WASTE AND WATER IN THE GANGAYA WATERSHED - ASSESSMENT REPORT -

Preliminary assessment and management advices for the Gangaya river and estuary in Vizhinjam, India

Positive Change for Marine Life, Kovalam & Vizhinjam, India

March - April 2018

Waste and Water in the Gangaya Watershed

- Assessment Report –

Positive Change for Marine Life – Global Programs
Kovalam & Vizhinjam
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Executive Summary

This report constitutes the first assessment of the Gangaya watershed, river and estuary undertaken on behalf of Positive Change for Marine Life. Its purpose is to describe the structure of the watershed, the main waste related problems and to propose methodologies to monitor the water quality and address the waste pollution issues.
First, we will introduce the geographical context of the river. Second, we will present our current overview of the hydrological structure and flow. Third, we will describe the potential threats to water quality recorded during our on-site investigation.

We will then propose procedures to monitoring the water quality in the lower part of the watershed. Finally, solutions to address water-pollution, sewage related wastes and liquid effluents from dumping sites will be proposed along with remediation techniques and management recommendations.

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1 INTRODUCTION

1.1 Project Description

The project, initiated by the international charity, Positive Change for Marine Life, aims at restoring the estuary of the Gangaya in Vizhinjam in order to provide a saner environment for the local population and to reduce the amount of waste and pollutants entering the ocean. Preventing the solid (plastic, metal, …) and liquid pollutions from reaching the ocean by limiting its production and improving its management upstream limits the effect of waste on the ocean ecosystem. It also supports the local economy though improving the quality of the fisheries that are amongst other threatened by the increasing amount of plastic in the ocean and the ever decreasing water quality of coastal and pelagic waters.
Phyto-remediation, community-based management and removal of plastic waste are the privileged means considered. In the framework of the larger PCFML project, education and awareness raising programs about waste management and water use issues will be implemented to support the technical aspect of remediation and waste management. Community based decision will be taken to decide which solution are the best suited to the population and the socioeconomic and geographic realities of the area.

1.2 Approach to water and waste assessment

The purpose of this preliminary assessment is, first, to provide a sound overview of the conditions regarding waste and water issues in the project area. Second to propose methodologies for the monitoring of the water pollution related to sewage and solid wastes in order to foster the reduction of pollutant in the estuary and the remediation of its waters. Third, to propose solution to treat the existing pollution and address the waste production issues. The document includes a discussion of the proposed project and the physical setting of the project area; it also provides a preliminary assessment of surface water and gather information about groundwater resources within the project area, it describes water quality impairments, and identifies potential water quality impacts, it finally proposes management strategies and solutions to be implemented within the project area.

2 AFFECTED ENVIRONMENT

2.1 General Setting

The current study focuses on the Gangaya watershed, located in the State of Kerala, in South-East India. The Gangaya is a river that takes its source in Balamarapuram, a small town situated 8 km inland from the village of Vizhinyam where it reaches the ocean. Its course is relatively straight from the 75 m above sea level where it starts to its estuary in Vizhinyam.

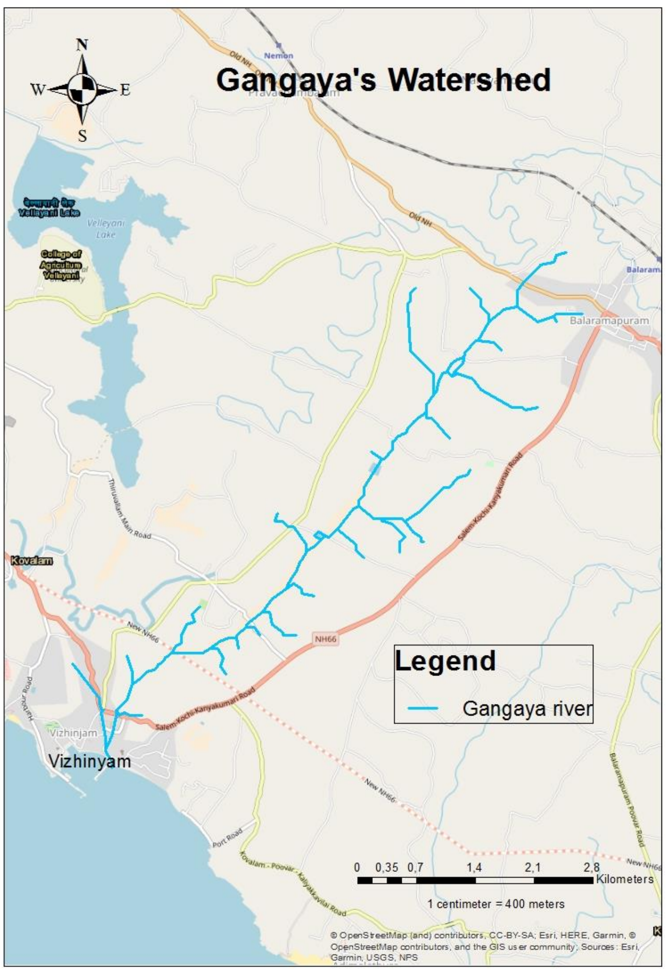

Figure 1 : The Gangaya's course and watershed.

2.1.1 Population and Land Use

The river gently flows down from the suspended sandy aquifer of Balamarapuram through the alluvial plains of the Gangaya's valley where bananas, paw-paw, tapioca, cucumbers and leafy vegetables are cultivated.

Figure 2 : Irrigated tapioca fields

Before 1990 the upper part of the valley was covered by rice fields but increasing water diversion for personal use have depleted the water in the rice fields leading to non-suitable growing conditions for this water reliant species. Local farmers thus undertook a transition from rice to less water-demanding crops such as banana and tapioca (the most represented species).

The crops are fertilized using a chicken manure-based fertilizer which seems not to cause much eutrophication issues in the upper part of the water shed.

Figure 3: Chicken-manure based fertilizer

Many villages and towns surround the valley, perched on its edges or hanging on its slopes, and many smaller streams connect the more densely populated area to the Gangaya’s river.

Figure 4: Secondary stream

The main highway, built for creating easy access to the shipping harbour being created on the coast South-East of Vinzhinyam, crosses the river a couple of kilometers upstream from the estuary. The river is then channeled under the highway and continues its flow through agricultural plains up to about 800m from its outlet where it starts meandering in a more built up environment until it reaches the channeled last hundreds of meters of its course.

Figure 5: The river is channeled under the highway

This last section being more heavily urbanized concentrates in the river many sewage outlets leading to heavy pollution and advanced eutrophication.

Figure 6: Heavily polluted and eutrophic section of the river

2.2 Topography

The topography of the watershed is characterized by an alluvial plain displaying a gentle slope (i.e.: 1% on average) from the source of the river to its estuary. The valley is delimited by steep slopes on both sides on top of which many villages and towns thrive.
Smaller streams flow down to the primary stream on steep slopes (i.e.: 10 % < slope < 55 %).

2.3 Hydrology

2.3.1 Regional Hydrology

Cf. regional water office : *www.hpkerala.org/*

2.3.2 Local Hydrology

2.3.2.1 Precipitation and Climate

The Gangaya watershed is set up in a tropical environment with a climate corresponding to the Aw class of the Köppen-Geiger classification, which corresponds to a topical savanna climate. A tropical savanna climate tends to either have less rainfall than a tropical monsoon climate or see more pronounced dry seasons than a tropical monsoon climate. The mean annual precipitations is 1774 mm whilst the mean annual temperature is 26.7 °C according to climate-data.org .
The following figure displays the evolution of temperature and rainfall throughout an average year in the area of Vizhinyam.

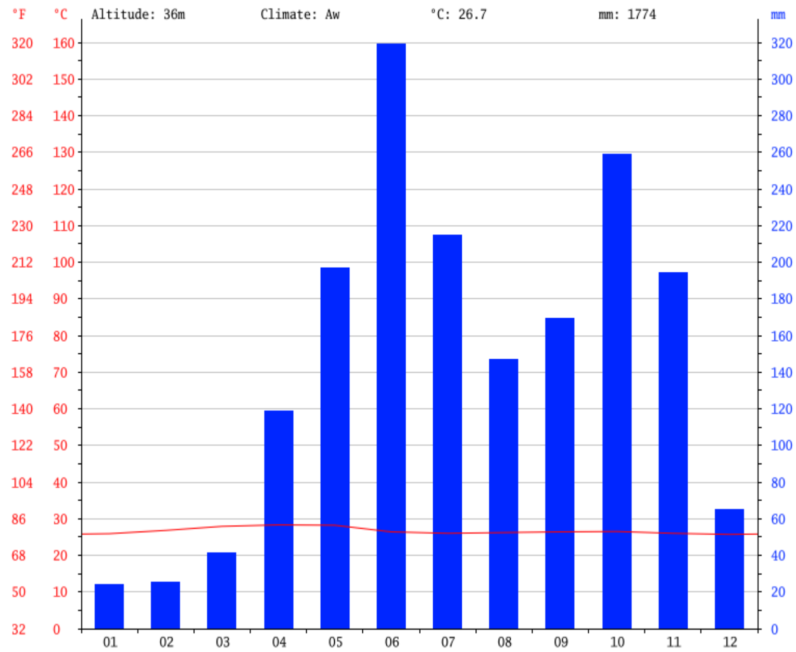

Figure 7: Mean annual rainfall and temperature of the Vizhinyam area

2.3.2.2 Surface Streams

The Gangaya river is composed of a permanent main stream linking the source dam to the estuary and of many non-permanent irrigation channels and secondary channels for agricultural use. Those channels are flooded when irrigation is necessary and drained when water is not needed or when the level of the river is too low to allow irrigation.

Figure 8: Main channel and irrigation channels in the upper part of the watershed

Temporary dams on the main stream are also set up to flood a designated area during the cultivation process which slows the flow and impact the discharge pattern. The last quarter of the river displays a narrower but more rapid flow entering the more urbanized area with small meanders and higher declivity. The flow becomes turbulent and allow for better oxygenation of the water.

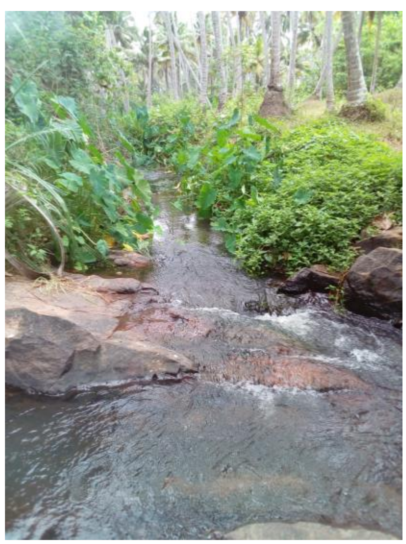

Figure 9: Turbulent section of the river

This turbulent flow then reaches a small dam that separates the estuary from the upper part of the river preventing any salty water from entering the upper part. The lower part is a laminar flow channeled with a gentle slope to the ocean. It is the area where most of the pollution is accumulated due to a building up of sewage waste from upstream but also from big sewage channels discharging in this area. The relative stillness of the water further degrades the water quality in this area.

Figure 10: From left to right: Sewage accumulation area, sewage infrastructure, channeled part of the river

Moreover, waste dumping sites are present on the banks of this part of the river and many solid waste (plastic, metal and organic matter) are present in the water in this area.

Figure 11: Open dump site near the river

2.3.2.3 Flood Plains

The 7 upper kilometers of the Gangaya's watersheds are characterized by alluvial plains with an intricate network of irrigation channels, dams and deviation streams that potentially act as floodplain in heavier rainfall events.

2.3.3 Groundwater Hydrology

No in depth investigation have been undertaken concerning groundwater hydrology in the study area. Nevertheless, it is believed, listening to local inhabitants and farmers, that the river is being fed by a suspended sandy aquifer sitting on a rocky base and being filled by water from the higher hills surrounding Balamarapuram. The sandy aquifer discharge water through underground streams that spring in many places in the upper part of the watershed creating small affluents to the Gangaya. The main spring give birth to the Gangaya just downstream from the basin dug at the aquifer level in Balamarapuram. During the monsoon season, the basin overflow directly into the Gangaya.

2.4 Soils

2.4.1 Soil Erosion Potential

Few investigations have been focusing on soil in this preliminary assessment of the situation of the Gangaya's watershed. Nevertheless, some observations have been made and could provide hints on soils characteristics and erosion potential.

Basic hand soil texture testing has been undertaken in the alluvial plains. The results show that the soil can be rolled into a cylinder that holds by itself. The feeling of the soil is gritty and bigger sand particles are visible in the sample this means that the soils has sandy-loamy texture.

Figure 12: Soil sample

The gentle slope of the alluvial plain reduces the risk for erosion but the many irrigation channels in which the water is flushed may cause dissolving soil aggregates on the banks and transporting the smaller particles of soil downstream.

Heavy rainfall may also cause higher erosion both on the channels banks and on the fields non-covered by vegetation. The high sand content will prevent a crust to be formed on the soil surface, but a heavy rainfall could drag away clay and loamy particles, hence reducing the texture quality.

Figure 13: Irrigated crops and high sediment concentration in irrigation channels

3 Current Water Quality and Objectives

The present section focuses on the main aspect of the project: the water quality. The preliminary assessment of water quality in the Gangaya's watershed provided an overview of the extent of the pollution, be it for solid waste material or due to excessive nutrients and chemicals in the water leading to eutrophication and anoxic environment.
In this section we will focus on the lower part of the watershed. This part is characterized by a slow laminar water flow in a channeled river bed. Open air dumping sites are adjacent to the river that collects its slurries: sewage systems are channeled into the Gangaya's main stream and heaps of solid waste end up in the river bed.

Figure 14: Various pollution sources

This section is the primary concern to address the water-related waste and pollution issues in this area. Upstream the waste is limited and less signs of eutrophication could be observed. The intensive crops and vegetated channels act as a primary pollution reduction filter in this area.
It is the heavy concentration of pollutants of many kinds and the concentration of sewage systems directed towards the lower part of the river that causes the main pollution issues and that results in the heavy degradation of the riverine and coastal ecosystems.

3.1 Surface Water Quality

Many signs of eutrophication have been observed during our field-based assessment, mainly in the lower part of the estuary, up to the first main bridge. Those signs include the development of phosphate and nitrate dependent algae and the absence or poor quality of aquatic life, aquatic plants are scarce and the biodiversity is reduced to a few species of grasses and algae.

Figure 15: Visual signs of eutrophic environment

Potential chemical pollution is expected and further water testing will allow the specific characterization of its composition, source and extent.

3.2 Groundwater Quality

Groundwater quality have not been tested in the framework of this project. Further investigation might be undertaken if deemed necessary after testing the surface water quality.

3.3 Objectives

The objectives of this project are to characterize and remediate the pollution in the estuary and its affluent. The aim is to reverse the eutrophication process, to foster biodiversity and to reduce chemical and solid pollution such as to obtain an ecologically sane environment. Regarding water quality, the water should become suitable for swimming and washing but we do not intent for the water to be perfectly safe to drink. No bacteriological treatment will be undertaken. The final objective is to restore a healthy ecosystem that does not threatened the health of the surrounding population and that discharge clean water in the ocean.

4 TESTING PROCEDURES

4.1 Introduction

A further investigation of the Gangaya's water quality is necessary to determine the severity of the pollution and its chemical constitution. It is expected to have a high level of nitrates and phosphate, which effects have been observed in the many eutrophic area, but other chemical pollutions might be present and less readily detectable through visual observations.

4.2 Water quality testing procedure

To test the water quality, water samples will have to be taken at different locations in the river. In each of those locations a 5 liters sample will be collected.

4.2.1 Sampling methods

If the sampling domain was completely homogeneous, a single sample would adequately represent its composition. However, this is rarely the case. The studied environments often are dynamic which will influence the extent, concentration and location of the pollutants. The sampling method must consider this non-homogeneity and the results must be interpreted bearing in mind the potential bias in the measure.

In the framework of this project, judgmental composite sampling will be undertaken. This means that areas where the pollution is expected to occur will be sampled in priority, but care will be given not to sample at the very source of the pollution to obtain a result that could account for the average pollution in the lower part of the river. The sampling will be done in specific locations at specific times and repeated, hence providing average water quality for each sampled point.
To account for the temporal variation of the conditions, each sample point will be sampled over 5 consecutive days and repetition might be needed at different period during one year.

In each of the location a 1000 ml bottle (potentially mounted on a stick if the water is too deep or too polluted to be done by hand) will be used to collect the water. The sample will be taken between 1/3 of the water column from the bottom of the river to 2/3 of the water column. It is important to sample water under the surface to reduce the possibility of bias in the measurement of dissolved oxygen. Care will be taken to fill the bottle to the top and to close it tightly leaving the least possible amount of air in the bottle.

During each sample, qualitative notes will be taken on the clarity of the river as well as on the current weather. Each sampling will be done at the same tidal level.

The flow rate will be measured by releasing a plastic ball tied to a 2m nylon string at the sampling point and measuring the time for the plastic ball to be dragged 2 m downstream. This measurement will be undertaken 3 times for each sampling and averaged to have a decent estimate. If the stream is too strong a longer string may be used.

The height of the water will finally also be monitored taking a reference level on one of the bridge's pole. This measure should ideally be undertaken at least twice a week during the tidal high and during the tidal low. This measure is important for assessing the extreme changes in water level for further plant implantation in the river bed.

4.2.2 Sampling locations

According to the field assessment of the river specific sampling area have been selected to address the pollution issues where it appears to be most needed while ensuring no substantive pollution source comes from up stream.

As stated earlier only the lower part of the river (i.e. downstream from the first dam) will be tested for water quality. Five locations are described below and will have to be sampled according to the above methodology.

Figure 16: Sampling locations

Location 1: the first sampling location is situated right upstream from the first dam near the first main bridge. It is expected that this location is not influenced by salty water and that it is less impacted by the pollution the water having been oxygenated just a few meters upstream and the sewage systems being more heavily discharged downstream.

Location 2: The second sampling spot is located right downstream from the concrete structure at the end of the buildings on the left side of the river bank coming from the harbor. Care must be taken not to be right in front of a sewage discharge.

Figure 17 : Sampling location 2

Location 3: The third sample will be taken off the first pedestrian bridge coming downstream from the first dam. The sample should be taken in the middle of the stream or where water is flowing.

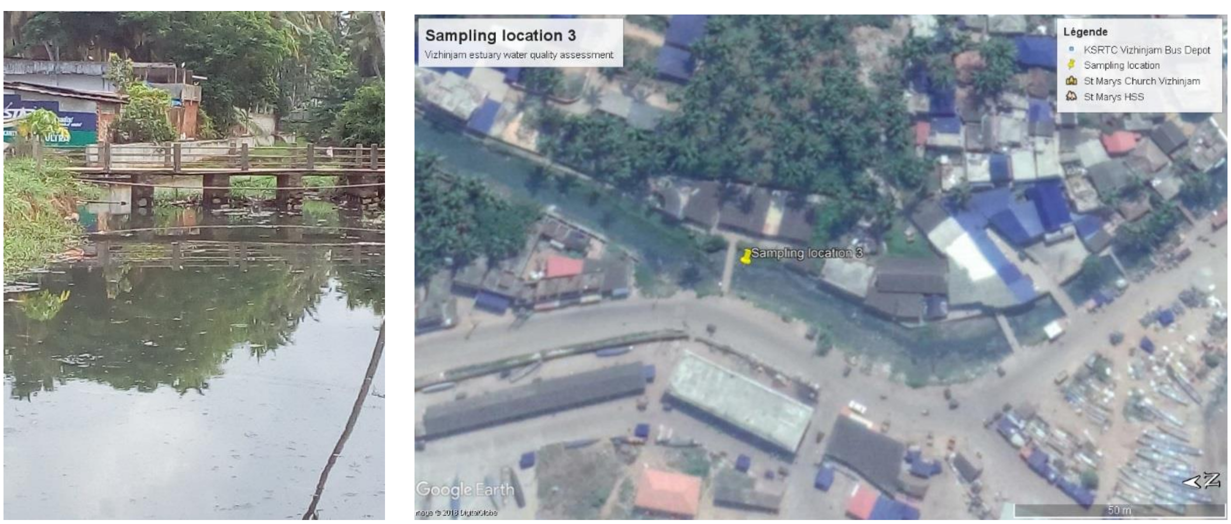

Figure 18: Sampling location 3

Location 4: The fourth sample will be taken from the bridge in front of the Church monument (i.e. the last bridge before the sea). The sample should again be taken where water is flowing.

Figure 19: Sampling location 4

Location 5: The fifth sample must be taken from the very last part of the river right before the start of the beach slope where the river takes a turn. This area is prone to salty water inputs from the ocean and the pollution might take a different form.

Figure 20: Sampling location 5

4.2.3 Analysis parameters

Various parameters[1][2] need to be accounted for to assess the water quality of the Gangaya river. The measure of those parameters will provide us with metrics on which to base our remediation strategy. Pollution characterization is mandatory for effective depollution and might need to be repeated through time to evaluate the progresses made.

pH: it is a measure of the acidity of a water solution. The pH of water will affect the habitat of the species and its viability. It will also influence other parameters such as ammonia toxicity and metal solubility. The pH value should stay between 6 and 9.

Conductivity: It is an expression of an aqueous solution's capacity to carry an electric current. It depends on the total concentration, mobility, valence and relative concentration of ions and it is related to the water temperature. It is a proxy measure of the total dissolved solids and of alkalinity. It is expressed in microSiemens/cm. The maximum value should be between 1000 and 2500.

Phosphorus: It is a very important plant nutrient and it often controls the growth of aquatic plants (algae, macrophytes). It enters the streams from fertilizers, human, animal and organic waste. Phosphorus is a natural limiting factor for plant growth since there is no atmospheric form of phosphorus. Large amount of phosphorus being discharged in the river may trigger exaggerate growth of algae and rooted aquatic plants which reduce light availability and may hamper oxygen regeneration. The maximum concentration should not exceed 0.03 mg/L.

Nitrogen: It is also an important plant nutrient that comes from fertilizers, human, animal and organic waste. Nevertheless, nitrogen also comes from an atmospheric source as it constitutes 80% of its composition. It thus diffuses into the water where it may be fixed by blue-green algae into an ammonia form. Nitrate contribute as well to the eutrophication problems. Sewage and agricultural fertilizers are rich in nitrogenous matter which may appear as nitrate in the aquatic environment due to bacterial action. The maximum acceptable concentration is 50 mg/L.

Chloride: Chlorine exists in every natural water and is a good indicator of relative salinity in estuarine environment (reaching 35000 mg/L in sea water and giving a salty taste when higher than 250 mg/L) and of pollution discharge in punctual locations. It is of interest to observe the inhomogeneity of chloride concentration in the studied area as it may account for pollutant sources. In natural waterways the chloride content is usually in the range 15-35 mg/L. We can consider that it causes few impacts under 250mg/L.

Dissolved oxygen: It is the dissolved form of oxygen that is essential for fish and aquatic organisms' respiration. Oxygen dissolves in water from its atmospheric gaseous form and from the photosynthesis of aquatic plants and algae. The concentration of D.O. always tend to equilibrate

[1] Parameters of water quality, interpretations and standards, Environmental protection agency www.epa.ir, ISBN 1-84096-015-3, 2001

[2] S. P. Gorde et al Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248 -9622, Vol. 3, Issue 6, Nov-Dec 2013, pp.2029-2035

with the atmospheric concentration to reach 100% saturation in the upper water layers. Excessive algae growth can induce over saturation of oxygen, but more often do we observe ‘hypolimnetic’ concentration when the high organic matter content and organisms (plants, fishes, bacteria’s...) absorb oxygen at a rate higher than its atmospheric diffusion.
Fishes typically need at least 3-5 mg/L of D.O. to survive. Moreover, D.O. is inversely related to water temperature, as the molecular agitation increase with temperature less oxygen can be trapped between the water molecules. In tropical environment it is therefore a very important parameter to consider for restoring a viable ecosystem. The saturation level can often be insufficient if high bacterial activity is taking place due to high organic content. In the case of eutrophication a large variability may occur between the diurnal phase when plant photosynthesis will oversaturate the D.O. and the nocturnal phase when plant will respirate more and create anoxic condition leading further deterrent reactions and fish kills. The D.O should be measured in situ or the samples should be stabilized by chemical reagents as the delay of testing might induce alteration in D.O. content. Care must be taken to fill the sampling bottle such that no air is left to skew the results. Ideally the dissolved oxygen should stay in the range 70%<% Sat. O_2 <120%.

Heavy metals: They are toxic for humans and animals and tend to accumulate in their bodies. They arise from piping, from industry, ores, transportation and from geological formation. Lead, mercury and cadmium will be tested only in location 3 where most concentrated effluents enter the main stream. Their maximum concentration is respectively 0,05 mg/l Pd; 0,001 mg/l Hg; 0,005 mg/l Cd.

5 PROPOSED SOLUTIONS

Different solutions are proposed in the following sections. They have been considered as the most relevant techniques in the studied context. Three part of the studied systems are specifically targeted: the main water body, the banks and the areas of heavy sewage discharge.
The proposed solutions have the following advantages:

- are relatively inexpensive;
- are easy to build and operate;
- are cheap to operate and maintain;
- necessit only periodic operation and maintenance;
- tolerate fluctuation of flow;
- utilize natural processes;
- are able to treat different pollution and water constituents;
- are characterised by a stability in the depollution processes;
- provide habitat and improve biodiversity.

Nevertheless, some drawbacks are also associated to using in-situ natural based remediation:

- may take a longer time to be effective compare to traditional water treatment plant;
- require longer period for the plants to be fully effective in their depollution functions;
- the biological components can be affected from chemical pollution in above tolerance concentrations;
- the structure may necessitate long-term maintenance;
- in the case of floating structures, they are more vulnerable to storm or floods;
- they do not tolerate long droughts.

Given those characteristics it is deemed that such low cost and maintenance and low-tech solutions are well suited to the conditions of the Gangaya's estuary. Moreover, regenerating biodiversity and a healthy ecosystem being one important aspect of the project, natural remediation or phytoremediation have been chosen as the main strategy for improving the estuary's water conditions.

The measures focus mainly on reducing the amount of nitrate and phosphate that are present in the water, on improving the availability of oxygen for fishes and aerobic bacteria and, on removing solid non-organic wastes and on improving the estuary's biodiversity while reducing other potential metallic and chemical pollutions.

5.1 Floating wetlands as hydroponic-based water remediation systems

Constructed floating wetlands are a prime solution for treating eutrophic water. It is proposed that such structures be built on slow flowing area of the lower part of the Gangaya's estuary to reduce the expected amount of nitrogen, phosphorous and BOD (biological oxygen demand).

It is shown that such structure combing the use of plants and microbial biofilms act as an efficient in-situ treatment solution to reduce nutrients, heavy metals and other pollutants.
Floating wetlands support many depollution functions[3]:

- Plant roots assist the filtration and settlement process of sediments, they help binding phosphorus and metals.
- Plant roots create a large surface for the development of micro-organisms fostering their activity of decomposition, nitrification and denitrification.
- The release of humic acids by plants induce a mild water acidification and an input of organic carbon which foster denitrification.
- Their design may lead to higher retention time of water than in natural wetlands.

Such floating wetlands have to be designed according to the characteristics and bio-climatic conditions of the Gangaya's river. It is optimal for those structures to cover minimum 20% of the surface in the area treated. Since, it is a flowing river, it should be limited to the areas where the flow rate is sufficiently slow to avoid damaging the structure or tearing out the anchors.

The structure is composed of a floating frame that is filled with fibers to allow hydroponics root development. As the roots develop they remove nutrient, fix and filter suspended organic particles and develop a huge net covered by microbial biofilm that reduce metallic and other forms of pollution.

The different processes taking place in such systems involve[4]:

- sedimentation and filtration of suspended particles;
- bio-degradation, adsorption and plant uptake of biodegradable organic matter;
- ammonification, nitrification/denitrification, plant uptake and media adsorption/ion exchange of nitrates;
- media adsorption, plant/microbial uptake, sedimentation and precipitation of phosphates;
- Adsorption and cation exchange, complexation, precipitation/co-precipitation, oxidation and hydrolysis, plant uptake, microbial oxidation/reduction (microbial-mediated processes), sedimentation and filtration of metals;
- Sedimentation, filtration, natural die-off, predation, UV irradiation, excretion of antibiotics from roots of macrophytes and adsorption of pathogens;

[3] Dodkins, I and Mendzill, (2014). Floating Treatment Wetlands (FTWs) inWater Treatment: Treatment efficiency and potential benefits of activated carbon. Sustainable Expansion of the Applied And Marine Sectors (SEACAMS), Swansea University, Wales. From : Vegetated Floating Islands Enhance the Ability of Wetlands to Reduce Nutrients and Other Pollutants | Request PDF. Available from: https://www.researchgate.net/publication/282579026_Vegetated_Floating_Islands_Enhance_the_Ability_of_Wetlands_to_Reduce_Nutrients_and_Other_Pollutants [accessed Sep 10 2018].
[4] Dordio, Carvalho and Pinto, Wetlands: Water "living filters"?, Department of Chemistry, University of Évora, Évora, Portugal

- Sedimentation, volatilization, biodegradation, adsorption, plant uptake, photolysis and chemical reactions of other types of pollutants;

Different plants have different impact on the depollution process. Nevertheless, all plants do not have the same phytoremediation potential. First, the plants have to survive in the polluted environment and tolerate high concentration of potentially toxic concentrations of pollutants. They need to be native plant of the area so that they are well adapted to the environment and won't become invasive species. Finally, they need to be able to absorb high level of pollution. The microbial biofilm that the roots and structure foster, plays moreover an important role in the water remediation process.

Given those criterions some plants have been selected that should be suitable for use in the Gangaya's estuary and its pollution. Further water quality investigation might nevertheless provide evidences for using different plants than the ones proposed here after.

Four plants species have been selected for being established on the floating treatment wetlands. Those plants are native plants of the area and naturally occur in the site's specific climatic and ecological conditions. More over they are good nitrogen and phosphate accumulating plants and have other properties well suited for this situation.

1. *Vetiversia zizanioïdes*

Vetiveria grass is a fast-growing grass that is non-invasive, very deep rooting perennial species. It is native to Kerala and phytoremediation using vetiver grass has been regarded as an effective technique for removing contaminants in polluted water, specially herbicides and pesticides, nitrates (due to its fast growth) and heavy metals (Al, Mn, Mg, As, Cd, Cr, Ni, Cu, Pb, Hg, Se, Zn). Moreover, the long root system will foster sedimentation under the floating treatment wetland and the development of a dense biofilm. I can also thrive in very high acidity, alkalinity and salinity conditions.

2. *Canna indica*

Canna indica, is a high accumulator of nitrate and phosphate making it a very useful plant to grow in eutrophic water. It tolerates highly polluted environment and it is a native plant of Kerala.

3. *Cyperus polystachyos*

It is an annual or sometimes a perennial. It is found growing commonly in seasonally flooded places, damp places, in marshes, swamps, in rice fields, river banks and at the margins of pools. It supports brackish water and is able to remove nitrogen, phosphates and metallic pollutants such as Cadmium and Zinc. It is a natural filtrating wetlands plant.

4. *Scirpus maritimus*

It is a perennial species that tolerates brackish water and that is native to India, it usually thrives in a norther area than Kerala but its strong depollution properties make it a prime species to introduce in the proposed floating wetlands. It has shown great efficacity at removing nitrogen and phosphate nutrient from landfill leachate, to uptake As and Hg from industrial waste water and in reducing the chemical oxygen demand (COD).

Those plants may be complemented with other native plants such as *Colocasia exulente, Nechamandra alternifolia, Ocimum tenuiflorum, Hibiscus hispidissimus* or other plants that have various properties such as repelling mosquitoes, etc..

The biomass produced can be harvested and composted before being tested for traces of heavy metals and used accordingly. Flowers and ornamental by-products can be exploited and sold for non-alimentation use. Further test on contaminants content in plant tissues should be undertaken before using side-products for animal feed or human alimentation. The very active research community in that field also provides some insights about the use of the plants. Further investigation should be undertaken to determine how the biomass produced could be used (metal recycling -if any-, energy production, animal feed or fodder, medicinal use, alimentation).

5.2 Creating natural filters in heavily sewage affected areas

This waste treatment solution is dedicated to areas where sewage is concentrated and channeled to the main river bed. The purpose of this solution is to reduce the amount of domestic grey water entering the river by filtering it through natural filters before it reaches the main stream. The proposed system necessitates more in-depth measurements and sizing than the previous solution and might incur higher cost while still maintaining the low financial input and energy compared to traditional treatment plant.

The concrete sewage infrastructures in Vizhinyam can be used for upstream waste management. Moreover, natural sewage channels could be transformed into natural filters.

Figure 22: natural sewage channel

Figure 21: concrete sewage infrastructure

The natural filters consist of creating compartment in the sewage concrete structure or reservoirs in the natural channels. Those compartments or reservoirs will be filled with different layers of mineral material and then planted with water depolluting plants such as reeds. Upstream from the first compartment will be placed a grease trap that will retain all the greasy materials and larger sediments that otherwise would clog the filter.

Typically, the filter contains the following layers (from bottom to top):

- Impermeable layer (concrete or pound layer)
- 1-1,5" round gravel layer 6" deep
- Pea gravel 6-25" deep
- (mulch)
- Wetland plants: Phragmites australis/karka, Typha domingensis/angustifolia, Aristea ecklonii, etc.

The water is entering the filter from the top and flows out from the bottom part enabling bacteria fixed to the gravels to treat the infiltrating water. The design might include a series of compartments with different plants and depth for optimizing the depollution process. In depth site investigation might appear necessary for setting up the most appropriate design.

In the case of natural sewage channels a proper reservoir will have to be dug out and filled with the appropriate material and plants. As this might be more expensive and workforce intensive other natural solution might be considered (i.e. planting depolluting plants immediately in the polluted areas with their individual substrate).

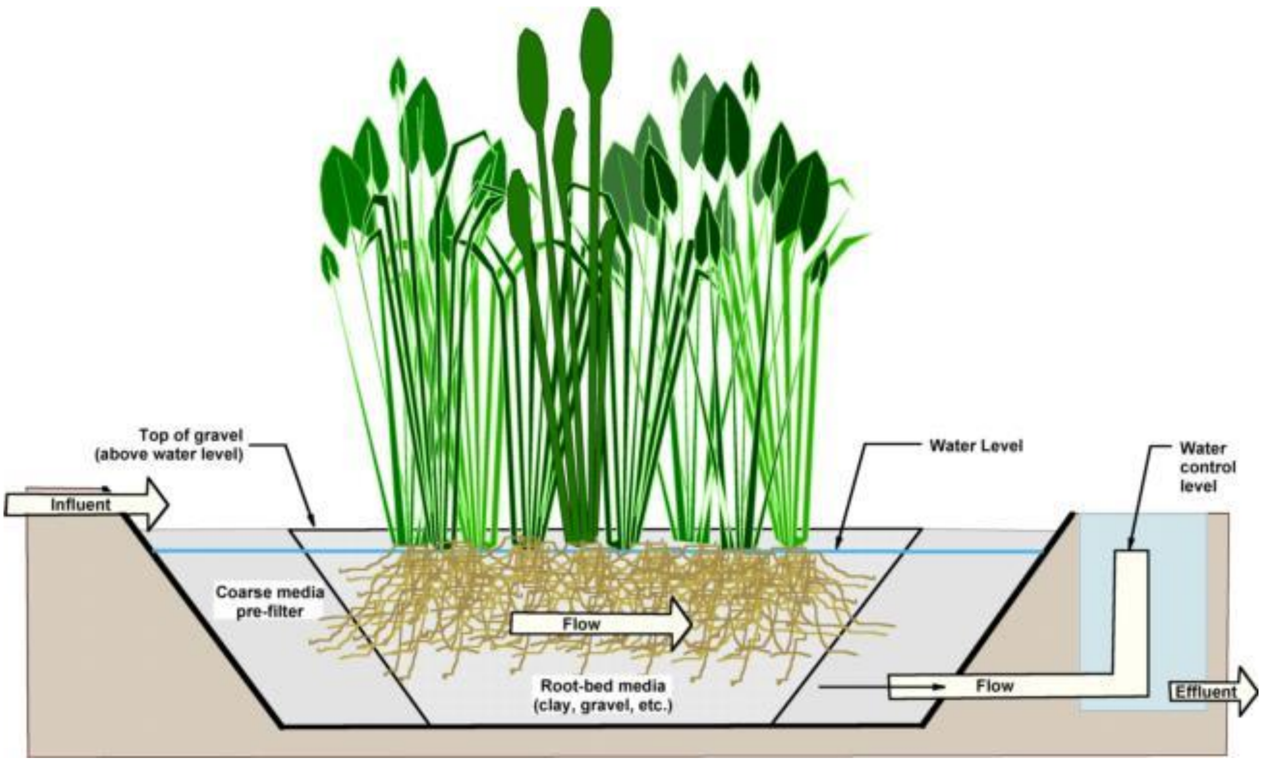

Figure 23: Constructed wetland similar to the proposed reservoir solution. [5]

At the end of the concrete sewage structure, an oxygenating structure should be put in place to increase the DO to the desired level. Such structure aims at creating turbulences in the flow such that the atmospheric oxygen dissolves in the water.
It may take the form of a flow form that fosters oxygenation of the water, of a rock cascade or of more complex system such as an oxygenating spin turbine, or an oxygen diffusor.

Figure 24 : Flow form, oxygenating spin turbines, oxygen diffusor

The first two options will be preferred in this situation as they don't require power and running costs. In case the DO happens to be too low, the later solutions might be envisaged for short term periods.

[5] **Source : http://rdissanayake.blogspot.com/2012/08/constructed-wetlands-as-method-of.html**

5.3 Planting the river banks and retention zone with depolluting plants

This last solution is part of the general objective to restore balanced natural ecosystem in the Gangaya's esturary. Several plant species have depollution properties. Their combined effect with the more invasive solutions will strengthen the restauration of the beneficial self-purification processes occurring in a healthy ecosystem.

Various plants[6] are proposed below to improve the health of the river banks and of the estuary. Some plant species are meant to be grown with submerged roots in the water while other need firm ground to grow.

Brassica napus, or Indian mustard, is a hyper accumulating plant of heavy metals, pesticides, herbicides and some radioactive components such as Cs137. *Helianthus Annuus*, sunflower, and *Sorghastrum nutans* are other hyperaccumulator of heavy metals and other pollutants. They can be combined with the latter to reinforce its effect and remove other components such as Hg, metalochlor, pesticides, herbicides and radioactive components.

Those plants provide high yield of organic material that can be used for energy generation and potentially for other uses depending on their content of contaminants. The sunflowers can be sold for non-food uses.

It is proposed that those plants along with phragmites grass (*Phragmites karka*) be established on the banks for one season in order to remove the main contaminants. Other plants can then be installed such as *Ocimum tenuiflorum, Lagenandra nairi.*

In the shallow water areas species such as *Nelumba nucifera* (Indian lotus) should be planted along with *Thypha angustifolia*, *Limnopoa meeboldii* and *Trapas natans*.

Nelumba nucifera is a very efficient plant at treating household waste water especially for the removal of SS, BOD5, TKN, NH 3 –N, NO 2 –N, NO 3 –N, TP[7] and coliform bacteria. It is also a strong water oxygenating plant.

Typha angustifolia is a hyperaccumulator of Pb and can degrade two commonly used herbicides, atrazine and alachlor.

Trapas natans is a native plant from the Indian sub-continent and it has been cultivated for years for its fruit. It is able to remove As ions from polluted water.

[6] Dhir, B., 2013. Phytoremediation: Role of Aquatic Plants in Environmental Clean-Up. Springer, New Delhi, India, ISBN-13: 9788132213079, Pages: 121.
Prasad MNV (2011) A State-of-the-Art report on Bioremediation, its Applications to Contaminated Sites in India. Ministry of Environment & Forests, Government of India. NewDelhi. Pages 90

[7] Soluble Solids, Biological Oxygen Demand, Total Kjeldahl Nitrogen, Ammonium, Nitrites, Nitrates, Total Phosphorus

Limnopoa meeboldii is an aquatic annual and sometimes a perennial. It grows bottom-rooted and floating in coastal lagoons that sometimes become brackish after the monsoon season. It is endemic to Kerala and would be worth reintroducing in the Gangaya's watershed for its ecological role.

A reassessment of the conditions will have to be made after each growing season to consider establishing other native species and restoring a naturally balanced ecosystem. Further on-site investigation would also be beneficial to foster the development of native established species in order to restore a balanced ecosystem.