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RESEARCH ARTICLE

ENVIRONMENTAL EFFECTS OF PORT ACTIVITIES IN COTONOU, BENIN (WEST AFRICA)

Akiyo Sylvain[1,2], Yabi Ibouraïma[2,3] and Dovonou Mehinto Flore[3]

1. Multidisciplinary Doctoral School, Space, Cultures, and Development (EDP-ECD).
2. Department of Geography and Land Planning (DGAT).
3. Pierre PAGNEY Laboratory, Climate, Water, Ecosystems, and Development (LACEEDE).

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Abstract

The environmental effects of port activities on the biological environment are one of the growing concerns due to the importance of ports for maritime trade and the environmental consequences they generate. Activities related to maritime transport, waste management, and dredging can disrupt marine ecosystems, introduce invasive species, and pollute the waters. The objective of this research is to analyze the environmental effects of port activities in Cotonou, Benin. The data comes from several sources, including field studies, research reports, and marine pollution data. The information includes water quality measurements, observations on marine biodiversity, and data on waste management practices in ports. The methods of analysis include case studies, statistical analyses of pollution data, and ecological impact assessments. Comparisons are made between port areas and surrounding marine areas to evaluate the effects of port activities. Risk assessment models are also used to understand the implications of the bioaccumulation of toxic substances in the food chain. The results of the research show that maritime transport is a major vector for the introduction of exotic species, which can disrupt local ecosystems. The discharge of hydrocarbons and solid waste has harmful effects on the health of aquatic organisms and raises concerns about the bioaccumulation of toxins. Dredging operations disturb marine habitats, burying organisms and introducing pollutants into the environment. Plastic waste poses a serious threat to marine life, leading to health issues for species and affecting the integrity of coastal ecosystems. The main hazards associated with port activities include fire, workplace and traffic accidents, water pollution, explosions, drownings, and contamination of the natural environment by toxic substances and accidental discharges. Discharges from ships at sea constitute one of the major sources of water pollution caused by maritime transport. Several types are observed. Cargo losses frequently occur during loading or unloading due to handling errors or faulty equipment. This can involve any type of goods.

Corresponding Author:- Akiyo Sylvain
Address:- Multidisciplinary Doctoral School, Space, Cultures, and Development (EDP-ECD).

Introduction:-

The environmental impacts of port activities on marine ecosystems are increasingly recognized as a significant area of concern due to the vital role that ports play in global maritime trade. As highlighted by **Halpern et al. (2008)**, human activities in coastal and marine environments have led to widespread degradation, with ports serving as focal points for various stressors, including pollution, habitat destruction, and the introduction of invasive species.

Maritime transport is a primary vector for the movement of aquatic species across regions, often facilitated by ballast water, as noted by **Carlton (1985)**. This unintentional transport can lead to the establishment of non-native species in new environments, potentially disrupting local ecosystems and outcompeting native species (Keller et al., 2011). Moreover, the discharge of pollutants, including hydrocarbons and solid waste, significantly affects water quality and marine life. Research by **Ghosh et al. (2014)** indicates that these pollutants can lead to acute and chronic health effects in marine organisms, raising concerns about bioaccumulation and its implications for human health as well.

Dredging activities, necessary for maintaining navigability in ports, further contribute to ecological disturbances by resuspending sediments and introducing contaminants into the water column (OECD, 2010). The resulting turbidity can inhibit photosynthesis and affect the overall health of marine habitats.

Given these challenges, the objective of this research is to analyze the environmental effects of port activities in Cotonou, Benin. By utilizing data from various sources, including field studies and pollution reports, this study aims to provide a comprehensive assessment of the impacts of these activities on the biological environment, thereby contributing to the development of effective management strategies for sustainable port operations

Environmental protection is essential for sustainable development. Worldwide, environmental management has become a critical issue for preserving both the environment and human health (ZAHRAHI, 2006). Human activities alter the environment, and these changes directly threaten human activities: to protect the environment and thereby ourselves, we must be able to control the consequences of our actions on the environment (PERSONNE, 1998).

The transport sector is no exception. While often driving economic growth and territorial development, transport activities leave a significant environmental footprint due to the nuisances they create. This justifies the efforts of governments worldwide, which have recently focused on promoting research at the interface of transport and the environment.

The industrial revolutions of the 19th century intensified various modes of transport; internationally, maritime and air transport are the most used, with maritime transport being predominant (AWASSI, 2010, cited by SALIFOU, 2013). As this sector becomes increasingly competitive and globalized, numerous changes are occurring within the organization of work in the port industry, affecting the environmental conditions of the sector (ILO, 2006).

Maritime ports serve as the gateways for foreign trade, with over 80% of international transactions passing through them (UNCTAD, 2006). They are the driving force behind the transport chain for coastal countries and even landlocked countries that rely on them for imports and exports. This is particularly true for the Port of Cotonou, which is vital for Benin and several countries in the West African sub-region. As a crucial commercial hub for the national economy, the Port of Cotonou hosts a multitude of economic activities, most of which are related to maritime transport, cargo handling, storage of goods, transit of used vehicles, and coastal development. Some of these activities, such as handling perishable goods, storing hazardous products, managing certain materials like clinker and sulfur, and maintaining port machinery and equipment, have negative environmental impacts.

The Port of Cotonou (PC) is located in the Gulf of Guinea, around the coordinates 06°21’22’’N and 02°26’30’’E, along a low sandy coastline at the southern edge of Cotonou (Figure xx). The objective of this research is to analyze the environmental effects of port activities in Cotonou, Benin.

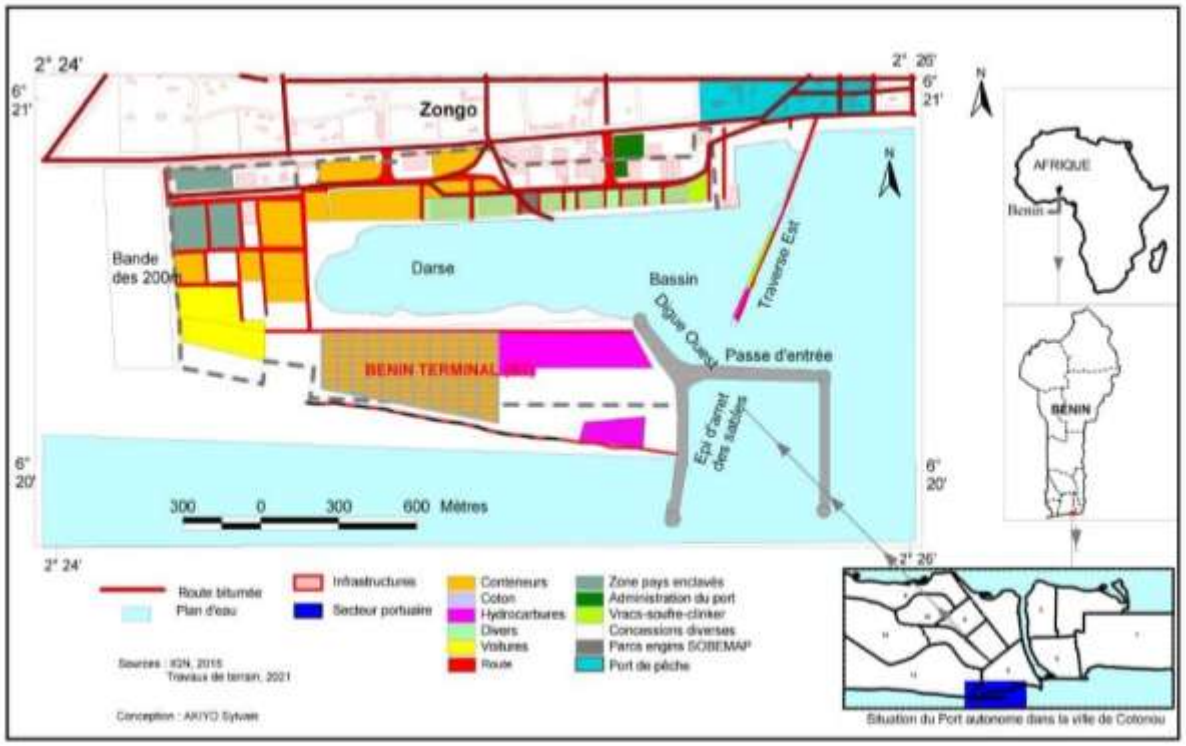

Figure 1:- Geographic Situation of the Autonomous Port of Cotonou.

Methodological Approach:-

Field Work

The overall objective of the study is to conduct a diagnostic analysis of the environmental implications of port activities. The selected site for this study is the port and its immediate surroundings. The target respondents must either work at or frequent the port and its vicinity.

Target Population and Sample

The entities operating on the port platform are the primary contributors to the generation of port waste. They represent the first category of the target population for this research. Following them are the port users and the waste collection companies. In general, the field interviews targeted operational managers from various companies working within the port area, officials from the DGE/PAC, team leaders executing activities on-site, drivers, and other users.

A stratified sample was selected from this population, considering the size of each socio-professional category and their degree of involvement in waste production at the Port of Cotonou.

For the investigations, twenty (20) companies were surveyed out of the twenty-three (23) selected, with three (3) individuals interviewed per company based on two criteria: being located in the port area or its immediate surroundings, and holding a valid operating license in this environment. Additionally, two hundred (200) randomly chosen users were surveyed from an estimated daily movement of approximately 2600 persons (PAC, 2012). Lastly, seven (7) solid waste removal companies were interviewed out of the eight (8) operating in this area.

In total, 267 individuals were surveyed for this research using various data collection tools and techniques.

Tools and Techniques for Data Collection

Several tools were utilized for this study, including an observation guide, interview guides, a survey questionnaire, information collection sheets, a camera, and a GPS MAP76C device. The various techniques employed are:

- **Field Visits**: During these visits, all port operations were monitored alongside environmental inspectors from the DGE/PAC. The port facilities were thoroughly inspected both on foot and in vehicles, with numerous photographs taken.
- **Interviews**: Individual and group interviews were conducted with various responsible parties from different organizations operating within the port area and with port users.

- Data Processing and Analysis
- Data Processing

At this stage, the survey sheets were manually processed, and the collected information was grouped by areas of interest, considering the established objectives. Microsoft Excel and Word were used to represent the data in tables and graphs. The cross-referencing of this information was analyzed, allowing for the identification of port activities, a closer view of the environmental externalities, and the proposal of solutions aimed at improving the port environment.

Data Analysis

After several readings of the collected data grouped by areas of interest, we highlighted the significant parts based on their relevance. We then analyzed the information received from the surveys, and finally, a triangulation was performed between the collected data, observations from the field, and secondary sources.

To evaluate and analyze the environmental effects of port activities, the Leopold Matrix (1971) and Martin Fecteau's grid were employed. The Leopold Matrix (Table I) was used to identify the environmental components affected as a result of the interaction between port activities and the components likely to be impacted.

Table I:- Interaction Between Activities and Environmental Components.

Sources/Activities	Components of the Environment Likely to Be Impacted					
	water	Air	Soil	Flora	Fauna	Human
A						
B						
C						
…						

Source : Leopold Matrix, 1971

Legend: A, B, C, the various activities likely to pollute the environment.

The Martin Fecteau grid was used to evaluate the significance of the environmental effects of the identified port activities. The adopted methodological approach yielded some results. However, the biophysical and institutional factors deserve to be highlighted.

Results:-

Overview of Port Activities by Operational Zone

According to the port security and traffic plan, the port is divided into six (6) zones, including the port basin, along with additional 200m and 300m bands. Various activities are carried out in these different zones.

Activities in Zone 1

Zone 1 of the Port of Cotonou is dedicated to the handling of bulk solids. This includes unloading followed by bagging of grains such as rice, sorghum, and millet. Export products like shea nuts and cashew nuts are loaded here. Additionally, chemical products such as fertilizers (Urea, NPK, etc.) are unloaded and bagged at the docks in Zone 1. Sulfur is removed and transported to the sulfur yard located opposite Dock 1.

The main operator in this zone is SOBEMAP, which generally handles the loading and processing of bulk carriers docking at the Port of Cotonou. Zone 1 also houses offices belonging to PAC and private structures.

Activities in Zone 2

This zone is reserved for container handling. It includes the container yards of various companies and houses the SOBEMAP garage, where maintenance and repair activities for the company's vehicles and equipment take place. It also contains offices belonging to PAC (both the old and new bases of the Firefighters) and private structures.

Major operators in this zone include SOBEMAP, COMAN S.A., SMTC, etc.

Photo 1:- Some Images Characterizing Zone 2.

Photographer: Akiyo, October 2019

Photo 1 shows part of Zone 2. This area is relatively clean because the goods being handled are in containers. Additionally, since container handling involves heavy machinery, this zone is less frequented by workers or dockers, which explains its relatively clean appearance compared to Zone 1.

Activities in Zone 3

Zone 3 of the port primarily houses various companies engaged in semi-industrial or industrial fishing activities. It is also home to the Cotonou Artisan Fishing Port (POPAC), where artisanal fishermen practice maritime fishing. POPAC is managed by the Directorate of Fisheries, with internal organizations like UNAPEMAB and the EDJATCHO association facilitating daily life.

The area that includes the commercial fishing port is shared with the base of the Military Navy, the PAC Floating Equipment Service, and several frozen product companies. Zone 3 is known for significant pollution due to the large number of people frequenting it.

Activities in Zone 4

This zone includes the East crossing of the Port of Cotonou or Dock C. It also serves as a handling area for products such as clinker, petroleum products, vegetable oils, and seafood. This crossing features both underground and aerial pipelines.

The docks in this crossing are used for unloading bulk solids and petroleum products; container ships cannot dock here as handling containers on-site is not feasible. Clinker and sulfur are typically unloaded at this crossing. Fishing trawlers also dock here to unload seafood products.

Activities in Zone 5

This is the area for hydrocarbon depots, which houses terminals for ORYX Benin (Photo 2), Bénin Petroleum Services (BPS), the gas terminal of SONACOP, and other oil depots under construction.

Photo 2:- Oryx Benin SA Terminal and BPS Terminal.

Photographer: Akiyo, October 2020

Activities in Zone 6 and the 200m and 300m Bands

Zone 6 is the water area of the port basin where ships dock. It is bordered to the north by the commercial dock, storage warehouses, and the fishing port; to the southeast by the sand stopgap; to the southwest by the Oryx and Bolloré docks; to the west by the concrete ramp and the building housing the management of COMAN SA; and to the east by the east jetty.

This area serves as the docking space for vessels. The primary activities occurring here include piloting, towing, mooring, refueling, and various forms of assistance to ships.

In addition to these six zones, the 200m and 300m bands include the unique buffer park, the truck gathering area for SOBEMAP, the container zone operated by COMAN SA, and the parking lot for Roro Terminal Benin SA. The main activities carried out in these areas include handling new and used vehicles and loading and unloading trucks.

Summary of Activities

Generally, the activities conducted at the Port of Cotonou can be summarized as follows:

- ✓ **Administrative and Management Activities**: These encompass all activities related to administrative management and the strategic organization of port operations conducted in the offices of various structures located on the port premises.
- ✓ **Ship Reception**: Activities related to the reception of ships include piloting, towing, mooring, refueling, and all assistance provided to vessels during their stay at the Port of Cotonou.
- ✓ **Cargo Handling and Storage**: This involves loading and unloading operations of ships and trucks, as well as activities related to stuffing, stripping, transferring, and storing goods at the dock, in warehouses, and designated storage areas, utilizing machinery, dockworkers, and specialized channels or pipelines. The handled goods include bulk materials (sulfur, clinker, gypsum), grains, fertilizers, shea and cashew nuts, containers, manufactured products, frozen products, hydrocarbons, fish products, and hazardous or perishable goods.

- ✓ **Construction and Maintenance of Port Infrastructure**: This includes construction work on docks and protective structures, the building and rehabilitation of warehouses and administrative buildings, dredging operations in the port basin, and maintenance of wastewater drainage channels and the basin.
- ✓ **Maritime Fishing**: Fishing activities at the Port of Cotonou mainly involve the processing and distribution of marine catch products.
- ✓ **Other Activities**: These include maintenance of equipment and technical materials, repair of malfunctioning trucks, upkeep of offices and warehouses, security, and catering services.

Waste Generated by Port Activities

Port activities generate several types of waste, including solid waste, liquid waste, gas emissions, and various hazards and nuisances.

Solid Waste

This includes waste categorized as household waste (DAOM), biodegradable solid waste (DSB), and non-biodegradable inert solid waste (DSNB). The following types are noted:

- ✓ **Waste from Ship Operations and Fishing**: Solid waste is produced onboard ships by the crew and passengers during the operation of the vessel and activities such as meal preparation (plastic materials, food waste, household waste, animal carcasses, etc.), as well as during cargo activities (losses, packaging materials, and securing materials typically made of wood or plastic known as dunnage, etc.). Fishing boats and traditional fishermen often discard used nets and lines, which are frequently made of plastics.
- ✓ **Products Spilled During Bulk Handling**: This includes sulfur, clinker, gypsum, fertilizers, grains, shea nuts, etc., which can form mud after rain and piles of residues from these products.
- ✓ **Waste from Maintenance of Equipment and Technical Materials**: This includes used batteries, used filters, worn tires, waste from welding rods, shavings from sharpening workshops, general mechanical scraps, and metal scrap consisting of machine parts, defective engines, and tracks from heavy machinery.
- ✓ **Container and Refrigerator Shells**: This also includes containers of spoiled products.
- ✓ **Wrecks of Ships, Vehicles, and Handling Equipment**.
- ✓ **Empty Pots**: These previously contained chemical products, paints, insecticides, and detergents.
- ✓ **Ashes from Incineration of Medical Waste**: This includes syringes, bandages, cotton, empty medicine boxes, expired medications, rubber gloves, etc.
- ✓ **Office Waste**: Papers, cardboard, ink cartridges, packaging, batteries, etc.
- ✓ **Waste from Residences, Businesses, and Food Outlets**: This includes packaging, plastic bottles, cans, food scraps, etc.

The system for collection, storage, and treatment has been adopted based on the type of waste generated. Household waste is disposed of in designated bins placed throughout the port area.

Plate I:- Shows the bins installed at the Autonomous Port of Cotonou.

Plate 1:- Some Bins Installed at the Port of Cotonou.
Photographer: Akiyo, 2019

Used tires are stored in piles on designated areas; scrap metal designated for recovery is separated from irrecoverable scrap and stored in distinct areas (Plate 2).

1) Plate 2: Some Used Tires Stored and Waste from Equipment Maintenance on SOBEMAP's Operation Areas
Photographer: Akiyo, 2019

A **B**

Plate 3:- Discharge (a) and Storage (b) of Used Oils in the SOBEMAP Garage Workshop.
Photographer: Akiyo, 2019

Filters are compressed and stored in barrels, while batteries are arranged in designated boxes. It is noted that 30% of unscrupulous actors use the dock to dispose of some of their waste.

Liquid Waste
This includes used oils and fats, wastewater, hydrocarbons, and residues from chemical products such as paints, various insecticides, and acids. Used oils consist of engine oils, spilled motor oils, and discarded or spoiled cooking oils. These are collected and stored in tanks and barrels constructed for this purpose (Plate 3).

Residual or wastewater from the port includes rainwater, wastewater from fish processing plants, sewage systems, vehicle and equipment washing areas, and wastewater from hydrocarbon operations (cleaning of tanks, storage vessels, pipelines, tank trucks, etc.). It also includes wastewater produced onboard ships (water from bathrooms, kitchens, and holds) and ballast water (seawater used to modify draft and center of gravity based on cargo to ensure ship stability at sea).

A network of drains runs through various sections of the port to collect wastewater produced on-site. The quantities drained are significant during the rainy seasons, during which various contaminants are washed into the marine environment. This wastewater is generally muddy with traces of oil.

Gas Emissions

Gas emissions consist of dust, exhaust fumes from engines, hydrocarbons from the degradation of biodegradable solid waste (DSB) and household waste (DAOM), fuel evaporation gases, and various particles. The emission of particulate matter in the ambient air of the port is linked to the handling of bulk materials (clinker, gypsum, and sulfur) and the movement of heavy vehicles within the port area.

Exhaust fumes come from heavy and light vehicles, ships, handling equipment, and generators. These are generally black and/or white smoke primarily composed of carbon dioxide, nitrogen oxides, sulfur oxides, and volatile organic compounds.

Plate 4:- Dust Emission During Clinker Unloading (a) and Sulfur Exposure in the Open at the Sulfur Yard (b).
Photographer: Akiyo, 2019

Evaporating gases from fuels through the vents of storage tanks are colorless and cannot be felt due to the height of the vents. Under normal operation, volatile organic compound (VOC) emissions are primarily due to the storage and handling of volatile hydrocarbons (Class I, flammable products) and volatile organic chemicals. VOC emissions from Class II hydrocarbons (fuel oils) are negligible due to the nature of the products.

No monitoring or sampling system for these emissions is in place.

Hazards and Nuisances

The main hazards associated with port activities include fire, workplace and traffic accidents, water contamination, explosions, drownings, pollution, and environmental contamination by toxic substances and accidental discharges.

Discharges from ships at sea are one of the major sources of water pollution caused by maritime transport. There are several types of incidents. Cargo losses frequently occur during loading or unloading due to handling errors or defective equipment. This can involve any type of goods, although petroleum products and other chemical substances are the most common. Non-hazardous product discharges are more frequent than spills of toxic or flammable materials because the precautions taken in handling them generally prompt much greater vigilance, resulting in far fewer negligent spills. Cargo discharges that occur when a ship runs aground or breaks apart in bad weather are much rarer but potentially more dangerous.

Furthermore, the dissolution of toxic substances contained in antifouling paints applied to ship hulls to reduce drag presents a risk, as 50% of these compounds are highly toxic, including biocidal products.

Nuisances Observed at the Port of Cotonou Include:

- ✓ Dust generated by road and rail traffic, especially during the handling of bulk materials.
- ✓ Exhaust fumes from heavy and light vehicle engines, ships, handling equipment, and generators.
- ✓ Noise from machinery, trucks, and ships.
- ✓ Massive spills of clinker and sulfur on the docks and along truck routes.

Efforts to combat nuisances such as surface water contamination, noise, vibrations, dust, and workplace accidents remain insufficient. After reviewing the various activities at the Autonomous Port of Cotonou, the environmental effects of these activities have been analyzed.

Environmental Effects of Port Activities

The intersection of port activities with environmental components has highlighted the affected environmental components (Table II).

Tableau II:- Interaction entre les Activités et les Composantes du Milieu.

Sources/Activities	**Components of the Environment Likely to Be Impacted**					
	water	**Air**	**Soil**	**Flora**	**Fauna**	**Human**
Administrative management		+	+			+
Ship Reception	+	+		+	+	+
Cargo Handling and Storage	+	+	+	+	+	+
traffic of land and rail vehicles	+	+				+
Maintenance of equipment and vehicles	+	+	+			+
Maritime Fishing	+	+	+		+	+
Construction and Maintenance of Port Infrastructure	+		+	+	+	+

Source: Fieldwork Results, 2018

Legend: + Affected Environmental Component

Port activities have various effects on different environmental components, including air, water, soil, and biological environments.

Effects on Air

Activities that impact air quality at the Port of Cotonou include the handling of clinker and gypsum, the handling and storage of sulfur and hydrocarbons, the operation of handling equipment, energy use, and transportation. These activities generate smoke, dust, evaporating gases, noise, and even odors.

The smoke emitted during port operations (from heavy and light vehicles, handling equipment, ships, generators, and fishing equipment) contains nitrogen oxides, sulfur oxides, carbon monoxide, carbon dioxide, volatile organic compounds (VOCs), and more, which have harmful effects on human health and the environment. These emissions can be irritating, suffocating, and toxic, posing a public health issue. Some of these gases, particularly carbon monoxide and carbon dioxide, contribute to ozone layer depletion and enhance the greenhouse effect.

Particulate matter from clinker, sulfur, and dust from the ground, resulting from handling and vehicle movement, disperses into the air and is inhaled by humans. These particles can cross the pulmonary alveoli and enter the bloodstream. Their effects on the cardiovascular system include increased oxidative stress, inflammation of vascular walls, increased blood viscosity, platelet activation, vasoconstriction, and a heightened tendency towards atherosclerosis (UNCTAD, 2007).

During hydrocarbon operations, the impact on air quality primarily arises from volatile organic compound (VOC) emissions from atmospheric storage tanks and losses from evaporation. Negative effects on air quality are also likely in the event of a leak or major spill.

Odors, mainly from VOCs associated with sulfur handling, cooling of ground or processed parts, degradation of household waste (DAOM), evaporation of hydrocarbons, and poorly maintained public restrooms, can pose health risks, potentially causing symptoms like headaches, nausea, and fatigue that may resemble allergies.

The main sources of noise include fixed machinery (fixed handling cranes, sharpening, grinding, welding), moving machinery (vehicles, heavy equipment, and ships), and generators.

Outside, the noise from vehicles and generators is noticeable, and the impact of noise primarily affects quality of life. Overall, noise pollution is particularly localized within the site. Its effects are physiological (oral communication disorders, hearing loss, cardiovascular, neurological, or digestive issues) and psychological (personality disorders, increased stress, sleep disturbances, fatigue, hypertension).

Effects on Water

Pollution sources arise from vehicle maintenance, equipment, washing containers that held toxic substances, administration facilities, restrooms, and ships. Wastewater is drained (except for that directly discharged by ships into the sea) with stormwater through a network of drains that channels it into the port basin. Contaminants include used oils, leachates, spilled acids, deposits of sulfur, and other toxic products discharged into the port, along with small solid waste and airborne particulate fallout.

The discharge of these wastes into port waters risks introducing organic, biological, chemical, and toxic pollutants.

The disposal of plastics into the sea represents a significant environmental threat, as these materials float on the water's surface and are non-biodegradable.

Furthermore, during hydrocarbon operations, significant impacts on the marine environment are likely in the event of spills and leaks. An oil spill (due to leaks and discharges) can have serious implications for health, safety, and groundwater quality. Hydrocarbons released into the marine environment in large quantities can be extremely damaging and toxic.

Similarly, dredging operations, necessary to allow large vessels to enter the port or maintain the port basin, are particularly concerning. These operations directly threaten the areas where they occur, introducing sediments into the adjacent water column, which then settle on the bottom. This causes various short-term effects on pelagic fish and benthic organisms (OECD, 2010). Suspended sediments increase turbidity, reducing light penetration and photosynthesis. The disposal of dredged materials poses serious ecological problems because the sediment deposits are contaminated with hydrocarbons, heavy metals, nutrients, and organochlorine compounds. Given that the port basin receives sediments from all areas drained by its sanitation network, these contaminants stem from a wide range of water pollution sources: industrial discharges, municipal sewage, surface runoff, etc.

Effects on Soil

The sealing of platforms limits soil pollution. Direct effects on soils include contamination from petroleum products, handling residues (sulfur, fertilizers, clinker, etc.), and waste.

Petroleum products contaminate the soil where they are handled (garages, fuel tanks, used oil recovery tanks, fuel distribution pumps, etc.). Rags and soil contaminated by used oils and sludge (from storage tanks and used fuel filters) pose environmental hazards, as they can pollute the soil and lead to poisoning in humans if improperly handled.

Similarly, during the handling of chemical fertilizers, sulfur, and clinker, these products can spill onto the docks, resulting in muddy runoff during rainfall that drains into the dock.

Plastic waste, due to its very slow decomposition, can release harmful substances into the soil.

Ink cartridges, hospital waste, and computer equipment contain silicon, which is hazardous to soil and groundwater. Incineration of these components is strongly discouraged, as it generates even more toxic substances for the environment.

Additionally, it is important to note that the establishment of the port required significant land use in the area. Ports often necessitate large expanses of land and water. The port occupies more than 1,300 hectares, considering the land taken up by road and rail infrastructure, warehouses, and industrial activities linked to the port. Given the ever-increasing size of ships, port authorities are developing docking facilities capable of accommodating longer vessels with deeper drafts, as well as terminals large enough to hold substantial quantities of goods.

Effects on the Biological Environment

The impacts of port activities on the biological environment are diverse and multifaceted.

Firstly, maritime transport serves as a primary means of transporting aquatic species from one part of the globe to another. These so-called "exotic" species are most often carried in ballast water, although they can also cling to the hull of the ship or arrive with the transported goods. Most of the invasive species that survive in their new environment (the dock and neighboring coasts) thrive and can displace other species or profoundly alter the balance of existing ecosystems. This can lead to a regression of phytoplankton, clearer coastal waters, a reduction in fish populations that rely on plankton for their larvae, and changes in the habitats of adult fish.

Secondly, the discharge of hydrocarbons, wastewater, and solid waste into port waters introduces organic, biological, chemical, and toxic pollutants. The disposal of dredging residues at sea can also have both short- and long-term impacts on the marine environment. In the short term, issues are related to the sediment deposition sites, primarily concerning the burial of marine organisms or their exposure to high concentrations of particles, contaminants, and suspended nutrients. Long-term effects are associated with the rate of recovery of the disposal site, the composition of the biological community that will subsequently redevelop, and the genetic and physiological impacts of exposure to contaminants. Regarding bioaccumulative toxic substances, there is also concern about the long-term potential for human exposure as these chemicals move up the food chain.

Finally, it should be noted that plastics released into the sea pose a threat to both marine species and coastal areas. Abandoned nets, drifting in the waters, lead to "ghost fishing," continuing to catch animals (GESAMP, 1990). Strapping materials can entangle marine mammals or birds, forming a loop that tightens as they grow. Marine organisms also ingest plastics, which can kill them or reduce the nutritional value of their diet. In addition to the harmful effects on marine life, plastics wash up on beaches, causing further pollution in these environments.

Discussion:-

The impacts of port activities on the biological environment are significant and warrant thorough examination. As highlighted in the previous sections, these activities introduce multiple stressors that can disrupt marine ecosystems.

Maritime transport plays a crucial role in the global spread of aquatic species. Exotic species often arrive in ballast water, which is a well-documented pathway for biological invasions. According to **Carlton (1985)**, ballast water is a significant contributor to the introduction of non-native species, which can outcompete local fauna and flora, leading to ecological imbalances. The proliferation of these species often results in the decline of native populations and alters entire ecosystems (Keller et al., 2011).The discharge of hydrocarbons, wastewater, and solid waste into port waters significantly impacts marine life. The introduction of pollutants creates a toxic environment for aquatic organisms. Research by **Ghosh et al. (2014)** indicates that exposure to hydrocarbons can lead to acute and chronic health effects in marine species, including reproductive and developmental issues. Moreover, the accumulation of toxic substances in the food chain raises concerns about human health as well, as noted by **Fry et al. (2010)**, who emphasize the long-term implications of bioaccumulation in fish and other seafood consumed by humans.Dredging operations, while necessary for maintaining navigability, have adverse effects on marine habitats. According to the **OECD (2010)**, sediment disturbance can bury marine organisms and expose them to harmful pollutants. The long-

term effects of dredging include changes in community structure and potential genetic consequences for affected populations, as highlighted by **McKinney et al. (2005)**.The issue of plastic pollution in marine environments is particularly pressing. The phenomenon of "ghost fishing," where abandoned nets continue to trap marine animals, is a significant concern. As noted by **GESAMP (1990)**, the entanglement and ingestion of plastics by marine life lead to mortality and reduced reproductive success. The broader implications of plastic waste on coastal tourism and ecosystem health cannot be overlooked, as discussed by **Jambeck et al. (2015)**, who emphasize the urgent need for improved waste management practices.

The effects of port activities on the biological environment are multifaceted and highlight the need for integrated management strategies. Addressing the introduction of invasive species, mitigating pollution from hydrocarbons and waste, managing dredging impacts, and tackling plastic pollution are critical steps in preserving marine biodiversity. Future research should focus on developing sustainable practices that minimize these impacts while ensuring the continued functionality of ports.

Conclusion:-

In conclusion, the environmental impacts of port activities on the biological environment are significant and multifaceted, warranting urgent attention and action. This study highlights the critical issues associated with maritime transport, waste management, and dredging that contribute to the degradation of marine ecosystems. The introduction of invasive species, pollution from hydrocarbons and solid waste, and the disturbance of marine habitats through dredging not only threaten biodiversity but also pose risks to human health through bioaccumulation of toxins in the food chain.The findings emphasize the need for integrated management strategies that address these challenges comprehensively. Effective measures must be implemented to mitigate the introduction of invasive species, reduce pollution, and improve waste management practices in ports. Additionally, continuous monitoring and assessment of the ecological impacts of port activities are essential to ensure the sustainability of marine environments.Ultimately, safeguarding marine biodiversity and maintaining the integrity of coastal ecosystems are crucial for the health of our oceans and the well-being of the communities that depend on them. Collaborative efforts among stakeholders, including port authorities, environmental organizations, and policymakers, are vital to creating a sustainable future for port operations and the marine environment.

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