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(RESEARCH ARTICLE)

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Determinant factors for rehabilitation and solutions for sustainable development of Hann Bay (Dakar, Senegal)

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Abstract

The degradation of Hann Bay (Dakar, Senegal) has reached extremely high levels with serious environmental, health and social consequences. The presence of inorganic pollutants and microplastics in the habitants represent a threat to wildlife and human beings. Thus, this study, which looked at the key factors for rehabilitating Hann Bay, also proposes solutions for the sustainable development of this area of Dakar region. The target area includes about 500,000 residents and hundreds of industrial units, most of which do not have a suitable sanitation system. Socioeconomic surveys and sediment sampling were carried out in 2022 on eleven sites across the communes of Hann-Bel Air, Dalifort Foirail, Thiaroye-sur-Mer, Sicap Mbao and Mbao.

The analysis of the collected sediment samples indicated that the limit values for lead and zinc set by Ministerial Order of August 9, 2006, have been exceeded at several sampling points, revealing that chemical pollution is still present in the bay and can lead to contamination of fishery resources or the escape of fish to the open sea. This alteration of the ecosystem may also explain frequent fry deaths noticed along the sites of Hann Marinas, Hann Pêcheurs and Cité ISRA.

Further to socio-economic surveys carried out among residents and workers in local industrial units, the recommendations for the rehabilitation and the sustainability of the bay focus essentially on the implementation of protective and preventive measures, the application of regulations, the development of communication and sensitization strategies, the acquisition of equipment and the reinforcement of the monitoring/surveillance

Keywords: Sediments; Pollution; Physicochemical; Lead; Zinc; Hann Bay; Senegal

1. Introduction

The target area of Hann Bay is located in the south of the Cap-Vert peninsula, in the east of the city of Dakar. It extends over approximately 17 km: it is bounded on the north by the former Rufisque road, to the south by Hann Bay, to the west by the base and to the east by the village of Petit Mbao. In Senegal, Hann Bay pollution has been a critical national issue and for decades it has mobilized the Government as well as various stakeholders. Hann Bay which was very busy, in the past, has turned into a place where significant quantities of polluted sediment are being produced. Besides, industrial units that were situated far from the urban center because of the nuisances they might cause, are nowadays close to houses. On the other hand, Triplet (2020), ecologist and director of the Somme Bay nature reserve in France, confirm that: "It is the permanent constructions that have led to accelerated sedimentation. In Hann Bay, there are a lot of permanent constructions. Furthermore, the dredging solution adopted in the Bay of Somme constitutes a good option

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for Hann Bay; however, its high cost remains a drawback, hence the imperative need for the rehabilitation of the sites in order to enhance the image and living environment of Hann Bay. Hann Bay is currently in a severely degraded state, as shown in Figure 1, with waste mixed up and stored abandoned in the open air, which is non-compliant.

"When waste is abandoned, dumped or treated in violation of the provisions of this law and the regulations adopted for its implementation, the competent services of the Ministry in charge of the Environment or the mayor shall, after formal notice, ensure the treatment of that said waste at the expense of the person responsible," Source: Law No. 2023-15 of 2 August 2023, Environmental Code.

This pollution also affects the sediments and the beach, it has driven away tourists, swimmers, and potential investor in this area. The pollution sources are diverse: household waste discharges, hydrocarbons, cargo vessel bilge water discharges, industrial and domestic effluents, among others. This is confirmed by Texeira (2017), who reveals, in the framework of his research on WHO standards, that:

Several factors combine in bays: eutrophication, sediment accumulation..."

What is our contribution to resolving sediment pollution? We will propose measures to better control the degradation of the area and consistently reduce the consequences of sediment pollution for its sustainable development.

2. Materials and methods

2.1. Presentation of the study area

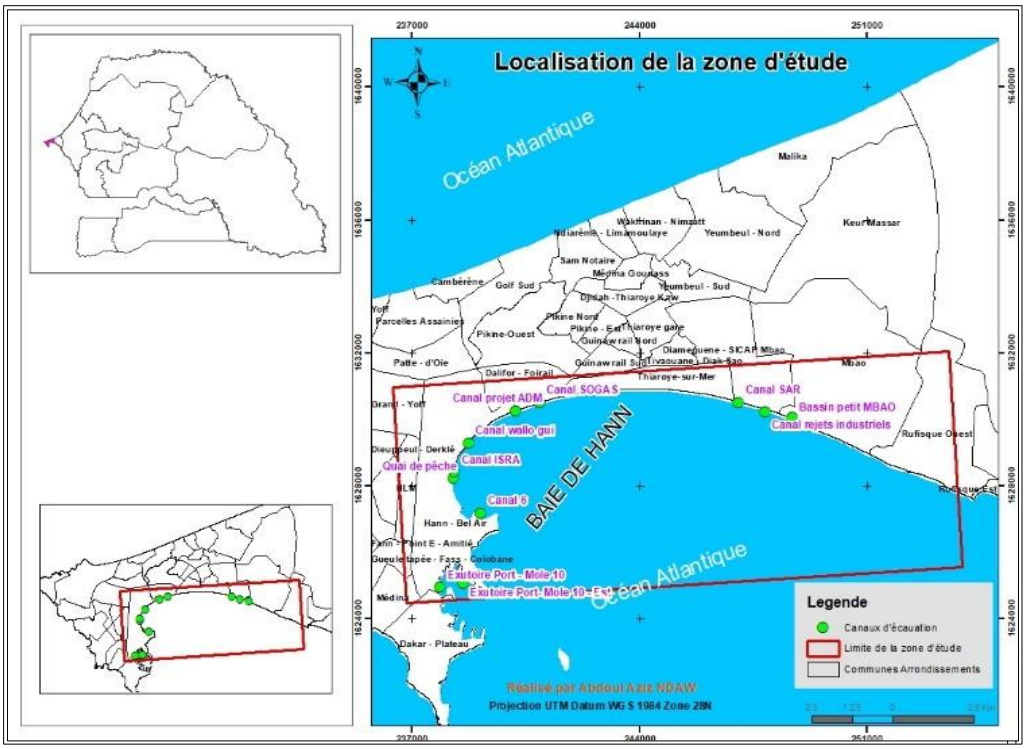
The Hann-Mbao study area (Figure 1) includes several communes, industrial units, households and various human activities which cause pollution through direct or clandestine discharges into the bay or into the pits. The main communes affected by the degradation of the bay (Hann-Bel Air, Dalifort Foirail, Thiaroye-sur-Mer, Sicap Mbao and Mbao) have expanded in terms of population and due to a lack of sanitation and sanitary infrastructure and the lack of an adequate system for collecting and disposing of household waste, the local populations dump their solid waste on the beach or in the bay.

This has very negative impacts on the environment, health and visual aspects and has harmful consequences for the sustainable management of the bay.

2.2. Sampling sites presentation

Sediment sampling was carried out from eleven sites along Hann Bay. All samples were collected in the commune of Hann-Mbao. Location of sediments sampling sites is shown on Figure 1 below.

Direct observations were made at the sampling sites to have an insight of the daily realities experienced in the bay. In fact, different aspects of the beach were observed: sediments, industrial waste water discharges, illegal connections, discharge channels, etc.



Source: author, May 2022

Figure 1 Location of sediment sampling sites

2.3. Reference standards

The national and international reference values used for sediment parameters, as well as limit values, are described in the table below. The choice of sediment sampling points along the bay was motivated, among other things, by the desire for greater representativeness of pollution levels and by knowledge of the most polluted sites from Hann to Mbao. As a result, eleven sampling points were selected, on both side of the different sites.

2.4. Samples, analysis and equipment

Sediment samples were collected from the following sites: Canal 6 (Hann Marinas), Canal Cité ISRA (Hann Bel Air Cite Isra), Port - Mole 10, Port- Mole 10 – est (Hann-Bel Air), Canal Quai de Peche (Hann Pecheur), Canal Wallo Gui, (Hann Pecheur) Canal Projet Adm (Dalifort), Canal Sogas (Dalifort), Canal Rejets Industriels (Thiaroye Sur Mer), Canal Sar (Mbao), Bassin Petit Mbao (Petit Mbao). Samplings selection and preservation were carried out manually and carefully in order to keep their characteristics as intact as possible in order to represent a reliable illustration of the characteristics of the site.

The sediments were stored in a dry state in sampling bags. For environmental characterization, we placed samples from each sampling point in airtight, inert bags.

Table 1 Normative references

The characteristics of the sediment samples taken are described in the table below.	Co pp er g/ kg	**Tolerance threshold**		nc g/ kg	**Tolerance threshold**	mi u m g/ kg	**Tolerance threshold**	ad g/ kg	**Tolerance threshold**	
		Order of August 9, 2006 45g/kg	OSPAR / Abidjan 27 g/kg		Order of August 9, 2006 276 g/kg		Order of August 9, 2006 90 g/kg		Order of August 9, 2006 100 g/kg	OSPAR / Abidjan 38 g/kg
1	4.48	4.48 < 45	4.48 < 27	7.04	7.04 < 276	4	4 < 90	4.48	4.48 < 100	4.48 <38
2	3.04	3.04 < 45	3.04 < 27	3.15	3.15 < 276	2.7	2.7 < 90	3.15	3.15 < 100	3.15<38
3	4.48	4.48 < 45	4.48 < 27	9.92	9.92 < 276	2.88	2.88 < 90	4.48	4.48 < 100	4.48<38
4	4.32	4.32 < 45	4.32 < 27	5.44	5.44 < 276	2.40	2.4 < 90	4.32	4.32 < 100	4.32<38
5	3.21	3.21 < 45	3.21 < 27	282.33	282.33 > 276	13.29	13.29 < 90	78.47	78.47 < 100	78.47>38
6	4.48	4.48 < 45	4.48 < 27	20.96	20.96 <276	27.36	27.36 < 90	5.44	5.44 < 100	5.44<38
7	3.04	3.04 < 45	3.04 < 27	15.53	15.53 < 276	2.14	2.14 < 90	28.91	28.91 < 100	28.91<38
8	3.04			5.51	5.51 < 276	2.36	2.36 < 90	3.38	3.38 < 100	3.38<38
9	3.04			8.89	8.89 < 276	2.70	2.7 < 90	3.15	3.15 < 100	3.15<38
10	4.16	4.16 < 45	4.16 < 27	15.04	15.04 < 276	3.52	3.52 < 90	4.48	4.48 < 100	4.48<38
11	2.90	2.90 < 45	2.90 < 27	46	46 < 276	68.20	68.20 < 90	3.30	3.30 < 100	3.30<38

Then the samples were sent directly to the laboratory of Analysis and Testing of Polytechnic Higher School (ESP) of Dakar to avoid deterioration or contamination and then, the analyses were carried out immediately.

Materials and equipment used to collect the samples are

- Latex gloves
- A shovel
- Plastic bags to collect sediments
- A felt-tip pen to mark and number the bags according to the sampling point
- A bag to contain all the sampling equipment

Figure 2 shows the protocol for collecting sediment samples from ISRA Canal 1. The samples were placed in airtight, inert bags for each sampling point, then stored and sent directly to the laboratory.

(Source: Author, December 30, 2021)

Figure 2 Sediment samples taken from ISRA Canal 1

2.5. Characteristics of the sediment samples collected

Table 2 below shows the sediment color, transparency, turbidity and odor for each sampling site.

Table 2 Characteristics of the sediment samples collected

Designation	Sampling sites	Neighborhood	X coordinates	Y coordinates	Color	Transparency	Turbidity	Smell
P1	Canal 6	Hann	238,260.60	1,628,202.96	Grey Dark	Opaque	Important	Unpleasant
P2	Canal ISRA	Cité ISRA	239,091.73	1,627,168.13	Black	Disorder	Important	Bad
P3	Port - Mole 10	Port	237,858.33	1,624,931.63	Grey	Opaque	Important	Normal
P4	Port-Mole 10 –Est	Port	238,558.24	1,625,045.82	Grey	Opaque	Important	Normal
P5	Canal Quai de Peche	Hann	238,281.56	1,628,395.79	Grey	Opaque	Important	Bad
P6	Canal Wallo Gui	Hann	238,737.17	1,629,279.62	Dark gray	Opaque	Important	Bad
P7	Canal Projet Adm	Montagne 6	240,171.51	1,630,239.51	Brown	Opaque	Important	Unpleasant
P8	Canal Sogas	Dalifort	240,929.63	1,630,497.61	Reddish	Disorder	Very important	Nauseating and strong
P9	Canal Rejets Industriels	Thiaroye-Sur-Mer /ICS	247,849.95	1,630,211.23	Black	Disorder	Very important	Very bad
P10	Canal SAR	Mbao	247,035.00	1,630,490.12	Clear	Sharpness	Important	Normal
P11	Bassin Petit Mbao	Mbao	248,681.25	1,630,055.53	Brown	Disorder	Very important	Infected

(Source: Author, July 2020)

3. Results and discussion

The analysis and interpretation of the results of the sediment samplings are based, on the one hand, on documentary and bibliographic data, and on the other hand, on field surveys carried out in the study area during visits .
Overall results indicate high concentrations on several sediment sampling sites along the Bay of Hann and non-compliance or risk of non-compliance for several parameters (zinc, lead, copper) with levels sometimes high above the limit value compared to standards.
This analysis shows the possibility of using sediment as a pollution indicator due to its high capacity to accumulate pollutants. The risk of high levels of heavy metals that can be found in sediments reveals the real danger of metals pollution. Sediments contain heavy metals and play an important role in the hydrological cycle.

3.1. Low risk of environmental copper toxicity to sediments 1, 3 and 6

Copper toxicity is quite significant for relatively low doses, and it has a harmful effect on the environment. Excessive concentrations of copper have a deleterious effect on the balance of the surrounding environment. Here, copper concentration complies with the limit value set by Ministerial Order and OSPAR for the 3 sites Canal SOGAS, Canal WALO GUI and ICS (4.48g per kg and per site). However, these sites should be monitored.

This risk of pollution can affect the availability of fishery resources and youth employment (source: author, 2022 survey report). It is mainly caused by natural factors, coastal shoreline retreat, industrial waste water discharges, illegal connections, uncontrolled discharges from populations, and dumped solid waste. Pollutants may be inorganic in nature (metals, chlorides, etc.) and are generally found in most industrial activities.

3.2. High toxicity of zinc in the receiving environment for sediments 5 and 11

For the PAD sediment on the east side, the concentration highly exceeds the set limit value. High zinc concentrations can cause damage and inhibit metabolic processes. Zinc tolerance plays a role in zinc toxicity because it becomes harmful when in excess.

For the Bassin Petit Mbao sediment, the result of Sediment 11 shows an increase compared to the other sediments which indicates low toxicity.

The pollutants present in sediments mainly come from human, industrial and domestic activities. This argument is reinforced by UNTERREINER (2015), who explains that: the sediments will continue to develop. Indeed, human-made structures have also affected the bay of Mont-Saint-Michel.

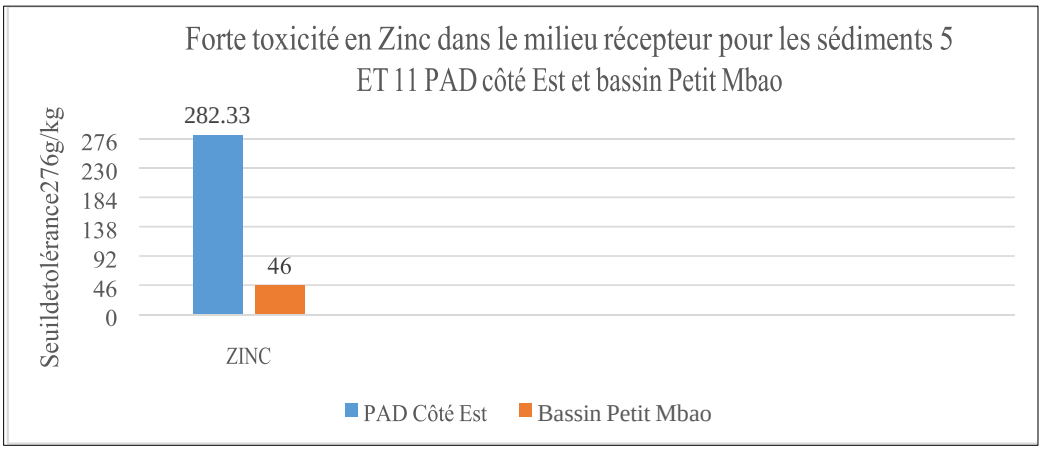


Figure 3 High zinc toxicity noted for sediments 5 and 11 PAD on the East side and Bassin Petit Mbao

3.3. Low risk of chromium toxicity in the environment for sediments 11 and 6

The low chromium concentration meets the limits set by the threshold, hence a low toxicity level. Chromium is a source of pollution and is very toxic to the surrounding environment and monitoring should be continued as it appears necessary to reduce pollution.

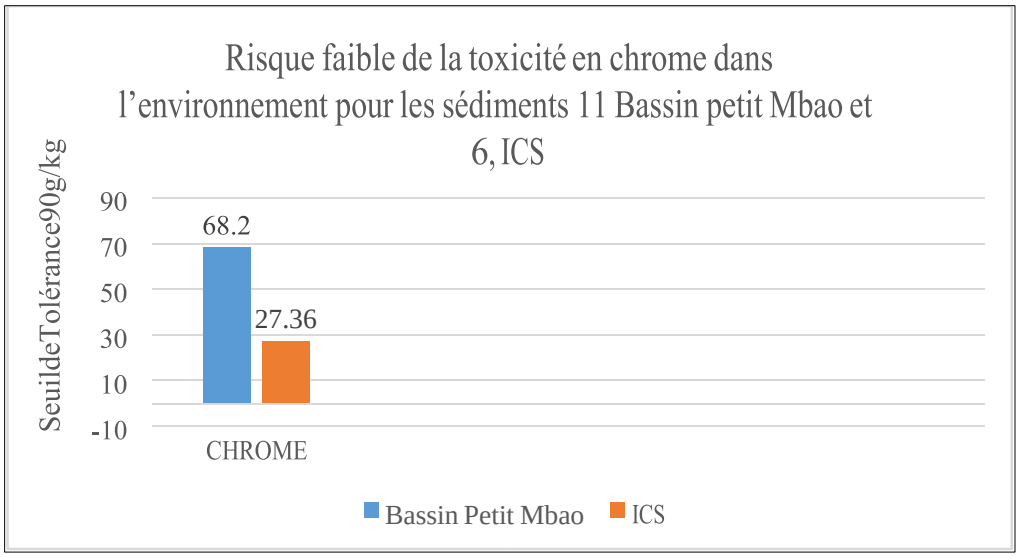


Figure 3 Low risk of chromium toxicity in the environment for sediments 11 Bassin petit Mbao and 6, ICS

3.4. High lead toxicity in the environment for sediment 5 PAD on the East side

The result of sediment 5 largely exceeds the threshold set in lead by OSPAR but this one is in accordance with the Ministerial order.

Lead is persistent and is a very toxic compound and a contaminant of concern to the receiving environment. A considerable decrease in its concentration indicates a trend towards improvement in the state of the environment, knowing that lead found in high concentrations in sediments is the source of a certain potential for biological effects harmful to the environment.

This is supported by SAGNA (2019), in his thesis, entitled: assessment of bioaccumulation of trace metal elements (pb, cd, hg, cu) in the pernaperna mussel, in the Bay of Hann. It reveals that the development of industrial activities and the establishment of habitats along the edge of the coast have increased the pressure on the coastal marine environment which is contaminated at certain places. It also indicates that "the presence of heavy metals in the bay results from causes derived from human activities. Their toxicity varies; as does their impact on the environment (lead accumulates in the bodies of aquatic organisms which suffer the consequences due to poisoning)".

Furthermore, the result of sediment 7 Quai de Peche canal 1 does not exceed the threshold set by OSPAR and the Ministerial order, hence a low lead toxicity.

3.5. Sharp increase of inorganic pollutants

There is a significant increase regarding inorganic pollutants: zinc, lead at the PAD-Est level, in the sediments, according to the graph above.

The levels of heavy metals found in the sediments reveal the real danger of metals. These concentrations of zinc and lead in the sediments cause a risk of pollution, which can cause negative biological effects on the environment and cause concern because of non-compliance with heavy metals (zinc threshold set on August 9, 2006, 276g/kg and threshold 0.038 for lead): lead and zinc (see figure).

The consequences of their accumulation are not negligible in this area known as the Port. This indicates a high toxicity of this sediment susceptible to cause damage to the environment. Indeed, the presence of high concentrations of lead and zinc in the various samples, contributes to potential dangerous aspect of the sediments. The high concentrations of lead and zinc causing biological pollution, are due to the presence of inorganic pollutants (source: ESP Analysis and Testing Lab, February 21, 2022), come from industries, illegal connections, households and various discharged waste. All this contributes to the potential dangerous qspect of the sediments. It is therefore advisable to continue the monitoring of these parameters in order to ensure environmental preservation.

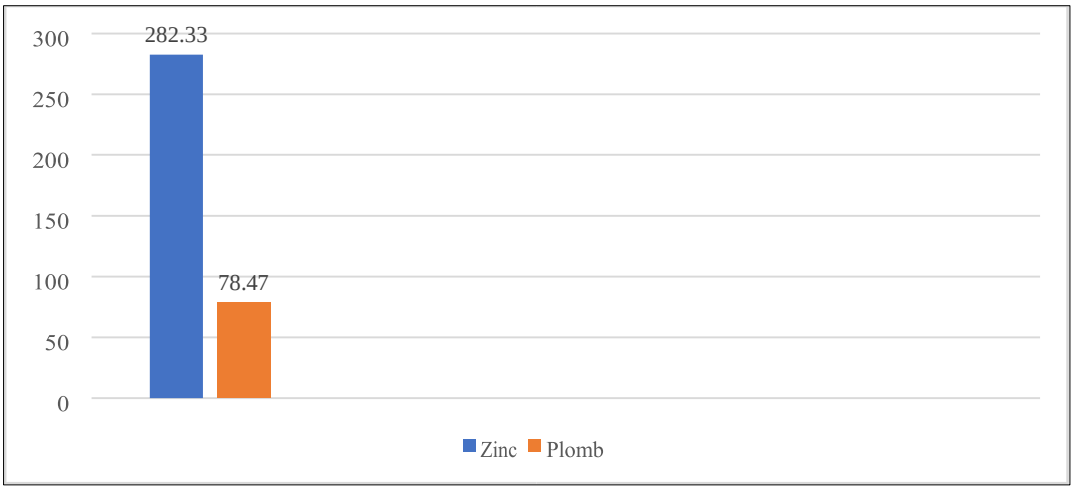


Figure 5 Sharp increase inorganic zinc and lead pollutants (g/kg) depending on the sampling points: PAD East Side

4. Conclusion

Finally, the following solutions proposed are general, regulatory, technical and their implementation will allow sustainable development of the target area

- Control and monitor the quality of sediments through regular sampling and prohibit swimming on beaches
- Identify the different elements potentially present in order to be able to assess them and verify the cleanliness of the sediments studied
- If possible, dredge the sediments
- Increase awareness among stakeholders to further combat pollution: the State, industrialists, populations, partners and the scientific community
- Revise the polluter-payer agreement protocol which is no longer relevant and have it signed by the stakeholders
- Raise awareness of the environmental code voted in 2023 for effective application and comply with housing construction standards
- Establish special protection standards for Hann Bay by decree as a marine protected area where the waters are protected in the communes of Hann and Mbao.In addition, DIENG (2022), Coordinator of the Hann Bay Decontamination Project, underlines that "the donors Chinese Development Bank, FDA and the Netherlands are positive and willing to rehabilitate the bay by implementing infrastructure

It is therefore necessary to act quickly and carry out effective treatments to restore the bay.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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[1] Louise Aminata SAGNA THIAW (December 2019), dissertation, entitled: "« évaluation de la bioaccumulation des éléments traces métalliques (pb, cd, hg, cu) chez la moule pernaperna, au niveau de la baie de Hann (Evaluation of the bioaccumulation of metallic trace elements (pb, cd ; hg,cu) in the perna perna mussel, in Hann Bay) ". 81p

[2] Cormy, Gaëtan,Report, Microplastic contamination of sediment in the Bay of St-Brieuc, 28p; Quote "« Les microplastiques sont de petites particules de plastiques inférieures à 5 mm, présents dans tous les habitats et représentant une menace pour la faune et pour les Hommes» Microplastics are small plastic particles less than 5 mm, present in all habitats and representing a threat to wildlife and humans. May 1, 2020

[3] Field survey report- source=author 2022

[4] Patrick Triplet: biologist, doctor of ecology, director of the Somme Bay national nature reserve, report on the Somme Bay nature reserve. 2023-2027, 267p

[5] Philippe UNTERREINER: 2015, SOGREAH (Grenoble Company for Hydraulic Studies and Applications),Lecturer at the National School of Bridges and Roads – quote, 1p: « le taux de sédimentation de la baie de Somme se révèle identique à celui de la petite baie du Mont-SaintMichel ». (the sedimentation rate of the Bay of Somme is identical to that of the small bay of Mont-SaintMichel).

[6] Sharon Teixeira (July 2017),report, memorandum on the rehabilitation of Cocody Bay (Ivory Coast), 145p

[7] Eirik Lindebjerg, (2022), responsible for the plastic file World Wide Fund for Nature (WWF), quote, 1p: « nous atteignons un point de saturation pour les écosystèmes marins qui fait peser une menace non seulement sur des espèces données mais affecte tout l'écosystème ». « la pollution plastique a atteint « toutes les parties des océans » (we are reaching a saturation point for marine ecosystems that poses a threat not only to individual species but affects the entire ecosystem." "plastic pollution has reached "all parts of the oceans.)

[8] Alassane DIENG (March 2022), coordinator of the bay decontamination project year,Senegal National Sanitation Office (ONAS),indirect quotation,www.onas.sn,1p, , « Les travaux de la dépollution de la baie de Hann ont été lancés le 25 décembre 2020. Le projet consiste à réaliser un intercepteur qui sera relié à une station d'épuration, un émissaire en mer..., des réseaux pour raccorder les unités industrielles et les maisons à l'intercepteur ». (The work to clean up the Bay of Hann was launched on December 25, 2020. The project consists of building an interceptor which will be connected to a treatment plant, an outfall at sea, etc., networks to connect industrial units and homes to the interceptor.)

[9] Environmental Code of Senegal, law2023-15 from August 2, 2023-Republic of Senegal 51p

[10] Senegal Horizon 2050 Reference Framework- transformation diary, 18p

[11] Analysis report -ESP Lab Oct 2020-February 2020, 1p(Characteristics of the sediment samples collected)