured at 8,776 square miles, which is the largest size since 1985.

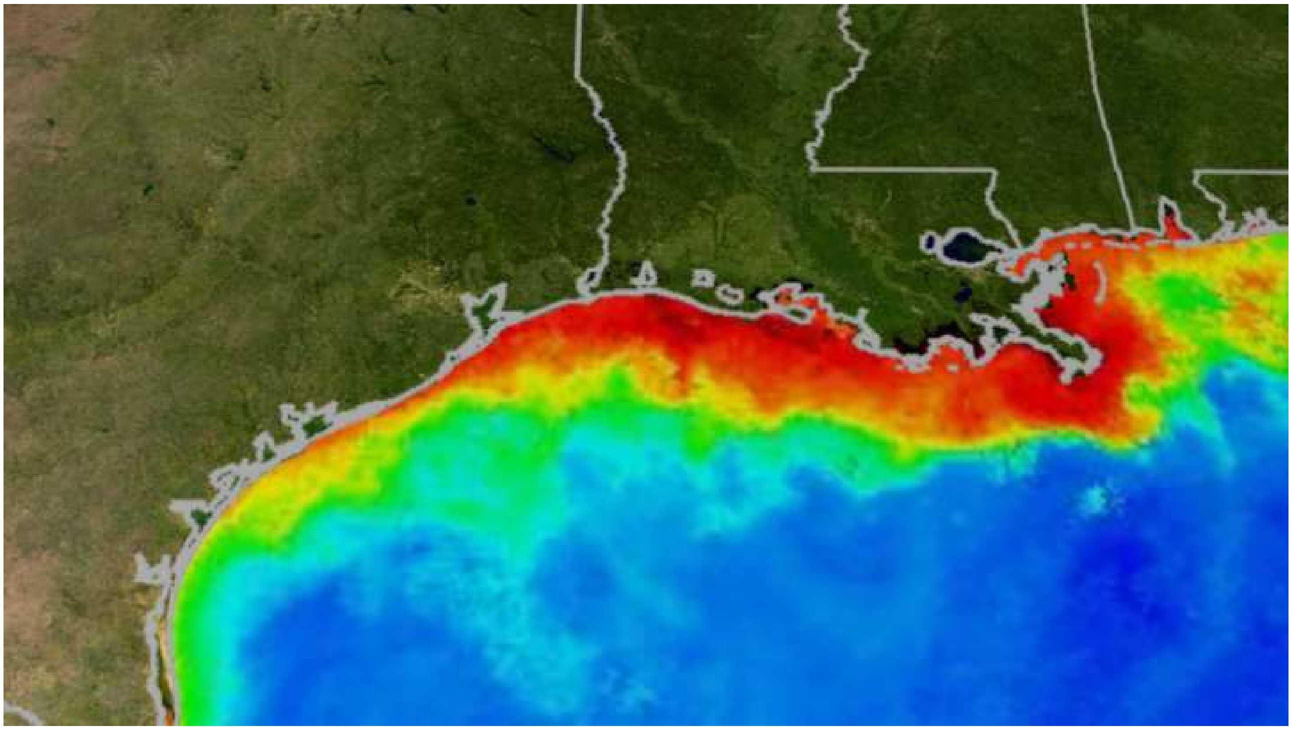


Figure 2. Dead zone area in the Gulf of Mexico in 2010 [7]

Causation

The identified cause of the oxygen-dead zone in the Gulf is the input of nutrients that were applied in agricultural fields along the Mississippi River. According to a study conducted by scientists from the Louisiana Universities Marine Consortium (LUMCON), the high flow of nitrate into the gulf is caused by a large number of agricultural crops. Agriculture along the Mississippi River mainly focuses on soy, wheat, corn, and livestock as the main commodities [8].

Agriculture runoff is caused by rainfall or snowmelt moving over and through the ground. As runoff moves, it absorbs and picks up natural and man-made pollutants that eventually flow through the ground into lakes, rivers, wetlands, coastal waters, and even our underground drinking water sources. For agricultural sewage, some of them were even directly released into the river and water system. Fertilizers and livestock manure contained in the runoff are the major sources of nitrogen and phosphorus, which stimulate algal growth in the marine environment.

The average nutrient load from 2001-2005 shows that 80% of the nitrogen came from Ohio/Tennessee and Upper Mississippi River Sub-basins, and the data also shows that Ohio/Tennessee and Upper Mississippi River Sub-basins were the major contributors to the release of phosphorous to the Gulf of Mexico, with Ohio/Tennessee contributed 38% and Upper Mississippi River Sub-basins contributed 26% [9].

The Mississippi River acts like a street drainage system. It connects 31 U.S. states and even parts of Canada, and the nutrients are eventually transported more than 1,000 miles downstream to the Gulf of Mexico. Besides, tillage and repeated cropping continuously deplete the soil of nutrients, reducing its ability to nurture plants and absorb water. To compensate for damaged soils, farmers use synthetic fertilizers increasingly. While this can temporarily help crops grow, it will further cause more nutrient waste to flow into the water bodies.

Amount and origin of nutrient outflow

According to NOAA, the heavy rain in May 2017, increased the water flow by 34 percent and carried above-average nutrients through the Midwest waterways into the Gulf. “An estimated 156,000 metric tons of nitrate and 25,300 metric tons of phosphorus flowed down the Mississippi and Atchafalaya rivers into the Gulf of Mexico in May 2022”, according to the USGS [10]. The research conducted by Cornell University biogeochemist Robert Howarth shows that in 1998, there were about 1.8 million metric tons of nitrogen flowing in the Mississippi River down to the Gulf of Mexico. Furthermore, studies from USGS suggest that over 60% of nitrates in the Mississippi originated in the Corn Belt north of the Ohio River, with 130 kilograms of nitrate put into the corn per hectare in 1996, in Iowa [11].

Effects brought by oxygen-dead zone in the Gulf of Mexico

- **Economic impacts:**

  Oxygen-dead zones would slow the growth of big shrimp, driving up the price of large shrimp over small shrimp. It was found that in years of severe hypoxia, the percentage of small shrimp sold increased. It also caused a reduction in the growth rate of brown shrimp. Most importantly, because brown shrimp is the largest commercial seafood market in the Gulf of Mexico, when there are years of widespread oxygen deprivation, the economic profits of local fishermen are adversely affected. A report shows that the overall damage to the fishery and ocean habitat is about 2.4 billion annually since 1980 [12].

  Furthermore, the economic cost of treating eutrophicated drinking water is considerable—a USDA study estimated the cost of removing nitrates from the U.S. drinking water supply from all public and private sources is more than $4.8 billion per year [13].

- **Ecological impacts:**

  oxygen-dead zones usually affect marine life in indirect and sub-lethal ways instead of directly killing the fish. They usually cascade through the food chain and thus cause reproductive impairments and reductions in growth potential. Hypoxia takes away food sources from fish and crustaceans and other marine life by affecting the bottom feeders, which creates a chain reaction in the food chain. Mobile animals can often survive low-oxygen environments by moving to areas of higher oxygen, but this migration pushes them into less desirable habitats, usually along the edges of the oxygen-dead zone.

  An experiment concluded that oxygen-dead zones reduced the abundance of Atlantic croaker by about 25% over the long term; the average number of eggs laid per individual of age 2 and age 3 croaker decreased by 6%; and the mortality rate of the croaker will increase by 20% if they continuously live in low-oxygen area for cumulated 40 years [14]. Research had shown that the oxygen-dead zone in the Gulf of Mexico had caused a 25% loss of brown shrimp habitat along the Louisiana coast, west of the Mississippi Delta [13]

Therefore, the major effects oxygen-dead zones bring to marine life I can be summed up as the loss of desirable habitat, higher mortality rate, decrease in population size, reduced growth rates, and lower fertility rate.

Recent solutions

- **Solutions in progress:**

  Countries, local governments, and organizations are working on continuous observation and monitoring. National Oceanic and Atmospheric Administration (NOAA) sponsors monitoring and research programs to further study the oxygen-dead zone and the impacts of dead zones on fish and fisheries in the Gulf of Mexico through the Northern Gulf of Mexico Ecosystem and Hypoxia Assessment Program (NGOMEX). The Gulf of Mexico/Mississippi River Watershed Nutrient Task Force uses annual dead zone measurements to determine whether efforts to reduce nutrient pollution in the Mississippi River Basin are effective. The Runoff Risk Advisory Forecast and new approaches are designed to help farmers apply fertilizer at an optimal time to limit nutrient runoff to the Gulf. (2017.8.2)

  “Yearly measurements enable us to help decision-makers fine tune strategies to reduce the size of the hypoxic zone in these waters and mitigate harmful impacts to our coastal resources and economy,” said Nicole LeBoeuf, director of NOAA’s National Ocean Service. (2022.8.3)

- **Existing proposal:**
  1. The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force's Gulf Hypoxia Action Plan 2008 aimed for reducing the size of the hypoxic zone, or "dead zone," in the Gulf of Mexico caused by excessive nutrient pollution from agricultural and urban sources in the Mississippi River Basin. The plan outlines a number of strategies to achieve this goal, including improving nutrient management practices on farms, reducing nutrient inputs from urban areas, and promoting the use of innovative technologies and practices to reduce nutrient pollution. The ultimate goal of the plan is to improve the health of the Gulf of Mexico ecosystem and the economic well-being of the communities that depend on it [9].

  2. The Mississippi River/Gulf of Mexico Hypoxia Task Force's Action Plans and Goal Framework aimed for reducing the size of the hypoxic zone, or "dead zone," in the Gulf of Mexico caused by excessive nutrient pollution from agricultural and urban sources in the Mississippi River Basin. The proposal sets out a goal to reduce the size of the hypoxic zone to an average of 1,950 square miles by 2035 and outlines a series of action plans to achieve this goal. These action plans include reducing

nutrient inputs from agricultural and urban sources, promoting innovative technologies and practices to reduce nutrient pollution, and improving monitoring and research efforts to better understand and address the issue of hypoxia in the Gulf of Mexico. The proposal also emphasizes the importance of collaboration among federal, state, and local partners, as well as stakeholders from the agricultural, environmental, and business communities, to achieve this goal [15].

- **Existing goals:**

  The Mississippi River/Gulf of Mexico Hypoxia Task Force set up a goal of achieving 1,950 square mile dead zones by 2035 [16]. However, according to the University of Michigan, aquatic ecologist Don Scavia said, “The bottom line is that we will never reach the action plan's goal of 1,950 square miles until more serious actions are taken to reduce the loss of Midwest fertilizers into the Mississippi River system.”

- **Existing technologies:**

  According to NOAA, innovative technologies and practices were being implemented in the Mississippi River Basin to reduce nutrient pollution by 2021. These technologies include technologies to remove nutrients from wastewater, practices on land to limit nutrients from entering waterways, and programs to support farmers in implementing conservation measures to protect water quality [17].

- **Existing difficulties:**

  Studies show that little progress has been made in reducing the amount of nitrogen runoff. The concentration of nitrate in 2017 was nearly the same as in 1980. Even though the government had already spent 28 billion on reducing the nitrogen run-off, the nitrate flow into the Gulf of Mexico hasn’t been reduced much [18].

  Furthermore, the cost of some implementation to farmers is prohibitively expensive, making some solutions unattainable. One of the main factors is cost. Some nutrient management practices, such as precision agriculture technologies or nutrient treatment systems, can require significant upfront investment. For farmers who may already be operating on thin profit margins, the cost of these practices can be a barrier to adoption. Another factor is knowledge and technical assistance. Nutrient management can be complex, and it can be difficult for farmers to know which practices will be most effective for their specific operation. Additionally, some farmers may not be aware of the latest nutrient management research and practices. Regulatory uncertainty can also be a factor. Some farmers may be hesitant to invest in nutrient management practices if they are uncertain about the regulatory environment and whether they will be required to make additional changes in the future.

  From the quote from Don Scavia and the nitrate record stated above, we can see that more work needs to be done if people want to improve the condition of dead zones in the Gulf of Mexico. Current measures help, but are not enough.

The second site: The Chesapeake Bay

Location and size

The Chesapeake Bay is located on the East Coast of the US. Oxygen-dead zones are mainly located in the Bay's mainstream and its tidal river, especially at the bottom waters, and they cover between 0.7 and 1.6 cubic miles in recent years, which is approximately 6.7×10^9 cubic meters during summer, as big as 5557 standard soccer fields. They cover about 40% of the Bay's area and 5% of its volume. Fortunately, the size of Chesapeake Bay was about 0.65 cubic miles in the summer of 2022, which became the smallest recorded dead zone in the past 38 years [19].

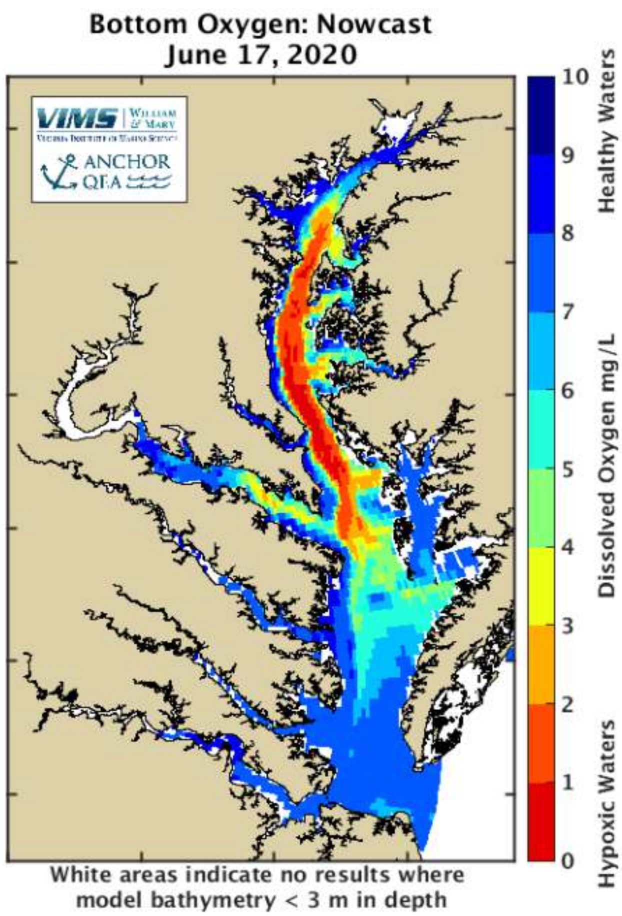


Figure 3. Oxygen-dead zone distribution in the Chesapeake Bay in 2020 [20]

Causation

Similar to the Gulf of Mexico, the oxygen-dead zones in the Chesapeake Bay are also caused by different factors.

Heavy rainfall: For example, the heavy rainfall in May 2011, which caused an extremely heavy flow of polluted water with a large amount of nutrient flow down from the Susquehanna River to the Bay, contributed to the pollution that occurs throughout the year.

Agricultural runoff: Agricultural runoff from farmland transports nutrients from fertilizers and livestock manure into rivers and streams before ending up in the Chesapeake Bay. Agriculture contributes 42 percent of nitrogen and 55 percent of phosphorous to the Bay, according to the estimates from the Bay Program [21]. Livestock dung and poultry litter make up about half of the nutrients entering the Bay, according to EPA (the United States Environmental Protection Agency) estimates from 2010. Estimates from the Chesapeake Bay Program's suite of modeling tools in the Environmental Protection Agency study Guidance for Federal Land Management in the Chesapeake Bay Watershed demonstrate that chemical fertilizers are responsible for 17 percent of the nitrogen and 19 percent of the phosphorus entering the Bay. Furthermore, according to the Environmental Protection Agency report Guidance for Federal Land Management in the Chesapeake Bay Watershed, manure accounts for 19 percent of nitrogen and 26 percent of phosphorus pollution reaching the Bay, based on estimates from the Chesapeake Bay Program's suite of modeling tools [22].

Urban and suburban runoff: Local streams that drain into the Chesapeake Bay downstream are highly polluted by urban and suburban runoff from developed regions that flush nutrients from fertilizers, septic systems, and other contaminants.

Facilities: Wastewater treatment facilities that discharge treated water, which usually still contains significant amounts of nutrients, into rivers and streams end up in the Chesapeake Bay watershed.

Air pollution: Nearly 30% of the overall nitrogen pollution in the Bay's waterways is caused by air pollution from our cars, factories, gas-powered tools, and power plants [19].

Amount and origin of nutrient outflow

According to the Natural Resources Conservation Service (NRCS) estimate [23], there are more than 83,000 farm operations near the Chesapeake Bay, accounting for nearly 30 percent of the 64,000-square-mile region and producing more than 50 commodities such as corn, soybeans, wheat, fruits, and vegetables. In 2017, approximately 1.7 million kg of phosphorus were released in total to the Chesapeake Bay watershed (Chesapeake Bay Program, 2018b). According to the TMDL, total phosphorus release by agriculture, urban emissions, and natural areas decreased by 16% from 2009 to 2017 (Chesapeake Bay Program, 2018a, 2018b).

Effects brought by the oxygen-dead zone in the Chesapeake Bay

The oxygen-dead zone in the Chesapeake Bay has had significant impacts on both the economy and the ecosystem of the region.

- **Economic impacts:**

  The Chesapeake Bay has traditionally been an important source of seafood, including blue crabs, oysters, and striped bass. However, the oxygen-dead zone has reduced the populations of these species, leading to decreased catches and economic losses for fishermen. For example, in 2017, the Maryland Department of Natural Resources estimated that the blue crab harvest in the Chesapeake Bay was down by 18% due in part to the dead zone [29].

Furthermore, the Chesapeake Bay is a popular tourist destination, with activities such as boating, fishing, and birdwatching drawing visitors to the region. However, the dead zone can create unpleasant odors and unsightly algae blooms, which can discourage tourists from visiting the area.

- **Ecological impacts:**
  When the water is low in oxygen, fish and shellfish may be unable to survive, leading to population declines. For example, a study published in the journal Marine Ecology Progress Series found that the dead zone has led to a decline in the population of bay anchovy, a key forage fish in the Chesapeake Bay [30].

  Besides, the Chesapeake Bay is an important stopover site for migratory birds, but the dead zone can impact their food sources and habitat. For example, a study published in the journal Estuaries and Coasts found that the dead zone has led to a decline in the abundance and diversity of invertebrates, which are an important food source for migratory shorebirds [31].

Recent measures

- **Solution in progress**
  The Chesapeake Bay Program, established by seven jurisdictions surrounding the bay's watershed (Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia, and the District of Columbia) and the United States federal government, is dedicated to monitoring the nitrogen and other nutrient content in the Chesapeake Bay to detect water quality.
  Besides, Chesapeake Bay Program Partnership's Modeling Suite works as an extremely important role as it can forecast the outcome of Chesapeake Bay's mitigation implementation outcome by calculating through a complex set of computational models based on the previous year's data.

- **Existing plan:**
  Total Maximum Daily Load (TMDL) is a protocol finalized by the US Environmental Protection Agency in 2010 to limit the amount of nitrogen, phosphorous, and other agricultural chemicals flowing into the Chesapeake Bay in order to recover the health of the bay.

- **Existing goals:**

TMDL is targeting to reduce the amount of nitrogen by 25%, phosphorus by 24%, and sediment by 20% between 2009 and 2025. Here are several goals in achieving the TMDL:

- Committing to more stringent nitrogen and phosphorus limits at wastewater treatment plants, including on the James River in Virginia (Virginia, New York, Delaware)
- Pursuing state legislation to fund wastewater treatment plant upgrades, urban stormwater management, and agricultural programs (Maryland, Virginia, West Virginia)
- Implementing a progressive stormwater permit to reduce pollution (District of Columbia)
- Dramatically increasing enforcement and compliance of state requirements for agriculture (Pennsylvania)
- Committing state funding to develop and implement state-of-the-art-technologies for converting animal manure to energy for farms (Pennsylvania)
- Considering the implementation of mandatory programs for agriculture by 2013 if pollution reductions fall behind schedule (Delaware, Maryland, Virginia, New York) [24]

Even though the arrangements were assigned, there were still uncertainties that didn't go along with the expectations, which included the wastewater sector in New York, the urban stormwater sector in Pennsylvania, and the agriculture sector in West Virginia [24].

- **Existing technologies:**

  Best management practices (actions taken by local governments, businesses, and individuals in the local community to prevent pollution, such as nutrients and sediment, from entering your local waterways, so-called BMPs) such as conservation tillage, cover crops, forest buffers, streamside fencing, nutrient management planning, and manure and poultry waste management are all the measures applied to certain farmers [25]. Best management practices include planting cover crops in the fall to reduce fertilizer needs in the spring and rotating food crops with legumes to reduce fertilizer needs because legumes add nitrogen to the soil. Nutrient management plans instruct farmers on how and when to apply fertilizer to crops, preventing the overapplication of nutrients. The Chesapeake Bay Program has a formal process for evaluating BMPs, which includes expert panels that determine whether something is a BMP, and, if so, how much pollution it is credited with reducing [26]. Once a BMP is in place, it can be tracked and reported as contributing to the achievement of water quality objectives. The District of Columbia, Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia are the six states that make up the watershed, and they all have verification procedures in place to make sure that BMPs are used correctly and effectively to reduce pollution [27].

Up until 2017, it was estimated that nearly 2 billion dollars had been spent on phosphorus pollution mitigation (US Office of Management and Budget, 2017), including initiatives like city projects to stabilize riverbanks and encourage pet waste cleanup initiatives, roadside ditch and highway runoff treatment practices, wastewater treatment facilities separating sanitary and dual water drainage systems to prevent storm-driven releases of untreated sewage, and adding advanced technologies [28].

Characteristics in common between the two sites

The causations at the two sites clearly show that agricultural runoff is the primary cause of oxygen-dead zones. The abundant nutrients, mainly phosphorus and nitrogen, were carried all the way down to both the Gulf of Mexico and the Chesapeake Bay, leading to the crazy algae bloom that led to depleted oxygen levels. Therefore, it is clear that the common factor in the growth of algae is excessive nutrients, and this is the factor that we should prioritize first.

Both sites have several detailed action plans and protocols regarding ameliorating the oxygen-dead zones. These plans contain precise and comprehensive local statistics of the dead zones and have reasonable measurements that could possibly be taken.

Both sites claim that the cooperation between policy and local farmers is crucial, and demonstrate that farmers need to work on some conservation strategies in order to decrease the usage of nutrients as well as the number of nutrients released into the river.

My suggestions for solutions

Progress is often the collective benefit of actions taken by state and federal agencies towards the oxygen-dead zone phenomenon, often devoted to improving science, restoring water quality, protecting the environment, or improving the efficiency of industrial and agricultural activities.

"Hypoxia Task Force states are focused on implementing our state-based and science-driven nutrient reduction strategies and scaling up and accelerating the adoption of proven water quality and conservation practices. The addition of new partnerships with both public and private partners in both urban and rural settings will pay big water-quality dividends in the future," said Mike Naig, Iowa Secretary of Agriculture and co-chair of the Hypoxia Task Force. For the dead zone problem, the intrinsic solution is to reduce the number of fertilizers flowing into the waterways.

Now, I am going to lay out my 10 recommendations for ameliorating oxygen-dead zones based on the existing measures and the causation characteristics of the two sites.

1. Currently, not all the sites have specific action plans for solving dead-zone issues, therefore, I suggest that every oxygen-dead zone area should propose individual action plans according to local conditions.

2. Proposals and protocols should be made in every state and specific area where dead zones exist or have the potential to be formed. Since local communities are more familiar with their situation and agricultural financial situation than the EPA, local communities need to determine the pollution limit, not the EPA. The EPA, instead, can focus on urging sites to establish plans for limiting pollution and setting up standard requirements for the solution plan. The EPA should not be in charge of setting up conservation requirements for every state because this might impose an overly heavy financial burden on the sites, ultimately leading to a fluctuation in the local economy.

3. To maximally reduce the financial loss brought by the mitigation and prevention measures, local communities and government could make a comparison. For example, in order to assess the economic threat caused by dead zones, the local government can collect sufficient data on two aspects. First, the population of farmers and the economic value of the agricultural area. Second, the population of fishers and the economic value of the dead zone area will be affected by the policy. For instance, it is challenging to compare the costs incurred by the $98 billion Mississippi Basin farm economy, which supports over a million farmers, with the benefits of maintaining the $3 billion fishing industry in the Gulf of Mexico, which generates at least 40,000 jobs [11]. From this case, we can see that it would be very hard to decide the overall economic benefit if the governments do not collect sufficient data and do the comparison. Therefore, based on the analysis of the economic benefits from both sides, the government should adjust the measures with the goal of reducing the area of dead zones, and finally come up with optimal policies.

4. Taking action strictly following the action plan. If the action plan is well-made, such as the TMDL and the Hypoxia Task Force Action Plan and Goals, in the local area, then executors should rigorously follow the plans in the action plan. Any additional action taken might cause irreversible damaging outcomes to the locals. Action plans and protocols should be discussed seriously between the action implementer and the team who proposed the action plan if any issue exists while implementing the policy.

5. Creating computer-simulating models and monitoring networks for better future prediction. Like what the Chesapeake Bay Program Partnership's Modeling Suite has done, computer modeling should be taken into crucial account for its ability to forecast the future tendency of different indexes of regional dead zones based on the previous years' data collection. This measure enables people to take advanced action and analyze the efficiency of the implemented measures.

6. Existing technologies like removing nutrients from wastewater and practices on land limiting nutrients from entering waterways need to be implemented by farmers. By collecting feedback and statistics on the effectiveness such as the amount of nutrient concentration in certain water resources after implementation, people can well define which method is useful

and where could be further improved. The selected methods should be popularized and shared with other sites, not only limited to certain farmers.

7. Effective measures should be better publicized and implemented. I have noticed that The Chesapeake Bay program had set up the BMP, which is a series of different methods that help farmers reduce the amount of sediment and nutrient flow into the Chesapeake Bay, and the effectiveness of how much pollution the respective BMP can reduce can be measured by The Chesapeake Bay's expert panel. The Chesapeake Bay program has also mentioned that once the BMP is implemented, they will have a formal process to evaluate and track the contribution BMP made to the objective of improving water quality and solving dead zone problems. Programs that can provide measures and do the following tracking and reporting can efficiently provide realistic results to the users. Individual distinct measures can be achieved because this program can also evaluate different BMPs at different locations by the expert panel. Therefore, I hope that a highly flexible and effective program like this could be popularized among more local governments and help as many individual farmers as we can.

8. I also noticed that there weren't many clear instructions to farmers regarding how much fertilizer exactly should they put into agriculture. When I was doing research, I was not able to find anything about how farmers are reducing the amount of nutrients going into the river or how they are using new technologies. Thus, I believe a specific standard of fertilizer input to crops should be set up by the local government, especially the input of nitrogen and phosphorus, to establish achievable limitations on the use of fertilizer. It would be even better to make the policy transparent - to post it on the Internet and empower everyone with the right to access the information as this would be helpful for other places to refer to and study.

9. Building greener communities. Infrastructures such as streets and driveways are heavily used in nowadays society. However, grassy areas and permeable cement can actually be extremely helpful in absorbing rainfalls and preventing the accumulation of rainfalls flowing into the rivers with nutrients from nearby farmland.

10. Popularizing the existence of oxygen-dead zones and emphasizing the hazardous outcomes brought by oxygen-dead zones. Unlike climate change, oxygen-dead zones seem not to be noticed by a lot of people. By mentioning this term, most people will cast their confusion toward it. In order to solve the problem together, people need to realize the seriousness of the problem, and by achieving this purpose, informing people of relative knowledge to enhance their consciousness is indispensable. Only by doing this will people be sincerely willing to reduce the nutrients and garbage usage in daily life; people will full-heartedly cooperate with the mitigation measures, and people will put their power into solving this global issue.

Conclusion

Though reducing oxygen-dead zones is a long-term effort that may not yield immediate results because the ecosystem has already been saturated by excessive nitrogen for a long time, people still need to continue to strive to save our one and only planet. Protecting the precious environment, not letting it be damaged and ultimately become a real “dead zone," needs to begin with action, starting now.

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