

# Application of a Simple Wastewater Storage System in a Protected Environmental Area in a Squatter Area-Port Royal in Jamaica

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The challenges associated with providing proper sanitation in squatter communities, needs to be addressed not only by the input of government regulators, but also should take into consideration community input, especially in areas with extremely sensitive ecosystems. This paper seeks to highlight the innovation of a community piloted sewage containment system unique to a small squatter settlement in Port Royal, a protected area and also one of Jamaica's oldest and historically important settlements. The research was conducted utilizing a structured questionnaire, field survey, and interviews, additionally a cost analysis of results to determine affordability in relation to income. The field survey was done along with a review of journal papers to investigate the environmental impacts of such a system in a protected area. The results of the investigation revealed that the system is a cost efficient method of managing domestic sewage waste, with 100% sanitation being achieved. In addition, the practice of shared usage and operation of the containment system as it regard construction and maintenance cost, indicates promise for community led approaches to sanitation. However, the amount of untreated sewage containing high levels of organic bacteria and nitrates that is being released in the soils and underground water sources, poses extreme risk to sensitive ecosystems and protected areas, suggesting its best suited for areas where soil absorption treatment systems are feasible.

**Key Words :** *Squatter Settlements, PWT containment system, sewage, protected areas, community led sanitation*

## 1. INTRODUCTION

Globally the impoverished has been experiencing grave challenges to provide proper sanitation systems that will ensure a healthy and clean living environment. This problem is a widely discussed topic by organizations and authors worldwide, who seeks to provide citizens with a solution to sanitation challenges, however, this paper specifically investigates proper sewage disposal.

Several developing countries in Latin America and the Caribbean have been making great efforts to fulfill such mandates, in part because of a growing population, scarce resources and strains on the urban poor to afford their basic needs. Improper sanitation not only poses threat to human health but also to the environment, more so to the protected ecosystems in especially in small island developing states (SIDS). Several strategies such as policy implementation, innovation and financial aid have been utilized to

minimize the threats to public health and environment. Jamaica has been doing its part in providing proper sanitation systems though limited, with an increase of only 2%, from 79.8% in 1990 to 81.8% in 2015 (WHO and UNICEF). Recently the National Environment and Planning Agency (NEPA), has reassessed and supplied updated regulations for the handling of sewage sludge, this will allow for better management and treatment of sewage. This process aims to increase land applications of treated sewage sludge that will minimize the risks to ground water contamination and public health, while improving soil conditions for agricultural purposes. .

Squatter communities in some instances face greater challenges to safely contain and treat sewage discharge, forcing the need to utilize innovation and intuitive measures that will lessen the impact on their daily lives [1]. Innovation also drives government agencies and other external stakeholders to make efforts to successfully address the challenges to

provide proper sanitation systems.

For this study, the Palisadoes Port Royal Protected Area (P-PRPA) squatter community was chosen because of their effort to ensure proper sewage containment for their environment, at a time when proper sewage containment systems are constructed at grave costs, ranging between USD 1000- 2000, this is almost equivalent to the annual income for poor households [2]. Additionally, the Marine ecosystem in P-PRPA (**Fig.1**) is classified under the SPAW Protocol as a Class 1 waters. This classification means these waters in the Convention area due to inherent or unique environmental characteristics are fragile biologically or ecologically to human use, and are particularly sensitive to the impacts of domestic wastewater [3]. Consequently, the incorporation of an unverified sewage system that has a direct impact on this area was chosen for review, under the following conditions:

1. Community Led Approach to Sanitation
2. System Cost and Socio-Economic Status of the Squatters
3. Implications for the natural environment (coastal habitats)

#### (1) Port Royal Jamaica Background

The community of Port Royal (**Fig.2**) dates back to the 1600's and is Jamaica's first unofficial capital and was one of the wealthiest ports in the Caribbean, until the famous Port Royal Earthquake and Tsunami in 1692 that sunk a section of the community below the sea.

Port Royal has been an archeological, ecological, historical research haven and tourist place of interest for many. The current population is approximately 1252 [4]. It sits in one of the most sensitive ecosystems in the island, being home to fish sanctuaries, nesting grounds for turtles, endemic plants and animal species, with an exceptionally high water table resulting from being surrounded entirely by water. It is located at the entrance of the Kingston Harbour and at the end of the Palisadoes. The economy of this small town relies heavily on fishing, tourism and service enterprises (restaurants).

Development and assignment of housing is the responsibility of the government of Jamaica and an unofficial charter called the Port Royal Brotherhood. STATIN [4], indicated a total of 338 households in this community, living in both formal and squatter areas. Port Royal has two (2) squatter settlements, firstly the Michelin Avenue settlement (**Fig.3**) and the second on the eastern edge of the small town, data from the Squatter Management Unit (SMU) indicates both settlements have a total of 47 dwellings.



**Fig.1** P-PRPA Boundary (source: Jamaica Protected Areas Trust, <http://www.jpat-jm.com/virtour/palisadoes/palisadoes.html>) .



**Fig.2** Aerial View of Michelin Avenue and Beach Side Settlements (source: Google Earth 2016)

The delay by the state to implement a suitable sewage treatment facility that would allow for the expansion of housing developments to accommodate growing families with close ties to the area, is a key cause for the burgeoning of squatter settlements. According to locals and the Squatter Management Unit both settlements are approximately 11 years old and are growing. The Michelin Avenue Squatter Settlement which is the area of concern is approximately 4,607.7sq.m in size with a total of 27 households.



**Fig.3** Image of the Michelin Avenue Settlement

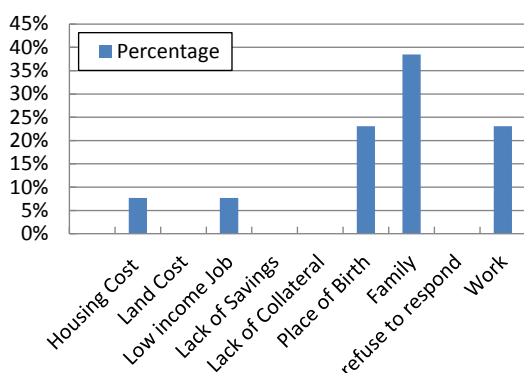
## (2) State of Port Royal's Environment

Jamaica has in total approximately 474 squatter settlements through out the entire island, ranging from 10 to 55 years old, accounting for approximately 20% of Jamaica's population. A significant number of these areas fall within or in close proximity to sensitive ecosystems such as bird sanctuaries, forests reserves and also marine and terrestrial protected areas. There are several anthropogenic threats to these areas such as, habitat loss and degradation, pollution, climate change and over-harvesting [5].

The P-PRPA faces similar anthropogenic threats experienced by the entire island and is a key biodiversity area, for ecosystems such as, nursery for fishes, turtles, crabs and home for several species of dune vegetation. These threats include problems such as over-harvesting (loss of fish stock), loss of mangroves and seagrass beds, removal of dune vegetation, squatting and nutrient enrichment that is affecting coral reefs, these factors have placed the area at high threat levels.

In terms of squatting the direct impacts has been ranked at a threat level 3 by the NEPA (1 being lowest and 5 being highest), while this may not appear severe, it is not completely removed from to other serious threats, such as the removal of vegetation (mangroves) as these areas are being utilized as land space for housing developments and so still merits necessary attention.

The reason for living in this squatter settlement has a weighted significance on the longterm environmental threats to an area that is a part of the global biological hotspots. According to **Fig.4**, the generational ties and personal links with this location in terms of place of birth and family reflected as over 50% of households, are fundamental to lasting threats to this sensitive ecosystem.



**Fig. 4** Reason for Living in the Port Royal Squatter Community

## (3) Management of the Port Royal Area

The protection of the P-PRPA ecosystems falls

under the purview of NEPA. It is classified along with the Palisadoes Area a small strip of mass extending off the island, south of Kingston. According to NEPA 2015 [6], "The Palisadoes-Port Royal Protected Area (P-PRPA) is approximately 7,523 hectares (75.23 km<sup>2</sup>) and encompasses both terrestrial and marine areas. The P-PRPA was declared a protected area under the Natural Resources Conservation Authority (NRCA) Act on September 18, 1998. However, prior to this, the Port Royal Protected Area was declared on 8 May 1967 under the Beach Control Act (BCA). It was also designated as Jamaica's second Wetland of International Importance (Ramsar Site) under the Convention on Wetlands of International Importance especially as a Waterfowl Habitat on April 22, 2005. The protected area also encompasses the Port Royal and the Palisades which is one of five heritage districts in the island, designated under the Jamaica National Heritage Trust (JNHT) Act."

There are several other environmental acts and policies both locally and internationally that seek to promote the preservation of this area, including Protocol Concerning Specially Protected Areas and Wildlife (SPA) and Convention on Biological Biodiversity, Wild Life Protection Act 1945 (and various amendment Orders and Regulations), Endangered Species (Protection Act 2000), Beach Policy for Jamaica (NEPA 2000) and Watershed Management Policy (NRCA 2003).

The location being classified as a Class 1 waters, means the incorporation of an unverified sewage system that could result in a direct impact on the marine areas would be violating the regulations and protocols of such ecosystems, **Table 1** outlines the parameters of the protocol in relation to the threats posed by Fecal Coliform and other human bacterial waste.

**Table 1** The Protocol Concerning SPAW Convention -Class 1 Waters (Source: UN1999).

The Protocol Concerning Specially Protected Areas and Wildlife (SPA) to the Convention (Class 1 Waters)	
Parameter	Established Limitations
<b>Faecal Coliform (Parties may meet effluent limitations either for faecal coliform or for E. coli (freshwater) and enterococci (saline water).</b>	Faecal Coliform: 200 mpn/100 ml; or
	E.coli:126 organisms/100ml
	benterococci: 35 organisms/100 ml

## 2. METHODOLOGY

The research area was chosen because of its individuality in addressing sewage containment challenges in the squatter community. Data was collected utilizing a questionnaire and structured interviews from regulatory agencies. Interview questions were designed to collect data on environmental challenges faced by the Port Royal area stemming from the practice of squatting. Responses were provided where possible, not all questions had available data for use.

The questionnaire applied provided the respondents' with clear communication about purpose for conducting the survey. It indicated the use of anonymity and outline that respondents were under no obligation to participate. The language took into consideration literacy needs of the population and not too tedious to discourage participation. Notwithstanding, there were some with reservations who refused to complete the questionnaire.

The questionnaire was designed into three (3) sections, section 1 recorded general data related to demographics and socio economic status, section two (2) solicited data relating to the infrastructure and usage. Finally the third section recorded information relating to design, construction and management of the system, including financial details and the environmental perspectives on their approach to sanitation.

All questionnaires were distributed to the household heads and collected immediately after completion. There were 27 households in the settlement, however only 13 improvised containment systems. Data was collected from 12 systems.

There are specific parameters such as policies and regulations surrounding the community of Port Royal that was considered when doing this research. For the sake of this paper the cost and efficiency scenario surrounding the improvised containment systems were analyzed, and compared to the closest other system in terms of cost bracket and popularity of use by other squatter and informal housing developments, the Absorption Pit system. Additionally, sanitation indicators were used to determine whether inhabitants were meeting national and international standards of sanitation.

## 3. SEWAGE SYSTEMS IN PORT ROYAL SQUATTER COMMUNITY

Implementing adequate sanitation systems in informal communities can prove difficult when con

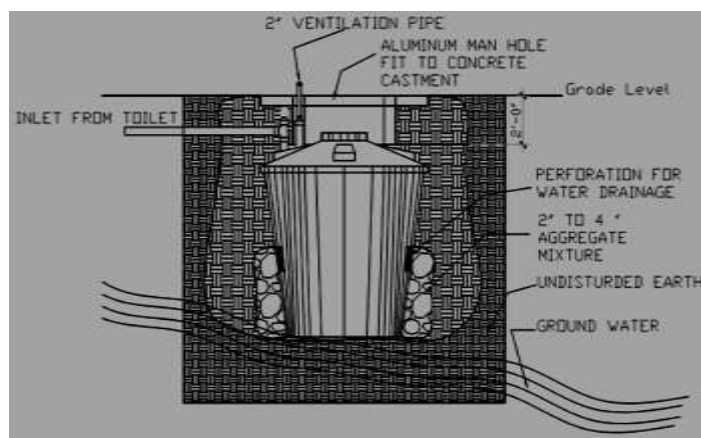


Fig. 5: Concept diagram of The PWT Containment System

sidering certain factors such as tenure and socio economic situations, additionally the location of the settlement provides added challenges as they tend to be in difficult to access and are sensitive areas. Because of the ecological composition of the P-PRPA, such as a high water table and extremely sensitive biodiversity, also the filtration characteristics of the soil, it is integral to utilize environmentally friendly sewage containment and treatment strategies.

There are several soil absorption systems in Jamaica that are approved for use inclusive of, septic tank, tile fields and absorption pits, however as per regulations are not suited for high water table areas and soil types with high filtration rates, which is a characteristic of the Michelin Avenue Port Royal settlement. However, the three (3) systems supporting the settlement are the Soak Away Pit, Absorption pit and the improvised Polyethylene Water Tank (PWT) Containment system (a sewage containment system that is distinctive to that area in Jamaica and the focus of this paper). There are 27 households in the Michelin Avenue Squatter Settlement, 48% of which utilizes the improvised containment tank. These systems are connected to both indoor and outdoor flush toilets that are also shared and unshared.

### (1) The polyethylene water tank (PWT) containment sewage system

The PWT containment tank (Fig. 5), also known locally as the Rhino Tank, was fabricated for the purpose of water containment. The consistent problems associated with water shortages in various parts of the country, creates a lucrative market for this product. According to the distributors, the tanks are durable and manufactured using "two (2) layers of prime grade linear polyethylene" this ensures no cracking, fading or rotting under the prescribed conditions, whether the change in use will impact the



**Fig. 6:** The PWT Containment System after construction with 546mm diameter Manhole cover.

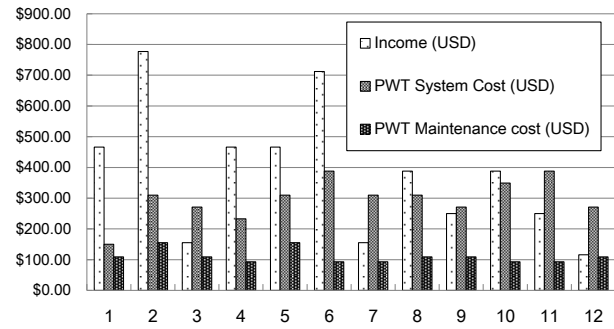
integrity of the tank is yet to be determined. The design of the sewage containment system by the residents had no consideration for the qualities expressed by the Manufacturer.

The capacity of the average size tank utilized is 7570 litres. The system is designed to accept only toilet waste and to allow for immediate release of the toilet waste into the containment tank. The top of the tank has 2 connections, 1) to receive the 4 inch pipe from the toilet and 2) a 2 inch pipe for ventilating the system. The sides of the tank are perforated to allow the water from the flush action to seep into the soil; the punctures are designed at a size that would allow water to be released, while retaining majority of the solids.

The tank is lowered to a depth that will cover it completely. There are occasions when water is found, a result of the high water table in the area, however the system is still placed in the hole. The sides in some cases are stacked with stones to prevent the sand from applying too much pressure onto the tank, in other cases reinforcement bars are placed inside to prevent disfiguring due to the force applied from the sand. The tank is then lowered in to the hole and the top sealed off with concrete allowing only the service opening such as in regular manholes to remain (**Fig. 6**).

#### 4. COST VS INHABITANTS SOCIO-ECONOMIC STATUS

According to the World Bank poverty ratio, billions survive on \$1-\$2USD per day. As it regard Jamaica, the World Bank [7] classifies the country as an upper middle income economy, with only 19.9% of the population below the poverty line. Utilizing the poverty headcount limit of \$3.10 per day, the income classification level of the inhabitants was determined. Average monthly income of a

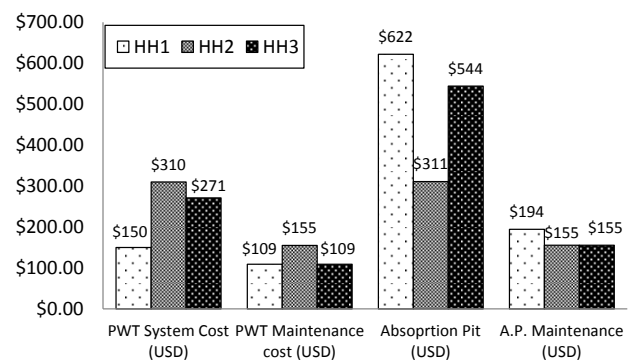


**Fig. 7:** Shows Monthly Income Earned vs Construction Cost and Maintenance.

household head in the settlement was \$360 USD, daily income was calculated at \$12 USD per day, that figure amounted to approximately 4 times the poverty limit, suggesting an average standard of living for these residents, supported by the questionnaire results, which indicated a 77% of the population describing their standard of living as average.

On average the monthly income for respondents when compared to construction cost of each unit was within an affordable limit (**Fig. 7**), even in the case where the monthly salary is half the cost of the system, hence, with the practice of shared usage, the cost is still within reach of the squatters.

In comparison to households with other systems, the PWT containment system has proven to be comparative in cost (**Fig. 8**), suggesting a supportive basis for it being the popular choice a total of 13 systems in a 27 household community. Additionally, an examination of the costs for construction, simplicity of design and maintenance of the system in relation to the economic status of the average household, reveals the affordability involved in adapting the improvised PWT containment system. Results indicate the system being implemented as recent as 1 ½ years and a 48% of households utilizing the system.



**Fig. 8:** Cost comparison for PWT system and Absorption Pit (Other) Sewage systems in three Households.



The capacity of the PWT containmennt system allows for multifamily use, with some systems having 2 to 3 households connected. Three households were utilized to provide a general idea of the construction and maintenance cost for the system. This shared access arrangement allows for greater affordability. In the case of the absorption system the maintenance cost is comparative, however the construction cost is significantly more. In addition, the absorption system has single household use.

The total cost for construction of the systems ranged from \$150-\$380 USD. The impervious material used in the manufacturing of the tank and the hydraulic conductivity of the sand, prevents any noticeable difference with amount of time required for sludge removal during the rainy and hurricane seasons; hence no additional cost is incurred. The time span between construction/installation and maintenance, further demonstrates the affordability of the system to users, and lays the foundation for the adaptation of regulations compatitible septic systems of similar make.

## 5. POTENTIAL FOR COMMUNITY LED SANITATION SOLUTIONS IN SQUATTER COMMUNITIES

With an estimated 2.4 billion people worldwide facing challenges with proper sanitation (UNICEF and WHO 2015), it is important to highlight instances where communities and individual households have applied innovation to incorporate sufficient means of sanitation, in this case sewage containment. Several initiatives has led to agency based and community led responses to sanitation in the urban and rural poor communities, Myers [8] highlights initiatives such as “Community –Led Total Sanitation (CLTS) and Community Led Urban Environmental Sanitation (CLUES)”, in addition authors such as Luthi et.al [9] have review comparatively the Household Centre Environmental Sanitation Approach with CLTS. CLTS like other community driven sanitation sloutions is focused on-community members solving the problems of open defecation without grant funding [9].

However, these accomplishments are not void of challenges; McGranahan [10] highlights four (4) main challenges experienced in community led sanitation initiatives:

1) *“The challenge of overcoming local collective action problems- Open defecation, unsanitary public latrines and the pollution of ground and surface water.*

- 2) *The challenge of finding solutions that public agencies or utilities will not only condone but contribute to.*
- 3) *The challenge of agreeing on improvements that is both affordable and acceptable.*
- 4) *The challenge of also addressing conditions not strictly within the water and sanitation sector, however defined, that undermine sanitary improvement efforts.”*

The potential for adaptation of otherwise successful community led initiatives in Jamaican squatter communities is promising, with a 65% of total containment system users (**Table 2**) practicing shared usage (2-3 households), without aids. Surprisingly, even with financial and space constraints, the Michelin avenue residents were able to strategize a working system that is at a comparative to maintenance cost to other standardized sewage containment systems, with an even lower construction/installation cost. A total of 12% of squatter settlements in Jamaica utilizes shared public pit latrine toilets [11] a solution that is driven by community in containing sewage, further strengthening the position of being able to incorporate community led shared sanitation management.

While the residents have managed to overcome the challenge of agreeing on a method of containing their human waste, suiting their financial restrictions, the potential for gaining approval from state and possibility for government support could prove difficult. In both situations (Michelin avenue and greater Jamaica), the sewage containment systems are being placed in areas that are not suited for the use of soil treated systems, suggesting implications for the natural environment particularly in watershed and high water table areas.

**Table 2:** Michelin Avenue Settlement Sewage Containment System Breakdown (Source SMU 2016)

Classification of Sewage Systems				
<i>Toilet Facility</i>	<i>Don't Know</i>	<i>Soak Away Pit</i>	<i>Absorption Pit</i>	<i>PWT System</i>
Flush Outdoor Not Shared			1	1
Flush Outdoor Shared				5
Flush Indoor Not Shared		2	1	3
Flush Indoor Shared	5		3	4
Other	1			
<b>Total Systems (26)</b>	<b>6</b>	<b>2</b>	<b>5</b>	<b>13</b>

**Table 3:** Shows the current situation with sanitation in Michelin Avenue

<b>Sanitation Indicators For Michelin Avenue Settlement</b>	
<i>Indicators</i>	<i>Comment on Indicator</i>
<i>Percentage of settlement population who take environmental aspects into consideration in their daily activities (Indicators for Environmental Monitoring in International Development Cooperation 2002)</i>	90 % of the sample population believes in the importance of protecting the environment. However, Only 54% considers the environment went conducting daily activities. Practice such as water conservation, proper sanitation and solid waste management is incorporated in their daily lives.
<i>People with access to safe drinking water (%) (Indicators for Environmental Monitoring in International Development Cooperation 2002)</i>	100% of sample population has access to safe drinking water. 92% gets water piped directly into their dwellings, while 8% access through public stand pipes.
<i>Population and other stakeholders who take usage of water environmental aspects into consideration in their daily activities (Indicators for Environmental Monitoring in International Development Cooperation 2002)</i>	The practice of water conservation when performing routine activities has been adapted by 52% of the respondents.
<i>Generation, collection, treatment and recycling of sludge, nutritive salts or other waste products (kg; % of generation, description) Percentage of waste water being treated (UN-Water 2014)</i>	Similar to the 63% of all squatter communities the inhabitants use the burning and dumping method for solid waste disposal, although they are able to access the municipal collection. Facility for collection of faecal waste exists, through the utilization of Absorption pits and Containment tanks. However, 0% of the black water associated with the containment tanks goes through a treatment process that meets regulatory standards.
<i>Number of persons per latrine and using safe sanitation services with handwashing facilities. Percentage of population using hygienic sanitation facilities (UN Water 2014)</i>	Average number of persons per toilet is 4. All facility has safe hand-washing facilities. All toilets are flush (indoor and outdoor). Total of 1 household practice open defecation. 96% of the population utilizes hygienic sanitation facilities.
<i>Percentage of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management. (UN Water 2014)</i>	UN Nations Protocol Concerning Pollution from Land-Based Sources and Activities to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, containment systems became obligated to this protocol immediately after implementation as of 1999. Entities such as the National Environmental and Planning Agency, Kingston and St. Andrew Corporation, Ministry of Health and the Port Royal Brotherhood has oversight responsibility for the implementation of suitable sanitation management. 100% of Administrative units has policies and/or procedures which the communities should follow. However, In the informal sector, household heads ensure sanitation facilities are installed.

**(1) Sanitation Indicators**

The connection between sanitation and poverty makes the act of creating sanitary surroundings a difficult task in low income communities. There are several indicators outlined by the UN-Water section for monitoring and targeting of sanitation goals. In the survey (**Table 3**), indicators outlining respondents' situation as it relates to sanitation and the environment were deduced. In general, the consideration for the environment by an approximate 90%, did not realize individuals practicing much protective measures. However, 94% of the squatter community's population has achieved the sanitation goals.

**6. ENVIRONMENTAL IMPLICATIONS OF THE PWT SYSTEMS**

Jamaica has approximately 37% of total number of squatter settlements in environmentally sensitive areas, forests reserves, protected and key biodiversity areas, water sheds and bauxite reserves [11]. The parishes of Kingston and St. Andrew, the location of the P-PRPA, have strict wastewater treatment rules prohibiting the use of soil absorptive systems for treatment of domestic waste water. This is a result of

the high water table, existing pollution load and other contaminants that are impacting the water table.

The NEPA requires that the minimum Feecal Coliform (F.C.) count in the discharged treated sewage waters to be at 200MPN/100 ml, the fact that there are approximately  $10^7$  -  $10^8$  MPN/100 ml in raw sewage in a typical system has serious implications for marine ecosystems. In a scenario where we consider a system with 2 families attached, totaling 8 people, passing feces once per day at approximately 8000 grams, totaling potential of over 104 million F.C. per day of untreated sewage being released in the soil, this highlights clearly the type of situation occurring in the small area that is Michelin Avenue. The dangers of organic bacteria on the biological environment outlines the intensity of the threat that exist in the application of this system on a protected environment. Although in some cases the water is not directly released in the sea, the fact that the system is tall enough that the hole to fit it reaches water level proves problematic, also it is widely known that sewage disposal in costal waters greatly impacts the coral reef health. The P-PRPA's reef system has been classified at a threat level of Very High, for reasons including sewage contamination that causes increased algal growth (**Fig. 9**), according to data from the NEPA 2007, >25% Coral Reefs in the P-PRPA is covered in algal growth. This algal growth has resulted in a reduction in the fish population, a major staple in the diet of the people of Port Royal, who also indicate they have observed a reduction in the amounts of fish they being able to catch in nearby waters.

Further, the natural condition of the sandy soils in this area, because of the minimal treatment of the sewage it offers increases the risk of contamination to water resources, and is compounded by rainfall [12] and the hydraulic conductivity. Although, the rates of enteric pathogen survival are lower in sandy soils with a low water-holding capacity [13], this reduction is not sufficient to prevent adding to the pollution load of the already strained water table.

In addition to the threats from this organic material to the environment, residents indicated that diesel oil or gas is poured into the tank to prevent the breeding of mosquitoes; this action now creates added environmental threats to underground water and aquatic life such as fisheries. The problem is further compounded by the fact that the system is buried not allowing for sunlight or proper aeration that would improve the conditions and minimize the effects of the contamination by the chemicals [14].

## 7. CONCLUSION

The current state of poverty in some countries limits the capacity of many to implement proper or even ecological solutions to sewage containment or sanitation; however, the innovative approach adapted by these community members represents the potential capabilities of impoverished communities at a time when significant numbers in developing countries including Jamaica are still practicing open defecation. The sanitation method chosen by this community mirrors some of the application of CLTS approach to excreta containment, and demonstrates the potential for implementing other such initiatives with the practice of shared usage, as 69% of the households using the PWT Containment System is shared. The costs associated with the installation and maintenance of the system indicates affordability for economies such as Jamaica.

The operation of the PWT containment system directly contravenes the rules stipulated regarding soil absorption systems in the P-PRPA and increases the risks to coastal and other such marine ecosystems, although the sand in its capacity acts as a filter and provides a particular level of treatment. The system releases black or foul water directly into the soil, feeding it with bacteria creating the potential for soil borne diseases, which has adverse effects for human and soil health [13]. In addition, creates added threats to coral reefs, crustacean, fish and other marine life by way of eutrophication, oxygen depletion, bio accumulation and other toxic effects, a problem experienced by other locations across the island [15; 16].

Although the natural attenuation of the soil allows for some level of purification, the type of soil and the high probability of bacterial migration, suggests that the PWT Containment system is unsuitable for areas with sensitive ecosystems and high water table.



**Fig. 9:** Shows the threat level to coral reefs in Jamaica [17;18]



Accordingly, the ability of the system to provide a sanitary living environment, suggests that consideration can be given to more suited areas zoned to allow treatment through soil absorption systems.

Further, the dangers of this system extends to the second settlement on the beach area of the Port Royal community and inside the mangroves, as a result of the traction gained, posing severe implications for other areas of critical habitats.

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## REFERENCES

- 1) McFarlane, C and Stephen, G.: Everyday Sanitation: A comparative study of Mumbai's informal settlements, Durham University, 2011.  
[https://www.dur.ac.uk/geography/everyday\\_sanitation/](https://www.dur.ac.uk/geography/everyday_sanitation/)
- 2) Ferguson, Dr. B.: The environmental impacts and public costs of unguided informal settlement; the case of Montego Bay, *Environ. and Urb.*, Vol. 8, No. 2, pp. 171-194, 1996.
- 3) Protocol Concerning Pollution From Land-Based Sources And Activities To The Convention For The Protection And Development Of The Marine Environment Of The Wider Caribbean Region, United Nations 1999
- 4) Population Census 2011. Statistical Institute of Jamaica
- 5) State of the Environment, National Environment and Planning Agency (NEPA) Jamaica 1997.
- 6) DRAFT Palisadoes-Port Royal Protected Area(P-PRPA) Management Plan 2015-2020, National Environment and Planning Agency, 2015.
- 7) Poverty headcount ratio at national poverty lines (% of population), World Bank, Global Poverty Working Group 2016.
- 8) Myers, J.: Urban community-led total sanitation; a potential way forward for co-producing sanitation services, *Waterlines* Vol.35, No.4, pp. 388-396, 2016.
- 9) Luthi, C., McConville, J. and Kvarnström E. : Community-based approaches for addressing the urban sanitation challenges, *International Journal of Urban Sustainable Development*, Vol 1, No. 1-2, pp. 49-63, 2010.
- 10) McGranahan, G. : Community-driven sanitation improvement in deprived urban neighbourhoods Meeting the challenges of local collective action, co-production, affordability and a trans-sectoral approach, 2013, <http://researchonline.lshtm.ac.uk/id/eprint/1236350>. DOI: 10.17037/PUBS.01236350
- 11) Ministry of Housing, Jamaica, "Rapid Assessment of the Problem of Squatting in Jamaica 2008)," <http://www.mwh.gov.jm/information-resources/reports/finish/9-reports/231-rapid-assessment-of-squatting-report> (unpublished)
- 12) Łuczkiwicz, A. and Quant, B.: Soil and Groundwater Fecal Contamination as a Result of Sewage Sludge Land Application, *Polish J. of Environ. Stud.*, Vol. 16, No. 4, pp. 587-593, 2007.
- 13) Santamaria, J. and Gary A. Toranzos, G.A.: Enteric pathogens and soil: a short review, *Int Microbiol* Vol. 6, pp. 5–9, 2003
- 14) Ayininuola, G. M. and Kwashima, O. F.: Effect of Diesel Oil Contamination on Soil Natural Recharge of Groundwater, 2015 2nd International Conference on Geological and Civil Engineering, IPCBEE, Vol. 80, No. 9, pp. 42-46, 2015
- 15) Lapointe, B. E., Thacker, K., Hanson, C. and Getten, L.: Sewage pollution in Negril, Jamaica: effects on nutrition and ecology of coral reef macroalgae, *Chinese J. of Oceanology and Limnology*, Vol. 29, No. 4, pp. 775-789, 2011
- 16) Henze, M. and Ledin, A.: Types, characteristics and quantities of classic, combined domestic wastewaters, Published in *Decentralised sanitation and reuse: Concept, systems and implementation*, Chapter 4, pp. 58-64, 2001
- 17) Burke, L., Reyta, K., Spalding, M. and Perry, a.: *Reefs at Risk Revisited*, World Resources Institute 2011
- 18) Burke, L., Kushner, B., Cooper, E., Edwards, P., Zenny, N., Maxam, A., Lyew-Ayee, P. and McIntyre, K.: *Coastal Capital: Jamaica The Economic Contribution of Jamaica's Coral Reefs*, World Resources Institute 2011

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