IOSR Journal of Applied Chemistry (IOSR-JAC)
e-ISSN: 2278-5736.Volume 15, Issue 6 Ser. II (June 2022), PP 37-42
www.iosrjournals.org

Heavy Metal Pollution on Tourist Beaches in the Province of Puerto Plata (Dominican Republic)

Vladimir A. Rodríguez Núñez[1], Roberto Luis Gómez Santana[2], José del Carmen Castillo Jáquez[3], Edward de Jesús Hernández Domínguez[4]

[1]*Department of Sustainability, Technological University of Santiago, Dominican Republic, sostenibilidad@utesa.edu*
[2]*Department of Sustainability, Technological University of Santiago & Ministry of Environment and Natural Resources, Dominican Republic drobertogomez@gmail.com*
[3]*Department of Natural Sciences, Technological University of Santiago, Dominican Republic, investigación@utesa.edu*
[4]*Project Assistant, Technological University of Santiago, Dominican Republic, edwardhernandez2@alumno.utesa.edu*
Technological University of Santiago, Santiago de los Caballeros, 51000, investigaciones@utesa.edu

Abstract:
Background: Beaches are key points for recreation and coastal tourism and a major source of income for many countries. Thus, good beaches attract tourists and degraded ones discourage tourism. Also, beaches and coastal areas are ecosystem areas and vital for the conservation of natural resources. The research goal in this paper was to analyze the concentration of heavy metals on the tourist beaches of the city of Puerto Plata (Dominican Republic) and its impact on the conservation of coastal marine systems and the development of recreational activities and tourism.
Materials and Methods: The methodology was drawn up by a certified laboratory and followed the methods of The United States Environmental Protection Agenda, through the Inductively Coupled Plasma (ICP) technique.
Results: Total Chromium was the main heavy metal found on the beaches of Puerto Plata. Other heavy metals found included Total Copper, Total Arsenic, Total Lead, and Total Cadmium.
Conclusions: These findings suggest action needs to be taken to lessen the impact of beach contamination on Puerto Plata's marine-coastal systems. The presence of these heavy metals has negative impacts on Puerto Plata province's tourism, resident population, and coastal marine ecosystems.

Key Words: *heavy metal, pollution, beach, tourism.*

Date of Submission: 15-06-2022 Date of Acceptance: 30-06-2022

I. Introduction

Beaches are under great pressure due to intense coastal development,[1] which can cause accelerated destruction of natural environments located in marine-coastal systems.[2] The importance of these areas lies in the wide variety of ecosystem services they provide: water storage, biodiversity, scope for tourism, the nutrient cycle, among others.[3] Improper use of them has negative impacts on the intrinsic performance of coastal-marine systems.[4] In particular, tourism development is one of the most popular coastal activities, providing a major source of income and employment for these destinations.[5] Consequently, the growth of coastal tourism is linked to considerable environmental deterioration.[6]

Heavy metal contamination is a major environmental concern in coastal areas, due to the risk they pose to living things.[7] The man-made contribution to heavy metals has risen in recent decades due to the urbanization and industrialization of coastal areas.[8] However, very few studies focus on metal contamination, sources and levels in marine-coastal systems.[6] In this context, tourism managers in coastal areas should bear in mind the analysis of heavy metals on beaches.

In The Dominican Republic, tourism has grown steadily over the years.[9] As a result, the country was visited by 6.4 million tourists and earned 7.5 billion dollars in 2019, with tourism accounting for 36% of the country's exports.[10] In The Americas, the country ranked fifth country by tourist numbers, after The United States, Mexico, Canada and Argentina. No less than 76% of The Dominican Republic's visitors came from The Americas.[10] However, as is true for other industries, the COVID-19 pandemic has hit tourism hard. In 2020, The Dominican Republic received 2.4 million tourists. The exact figure for tourism revenue in that year has yet to be ascertained.[10] These data, although they place The Dominican Republic as the fourth tourism destination in the

Americas in 2020, after Mexico, The United States and Canada, are mediocre given the country's relationship with tourism.[9]

Seaside vacations account for most of The Dominican Republic's tourism industry.[11] However, coastal-marine waters and soils in some of these areas have been found to have worrying levels of pollution, mainly due to organic matter that comes from wastewater collector discharges, often containing a high volume of urban waste.[12] This situation offers scope for identifying the effect of human pressure on coastal marine ecosystems and thus helps in drawing up new strategies to improve the ecosystem management of marine resources.[13]

The city of Puerto Plata is one of the country's biggest seaside tourism destinations in The Dominican Republic, ranking second after Punta Cana.[14] In light of the foregoing, the research goal was to analyze the concentration of heavy metals in Puerto Plata's tourist beaches, their impact on the conservation of coastal marine systems, and the development of recreational activities and tourism. This research makes three contributions. First, based on this research, the heavy metals found at one of The Dominican Republic's main seaside destination are analyzed. The findings should help the Government come up with policies for reducing soil contamination in the study area. Second, it establishes a methodology for analyzing soil and beach quality in other areas of interest in the country. Third, some key management recommendations and strategies are proposed for policymakers and stakeholders that could be considered in future post-pandemic management schemes.

II. Material and Methods

This section has been split into four parts. First, the geographic area of study and the sampling areas are presented. Next, the variables measured in this research are described, as well as the materials and methods used to obtain the data and, finally, the program used for the tabulation and analysis of the data is presented.

Geographical area of study and sampling areas

This research was carried out in the city of Puerto Plata in the province bearing the same name, which is The Dominican Republic's Northern Region. This destination was chosen for the following research reasons:[15]

a) Tourism is the main economic activity in the city and province of Puerto Plata, accounting for 33% of total jobs.
b) It is the main tourist destination in The Dominican Republic for tourists from North America, with Canada (57%) and The United States (42%) being the two main countries of origin.
c) This geographical area has beaches with All-Inclusive resort hotels and is The Dominican Republic's second largest seaside tourist destination.
d) This destination has the country's main cruise port, receiving 59.2% of total travelers in 2019.
e) It has attractive complementary offers that make it a complete seaside destination. The average annual hotel occupancy rate is 55.7%, exceeding 80% in January, February and March.
f) The Central Government is seeking to double the number of tourists arriving at this destination.

The soil quality study was carried out in the marine-coastal areas located in tourist or recreational points of the city. To select the sampling points, the following procedure was adopted:

a) Phase 1: The research team located and selected the main tourist and recreational points of the city of Puerto Plata, using the Google Earth tool.
b) Phase 2: Three field visits were carried out in the city's marine-coastal systems at the locations previously selected in Google Earth. These visits were made in January and February 2019.
c) Phase 3: Three technicians from the Ministry of Environment and Natural Resources of The Dominican Republic, two from the Puerto Plata Aqueduct and Sewer Corporation (CORAAPPLATA) and two from the Playa Dorada Hotel and Condominium Owners Association were interviewed.
d) Phase 4: A new visit was made along the coast, in order to take aerial images with a drone. The aim of this activity was to obtain images of the vulnerable points of the coast where the mouth of a water body could be observed where it reached the sea. Through the images, information was obtained on the accumulation of solid waste in coastal areas, and the real proximity of human and industrial settlements to the coast and to water bodies.
e) Phase 5: The information obtained during the visits, photographs and interviews was analyzed, and the sampling areas were selected within the four areas with the greatest impact on tourism in the city and province: Costambar and Cofresí Beaches, Puerto Plata waterfront, Costa Dorada Beach and Playa Dorada Beach.

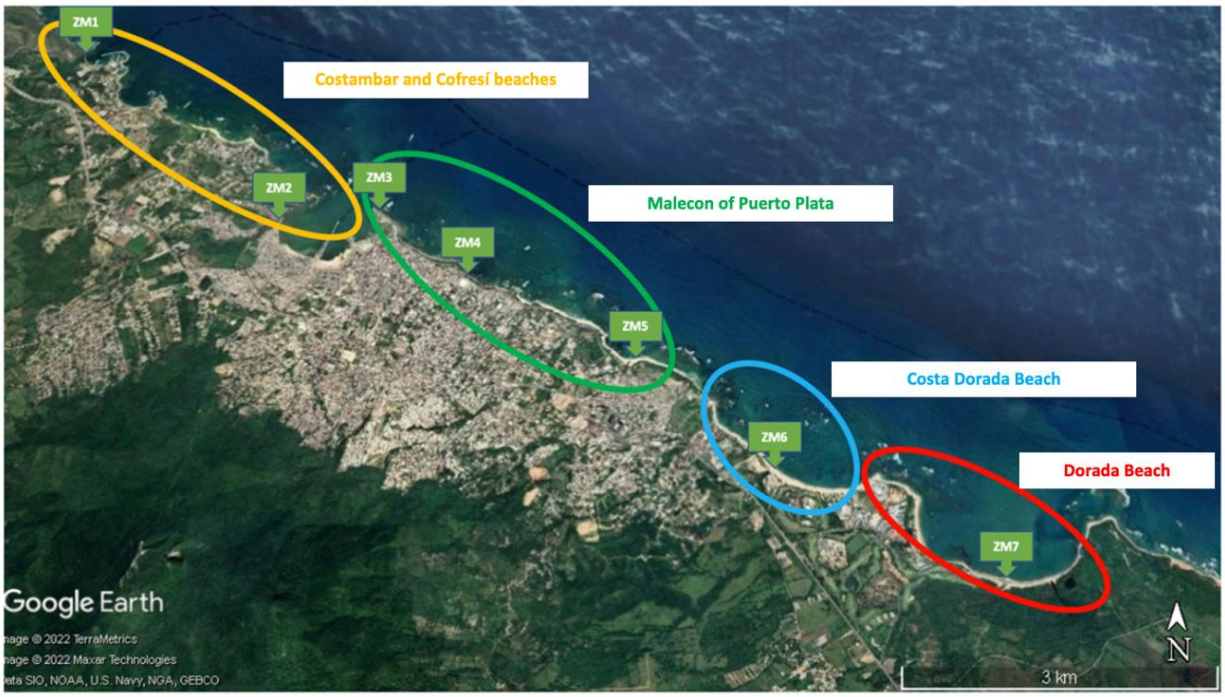
The sampling zones are given in Table no 1 and Figureno 1.

Table no 1: Areas sampled.

Code	Name of the sampling area	UTM coordinates		Location
		X	Y	
ZM1	At the mouth of the Maggiolo creek, opposite the Ocean World Marina	318253	2193107	Costambar/Cofresí Beaches
ZM2	At the mouth of the San Marcos River, south of the baseball field	321041	2190493	Costambar/Cofresí Beaches
ZM3	In the surroundings of the San Felipe Fortress	322372	2190645	Puerto Plata waterfront
ZM4	In the coastal strip, at the mouth of the canyon, opposite La Sirena store	323505	2189802	Puerto Plata waterfront
ZM5	On Long Beach, near the storm drainage channel	325399	2188706	Puerto Plata waterfront
ZM6	At the mouth of the canal, in El Pueblito	326900	2187409	Costa Dorada Beach
ZM7	At the mouth of the Muñoz River in Playa Dorada	329078	2186277	Playa Dorada

Source: The authors.

Figure no 1: Location of sampling points.



Source: The authors.

Research variables, materials and methods

The geographic coordinates of each sampling point (X, Y) were determined under the UTMDATUM WGS84 system, using a Garmin GPS, GPSMAP 64 model, which is a high-sensitivity GPS and GLONASSreceiver with a Quadrifilar Helix antenna. Soil samples were then taken from the soil at these points. The parameters analyzed are shown in Table no 2.

Table no 2: Parameters, unit of measure, method and instrument or technique.

Parameter	Unit of Measurement	Method	Instrument or technique
Total Arsenic	mg/Kg	EPA 6010B	Inductively Coupled Plasma (ICP) Optimum 4300DV
Total Cadmium	mg/Kg	EPA 6010B	
Total Chromium	mg/Kg	EPA 6010B	
Total Copper	mg/Kg	EPA 6010B	
Total Lead	mg/Kg	EPA 6010B	

Source: The authors.

The services of Environmental Quality Laboratories SRL (EQLAB), with headquarters in Puerto Rico and with a facility in The Dominican Republic, were contracted. This company has over 20 years of experience in water quality analysis in The Dominican Republic and has environmental accreditation from the Ministry of Environment and Natural Resources of The Dominican Republic, The United States Environmental Protection Agency (USEPA), The United States Food and Drug Administration (USFDA), the International Organization for Standardization of Information, and the National Environmental Laboratory Accreditation Program of The United States (NELAC). The samples were taken during 2019, in three different periods of the year: March (the driest season), June (rainy season) and September (cyclonic season). For each of the three samples carried out throughout 2019, data were obtained for each sampling zone during the same day and between 7:00 A.M. and 1:00 P.M. In addition, the same schedule was used to obtain the data in each of the seven sampling areas during the three sample collection periods.

Data analysis tools

The data obtained in the laboratory were tabulated in Microsoft Excel 2019 and subsequently analyzed with the SPSS statistical program.

III. Results and Discussion

With regard to metal concentrations, Table no 3 shows the five elements sampled separately, taking into account the differences in their values to enhance their interpretation. Results are shown for each of the three samples taken.

Table no 3: Results of heavy metals appearing in the sampling (mg/kg).

	Total Arsenic			Total Cadmium			Total Chromium			Total Copper			Total Lead		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ZM1	3.2	2.5	3.3	0.6	0.2	0.2	65.0	94.6	83.3	21.4	22.2	23.2	3.4	3.3	3.2
ZM2	6.9	3.8	3.1	1.1	0.2	0.2	107.0	65.6	58,7	13.0	12.5	9.1	6.7	5.8	5.0
ZM3	8.6	10.4	8.0	0.3	0.2	0.1	6.1	6.5	5.6	5.4	5.6	4.8	11.0	15.0	32.7
ZM4	8.3	3.2	2.6	0.9	0.2	0.2	46.0	87.0	57.6	19.0	27.1	18.8	28.4	3.4	18.3
ZM5	2.4	2.0	1.2	0.1	0.0	0.1	9.6	9.8	7.1	0.0	1.1	0.8	0.8	1.3	1.2
ZM6	3.8	3.3	3.7	0.1	0.1	0.1	10.1	7.4	9.5	0.0	0.8	0.8	0.8	1.3	1.2
ZM7	8.4	7.6	9.8	0.3	0.2	0.1	23.5	21.5	21.8	3.4	2.9	3.5	1.7	1.7	2.1

Source: The authors. 1 refers to the first sampling; 2 refers to the second sampling; 3 refers to the third sampling.

Focusing specifically on each heavy metal, at the first sampling, a distribution of Total Chrome > Total Copper > Total Lead > Total Arsenic > Total Cadmium was observed. In the second sampling, the distribution was Total Chromium > Total Copper > Total Arsenic > Total Lead > Total Cadmium. For the third sampling, the distribution was Total Chrome > Total Lead > Total Copper > Total Arsenic > Total Cadmium. Therefore, Total Chromium was the heavy metal with the greatest presence in each of the samples, and Total Cadmium the one with the least presence.

By zones, the highest average values of total chromium were observed in ZM1 > ZM2 > ZM4 > ZM7 > ZM6 > ZM5 > ZM3. The highest average values of total copper were observed in ZM1 > ZM4 > ZM2 > ZM3 > ZM7 > ZM5 > ZM6. The highest average values of Total Lead were observed in ZM3 > ZM4 > ZM2 > ZM1 > ZM7 > ZM5 and ZM6. The highest mean values of Total Cadmium were observed in ZM2 > ZM4 > ZM1 > ZM3 > ZM7 > ZM6 > ZM5. The highest mean values of Total Cadmium were observed in ZM3 > ZM7 > ZM4 > ZM2 > ZM6 > ZM1 > ZM5.

Most of Puerto Plata's main tourist beaches lie in two areas: ZM1 and ZM2 (Costambar and Cofresí); ZM6 and ZM7 (Costa Dorada and Playa Dorada). These settings are greatly affected by human practices linked to economic activities and rapid demographic and urban growth,[6,16-18] although many beaches can be contaminated by heavy metals through natural processes.[19]

In general, the areas with the highest heavy metal contamination of soils ZM1, ZM2 and ZM4. In the case of Puerto Plata's beaches, the concentration of metals in coastal sediments is closely linked to pollution carried by surface runoff from the land side. The general environmental conditions and physical properties are also conducive to these accumulation processes, albeit with high variability.

Therefore, both tourism activity and ecosystems are endangered by the significant presence of heavy metals on beaches. These heavy metals can be lethal to organisms, lessening growth rates and changing behavior and development.[20] As for chronic effects, many heavy metals can cause cancer, affect neuronal and

cognitive functions, and even damage the immune system of living things.[21,22] Heavy metals bioaccumulate in organisms and therefore tend to be stored in the fatty tissue of the animal. In the food chain, the population is also affected, because many heavy metals are found in foods that come from the ocean and are consumed by the population, including tourists.[23,24]

IV. Conclusions

Beaches are key points for recreation and coastal tourism and a major source of income for many countries. Thus, good beaches attract tourists and degraded ones discourage tourism. The research goal in this paper was to analyze the concentration of heavy metals on the tourist beaches of the city of Puerto Plata (Dominican Republic) and its impact on the conservation of coastal marine systems and the development of recreational activities and tourism. Total Chromium was the main heavy metal found on beaches, although other heavy metals were also detected. The presence of these heavy metals has negative impacts on Puerto Plata province's tourism, resident population, and coastal marine ecosystems.

The Government of The Dominican Republic, through the Ministry of Environment and Natural Resources should carry out comprehensive, periodic monitoring on the quality of Puerto Plata's beaches. Here, carrying out periodic sampling during the year, and more frequently during the tourist season would be of great benefit in analyzing the dynamics of metals under different anthropogenic pressures. Furthermore, water and sediment samples should be monitored at different strategic points on the beach, such as river and stream mouths. Measurement of various physical-chemical variables bearing on metal dynamics at all sampling sites is also recommended. Urban runoff should also be sampled after rainfall. In addition, it is important to invest in filling data gaps on national coastal and marine ecosystems through survey, modeling and mapping employment schemes.

Acknowledgements

The authors of this paper would like to thank the Ministry of Higher Education, Science and Technology (MESCyT) of The Dominican Republic, which supported the research project "Pollution Management Model in Coastal and Marine Systems in the Northern Region of The Dominican Republic", through the National Fund for Innovation and Scientific and Technological Development (FONDOCyT) 2016-2017.

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Vladimir A. Rodríguez Núñez, et. al. "Heavy Metal Pollution on Tourist Beaches in the Province of Puerto Plata (Dominican Republic)." *IOSR Journal of Applied Chemistry (IOSR-JAC)*, 15(06), (2022): pp 37-42.