Environmental impacts of the hydrocarbon spill caused by heavy rains. Case study in the bay of Cienfuegos, Cuba.

Tania Lozano Robaina[*], Bin Xu[**], María E. Castellanos González[***]

[*] Master candidate, Tongji University. UN Environment-Tongji Institute of Environment for Sustainable Development (IESD): College of Environmental Science and Engineering.
[**] State Key Laboratory of Pollution Control and Resource Reuse, College of Environmental Science and Engineering, Tongji University, Shanghai 200092, P.R. China.
*** Center of environmental studies of Cienfuegos. Ministry of Science, Technology and Environment of Cuba.

DOI: 10.29322/IJSRP.9.07.2019.p9199
http://dx.doi.org/10.29322/IJSRP.9.07.2019.p9199

Abstract- Hydrocarbon spills are events that cause a lot of impacts on fragile ecosystems, such as the marine environment, with fatal consequences, the short-term environmental impact can be serious and cause severe damage to the ecosystem and people who live in coastal areas, affecting their livelihoods, therefore, it is necessary to take measures to reduce, control or mitigate them, in order to recover the affected areas and generate preventive measures to prevent future spills. This document analyzes the environmental impact caused by the hydrocarbon spill in the Bay of Cienfuegos and proposes an environmental impact assessment to contribute to an adequate environmental management.

key words: Climate Change, Heavy Rain, Hydrocarbon Spill, Environmental Impact Assessment, Environmental Management and Environmental Impact.

I. INTRODUCTION

Among the most pressing environmental problems that characterize the XXI century is climate change, with great repercussion in countries with coasts and especially in those with characteristics of the islands, due to the rise in sea level and the effects on strongly interrelated ecosystems. The phenomenon of climate change has gained unusual relevance in the international arena. Its appearance has reactivated the environmental policy as a whole and, in particular, environmental education for sustainability, and is considered the main environmental problem facing contemporary society, from which significant impacts are expected with socio-economic, environmental and socio-cultural consequences. which is a knowledge gap that must be studied to estimate future scenarios that allow establishing, from the present, mitigation and adaptation measures in correspondence with the affectation.

Cuba is a coastal country because it is an island surrounded by the Caribbean Sea, due to its geographical location in the archipelago, it is exposed to the passage of meteorological phenomena such as cyclones and hurricanes, the cyclonic season extends from June 1 to November 30, being the period of the year in which there are more favorable conditions for the formation of these organisms.

Cuba, therefore, is not alien to this reality, climate change is of vital importance for the country, since it determines the greater development of its economic stability and, consequently, social stability. Special attention is paid to Cuban coastal areas that are directly affected by rising sea levels, as well as heavy rains and waves due to intense hurricanes that can cause coastal flooding and the destruction of natural and built heritage. Similarly, the gradual increase in sea level, the main threat, implies a slow decrease of the surface and the low places, causing, in turn, the salinization of the aquifers. Therefore, the Economic and Social Policy of Cuba reflects all these important issues for the nation, which can be seen in Guide 133 of the VI Congress of the Communist Party of Cuba since 2011 (PCC, 2011).

The prioritization of studies designed for this purpose stands out, hence the emergence of the National Science, Technology and Innovation Program on Climate Change (AMA, 2012), as well as the incorporation of the theme in the cycles of the National Environmental Strategy (2016 -2020). More recently, it emerged as the state Plan: The task of life (CITMA, 2017), in view of the urgency of having knowledge about the status and evolutionary trends of the Climate System, its impact on prioritized natural and socioeconomic environments.

The report of the Intergovernmental Panel on Climate Change (IPCC, 2001) states that this is a natural process accelerated by the ways in which society has been related to nature in recent centuries, so it is necessary to raise awareness among men of the imminent. The danger represented by this process is to look for alternatives for adaptation and, in turn, mitigate this effect to give continuity to life on the planet.

The tropical cyclone is considered the most destructive of meteorological systems, its main impact occurs in coastal areas as a result of strong winds and floods caused by heavy rains and storms, as well as by the action of strong waves. Considering the frequency of occurrence of hurricanes in the Caribbean area and the probable incidence of the effects of climate change, an increase in the intensity and quantity of these phenomena is expected (INSMET, 2008).

Climate change that influences climate variability is affecting many countries, especially those in subtropical and tropical areas.

For this reason, in Cuba there was a phenomenon of heavy rains (Subtropical Storm Alberto) in 2018 that caused a technological disaster in the oil refinery and, consequently, a spill of hydrocarbons to the bay of Cienfuegos.

The Bay of Cienfuegos is a well-studied ecosystem that includes studies on oil pollution, but to act in response to this disaster, more information is needed to carry out environmental management actions.

In view of this situation, insufficient information was identified to carry out the environmental management to mitigate the effects of the oil spill caused by the heavy rains in the Cienfuegos Bay, so in this document the following scientific question is proposed:

How to contribute to an adequate environmental management of the oil spill caused by heavy rains in the bay of Cienfuegos in 2018? Therefore, it is considered necessary to carry out an Environmental Impact Assessment (EIA) of this accident, considering that the EIA is one of the most powerful instruments to carry out an adequate environmental management, since it allows to analyze the impacts from the point of natural, socio-economic and sociocultural view and is used as an instrument to identify, predict and interpret environmental impact, as well as to prevent the negative consequences that certain actions can have on human health, the well-being of communities and the ecological balance.

According to Morgan, the emergence of environmental impact assessment (EIA) as a key component of environmental management in the last 40 years has coincided with the growing recognition of the nature, scale and implications of environmental change caused by human actions. During that time, the EIA has developed and changed, influenced by the changing needs of decision makers and the decision-making process, and by the experience of the practice (Morgan 1998).

II. PROPOSED CASE STUDY

The research study focuses on the bay of Cienfuegos, is a bay of stock that extends over an area of 88 km2 and has 100 km of coastline, (León et al., 2018) with an average depth of 14 m, connected to the Caribbean Sea by a narrow channel of approximately 3 km Km long and a depth of 30 m. It has 5 associated hydrological basins that are: the basin of the Damují River, Arimao, Salado, Caunao and Arroyo Inglés. The topography of the bay is simple, but includes a low between Cayo Carenas and Punta de la Cueva. This wall submerged to a depth of approximately 1 m divides the bay into two well-defined hydrographic cells. The northern cell receives most of the impact of the urban waste discharges from the city of Cienfuegos, the industrial zone and the fluvial contribution of the Damují and Salado rivers that irrigate a large industrial zone. The south cell receives a less anthropic impact, which is contributed by the Caonao and Arimao rivers. Part of this southern area is a protected area that represents an important niche of migratory birds in the Caribbean region, as well as marine species in conservation status.

Fig. 1. Bay of Cienfuegos
Source: Stations Network State Program Environmental Quality of the Bay of Cienfuegos and areas analyzed by the ICA, 2018

The Bay of Cienfuegos, is the most important natural resource not only of the city, but also at the national and regional level, around which all the economic, social and cultural life of the territory revolves, which in turn combines with traditions, customs and legends dating from the 19th century, from the time of the city's founding, because according to Vázquez, the history of any island country is linked to water, both by the effect of the seas and rivers, on history, on food. (Vázquez, 2009) Therefore, the presence of the coast and strictly coastal activities (sport fishing, beach, diving, among others) are deeply rooted in the culture of Cienfuegos.

1. Cienfuegos has a bay of economic, social and cultural importance, not only for its territory, but also for the country and the region, which makes the difference with respect to others of its kind.
2. Cienfuegos has a historical background where you can see interesting attempts to find integrating alternatives and a concern of its inhabitants for the quality of its waters.
3. Cienfuegos already has a job based on concrete information on the application of the Integrated Coastal Zone Management (ICZM) approach that has served as the basis for the socialization processes carried out between 1997 and 2007.

Therefore, this research proposes to know the environmental impacts in the short, medium and long term in the bay of Cienfuegos caused by the hydrocarbon spill.

III. CURRENT SITUATION

The bay of Cienfuegos, as a result of the intense rains that occurred in 2018, (Subtropical Storm Alberto) was affected by a discharge of hydrocarbons from the oil refinery because this meteorological event exceeded the extreme conditions of precaution and risk reduction , the Refinery has no conditions to face disasters of such magnitude, the amount of rain exceeded all forecasts, affecting 70% of the ecosystem.(CEAC, 2018)

Visible environmental impacts: loss of biodiversity (wildlife, biodiversity), loss of landscape (aesthetic degradation, oil spills).

Potential: deforestation and loss of vegetation cover, contamination of surface water, decrease in water quality. (physical-chemical, biological)

Other environmental impacts: food insecurity. (damage to crops)

The disappearance of the white shrimp in the northwestern zone (a species that was a symbol of the city and next to the pink shrimp was the main fishing resource of the bay)

Visible: Loss of landscape (sense of place)

Potential: loss of livelihoods.

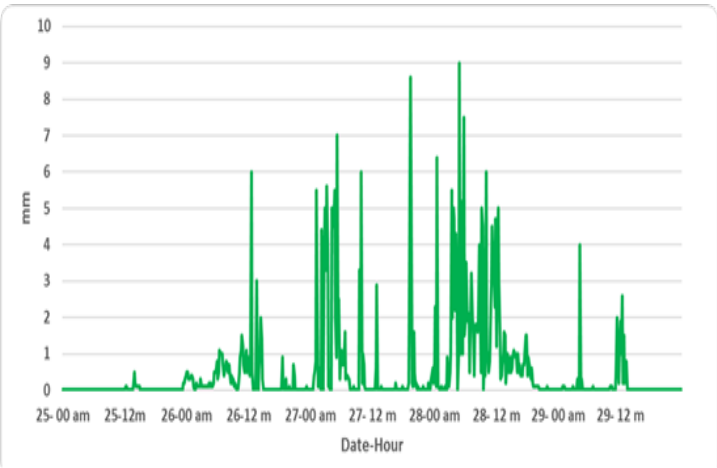

Fig. 2. Amount of rain fall. Subtropical Storm Alberto.
Source: Cienfuegos Meteorological Center, 2018, INSMET

IV. ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

The impact will be analyzed from the ecological, socio-economic and socio-cultural dimension.

Ecological dimension: the impact will be evaluated considering the physical-chemical quality indicators of the waters and their sediments (salinity and concentration of hydrocarbons in the sediments). The biodiversity indicator (behavior of phytoplankton, mangrove, macroalgae and molluscs) will also be evaluated.

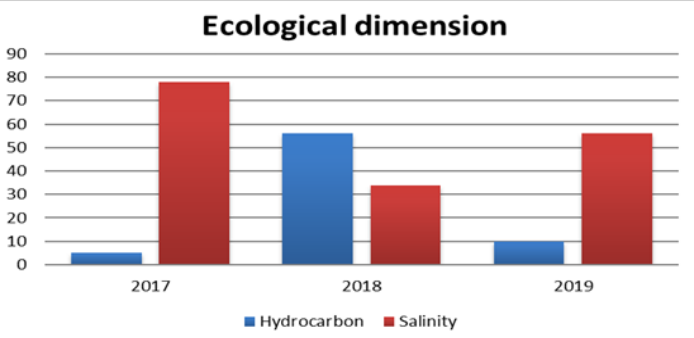

Fig 3. Behavior of the hydrocarbon and salinity indicators in the years 2017, 2018 and 2019.

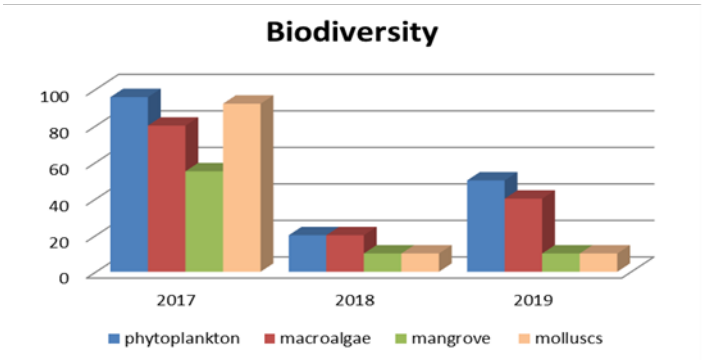

Fig. 4. Behavior of biodiversity in the years 2017, 2018 and 2019.

Socioeconomic dimension: the economic damage will be evaluated by the prohibition of the entrance of the cruise ships to the bay, which will affect tourism. In addition, the prohibition of entry of oil tankers to the refinery and its effect due to stop refining and the prohibition of the entry of transit vessels to receive the services of the Shipyard.

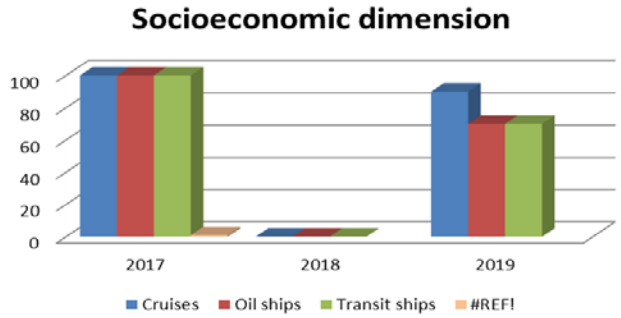

Fig.5. Behavior of the socioeconomic dimension according to the indicators of: Entrance of cruises to the bay, the entrance of oil tankers to refine oil and the entrance of transit ships to receive the service of the shipyard

Sociocultural dimension: the damage to the population will be assessed by the suspension of the use of its beaches, the prohibition of the practice of sport fishing, the prohibition of nautical sports and the change of the cultural landscape, taking into account the impact of the enjoyment of the boardwalk, sunset, among others.

These damages occurred in the short, medium and long term; for its evaluation, work will be done with the existing baseline.

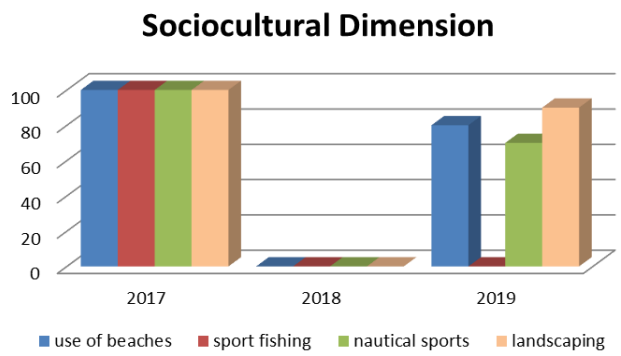

Fig. 6. Behavior of the sociocultural dimension according to the indicators of: Use of the beaches, nautical sports, sport fishing and landscaping.

Baseline

The Bay of Cienfuegos has been well studied, including studies on the pollution of hydrocarbons in this ecosystem; there is a baseline on the chemical quality of the water and sediments of the bay before discharge, which will allow comparing the phenomenon before and after the occurrence. There is also information on phytoplankton and other biological organisms that allow to evaluate the impact caused to the ecosystem.

Methodological guide for the evaluation of environmental impacts and damages in disaster situations.

The Guide for the evaluation of environmental impacts and damages of disaster situations is the result of the integration of three methodological documents, prepared by the Ministry of Science, Technology and the Environment and responds to the indications issued in the President's Directive No.1 of the National Defense Council for disaster reduction in 2010.
The considerations of the State Plan for the Confrontation of Climate Change (Life Task) and the Sendai Framework for Disaster Risk Reduction 2015-2030, of which Cuba is a signatory, have been taken into account.
Its objective is to methodologically guide the processes of identification, inclusion, discussion and homogenization of the impact and damage assessment of disaster situations.

Qualitative and quantitative data.

Quantitative and qualitative data will be collected, this will facilitate the better understanding of the phenomenon, they will also allow to triangulate, compare, relate and interpret the acquired information to better understand the phenomenon to be studied. From the first qualitative phase the researcher builds a second quantitative phase to test or generalize the initial results. Finally, how the quantitative results are interpreted make up the initial qualitative results.

Application of the software for the evaluation of the constructed matrix of cause-effect.

For the preliminary evaluation, the RIAM (Rapid Impact Assessment Matrix) methodology will be used, which allows a quick and clear evaluation of the impacts.
Environmental impact is understood as the direct or indirect consequence, of a beneficial or adverse nature, that occurs for man and the natural and socioeconomic systems on which his well-being depends, as a result of an environmental change caused by an action or set of actions of natural or human origin.
The evaluation system is feasible only when it is carried out by a multidisciplinary team. This allows the data of different components to be analyzed against common criteria, within the same matrix, offering a quick and clear evaluation of the impacts.

The evaluation criteria fall into two main groups:

A) Criteria related to the importance of the condition, which can individually change the score obtained.
B) Criteria that are of value for the situation, but that individually are not able to change the score obtained.
The sum of the group (B) is then multiplied by the result of the group (A) to provide the final result of the evaluation (ES) for each condition. The process can be expressed:
(a1) x (a2) = aT
(b1) + (b2) + (b3) = bT
(aT) x (bT) = ES
Where:
(a1) and (a2) are the individual scores of the criteria for the group (A)
(b1) to (b3) are the individual scores of the criteria for the group (B)

- aT is the result of the multiplication of all the scores of (A)
- bT is the result of the summation of all the scores of (B)
- ES is the Criterion Evaluation Score

Criteria of group A)

A1) Importance of the condition: a measure of the importance of the condition, which is evaluated against the spatial borders or human interests that affected it. The scales are defined:
4 = Important for national / international interests
3 = Important for regional / national interests
2 = Important for areas immediately outside the local condition
1 = Important only for the local condition
0 = Unimportant

A2) Magnitude of the change / effect: magnitude defined as a measure of the benefit / harm scale of an impact or condition.

+ 3 = Great benefit
+ 2 = Significant improvement of the status quo
+ 1 = Improvement of the status quo
0 = No change
-1 = Negative change in the status quo
-2 = Significant negative change
-3 = Great damage or change

Criteria of group B)

(B1) Permanence: defines if a condition is temporary or permanent, and should be seen only as a measure of the temporal status of the condition.
1 = No change / not applicable 2 = Temporary 3 = Permanent
(B2) Reversibility: this defines if the condition can be changed and is a measure of control over the effect of the condition. It should not be confused with permanence (eg, an accidental toxic spill in a river is a temporary condition (B1) but its effect (death of fish) is irreversible (B2), a job of sewage treatment in a village is a condition permanent (B1), the effect of its tributary can be changed (reversible condition) (B2).
1 = No change / not applicable 2 = Reversible 3 = Irreversible

(B3) Accumulation: this is a measure where it is evaluated whether the effect had a simple direct impact or if it will cause a cumulative effect over time or a synergistic effect with other conditions. The cumulative effect is a way of judging the sustainability of a condition, and should not be confused with a permanent / irreversible situation. For example, the death of an old animal is a permanent and irreversible, but not cumulative, because the animal is considered that no longer has reproductive capacity.
The loss of shrimp in the post-larval stage, in its natural environment, is also permanent and irreversible, but in this cumulative case, as the subsequent generations of these larvae will also have been lost.
1 = No change / not applicable 2 = No cumulative / simple
3 = Cumulative / synergistic

The RIAM requires the specific evaluation of components that must be defined and are divided into four categories:

Physics-Chemistry (FC): covers all physical-chemical aspects of the environment, including non-biotic (finite) natural resources and the degradation of the physical environment by pollution.

Biological-Ecological (BE): covers all biological aspects of the environment, including renewable natural resources, conservation of biodiversity, interspecific interactions and contamination of the biosphere.

Socio-Cultural (SC): covers all human aspects of the environment, including social issues that affect individuals and communities, along with cultural aspects, including the conservation of cultural heritage and human development.

Economic-Operational (EO): qualitatively identifies the economic consequences of environmental changes, both temporary and permanent.
The evaluation criteria are formed on a scale of Liquer, which goes from a greater positive impact to a greater negative impact. It is important to note that a moderate negative impact is already very damaging.
Once the ES scores are placed in ranges bands, these can be shown individually or grouped according to the type of component and presented in graphic or numerical form. The complete EIA report will detail the criteria used, the components derived from the scope, the RIAM matrix and the presentation of the results of the RIAM method, together with primary information concerning the management alternatives applied.
The RIAM system has been described on a theoretical basis and has been computerized for its simple and fast use. The values obtained through the evaluation process are classified according to this method as shown in table 1.

Band ranges Average (ES)	Range of values Alphabetical (RV)	Range of values Numeric (RV)	Evaluation criteria
108 a 72	E	5	Greater positive impact
71 a 36	D	4	Significant positive impact
35 a 19	C	3	Moderate positive impact
10 a 18	B	2	Positive impact
1 a 9	A	1	Potentially insignificant impact
0	N	0	No change / status quo / not applicable
-1 a -9	-A	-1	Insignificant negative impact
-10 a -18	-B	-2	Negative impact
-19 a -35	-C	-3	Moderate negative impact
-36 a -71	-D	-4	Significant negative impact
-72 a -108	-E	-5	Greater negative impact

Table 1. The values obtained through the evaluation process according to this method.

Technical report of the Preliminary Evaluation.

The preliminary report will be based on the qualitative and quantitative information available.
The economic valuation of the damages to the goods and services of the ecosystems will be carried out, working with the main ecosystems.
The damages will be expressed, explaining the immediate and expected effects in the short term. In addition, the affectations, alterations and modifications evidenced will be described.
The most significant aspects will be captured, briefly and directly, highlighting the main problems that require priority, to support the decision-making process, will be oriented towards prevention, not create new vulnerabilities and achieve more efficiency in the stages of the disaster risk cycle of reduction.
Specific and clear recommendations will be prepared, defining responsible persons and deadlines, and will be aimed at perfecting the stages of the disaster risk reduction cycle.

V. CONCLUSIONS

This paper presents the environmental impacts caused by the hydrocarbon spill in the Cienfuegos Bay, therefore, it is proposed to make an environmental impact assessment to know the short, medium and long term damages to the ecosystem, for this, it is proposed work from the existing baseline and compare the behavior of the previously analyzed parameters, as well as the use of the methodological guide for cases of environmental disasters and finally the application of the RIAM method, which will allow a clear and precise evaluation of the impacts The potential of the Environmental Impact Assessment will allow the identification of the theoretical elements that will be taken into account to achieve an adequate environmental management in the ecosystem to be studied, as well as provide a complete diagnosis of the real situation or the situation of the ecosystem in terms of environmental, socio-economic and socio-cultural parameters as basic knowledge to make decisions at different levels for disaster risk management, in the same way that it will reduce the environmental risks generated by climate change.

VI. REFERENCES

1. PCC (2011). Lineamientos de la Política Económica y Social del Partido y la Revolución VI Congreso del Partido Comunista de Cuba, 18 de abril de 2011, en el Año 53 de la Revolución.
2. AMA (2012). Agencia de Medio Ambiente. Ministerio de Ciencia, Tecnología y Medio Ambiente de Cuba.
3. CITMA (2017). Enfrentamiento al Cambio Climático en la República de Cuba: Tarea Vida. La Habana, Cuba, CITMATEL.
4. IPCC (2001): Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, USA, Cambridge University.
5. INSMET (2018). Cienfuegos Meteorological Center Ministry of Science, Technology and Environment of Cuba.
6. Morgan, R.K., (1998). Environmental impact assessment: a methodological perspective. Dordrecht: Kluwer Academic.
7. León A. R., (2018): Coord. Informe del proyecto: Aplicación del enfoque de Manejo Integral de Cuencas y Áreas Costeras como respuesta a los efectos del cambio climático: Estudio de la región centro – sur de Cuba. Memorias Taller Final de Programa de cambio climático. Agencia de Medio Ambiente.
8. Vázquez Rodríguez, J. (2009). "¿Existe una cultura del mar en Cuba?", CATAURO, n°19.
9. CEAC (2018). Center of environmental studies of Cienfuegos. Ministry of Science, Technology and Environment of Cuba.

AUTHORS

First Author – Tania Lozano Robaina, Master candidate, Tongji University, UN Environment-Tongji Institute of Environment for Sustainable Development (IESD): College of Environmental Science and Engineering: Email: tanialozanobaco1972@gmail.com

Second Author – Bin Xu, State Key Laboratory of Pollution Control and Resource Reuse, College of Environmental Science and Engineering, Tongji University, Shanghai 200092, P.R. China. Email: binxu@tongji.edu.cn

Third Author – María E. Castellanos González, Center of environmental studies of Cienfuegos. Ministry of Science, Technology and Environment of Cuba, Email: elena@gestion.ceac.cu

Correspondence Author – Tania Lozano Robaina, Master candidate, Tongji University, UN Environment-Tongji Institute of Environment for Sustainable Development (IESD): College of Environmental Science and Engineering: Email: tanialozanobaco1972@gmail.com
Contact number: +86 132 6275 6529
Address: Zhangwu Road 100, Yangpu District, Shanghai. China. 200092.