Revitalizing the Nullahs of Mumbai

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Abstract:

Nullahs have become one of the largest negative spaces in the city today. They have become an impactful problem causer leading to a wide range of problems. But are nullahs supposed to be the way they are today? The reasons for the current state of nullahs in Mumbai include the industrial revolution of the 1890s, settlement of the Koli community, lack of care by the BMC, and mentality of the people. Nullahs have drastically affected the Koli fishing community, which played a major role in making Mumbai what it is today, by forcing them to travel far into the deep sea to fish. Nullahs also affect the marine ecology of Mumbai, which already receives little attention. Due to the tight fabric of the slums, it is difficult to set up proper garbage disposal facilities, so people resort to throwing their garbage into the nullahs in hopes that it will be carried away. Additionally, illegal sewage pipes are directly connected to these nullahs. As a result of all these actions, the slum dwellers face the consequences during floods, hindering their economic and other activities. Poor water quality during floods can also bring diseases like dengue fever, malaria, typhoid, cholera, vomiting, headache, asthma, and more, resulting in loss of school and workdays, and affecting their mental performance. The surrounding areas remain unsanitary for long periods, and the garbage from the nullahs enters the sea, polluting the beaches every day. The development along the nullahs is also affected by the ill effects that nullahs bring, causing the properties adjacent to them to be sold at a lower price. This situation must change.

However, an ethical interrogation can transform the nullahs into an asset for all by creating a circular economy that maintains a balance between People, Planet, and Profit.

Keywords:

Nullahs, Channelization, Waterlogging, City Movements, Circular Economy

Introduction:

Nullahs were originally natural watercourses or rivers that helped regulate groundwater and disperse stormwater. However, they have become clogged with garbage and sewage, which prevents them from functioning properly. Instead of flowing downstream, during heavy rainfall, water seeps onto the streets along with filth.

Mumbai, being a coastal city, has a network of natural and man-made drainage channels, known as nullahs, that carry rainwater and sewage out to the Arabian Sea. Mumbai has over 300 km of nullahs that were originally natural watercourses or rivers connected to the sea and tides. These water bodies played a crucial role in regulating groundwater levels and dispersing water from the land during heavy rain.

Unfortunately, they have been abused and turned into open sewage drains, with effluents flowing out into the sea. The condition of these nullahs has been a longstanding issue in the city, particularly during the monsoon season when heavy rains lead to flooding and waterlogging.

The nullahs are often clogged with garbage, plastic waste, and silt, which hampers the flow of water and exacerbates the flooding problem. In addition, encroachment of the nullahs by slums and illegal buildings has further reduced their capacity and made them more vulnerable to blockages. The thoughtless discharge of domestic waste into the nullahs poses a serious threat to the health and well-being of citizens.

The nullahs carry a significant amount of untreated sewage and industrial waste, which not only causes water pollution but also affects the marine ecosystem in the Arabian Sea. The accumulation of garbage and plastic waste also adds to the pollution levels. The poor condition of the nullahs increases the risk of waterborne diseases. The residents living in the nearby areas are particularly vulnerable to such health hazards.

Sadly, the city has neglected its natural assets, considering these areas as dumping grounds both physically and metaphorically. The local fishing industry has also been severely affected, leading to a drastic reduction in its size. Instead of building the city to accommodate

problems, the emphasis should be on resolving the issues causing the problems. The city needs to consider its resources and take a more sustainable approach to its development.

Research Methodology:

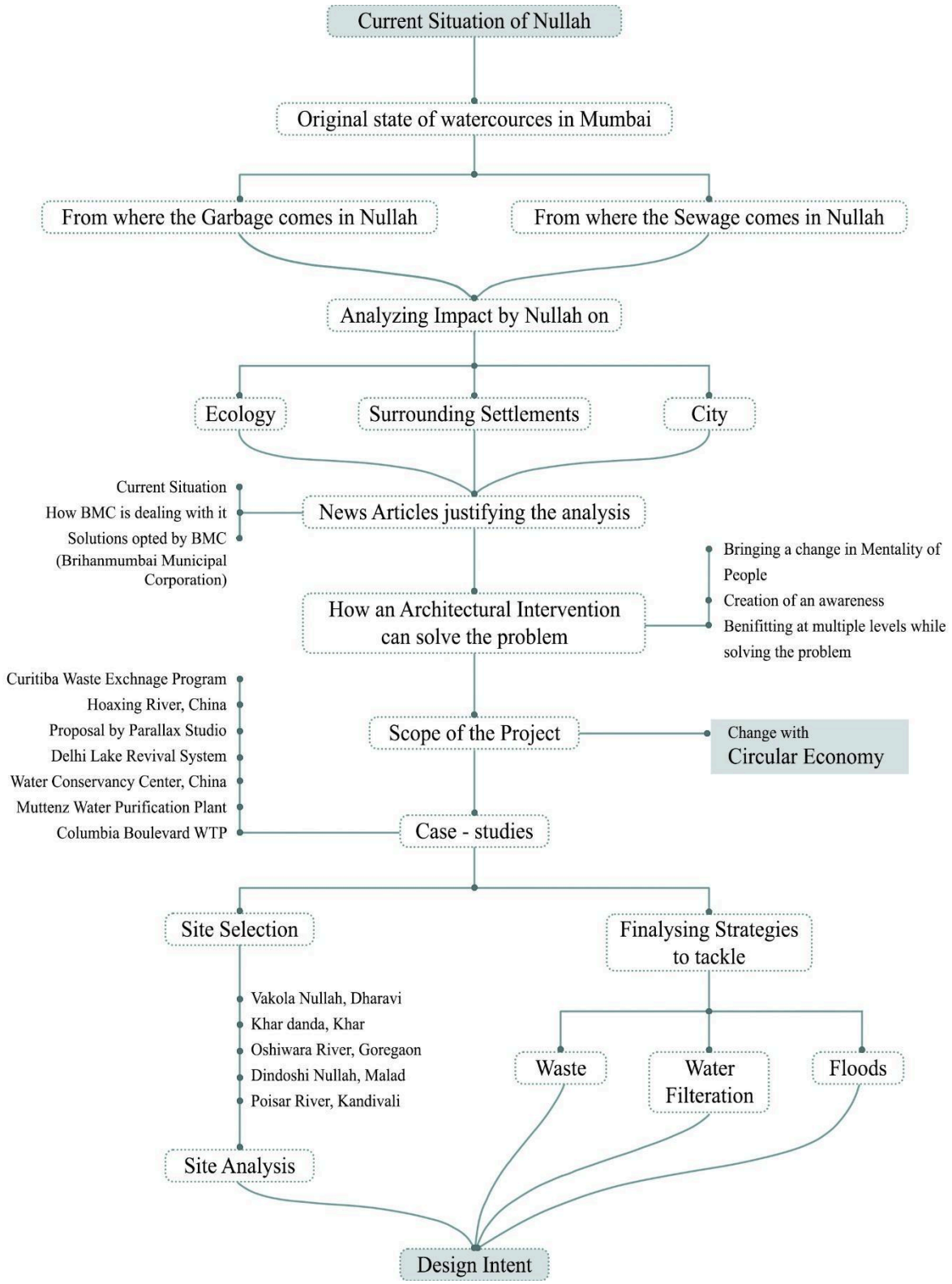
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Fig. 1: State of Nullahs in Mumbai (Source: DNA India)

When stormwater drains carry sewage, plastic, and other chemical pollutants from human activity, they choke the life in the water bodies they drain. The plastics remain in the environment, becoming a source of microplastics that then find their way into the food chain and bio-accumulate in humans. It is not news that there is a crisis; in fact, it took another catastrophic event, the Mumbai floods of August 29th, 2017, after the floods of July 26th, 2005, to bring this crisis to light.

Source of Garbage in Nullah:

Near the natural watercourses of Mumbai like rivers, creeks, and Nullahs, Koli Settlements were earlier established, as these community's' primary occupation was fishing. This rise in the fishing industry leads to an increase in trade, business, development of the port, and many more.

In the 1890s, industrialization and a massive rise in migration of the working class from different parts of the country led to slums in Mumbai. Due to insufficient housing for the migrant working population, slums and pavement dwelling conditions came up near these Koliwada villages.

Since other parts of the city developed at a faster rate, the settlements which were earlier villages have now become the present-day slums. These clusters got divided from the rest of the city by roads, rivers or nullahs. The living condition in these slum settlements is one of the worse in the city.

Since the fabric of these settlement areas are too tight, there is not any garbage disposal service available by the BMC. Because of the very small width of lanes in-between houses, carrying of garbage for the community becomes difficult. Although vans do ply on the main road, none of them go into the slum areas to pick up litter.

Because of the unavailability of any garbage disposal facility in the vicinity, people tend to throw their waste outside. Outside of their homes, there is not any space; people resort to throwing their garbage into the nullah. The mentality of the people behind it, as the nullah or river is flowing, the waste thrown in it will eventually flow away and will not stay here. But due to the increase in the infiltration of garbage, the nullahs or rivers hardly flow now. Every day 80-110 Tons of waste get directly thrown into the Nullahs every day. 93% of the total waste found in the Ocean is Domestic Waste.

Source of Sewage in Nullah:

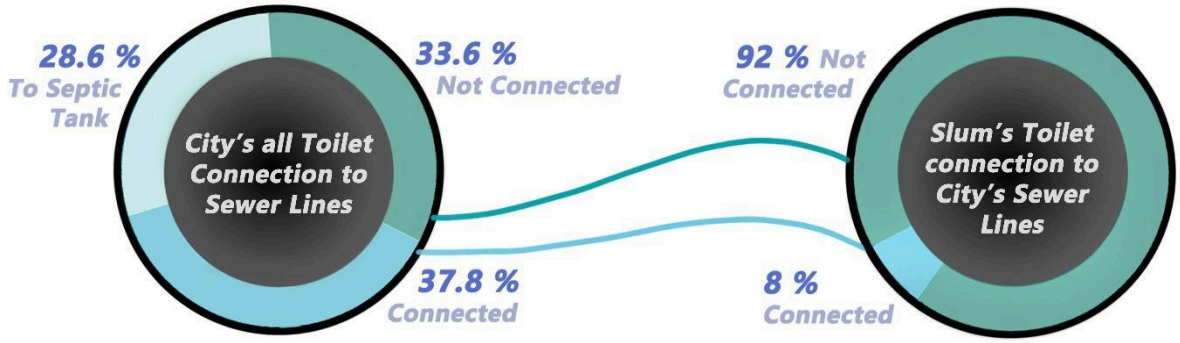


Fig. 2: Mumbai Sewage Disposal Analysis (Source: Author)

Mumbai is the city with the highest population in India, at over 20 million, and more people keep coming into the city looking for opportunities. A major issue with an unplanned city with one of the highest population densities is sanitation and sewage management.

Mumbai produces a staggering 2,371 million litres of sewage daily out of which only 2,016 million litres are redirected to Sewage Treatment Plants (STPs). A 2011 census report found 37.8 percent of Mumbai's population had a latrine system directly connected to sewers, while 28.6 percent had septic tanks., 21 percent of the city population used public latrines while the rest 7.7 percent resorted to open defecation. Out of the 33.6% not connected, 92% of them are slums illegal sewage lines as only 8% of city's sewage line is connected to city's sewage line.

Except the one in Colaba, the remaining 6 STPs in Worli, Bandra, Versova, Malad, Bhandup and Ghatkopar, some of which were constructed more than 20 years ago, are currently not fully equipped to purify the quantum of sewage water coming and continue to discharge polluting effluents into creeks. Though sewerage lines are laid in above zones, due to rapid expansion, development, dense population and non- accessibility etc sullage in some of the

parts particularly in extended suburbs and slums are connected to storm channels, which must be segregated. Mumbai's storm water drains (SWDs), which are supposed to carry rainwater, are connected to illegal sewerage lines. In this way, sewage is dumped into the sea or creek without being treated by SWD pumping stations.

Though sewerage lines are laid in above zones, due to rapid expansion, development, dense population and non- accessibility etc sullage in some of the parts particularly in extended suburbs and slums is connected to storm channels, which is required to be segregated. Further, Mumbai's storm water drainage system network (SWD) is connected to illegal sewer lines, designed only to carry rainwater. Due to this, sewage is dumped into the sea or creek without being treated. With this increased load of garbage, sewage and frequent thunder storms, city drainage lines are bound to suffer.

Fig. 3: Illegal Sewage lines connected to Nullahs (Source: Author)

These sewage lines connect to the nullahs or rivers without any filter, and these nullahs carry sewage open to the ocean without any filter. This unfiltered garbage and sewage lead to the effects of climate change.

The slums need toilets; toilet needs sewage management; illegal settlements lead to unauthorized sewage lines. These unauthorized sewage lines directly connect to nullahs or rivers. As they cannot connect to the city’s sewage lines and no strict law on nullahs and

rivers makes them connect these lines to the nullahs. 107 Nullahs in the west directly opens into Arabian Sea without any filtration.

According to the BMC Survey, over 76,400 sewage lines have been illegally connected to SWDs, open nullahs, rivers and creeks.

Water Quality Standards recommended by NGT:
Biochemical Oxygen Demand (BOD) level is 10.
pH value ranges from 5.5-9.0.
Total Suspended Solids (TSS) is 20.
Chemical Oxygen Demand (COD) is 50.
Faecal Coliform (FC) level is 230 per 100 millilitres.

Impact of Nullah on Ecology:

How Nullah Water affects Marine Ecology?

If poor water quality is accompanied by sewage and plastic debris, The level of oxygen in the area will decline. The discharge of sewage will not only kill marine life but will also lead to a drastic decrease in fish stocks. There is no way to halt the influx of wastewater into the ocean.

Endangered Marine Species found near the coast of Mumbai due to Water Pollution:

Fig. 4: Mumbai's endangered marine ecology (Source: Marine Life of India)

Around 2,100 million litres a day (MLD) of waste water & sewage is released into the creeks & Arabian Sea. Due to wind direction and wave movement, some of these ends up on the beaches itself. Sewage mainly contains human excrement. The sewage that contains raw and primary treatment bacteria is highly dangerous because of the high levels of bacteria. This can lead to a number of diseases, such as nausea, vomiting, and diarrhoea. Besides, bacterial infection can cause skin infections. In sewage treatment, all marine life is killed as the environment becomes very polluted. This occurs because of untreated waste entering the ocean.

Quality of water near the coast of Mumbai:

Mumbai's dirtiest water is around Juhu, Girgaum Chowpatty, and Haji Ali. However, the city worst water quality is found in the Mithi River which flows into Mahim Creek. And none of the waterbodies in Mumbai lie in the satisfied index.

Location	Water Quality Index
Mithi – Most polluted river water	28 (Very bad/ heavily polluted)
Juhu - Most polluted coastal water	44 (Bad/polluted)
Girgaum Chowpatty	45 (Bad/polluted)
Haji Ali	45.2 (Bad/polluted)
Mahim	45.2 (Bad/polluted)
Worli Sea Face	46.1 (Bad/polluted)
Nariman Point	46.8 (Bad/polluted)
Dadar	46.8 (Bad/polluted)
Versova	47 (Bad/polluted)
Gateway of India	47 (Bad/polluted)
Thane creek	48 (Bad/polluted)

Fig. 5: WQI levels recorded by MPCB in Mumbai (Source: Hindustan Times)

The Maharashtra Pollution Control Board (MBPC) conducted a water quality analysis along Mumbai's coast between January and May in order to create the Water Quality Index (WQI). Juhu, Girgaum, and Haji Ali recorded levels of 44.45, 45.2, and 45.8 respectively; Mahim recorded a reading of 45.2; Worli Sea-face registered 46.1; Nariman Point displayed 46.8 readings; Dadar Chowpatty exhibited level at 46 while Mithi had an index value of 28 which means their water is highly polluted according to MBPC standards.

Marine biologists research concludes good WQI means high levels of oxygen in the water. "The level of oxygen will decline if poor water quality marred with sewage and plastic take over the surface of areas close to the coast. Not only will it wipe out marine life, it will lead to a tremendous drop in fish catch," said E Vivekananda, consultant and scientist, Central Marine Fisheries Research Institute.

Untreated sewage can provide high levels of organic material, which can provide food for all bacteria. These bacteria consume the dissolved oxygen in the sea, so it has less oxygen. And because of this deoxygenation, sulphur dioxide and hydrogen sulphate are produced. These gases are notably pungent and launch a foul smell.

Impact of Nullah on Slum Dwellers:

Impact on their Occupation:

Fig. 6: Impact on people's occupation (Source: Homegrown)

The Slum-dwellers home is usually just the ground floor with a mezzanine just for sleeping purpose. The ground space becomes the multi-functional space, where it used by their small business which is happening inside their house and for many theirs only source of income. When flash flood happens due to nullah, their occupation gets a complete stop.

Impact on their Health:

Sewage and wastewater carry some bacteria and diseases like E. coli, shigellosis, typhoid fever, salmonella, and cholera. Bacteria may

cause diarrhoea, fever, cramps, and sometimes vomiting, headache, weakness, or loss of appetite. The smell and stinginess of nullah brings Mosquitos which leads to increase in Malaria and Dengue cases.

Fig. 7: Impact on people's health (Source: Yeni Safak)

Impact on their Home:

When the area gets filled with water due to local flooding, the income source gets shuts completely with very less savings, sustainability of running house becomes a problem. The loss of infrastructure of their home due to flooding leads to further expenditures to every time. Also, the mental state of rest having inside the home is lost.

Fig. 8: Impact on people's home (Source: The Wire)

Other Impacts on their Life due to problems created by Nullah:

- Loss of School Days
- Missed days of Work
- Economic Activity Hampered
- That leads to delay in other activities.
- Poor Health status of the community
- Nearby Area Unclean
- Personal Hygiene Compromised
- Water Conflicts
- Less faith in Government Services

The extreme precipitation on 26 July 2005, imposed a huge monetary burden on the poor of income loss, damage to structure of the house or premises, damage to household assets and appliances and damage to vehicles. Families below poverty line as well as poor and low‐income households suffered relatively greater magnitude of losses compared to their relatively better off counterparts.

Key findings from flood exposure analysis:

Large variety of households live close by and are immediately exposed to continual and

localized floods throughout the flood-prone wards in the city. The percentage of slum dwellers located near the flooding spots is very high. These are the most vulnerable sections of the population and are directly exposed to flood waters due to their location on the roadsides or in low-lying areas. Besides slum households, other low and middle-income households residing in apartments are exposed to recurrent floods in large numbers.

Apart from the households in and near the flooding spots, people transiting through the areas for work or to use transport services or any ither amenities are also directly and indirectly exposed to floods. The direct exposure of population in transit happens when they use the services and amenities located near the flooding spots. There are a number of shops, markets, schools, hospitals and public utilities which are located near these spots.

The nature of all the land uses around the chronic and localized flooding spots highlights the significant amount of asset and wealth exposure to recurrent floods.

Impact of nullahs on city:

This disparity is not unique to India. With over 54% of Mumbai's population concentrated into the city's dense informal settlements and forced to occupy just 5% of the city's land, the city has a fragmented and polarized metropolitan landscape. Many of the settlements have been disconnected to formal water and sanitary systems. These settlements therefore rely on a complex informal system of water procurement, storage and distribution involving unmetered and metered municipal stand posts and group connections, illegally dug wells, boreholes, private tankers, improvised municipal pipes, etc.

Drastic Inequality in the Urban Fabric of Mumbai:

Fig. 9: Unequal Scenes in Mumbai (Source: John Miller)

These images are famous, seen in social media and Films but the thing ignored in this drastic inequality shown is the Nullah running around the Slums. The slums around these nullahs are always ignored because of the ill-effects the Nullah brings like smell and floods.

Also, the building which are developed around the nullahs are not being sold at that pace because of similar ill-effects of nullah. They are being sold are also done at a lower rate than the surrounding. Thus, the growth of the city is hampered where there are problems which are caused by the nullah.

The nullahs are connected as a long stretch which runs through the city and finally opens at the end in the ocean. If the nullah at any point gets completely filled with garbage and ends up being choke at any point, then the water of the earlier part stops flowing. As the water stops to flow, the drain starts filling more and more, and after a time the nullahs or drains gets so filled that it starts throwing water outside the drain.

This flowing of water backwards makes the area around it flood. The areas close to the choked point becomes more flooded than the area farther from the choked point, as the water accumulated at the nearer end is more than the earlier. Also, the quick back pressure is sudden and more near the nearer point which leads to flooding of the area faster as compared to the farther point where the back pressure is reduced.

Mumbai killing the fishing villages that made it:

Fig. 10: Fishing Port at Worli Koliwada (Source: Author)

The lack of sustainable fishing practices, along with pollution of nullahs and rivers filled with garbage and sewage, has far-reaching implications for the future of seafood consumption, the health of the ocean and the livelihood of fishermen in Mumbai. This has led to only decrease in the fishing activity over the years due to high maintenance.

Most experts agree on the dangers of over and out-of-season fishing, but the problem is complicated by issues of livelihood of the fisherfolk as well as industrialization, pollution, and land encroachment in coastal areas.

Annual Monsoon Menace & Water-clogging:

In last 10 years, Mumbai has incurred losses worth ₹ 140 million due to flooding. All through the year, Mumbai's canals, creeks and rivers – which are natural storm drain systems – are clogged with silt, garbage and untreated sewage.

BMC spends every year ₹ 125 crores just to do distilling of the nullahs which eventually again gets in the same condition within a week. In response to this annual monsoon menace, the government and civic authorities have taken measures to clean and desilt the nullahs and implement a ban on single-use plastics. However, a more concerted effort is needed to ensure that the nullahs are kept clean and maintained throughout the year to prevent water-clogging and flooding during the monsoon season.

Problem with Mentality of People:

One of the main sources for the issue is the indiscriminate dumping of garbage by the people. For it to stop, solution needs to be though which would cover a wide range of issues related to people's attitudes and beliefs, not just limited to garbage disposal. It implies a need for a shift in people's thinking or behaviour to address the problem.

Nullah is always considered as a negative space in the city. The problem with considering it as a negative is that, people deteriorate the nullah without the feeling of guilt without considering the consequences it would bring along with it.

Fig. 11: Women dumping waste in Nullah (Source: The Japan Times)

The rivers or nullahs being a flowing water body, people throw their waste into it considered it will flow away and not stay around them. Also, the waste thrown on the road, pass through the drains and end up at the nullahs.

Controlling and cleaning up litter is one way to address the problem of trash in the marine environment – and we certainly support this approach. The problem is that we can't clean up all the trash that pollutes waterways, and clean-up doesn't address the unsustainable consumption of resources involved in producing packaging and single use disposable goods. Furthermore, as the amount of disposable packaging and products continues to increase, controlling litter through public education and clean-up of streets and waterways requires significant and sustained funding that is rarely available. Enforcement of fines for littering is not often a priority for regulation enforcement, especially in city areas where crime takes precedence.

Only cleaning not the solution:

There need to be a change in the mentality of people regarding waste throwing. As

there not any waste collection from BMC near the Slum Areas, they must deal it with themselves.

And hence they do by tying all their home's single day waste in a plastic polyethene bag and toss it around not anywhere in the locality but in the nullah. Fig. 12: No change in situation even after Cleaning (Source: Mid-day)

According to a report by Mid-day, it shows the situation of Nullah before and after the cleaning procedure. The wild plants may take a time to grow, but the garbage in the nullah comes to the same situation just after a week. According to BMC quotations, the distilling work is supposed to be done for 3 times a year but is done just once before monsoons. But apparently even 3 times a year is not enough and the problem not only lies in the number to intervals, but demands a solution which can solve the source of this garbage in the nullah.

Key elements of land-based sources of marine litter include litter, trash, particles from construction, ports and marinas, business and industrial facilities, and trash blown out of garbage containers, trucks, and landfills. 60-80% of the marine debris in the ocean comprises of plastics. In addition, plastics are broadly dispersed in the ocean water column, on the seafloor, and in each and every ocean on the planet. Plastic outweighs plankton 46 to 1 in the well-known Pacific garbage patch. This number extended almost tenfold in the closing decade and is predicted to do so again in the coming decade.

Plastic particles injure and kill fish, seabirds, and marine mammals. Marine plastic air pollution has impacted at least 267 species worldwide, together with 86% of all sea turtle species, 44% of all seabird species, and 43% of all marine mammal species. The effects encompass fatalities as an end result of ingestion, starvation, suffocation, infection, drowning, and entanglement. Plastic particles adsorb and transports pollutants, which can bioaccumulate up the food chain, polluting seafood. Food waste accounts for 73% of Mumbai's waste. The amount of garbage that ends up in Mumbai's overcrowded landfills will decrease by 93% if this food waste is properly recycled and managed. Every day, Mumbai generates between 7,000 and 7,500 tonnes of solid waste. Around 80 to 110 metric lots of plastic waste, quite a bit of it single-utilize plastic, is being unloaded into Mumbai's channels and water channels consistently.

Recycling is only Part of the Solution. Many people forget that reduce and reuse come before recycling in the 3Rs of waste management (Reduce, Reuse, and Recycle). While recycling is certainly important, there is often too much focus on diverting single-use disposables from the landfill by recycling or composting instead of stopping this waste before it starts. These materials are aid intensive to produce, manufacture and recycle – standard packaging and single-use merchandise symbolize an unsustainable use of treasured sources (oil, trees, energy, water).

Generating awareness among people:

If people are aware of the problems associated with the degradation of water bodies, it can reduce. Or else, the load will eventually keep on increasing after a point, every system would fail. Hence, an awareness needs to be spread specially in the community of slum-dwellers to not throw the garbage in the nullah instead can be segregated and utilised for different functions.

Since there is a demand for recycled garbage intuited companies of getting segregated dry waste. Slum dweller's segregated dry waste can be sent over, to those companies gaining a commission from the same. The remaining wet waste can be composed to make it into fertilizers, which is also revenue - generating.

Non-profit organizations currently manage the dry waste segregation centres. Ragpickers collect usable material from the garbage to sell it to scrap dealers and the rest of the material is sent to dumping grounds. Now, BMC plans to allow setting up of mechanised segregation facilities using funds from the plastic bottle manufacturers. The plant will separate dry waste components and prepare material which is recyclable. The specific facility will be managed, and dry waste will be collected directly from homes by private companies.

Solving Poverty with Waste Management (Circular Economy):

Every year, more than 2 billion tons of solid waste are produced all over the world, or roughly 5 times the weight of all of humanity. If nothing is done, this number is expected to rise by 70% in the next 30 years. Put this waste back into the system and use it as a resource

to solve the problem. This helps generate revenue and maintain a balance between the 3Ps of the system: People (Society),
Planet (Environment),
Profit (Economy).

A program, were Environmental Problems gets solves, the people get facilities as well as the government earns.

Instead of solving / cleaning the oceans and rivers first, if we focus on the source of the pollution which are these nullahs and people living besides them! Then, the results will be automatic and be seen quickly! In spite of the scarcity of natural resources, employing a circular economy in waste management contributes to the creation of new industries, jobs, and economic stability.

For instance,

- Employment in the sectors of collection, segregation, and processing of the plastic and paper waste will increase.
- Training people to repair and refurbish electronic products, appliances, and vehicles has shown an increase in small-scale industries and employment rates as was seen in the Remanufacturing Model of circular economy in Ghana.
- Upcycling waste fabrics into useful products like bags, decor, toys, and more could also be taught to communities.

Building a Circular solution for any city can help tackle more than one social, environmental and/or economic issue as it has the potential of being sustainable and effective with Citizen participation and technological advancements.

Why need of an Architecture Intervention:

Impact on Human:
Water pollution truly harms biodiversity and aquatic ecosystems. The toxic chemicals can change the colour of water and increase the amount of minerals - also known as eutrophication which has a bad impact on life in water. Thermal pollution, which means rise

in the temperature of water bodies, also contributes to global warming causing serious hazard to water organisms.

Impact on Environment:

Water pollution has very negative effects on every living organism's health. A lot of diseases result from drinking or being in contact with contaminated water, such as diarrhoea, cholera, typhoid, dysentery, or skin infections. In zones where there is no available drinking water, the main risk for the human is dehydration.

The objectives of the Clean-up of nullahs in Mumbai are:

- Creating behavioural changes in the citizens living in the River Catchment Area by providing awareness training and workshop on effective solid waste management.
- Cleaning the river catchment area to protect the ecosystem and ensure a healthy environment.
- Recycling and valorising the collected waste into valuable fuels, chemicals, bio-energy and bio-fertilizer instead of sending it to the landfills.

The system includes:

- Concentration and collection of the floating waste present in the river.
- Sorting the waste.
- Recyclable plastic would be recycled.
- The low value/mixed plastic waste which could not be recycled would be converted into oil but the process of Pyrolysis.

The project will help Mumbai:

- Reduce the plastic waste entering the oceans through the Mithi River.
- Collect the raw material to be processed into valuable products, and
- Engaging the ecosystem of stakeholders in India to transit from linear circular to a more sustainable circular economy.

Thus, there need to be a social cultural program among the slum dwellers which can bring change in the way people deal with waste and deposit it. Hence, there can be a waste collection centre happening which can preach them to segregate the waste and then collect it.

The segregated waste can then be considered as a resource and can be used at multiple ways such as dry waste and plastic can be send to recycling companies, wet waste can be used for composting and can be converted into fertilizers which can be a revenue generation program also the remaining can be sent to waste to energy plant developed near Haji Ali, Worli.

Also, the water coming from Nullah is currently directly without any treatment is disposed. The water in the Nullah contains sewage, garbage as well as chemical effluents which pollutes the water and the ecology in a major way hence treatment of this water need to be made. The problem is, there is no place around the nullahs in Mumbai for any treatment plant and hence the treatment process needs to be made over the nullah itself.

Also, along with the cleaning, there needs to be awareness spread and the awareness program needs to be tied with a program that largely draws people in along bringing on the similar theme. There are also certain type of spaces and programs which the areas around slums lack, that can be provided to the people that can help improve the lack of socio-cultural place happening.

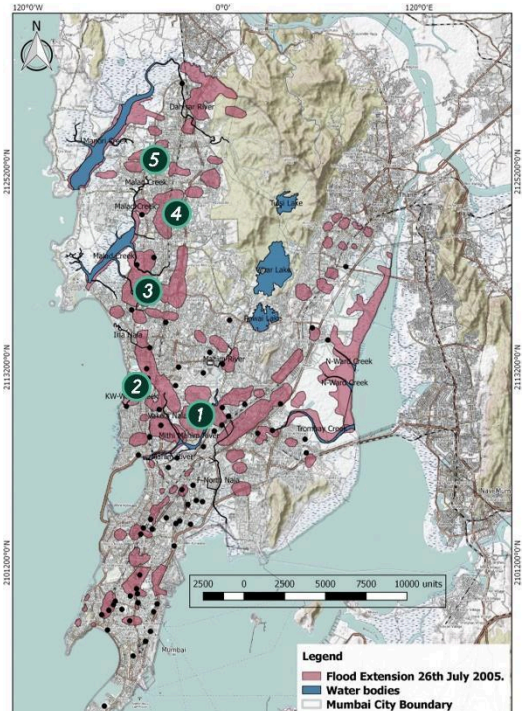
Intervention should be:

Socially:	Quality of Life.
	Accessibility to basic Services, Resources, and Infrastructure.
Environmentally:	Resource Perseverance and Management.
	Apply different Sustainable Development Goals.
Economically:	Utilizing waste as a resource.
	Culture Awareness.

Site Selection Criteria:

Problems associated with nullahs are different for different cities. For Mumbai city particularly, the main issue comes from the slum settlements adjoining nullahs.

As the fabric of the slum is tight, proper garbage disposal is not being able to carry forward.



Hence, slum dwellers have to lead to throwing garbage in the flowing nullahs. Also, illegal sewage lines build by them are connected to these nullahs, which eventually flow into the sea without any filter. This scenario may or may not be applicable outside Mumbai.

Fig. 13: Site Location (Source: Author)

Thus, the study area revolves around some criteria.

Evaluation of Potential Sites					
Sites	1 Vakola Nullah, Dharavi	2 Khar Danda, Khar-West	3 Oshiwara River, Goregaon	4 Dindoshi Nullah, Malad	5 Poisar River, Kandivali
No. of Slums	●●●●	●●●●●	●●	●●●●	●●●●●
Frequency of Flooding	●●●●●	●●●●●	●●●	●●●●●	●●●
Impact of Flooding	●●●●	●●●●●	●●●●●	●●●	●●●●●
Worse Condition of Nullah	●●●●●	●●●●●	●●●●	●●●●●	●●●●
Place of Importance	●●●●●	●●●●●	●●●●	●●●	●●●●
Connectivity to reach	●●●●●	●●●●	●●●●	●●●	●●●●
Closest to the Ocean	●●●●	●●●●●	●●●●	●●●	●●●●

Fig. 14: Site Evaluation (Source: Author)

After shortlisting 5 potential risk zones, the sites were evaluated on the intensity of common problems found similar throughout them. The evaluation criteria were: no. of Slums, frequency of Flooding, Impact of Flooding, worse condition of Nullah, place of Importance, connectivity to reach and closeness to the ocean. After Evaluation, Khar Danda in Khar (West) was selected as the site.

Overview of Khar Danda:

There is another reason for the formation of slums in Mumbai. As the city grew, it took over land traditionally used for cotton agriculture. The Koli fishermen & Gaothans (the urban villages and original inhabitant of the city) were displaced during the development of the harbour and port. Those who oved out of the fishing villages improvised their living space which was often far shabbier than before. This process continues even now.

Similarly, the formation of Gazdhar Bandh, a large pocket of self-built self-sustainable slums in Khar near to Juhu, resulted from various parameters. Gazdar Bandh, a densely populated

slum community located in the Western suburbs of Mumbai is one such case. Largely it owes to the generic problem of state body (MHADA) for not being able to provide affordable housing to the needed people, along with the absence of any policy existing or created to able to create housing stock for the urban poor. These two issues coupled with large scale land development and market driven real estate resulting in highly unaffordable housing in Mumbai.

Walking through the narrow lanes of this densely populated slum fabric in Mumbai's bustling commercial district, one may not become aware of its informal conditions. The dense social life, ongoing economic activities and thickly populated residential and working spaces are actually the outcome of unique connections between people and places in 10 the past three or more decades. The utopian urbanism renders place based visual identity to this urban space still remains dreams and excluded from the Master Plan.

However, there are other reasons that has necessitated the formation of this large slum pocket specially in the heart of the western suburbs in Mumbai. The first condition as being the unchecked land which is designated as "NDZ" (No Development Zone). Secondly, the land is also situated in an estuary condition, characterized with sensitive ecology. Land with such conditions is never negotiated within the DP or development plans either as subject of land development or subject of the ecosystem. Such dubious responses have allowed unchecked encroachment and lately resulted in the formation of the large slum pocket as a spatial illegality.

Existing Data of Gazdar Bandh Slum:
Total Slums – 1200 approx.
Total Population (Approximate): 65,000 (90% Hindus From Uttar Pradesh And Maharashtra)
Photo Documentation:

Fig. 15: Photo Documentation of Nullah at Khardanda (Source: Author)

Visiting the site proved the analysis done before. The nullah was filled with garbage around the edge with only a narrow water stream seen. People were coming up with their household waste in a polythene bag, tied and were tossing around it to the nullah, with the notion that the water will flow away the garbage with them. Due to this we can see a sheet of garbage floating on the nullah.

The site also has a pumping station, it was built to throw the flood water into the sea. But, as the nullah is filled with garbage, the insertion junction of the pumps was choked with garbage and the Pumping Station was performing inefficiently. The sea wall built is a useful feature, where it helps to stop the ocean water entering the nullahs in times of high tides.

There were many illegal sewer lines connected without any filtration to the nullahs. As these slums locality are not to the city's sewer lines, the slum dwellers themselves together built the sewer lines that connect to the nullah and eventually meet up the sea.

The sewage and the garbage dump in the nullah made the area around filled with very fouled smell and mosquitos constantly spread around the nullah.

Interviewing the locals came to know that, they have to throw the garbage into the nullah as there was not any garbage picking facility available by the BMC in the interior of slum cluster due to Space Constraint. Also, there weren't many public toilet facilities available for them.

Site Analysis Maps:

Fig. 16: Figure & Ground Map of Khardanda (Source: Author)

Fig. 17: Building Heights Map of Khardanda (Source: Author)

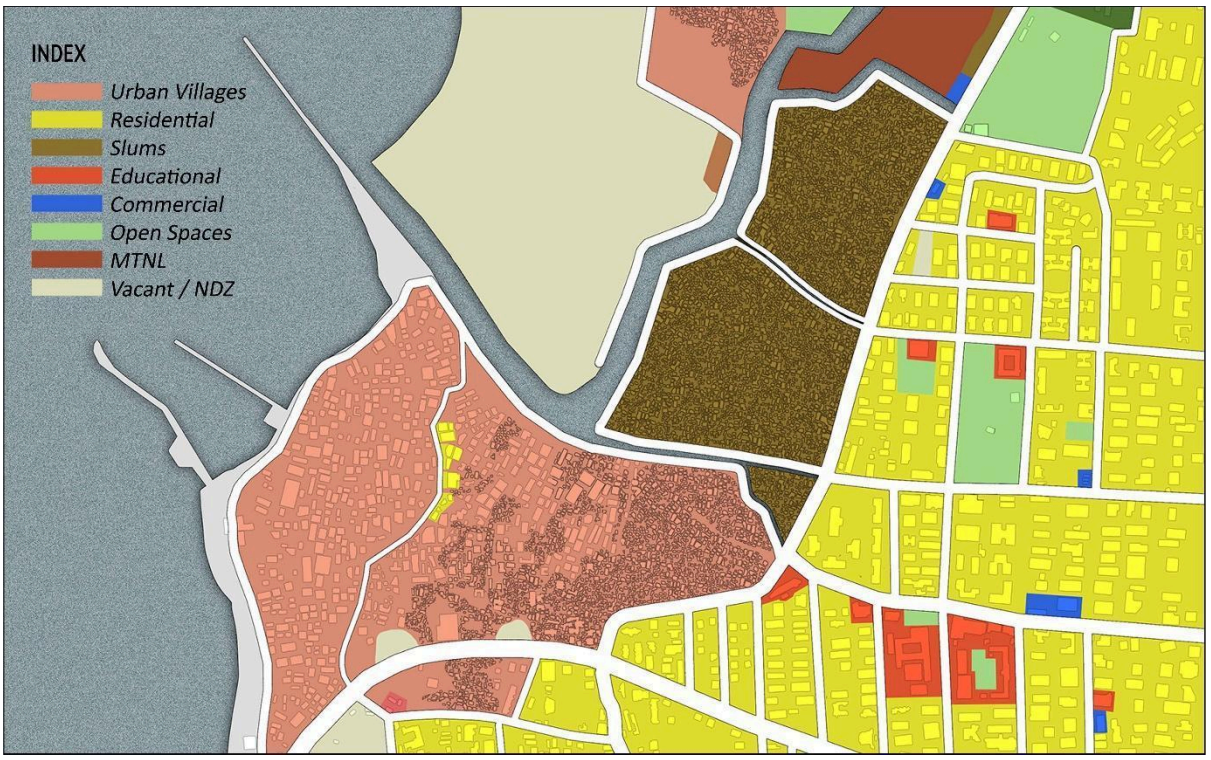


Fig. 18: Land Use Map of Khardanda (Source: Author)

SWOT Analysis:

Strength

- Close to the sea, hence what garbage we see on Nullah floating, directly goes to the sea.
- Connected to the better areas like Juhu Tara Road, Linking Road and more.
- Pumping Station with Sluice Gate helps in better control of water treatment management.

Weakness

- Less connectivity across the slums and nullahs which restricts more movement around.
- No awareness to the local residence about the consequences that takes place because of the ill-treatment of nullah, to their residence as well as to the city and environment.

Opportunity

- Planting of potted plants throughout the edge of the nullah by the locals itself shows the regret by the community on the current state of nullah and an opportunity to solve them.
- Huge heap of waste shows the need of a special waste disposal system for the same.

Threats

- No proper demarcation of some parts of the nullah in DP Remarks 2034, the part of the nullah marked for development can lead to unsustainable development in the future.

Program:

Programs are divided into three parts:

For Water Treatment, for Local Residents and for Visitors (Future Development).

Out of which, two main user dependent groups are, for residents and the one for visitors. As the local residents include mainly the neighbouring slum areas, and the visitors will be completely different user group for both the programs.

Thus, having a common entrance & exit for both the group programs isn't a viable solution. Hence, two different approaches for the programs in these two different groups where each approach is placed to attract more users of the same user groups.

1. For Water Treatment:

Nullah Water Treatment & Illegal Sewage Lines Treatment

To treat the water incoming from the previous part of the Nullah as well as the Illegal Sewage Lines built by the Slum Dwellers which are opening directly into the Nullah, so that the water released is safe enough to release into the ocean.

2. For Local Residents:

Community Facility Provisional Centre

As cleaning the nullah water is not enough, to stop the people from throwing their waste onto the Nullah a behavioural change needs to be taken place. Hence, providing a Waste-to-Incentive Exchange Centre, where in exchange of their waste incentive will be given based on the category of people along with many facilities which are lacking in the locality to make the space more inclusive and of use to the people.

3. For Visitors:

Water Experiential + Awareness Centre

By providing previous two functions, the issue is being solved at the local level. But, to create a much larger impact of the issue, if people are aware of the problems associated with the degradation of water bodies, it can reduce. Or else, the load will eventually keep on increasing after a point, every system would fail. But a centre just for awareness would attract fewer people. Hence, a Water Experiential Centre would attract more people to make aware.

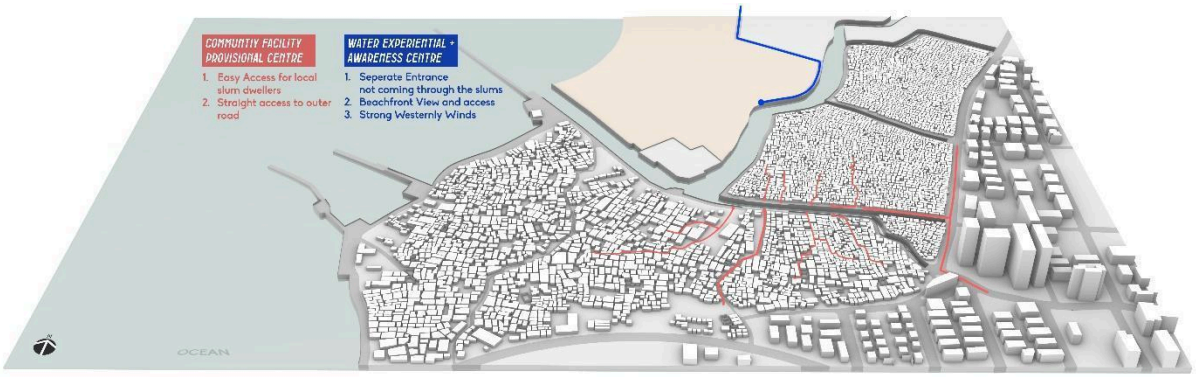


Fig. 19: 3D of Khardanda with Entry Points (Source: Author)

1. For Water Treatment:

A. For Water Treatment: **RENEU Water Filtration System**

Since, traditional STPs take up huge amount of space, release bad odour and demand high cost of Build & Operation, which both are not possible for the context of the current site hence using a new Filtration Based Nullah Water cleaning method called 'RENEU'.

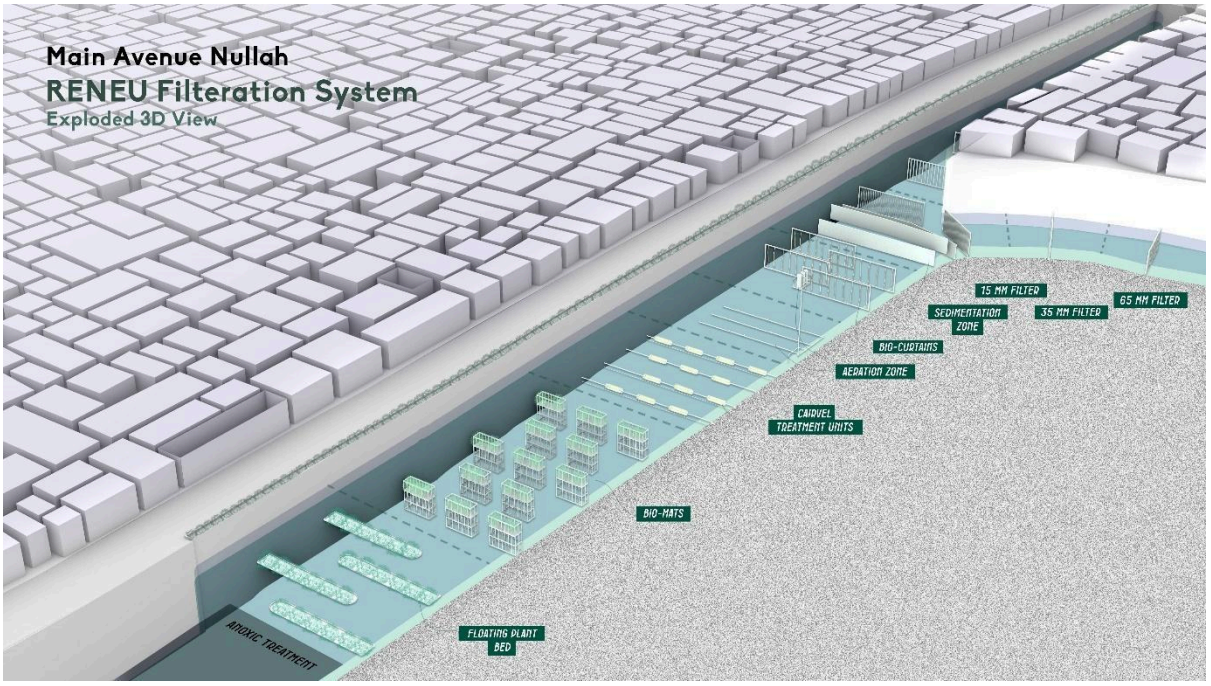


Fig. 20: RENEU Filtration System (Source: Author)

The CSIR-NEERI have designed and developed RENEU (Restoration of Nallah with Ecological Units)— a combination of engineering and biological tools to renew the nallahs. There are sewage treatment systems, but these do not address even 30% of the domestic wastewater generated in our country. RENEU is a cost-effective, ecologically sustainable,

long-lasting, easy to use, maintenance-free and efficient technology that meets pollution control norms on water quality was needed.

System consists of partitions of:

1. Screening-cum-stilt Traps *(Half the width of nullah)*
2. Sedimentation *(60 M)*
3. Anoxic Zone *(60 M)*
4. Bio-curtains (40 M)
5. Aeration Zone (20 M)
6. Bio-mats (40 M)
7. Cairvel Treatment Unit (40 M)
8. Floating Plant Bed (40 M)
9. Disinfection Unit (At the end)

Benefits:

1. Clean and green environment.
2. Reduction in water pollution.
3. Low capital cost and O & M cost.
4. No need of extra land space.
5. No odour and mosquitos.

*[*The length of the different steps is fixed considering the depth of 1-4 M. If the depth is more or less than the prescribed, the length may vary]*

B. For Illegal Slum Sewer Lines: **ECO STP**

The ECOSTP technology does not use chemicals or energy to treat the sewage water. Sewage is treated by a combination of microorganisms, plants, and gravel to and return clean water back to mother earth. The treated water can be thrown into the sea or used for irrigation. The nature inspired solution of ECOSTP, gets away from the Conventional STP which requires a lot of heavy maintenance to treat the sewage water. It uses plants as a filter in end.

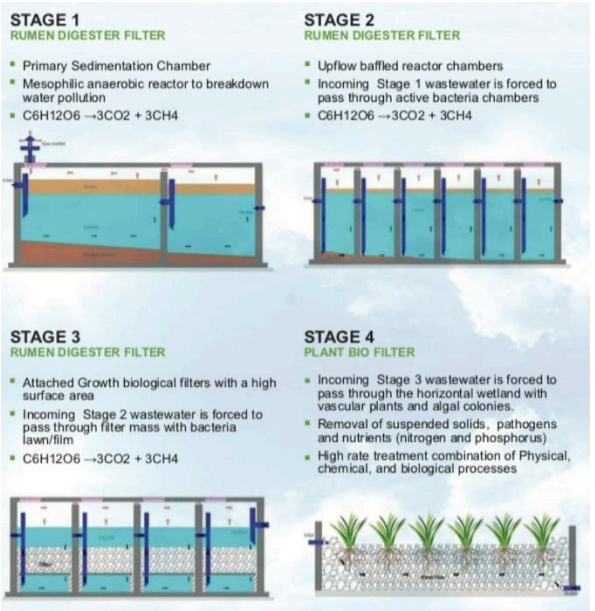


Fig. 21: ECO STP System (Source: EcoSTP)

Landscape Species that help in Water Filtration:

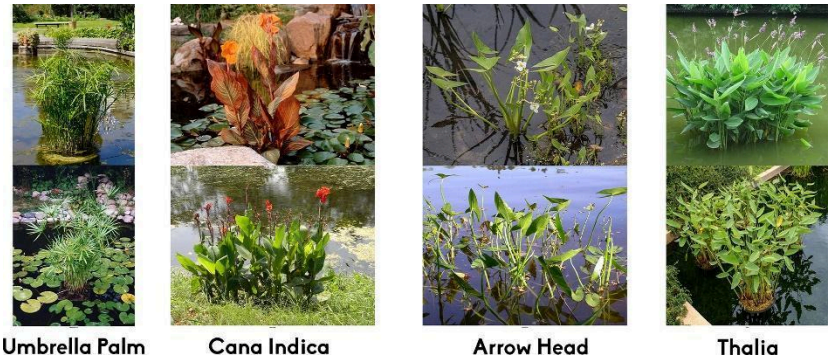


Fig. 22: Plants for Water Filtration (Source: Author)

2. Community Facility Provisional Centre:

A. Programs: **Waste - to - Incentive Exchange Program**

Fig. 23: Waste to Incentive Exchange System (Source: Author)

As cleaning the nullah water is not enough, there needs to be brought a behavioural change to bring a change. Thus, a Waste-to-Incentive Exchange Program where the slum dwellers will give their segregated waste to the centre and in exchange per say 4kg of waste can get 1 kg of waste in exchange of fruits and vegetables. For office goers, travel passes of bus and train, for students' stationery or discount coupons for medicines.

Looking at the benefits this Waste - to - Incentive Exchange Program will provide, every Slum Dweller would be eager to provide their Domestic Waste to the centre. This would completely reduce the waste thrown onto the Nullah as well as in the surroundings. The next

phase should be teaching them about Waste Segregation, which will eventually reduce the Workload.

The wet waste provided by them would be converted to fertilizers at the site itself. Whereas the dry waste would be given to the Companies that demand segregated recyclable waste in exchange of some incentive.

Polyclinic:

Health issues is a major concern living in such a close fabric and is also being ignored by them due to economical deficiency, providing a free Polyclinic check-up which is in line with the scheme of BMC of free polyclinic.

Carpet Dying:

As there was Carpet Dying happening at the shore of the sea which was releasing harmful chemicals into the sea, thus formalising it to provide in the structure where the dyed water will be purified.

Community Toilets:

Also providing Community Toilets for ever increasing demand of it in the highly dense slum areas.

Roof Top Open Area:

To make the structure more inclusive, a Roof Top Open Area for also creating a place for celebrating festivals and everyday play. By making this more inclusive and engaging for every group of people, it will also lessen the risk of potential TB by getting exposed to sun.

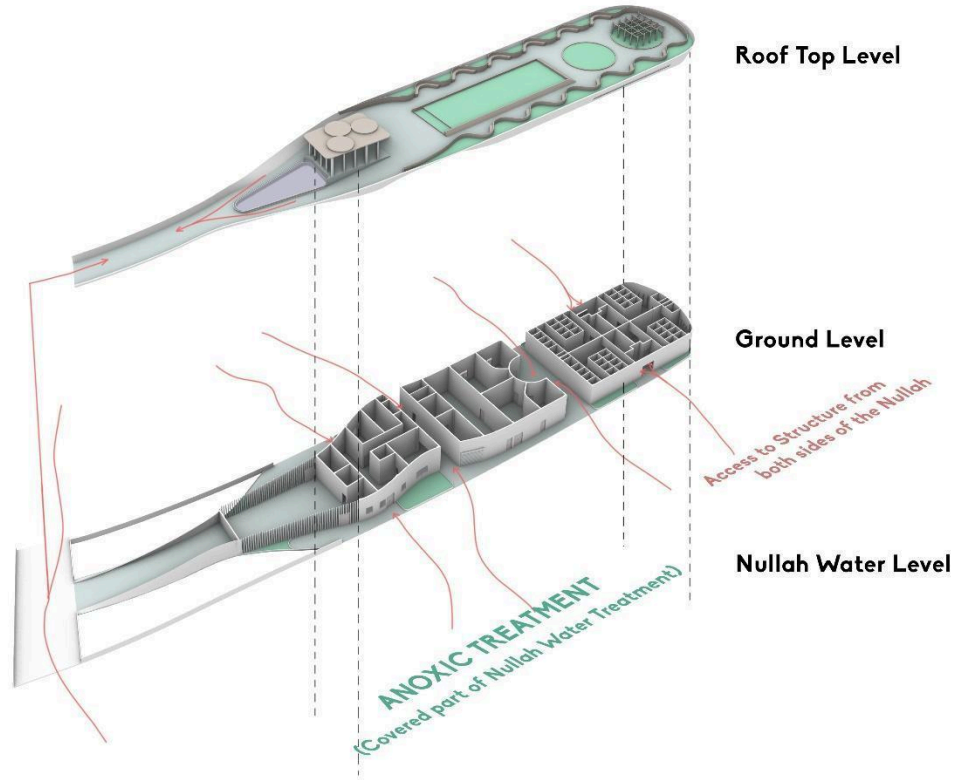


Fig. 24: Community Facility Provisional Centre Axo (Source: Author)

Ground Floor Plan of Community Facility Provisional Centre:

Fig. 25: Community Facility Provisional Centre Ground Floor Plan (Source: Author)

Roof Plan of Community Facility Provisional Centre:

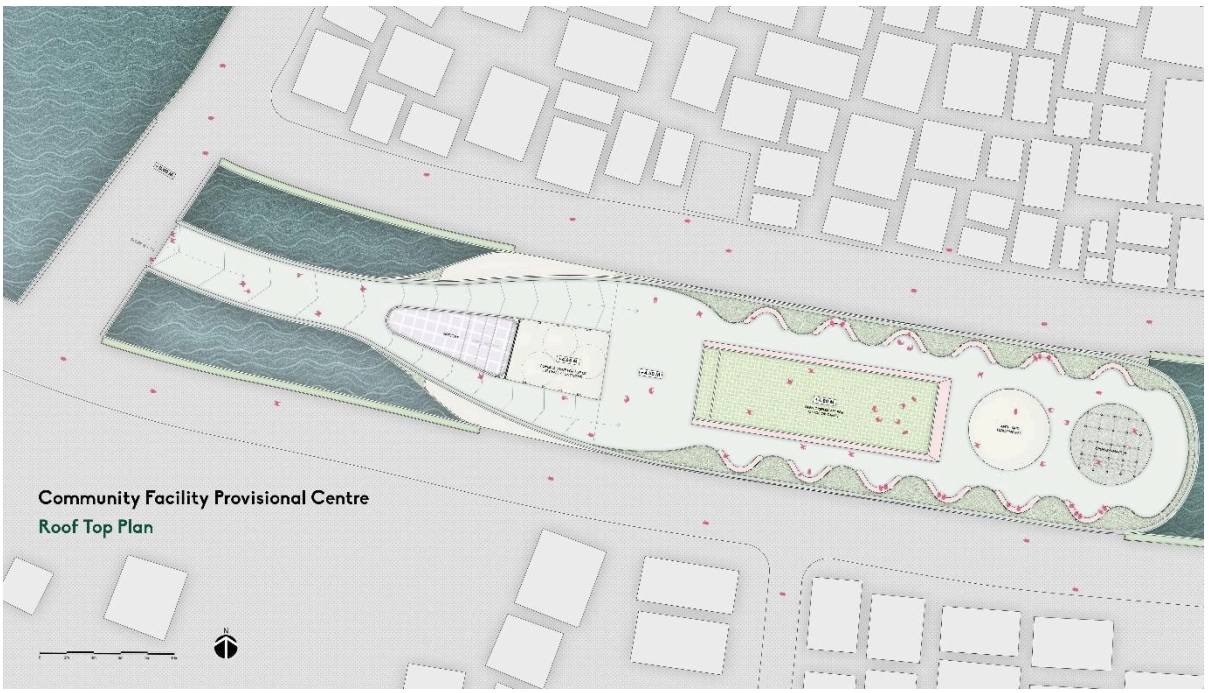


Fig. 26: Community Facility Provisional Centre Roof Plan (Source: Author)

A Lateral Section through Community Facility Provisional Centre:

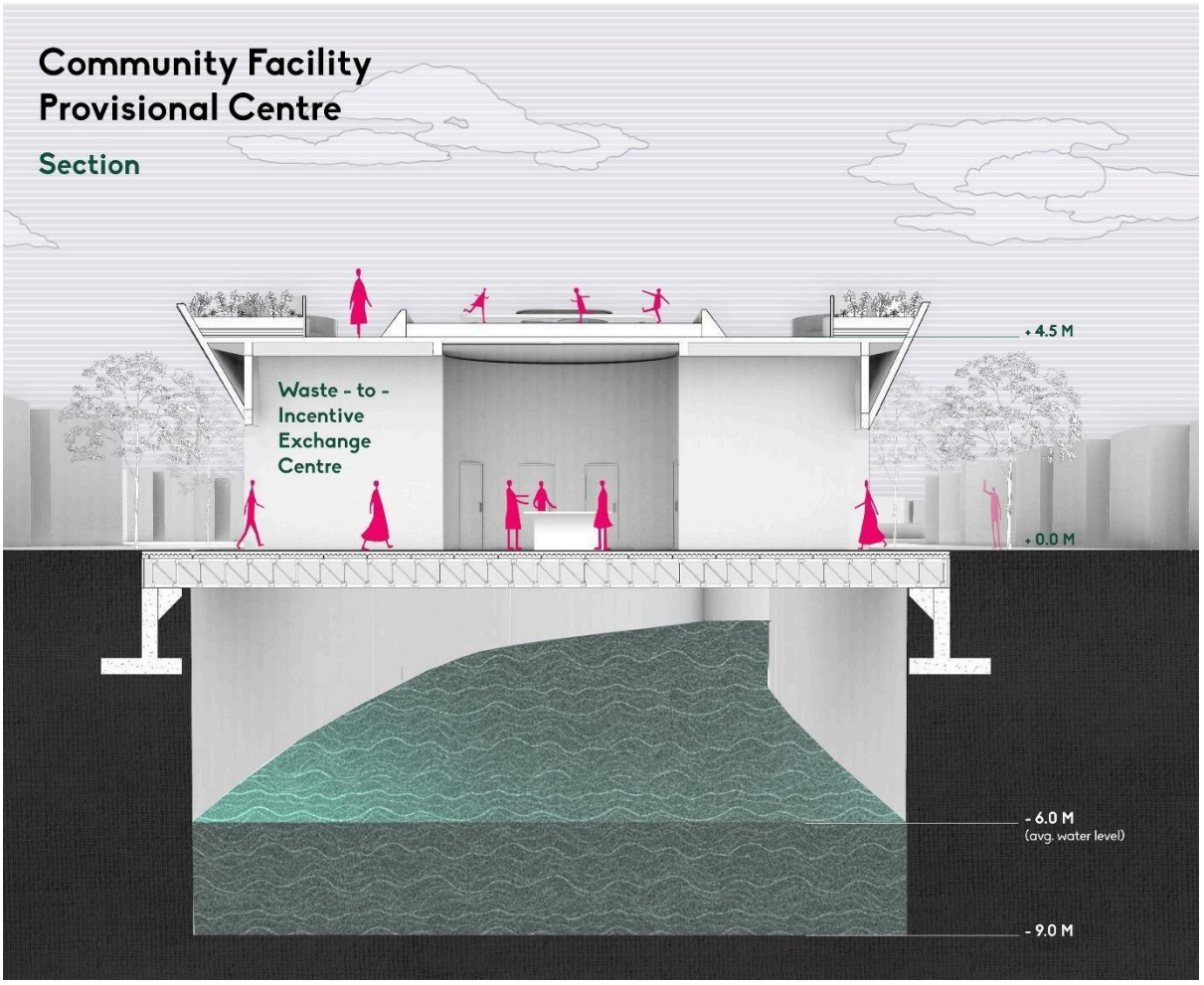


Fig. 27: Community Facility Provisional Centre Section (Source: Author)

The Structure sits on a Transfer Girder, so no part of the Structure affects the flow of Nullah. Also MODULAR for all types of widths.

Thus, with this design and the situation of Nullah and Slums similar in and around Mumbai, the design being Modular can be repeated at any site where similar problem exist. Any site with any width of the Nullah can be adjusted due to the design.

As the project is designed to be modular, the design can be scaled to different locations to fully solve the issue. If implemented on all problem causing points, the issue will be drastically solved.

These places throughout the city will become a new typology of environmental as well as a Social Space insert in these Slum Communities.
A 3D Visualisation of Roof Top Garden on Community Facility Provisional Centre:

Fig. 28: Community Facility Provisional Centre 3D (Source: Author)

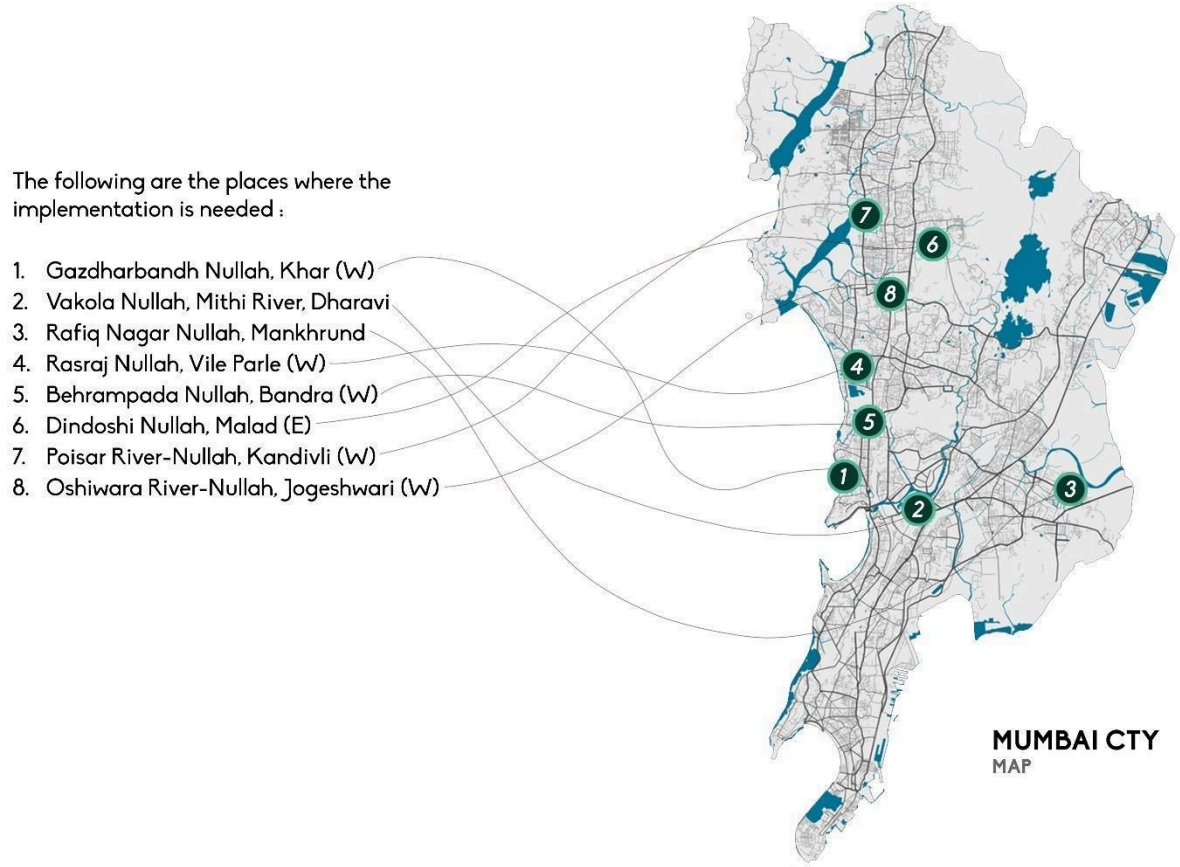


Fig. 30: Future Expansion Sites (Source: Author)

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Conflict of Interest:

Authors have no conflict of interest to declare.

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