SYSTEMATIC REVIEW OF POLLUTANTS IN SANTIAGO DE CUBA BAY

ABSTRACT

The bay of Santiago de Cuba is the second in importance and contamination in the country. Aggressive waste discharges with organic and inorganic materials, heavy metals, masonry residues, grease, oils and hydrocarbons, among others, are discharged into the bay. A systematic review of databases, publications, web pages and other documents was carried out in order to find out more about contamination. Eighty-five percent of the main reports refer to organic matter contamination and waste characterization, followed by hydrocarbon contamination (15 %). This makes the work related to sustainable management in the bay insufficient.

Keywords: contaminated water, contamination, bays, hydrocarbons.

INTRODUCTION

Coastal zones are one of the most important regions from a natural and social point of view, as they are very sensitive to the synergy between climate change and socioeconomic activity. Their ecosystems are responsible for a quarter of global primary production and are home to some of the highest density population centers, with high growth rates, intense tourist, industrial, maritime-port activity and also receive large inputs of pollutants (Planos et al., 2012).

Within the southeastern coastal area is the bay of Santiago de Cuba, classified as a pocket bay and considered the second in importance, population and pollution in the country after the bay of Havana. In accordance with the socioeconomic development of the province, this area has undergone changes, dating back to the existence of aboriginal settlements before 1492, with areas covered by natural forests, abundant timber trees, royal palms, different tree and shrub species and a wide diversity of marine and terrestrial fauna (Villasol, 1979).

The Santiago Bay has a narrow entrance channel that limits water renewal and covers an area of 11.9 km^2 with a perimeter of 41 km. Its maximum length is 6.5 km, with an average depth of 8 m and a maximum depth of 21 m. There are also two small keys: Cayo Granma, the largest, with an area of 10.5 ha, and Cayo Ratones (1.4 ha). The surface water it receives comes mainly from the Cobre, Los Guaos, Gascón, Yarayó rivers and the Trocha (Yarto) drain (Valdés and Regadera, 2012).

One of the issues of interest for Cuba is the environmental protection of coastal areas and their ecosystems, including the bay, which is considered a strategic point for the country, since it allows the transportation of all types of cargo to and from Santiago de Cuba, as well as to the countries of the Greater Caribbean, North America, South America, Europe and Asia.

The Mesoamerican Biological Corridor program (Putney and Vela, June 2007) states that solving environmental problems requires a general approach that does not always require technological solutions, since the social aspect plays a preponderant role through a real transformation of our attitudes and behavior. It also considers that it is a long and slow process, in which degradation has the greatest progress, so it is necessary to have mechanisms to face

situations with a close relationship between economy, environment and society, pillars of sustainable development.

The area surrounding the bay is the most industrialized in the province of Santiago de Cuba, so pollution is one of the main problems in this ecosystem. The organic load and hydrocarbons are the main pollutants, causing a wide variety of impacts, in addition to the presence of heavy metals. All these factors affect not only water quality, but also the flora and fauna present in this ecosystem and human health.

MATERIALS AND METHODS

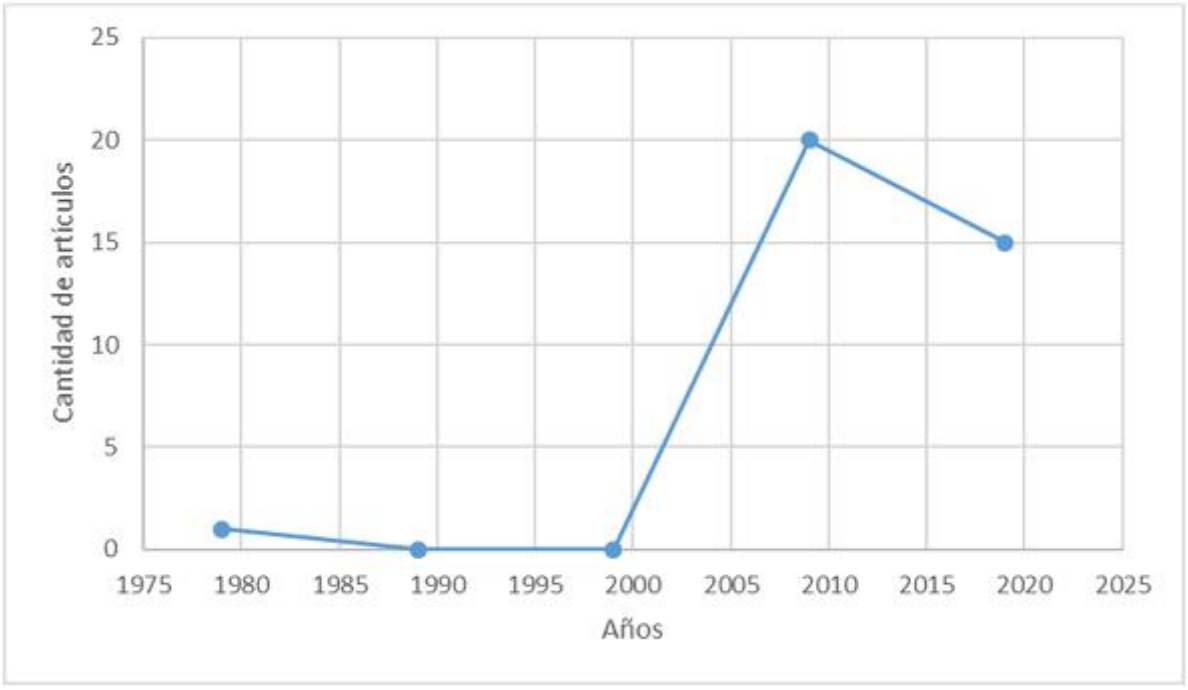
Articles from different databases were reviewed: Web of Science (ISI), ScienceDirect (Elsevier), EBSCO and Google Scholar. The Keywords were Santiago de Cuba bay, contamination, oils and fats, industrial zone and hydrocarbon contamination.

The articles were compiled and selected using the flow chart of the Prisma protocol (2009), with the objective of homogenizing the information and discarding those that did not fall within the focus of the study. The following inclusion criteria were used: contamination in the bay, environmental management, hydrocarbons, fats and oils, and vulnerability. As a result, a total of 150 articles published between March 1996 and December 2018 related to the subject were obtained, of which 37 were of interest for the analysis.

RESULTS

A trend analysis shows that the main articles referring to the presence of pollutants and their impact on the bay were written after 1990, with greater emphasis after 2000. Prior to 1990 there was not much reference to pollution problems in the bay, so it is inferred that the existing conditions were in accordance with the required environmental quality (Figure 1).

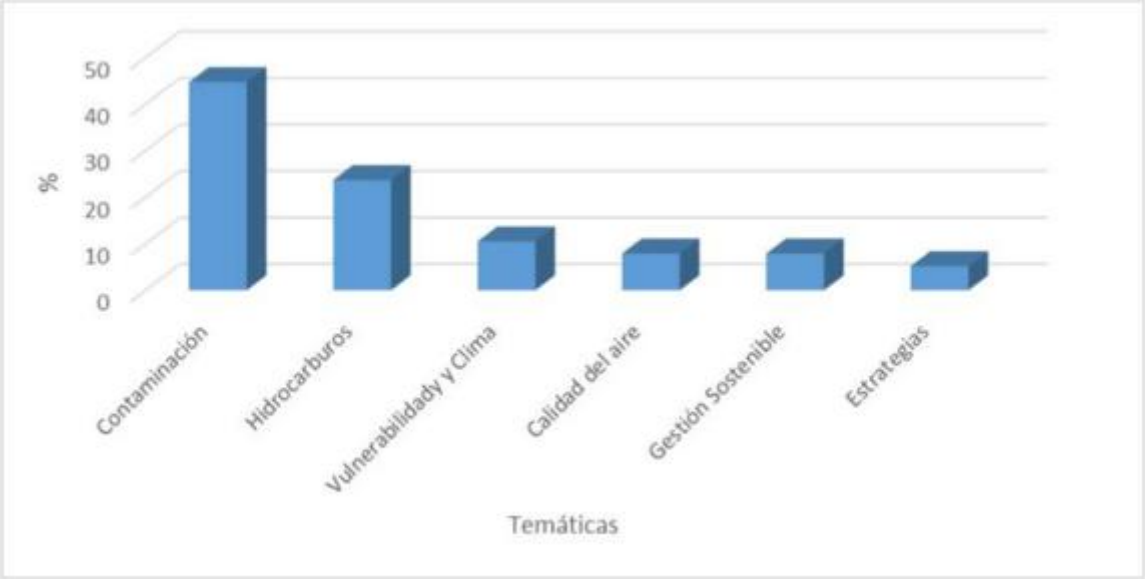
Figure 1. Trend over time on articles referring to pollution in the bay. Period 1979- 2018



Source: Authors

Between 2000 and 2018, 50 % of the studies found refer to the contamination of organic compounds and characterization of the waste from the main companies that discharge into the bay and the presence of heavy metals. Twenty percent of the studies reported on hydrocarbons, fats, oils and the various techniques used for their evaluation. In smaller proportions, topics on climate change, environmental strategies and sustainable management are included (Figure 2).

Figure 2. Main contamination issues in the bay



Source: Authors

Contamination

The bay has been the subject of study for a long period of time because of the importance of caring for its waters and surroundings for the conservation of the species that inhabit it, the goods and services that this ecosystem offers, and the socioeconomic development of the country.

Pollution is of growing interest due to the problems it causes to the environment. Chabalina and Beltran (2008, 2012) carried out an evaluation of the water quality of Santiago Bay for seven consecutive years (1983-1990). They found that the most polluted areas were the mouth, the port area and the inner lobe; the latter was the most affected, especially with the presence of organic matter from the Yarayó River and the Trocha drainage.

Pollution in the bay is the cause of environmental problems on the coast. Álvarez and Gómez (2009), Gómez et al. (2001) state that of the 52 neighboring industries, 75% have some type of waste treatment, but only 45% of them have appropriate procedures to effectively reduce the pollution load; this is evidenced by Abalos et al. (2007) when they reveal that the edible oil refining plant discharges an organic load of 2,896.74 kg per day into the bay.

The potentially polluting companies and the type of discharge, whether hydrocarbons, heavy metals, organic matter, or others, are well identified. The waste from the Hermanos Díaz Refinery, the Rente Thermoelectric Plant, the Celia Sánchez Manduley Textile Combine, the Santiago Combine, which includes the Hatuey brewery and the alcohol and aguardiente distillery have been characterized. The latter stands out for the aggressiveness of its organic waste and high BOD5 values (25,000 and 30,000 mg/L), in addition to nitrogen and phosphorus inputs,

which cause water eutrophication processes (Poveda et al., 2009; Arias, 2008). All of the above confirms the presence of elements that directly affect soil, water and atmosphere, with different effects on ecosystems.

Although it is posited that most of these companies are within the environmental improvement system, there is still insufficient monetary and educational availability to improve environmental performance (Poveda, 2014).

The presence of heavy metals was monitored in several Cuban bays, the results are shown in Table 1. The most contaminated are the bays of Santiago de Cuba and Havana (Chabalina and Beltran, 2008).

Table 1. **Concentration of heavy metals (ug.g^{-1} ; Fe in %) in the sediments of different Cuban bays.**

Areas	Cu	Pb	Zn	Co	Faith	Mn	Ni
Havana	65260	65334	80497	<3.014	1.41-4.09	137465	24-228
Matanzas	1560	20-56	20152	8.0-28	0.53-4.10	54325	42-229
ZonaVaradero-Cárdenas	1.667	<2.53.0	4.5125	<2.59.0	0.38-2.69	61496	5-97
Nipe	9.640	2.5-28	28-96	12154	1.68-17.58	2371689	1202178
Levisa	1-91	4.6-46	2-174	7.7881	0.0434.34	1253719	3011215
Cabonico	1366	6-35	22-68	11-79	2.65-14.45	3071208	3461090
Santiago deCuba	35194	7.7213	102603	6.48.6	1.6-4.39	158472	6-15
Cienfuegos	32144	6.8103	57195	6.4-16	1.75-5-60	300997	22-46

Source: Chabalina and Beltran (2008), Regadera, Gómez and Beltran (2014).

Regadera et al., (2009) and Regadera, Gómez, and Beltrán (2014) evaluated a great variety of physical, chemical, and bacteriological indicators in surface waters and at 8 m depth in both seasonal periods. A Abstract of the results is shown in Table 2. The shaded grids do not comply with the values established by the standard NC:25/1999 (Oficina Nacional de Normalización, 1999), chosen as a reference.

Table 2. Abstract of the average results of the parameters evaluated between 2009-2014. Legend: **= Mandatory compliance parameters.

Parameters	UM	2009	2012	2014	Reference (Good Quality)
Transparency	m/% prof	1.3	1.6	0.8	50-100
Salinity**	You	35.6	33.5	29.4	26-35
pH**	mgL-1	8.1	8.2	7.9	8.1-8.3
OD**	mgL-1	6.5	6.5	8.2	> 5
NO_2	mgL-1	0.28	0.01		<0.05
NO3	mgL-1	0.93	0.13	0.34	<0.01
NH4	mgL-1	21.9	0.12	0.21	<0.03
PO4	mgL-1	0.59	0.17	0.13	<0.5
PT	mgL-1	4.5	0.51	0.23	
SiO3	mgL-1	2.5	0.289	0.07	
SST	mgL-1				<100
CE	mScm-1				

Chlorophyll	mgm3	18.3		3.9	
HPDD	ugL-1	2009	3.05	0.33	
CTT	MPN/100mL	1.3		2014	<200

Source: Regadera et al. (2009)

The results presented by Regadera et al. (2009) and Regadera and Valdés (2012) refer to the variation of these compounds according to the established norms and highlight the decrease in salinity, although within the established limit; they also recommend a follow-up in subsequent monitoring. Nitrogen compounds are above the standards, associated with the decomposition of organic compounds by dragging in surface waters and the contributions of natural processes. This classifies the water quality as doubtful and prone to eutrophication processes.

With respect to coliforms, the concentrations reported were above the norm, associated with the residual sewage load of part of the population of San Juan.

In the environmental study conducted by Geocuba-Serpo (2015) for the port development, it was shown that even the bay still receives a high pollutant load, measured as Biochemical Oxygen Demand (BOD), generated and emitted to the environment by the main sources, considering that 89.68 % of the load that reaches the bay is by the dragging of surface waters, which shows that a malfunction in the treatment systems still persists.

The care of water resources is an issue of interest stipulated in the National Environmental Strategy, and from there, provincial adjustments are made for the protection of these resources.

In Santiago de Cuba, the Ministry of Science, Technology and Environment (Citma) (2020) established within the Provincial Environmental Strategy the care of the bay of Santiago de Cuba due to the importance of the bay. The first phase corresponded to the period 1999-2005. During this period, the lack of environmental awareness and education among the population, low management standards, insufficient environmental policy in development plans and programs, and poor application of the legal system were identified as strategic problems, which, together with the lack of material and financial resources, prevented the achievement of higher levels of environmental protection in the bay, with direct influence on health, quality of life, successful development of economic activities and the conservation of its scenic beauty.

An example is the environmental perception study conducted in the community of Cayo Granma by Gómez et al. (2009) on the identification of environmental problems in the communities of Cayo Granma; the result showed a limited knowledge of the environment on the part of the inhabitants.

The need to implement integrated coastal management as a tool for sustainable planning of resources and protection of the coastal zone, as well as issues related to climate variability and the occurrence of extreme events, was raised. This analysis considered the population of the Cayo Granma, Los Cangrejitos and Van Van communities to be of medium vulnerability (Milanés and Pacheco, 2011).

Hydrocarbons

Hydrocarbons are another focal object of attention within the bay. Of the articles reviewed, 12.3% focused their analysis on decontamination and the novel techniques applied, which are still inefficient. Téllez (2003) proposed a contingency plan against oil spills as a partial solution.

Taking into account the characteristics of the bay with respect to the replacement time of its waters, another of the studies was framed to corroborate the persistence of organic compounds and hydrocarbons in the waters over a long period of time. There are several remediation techniques for aquatic and terrestrial ecosystems used internationally to minimize the impact of hydrocarbon pollution, among which the following stand out: incineration of pollutants, evaporation, dispersion and washing; all of them are expensive technologies that do not necessarily ensure mineralization, i.e., transformation to the most oxidized forms of pollutants (Fernández et al. 2015).

In Cuba, BIOIL-FC (a product consisting of a consortium of five bacterial strains), produced and patented by the Centro de Bioactivos Marinos (Cebimar), has been used to treat marine ecosystems impacted by hydrocarbons. This product was tested in soils contaminated with fuel oil and gasoline, combining bioaugmentation and biostimulation with nutrients.

In the work presented by Nápoles et al. (2007), the environmental impact caused by the oil industry was assessed by means of a cause-effect matrix. The most affected factors were air, health and hygiene, soil, surface water and groundwater, while the most aggressive impacts were in the malfunctioning of the liquid waste treatment system and the emission of gases, mainly sulfur dioxide (SO_2).

Bermúdez (2012) applied a BIOIL-FC bacterial consortium for the environmental cleanup of a coastal area contaminated with hydrocarbons, located in the north-central portion of Cienfuegos Bay, with satisfactory results. Similar works were presented by Mesa and Falcón (2017), Rodríguez et al. (2016), Santana et al. (2015); in all cases the hydrocarbon levels were well above that established by NC/22, 1999 (Oficina Nacional de Normalización, 1999).

The low perception of environmental issues in the Port Administration of Santiago de Cuba was identified as a problem. For this reason, it was proposed to incorporate the environmental variable in the development of its activities, since it does not interfere in the efficiency of its operations, which would allow it to carry out environmentally safe and sustainable activities.

Air

Another aspect found in the review is air quality. The areas around the bay are home to a population of approximately 54 662 inhabitants (Cuba. National Office of Statistics and Information (ONEI), 2014). González and Reyes (2005) evaluated the presence of settleable dust of industrial origin in the bay, which demonstrates the persistence of the gases carbon dioxide (CO_2) and sulfur dioxide (SO_2). Another study, conducted by Geocuba-Serpo (2015), evaluated the concentration of the gases CO_2 , N_2 , O_2 , CO, H_2 , C and SO_2 in the morning hours, a problem attributable to the industrial process. The values found were within the maximum values allowed by NC/39, 1999 (Oficina Nacional de Normalización, 1999). Due to the importance of this, it is recommended to extend the analysis period in order to obtain definitive results.

CONCLUSIONS

- Studies referring to the bay of Santiago de Cuba were compiled and reviewed, 87% of them concerning pollution from its various aspects. These showed that inadequate conditions still persist in the technological processes of the industries surrounding the bay.

REFERENCES

Abalos, A., Marañón, A., Fernández, J.M., Aguilera, I. and Despaigne, F. (2007). Characterization of wastewater from the edible oil refining plant ERASOL. CENIC Rev. Ciencias Biológicas, 38(3), 220-223. https://www.redalyc.org/pdf/1812/181221643008.pdf. https://www.redalyc.org/pdf/1812/181221643008.pdf

Álvarez, I. and Gómez, L. (2009). Goals for an ICZM initiative in the inner lobe of the bay of Santiago de Cuba. Ciencia en su PC, 4 October-December, 70-93. https://www.redalyc.org/pdf/1813/181317813006.pdf. https://www.redalyc.org/pdf/1813/181317813006.pdf.

Bermúdez, J. (2012). Bioremediation of hydrocarbon contaminated soils from the use of an allochthonous bacterial consortium in the coastal area of Punta Majagua. Cienfuegos, Cuba (Thesis in option to the degree of Master of Engineering in Environmental Sanitation). Martha Abreu Central University of Las Villas. Santa Clara,

Cuba. https://dspace.uclv.edu.cu/bitstream/handle/123456789/3176/Jelvys%20Berm%C3%BAdez%20Acosta.pdf?sequence=1&isAllowed=y

Putney, A.D. and Vela, C. (June 2007). Project RLA97G31. Establishment of a program for the consolidation of the Mesoamerican Biological Corridor (MBC) (Evaluación cierre Evaluación Proyecto CCAD-PNUD-PNUMA-GNUMA/GEF-GTZ. Informe Final). https://erc.undp.org/evaluation/documents/download/3112

Chabalina, L. and Beltran, J. (2008). Marine pollution in bays and coastal areas of Cuba and the Greater Caribbean (Report 1). Center for Engineering and Environmental Management of Bays and Coasts. Havana, Cuba (unpublished).

Chabalina, L. and Beltran, J. (2012). Marine pollution in bays and coastal areas of Cuba and the Wider Caribbean (Report 2). Center for Engineering and Environmental Management of Bays and Coasts. La Hababa, Cuba (unpublished).

Cuba. National Office of Statistics and Information (ONEI). (2014). Statistical Yearbook of Santiago de Cuba. http://www.onei.gob.cu/mapa/provincia/santiago.

Cuba. National Standardization Office (1999). Cuban Standard NC: 25- 1999 Evaluation of water objects for fishing use. Specifications. Havana, Cuba: author.

Cuba. National Office of Standardization (1999). Cuban Standard NC: 22 -1999 Bathing places on coasts and in inland bodies of water. Sanitary and hygienic requirements. Havana, Cuba: autor Cuba. National Standardization Office (1999). NC 39: 1999 Air quality. Hygienic-sanitary requirements. Havana, Cuba: author. http://jabber.otn.camaguey.cu/FTP-NORMAS/Normas/NC-1999/NC%2039-1999.pdf

Ministry of Science, Technology and Environment (Citma) (2020). National Environmental Strategy 2016/2020. Havana, Cuba. https://www.cubahora.cu/uploads/documento/2019/05/21/estrategia-ambiental-nacional-2016-2020.pdf

Fernández, M.A., Rodríguez, D., García, I., Santána, M. and Córdova, V. (2015). Behavior of organic pollution in the bay of Santiago de Cuba. Ciencia en su PC, 1 January-March, 29-42. https://www.redalyc.org/pdf/1813/181338814003.pdf

Geocuba-Serpo (2015). Environmental Impact Study to the Multipurpose Terminal Project Puerto Santiago de Cuba.

Environmental Baseline (unpublished).

Gómez, L., Larduet, Y. and Abrahantes, N. (2001). Contamination and biodiversity in aquatic ecosystems. The phytoplankton of the bay of Santiago de Cuba. Rev. Invest. Mar. 22(3), 191-197. https://www.researchgate.net/profile/Liliana-Gomez-Luna/publication/237494417_CONTAMINACION_Y_BIODIVERSIDAD_EN_ECOSISTEMAS_ACUATICOS_EL_FITOPLANCTON_DE_LA_BAHIA_DE_SANTIAGO_DE_CUBA/links/54fb5d620cf2c3f524204830/CONTAMINACION-AND-BIODIVERSITY-IN-AQUATIC-ECOSYSTEMS-THE-PHYTOPLANKTON-OF-LA-BAHIA-OF-SANTIAGO-DE-CUBA.pdf

Gómez, L., Méndez, J., Sao Cancio, I., Wilson, J. and Olivares, G. (2009). An analysis of environmental perception in two communities of Santiago de Cuba: Cayo Granma and Ducureaux . Ciencia en su PC, 4 October-December, 120-130. https://www.redalyc.org/pdf/1813/181317813009.pdf

González, A., and Reyes, O. (2005). Evaluation of the environmental impact of industrial atmospheric pollution in the bay of Santiago de Cuba. Revista Cubana de Quimica, XVII(3), 43. https://www.redalyc.org/pdf/4435/443543687016.pdf

Arias Lafargue, T. (2008). Characterization of some of the main pollutant sources in the bay of Santiago de Cuba and their consequences on the environment. Tecnología Química, XXVIII(2), 79-89. https://www.redalyc.org/pdf/4455/445543756010.pdf. https://www.redalyc.org/pdf/4455/445543756010.pdf.

Mesa, L. and Falcón, J. (2017). Evaluation of the degree of oil contamination in waters of the bay of Santiago de Cuba. Rev. Boliviana de Química, 34(2), 56-64. http://www.scielo.org.bo/scielo.php?script=sci_arttext&pid=S0250- 54602017000200003&lng=en&tlng=en.

Milanés, C. and Pacheco, A. (2011). Coastal settlements in the bay of Santiago de Cuba: studies of their urban vulnerability. Rev. Arquitectura y Urbanismo, XXXII(3), 18-26. https://www.redalyc.org/pdf/3768/376839863005.pdf

Nápoles, J., Ábalos, A., Pérez, N., Marañón, A. and Díaz, E. (2007). Environmental impact of the oil industry in Santiago de Cuba. Characterization. Tecnología Química, XXVII(2), 83-91. https://www.redalyc.org/pdf/4455/445543753013.pdf. https://www.redalyc.org/pdf/4455/445543753013.pdf.

Planos Gutiérrez, E. Rivero Vega, R. and Guevara Velazco, V. (eds.) (2012). Climate Change Impact and Adaptation Measures in Cuba. Havana, Cuba. http://www.redciencia.cu/geobiblio/paper/2012_Planos_Impacto%20y%20Adaptacion, %20Libro.pdf.

Poveda, I., Morales, M. and Rizo, M. (2009). Influence of the enterprise as an economic agent of sustainable development in the coastal area of the bay of Santiago de Cuba. . Ciencia en su PC, 4 October-December, 94-103. https://www.redalyc.org/pdf/1813/181317813007.pdf

Poveda, I. (2014). The dimensions of development in polluting state-owned enterprises in the bay of Santiago de Cuba. Ciencia en su PC, 2 April-June, 86- 94. https://www.redalyc.org/pdf/1813/181331790006.pdf

Regadera, R., Gómez, L., Gómez, Y. and García, E. (2009). Monitoring of the environmental quality of the ecosystem of the bay of Santiago de Cuba (Partial report). Havana, Cuba (unpublished).

Regadera, R. and Valdés, M. (2012). Monitoring of the environmental quality of the ecosystem of the bay of Santiago de Cuba (Executive Abstract). Havana, Cuba (Unpublished).

Regadera, R., Gómez, Y. and Beltrán, J. (2014). Control of the environmental quality of the marine ecosystem of the bay of Santiago de Cuba (Research-Development and Technological Innovation Project). Center for Engineering and Environmental Management of Bays and Coasts (Cimab) (Unpublished).

Rodríguez, D., Santana, M.A. and Creagh, B. (2016). Contamination by fats and oils in bathing areas of the bay of Santiago de Cuba. Part # 1: Chemical determination. Science in your CP, 1 January-March, 77-88. https://www.redalyc.org/pdf/1813/181345819007.pdf. https://www.redalyc.org/pdf/1813/181345819007.pdf

Santana, M.A., Rodríguez, D., Díaz, M. and Salazar, P. (2015). Evaluation of hydrocarbon contamination of the bay of Santiago de Cuba. Rev. Cubana Química, 28(2, May-August), 554-560. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2224- 54212016000200002&lng=en&tlng=en

Téllez, D. (2003). Plan de contingencia contra derrills de hidrocarburos, una práctica sensata del manejo integrado de zonas costeras (Thesis in option to the academic title of Master of Science in Integrated Management of Coastal Zones). Universidad de Oriente, Center for Multidisciplinary Studies of Coastal Zones. Santiago de Cuba, Cuba (unpublished).

Valdés, M. and Regadera, R. (2012). Monitoring of the environmental quality of the ecosystem of the bay of Santiago de Cuba (Partial Report). Havana, Cuba (Unpublished).

Villasol, A. (1979). Preliminary report on water pollution in the bay of Santiago de Cuba. Partial Report. Item 02 Contamination of waters in the port of Santiago de Cuba. Cuba (unpublished).