Scholars Bulletin ***(Agriculture)***
An Official Publication of "Scholars Middle East Publishers"
Dubai, United Arab Emirates
Website: www.saudijournals.com
ISSN 2412-9771 (Print)
ISSN 2412-897X (Online)

Coastal Sediments Polluted by Petroleum Hydrocarbons (C10-C40): A Review on Its impacts on the Coastal Ecosystems of Mauritius

Gireshsingh Mungla*[1], Sunita Facknath[2], Bhanooduth Lalljee[2]
[1]Faculty of Agriculture, University of Mauritius, Réduit, Mauritius
[2]Agricultural and Food Science, University of Mauritius, Réduit, Mauritius

***Corresponding author**
Gireshsingh Mungla

Article History
Received: 05.02.2018
Accepted: 19.02.2018
Published: 28.02.2018

DOI:
10.36348/sb.2018.v04i02.008

Abstract: Contamination due to petroleum hydrocarbons may result from many sources. In Mauritius, coastal sediment pollution results mostly from anthropogenic sources such as industrial activities and the sea activities, mainly at the harbour. While some authors affirmed that sea activities polluted the coastal sediments, and the concentration of pollutants was found to be higher in the harbour, likewise, an investigation was set to quantify the amount of total petroleum hydrocarbon (TPH), ranging from C10 to C40, in the neighbouring coasts from the Mauritius harbour at Port-Louis and to determine its effect on the coastal ecosystems. Three coastal sites were selected, namely, Tombeau Bay (C-BDT), Pointe aux Sables (C-PAS) and Mer Rouge (C-MER). Results showed that the most polluted the coastal sediments was Pointe aux Sables (451 mg/kg) followed by Tombeau Bay and Mer Rouge (less than 66 mg/kg) both. Despite that the chemical properties of the sediments analysed were favourable for microbial biodiversity, results showed that there was a much richer microbial biodiversity in less contaminated sediments while greater microbial activity (respiration rate) in the contaminated environment, C-PAS. Given that the toxicity of TPH in soil was established at range greater than 1000 mg/kg, it was noted that despite the C-PAS site was the most polluted, it did not reach the permissible limit. However, due to the urbanisation and intensive use of the sea for ship activities, the concentration of the level of pollution due to TPH is expected to increase in the forthcoming years.
Keywords: Coastal sediment, anthropogenic sources, total petroleum hydrocarbon, ecosystems.

INTRODUCTION

Coastal and estuarine sediments of industrial neighborhood are the largest depository and potential source of metal pollutants and petroleum hydrocarbons in the marine environment. In order to differentiate between anthropogenic and natural loads of contaminants it is essential to understand the sedimentological regime of the regions under study. Petroleum may be defined as any mixture of crude oil, condensate and natural gas. Crude oil and gasoline are normally heterogeneous substances comprising almost entirely of hydrocarbons. To each carbon atom, there are two hydrogen atoms bonded forming a hydrocarbon chain. Nevertheless, along with the main elements present in crude oil, there exists also minute amount of nitrogen, sulfur and oxygen which are categorized as hydrocarbon derivatives [1]. Petroleum hydrocarbon are still used as the main source of energy and hence resulted in an important global environmental pollutant [2]. Since Mauritius is a developing country, many of the impacts of petroleum hydrocarbons are associated with the construction of common infrastructure such as roads, airports, hatbour and also rely on imported products via the sea. Furthermore, another source of anthropogenic petroleum contamination reported by Muniz *et al*. [3] was sea activities especially in the harbour. The latter investigated heavy metals and total petroleum hydrocarbon contaminations in sediments in one harbour in Uruguay, where results showed heavy pollution due to heavy metals and spotted pollution by TPH.

The behavior of petroleum hydrocarbon contaminants (retension, sorption, transport and volatilisation) also depends on the properties of the contaminated medium. These properties include; texture, moisture content and mineralogy [4, 5]. It was reported by Pichtel and Liskanen [6] that diesel, an imperative component of petrol, approximately 10.6 % of the organic was lost through volatilization over a period of 150 day. Since, this organic compound bound firmly to the clay particle of soil and sediment, volatilisation rate does not only depend on the climatic factors. After a spill, the petroleum wills are dispersed in the sediments.

Coastal and marine ecosystems offer services, comprising of food, mineral resources, fuel, timber and pharmaceuticals, and also play important regulating as well as supporting roles including nutrient cycling, climate regulation and storm protection. Moreover, they also provide opportunities for tourism, recreation, trade, research, and education, and have extensive cultural, aesthetic, and spiritual value. The concept of Ecosystem-based Management (EBM) is an integrated approach which encloses the entire ecosystem, including the human species [7-9]. Marine EBM includes consideration of the interactions among ecosystem components and the cumulative effects of multiple activities. The main reason why ecosystem-based approaches are preferable is that researchers have found overwhelming evidence of ecological interactions in coastal and ocean systems, which are vital to the health and resilience of these systems. When these interactions are altered or severely degraded (that is; due to decline in number of species, destruction of key habitats and alteration in disturbance regimes), the aptitude and efficiency of coastal and marine systems to recover from disturbances declines and so does the provision of valued services [10-12]. Hence, the aim of the experiment was to review the impacts of petroleum hydrocarbon on the coastal ecosystems in Mauritius. The objectives are to quantify the total petroleum hydrocarbon contaminants (TPH) given that the toxicity of TPH in soil was established at range greater than 1000 mg/kg [13] with carbon chain ranging from C10 to C40, in coastal sediments neighbouring the harbour, since sea activities are the highest and hence determine the probable impacts of TPH pollution on the ecosystems.

METHODS

Site selection

The coastal sites were selected based on their history and usage background. Three sites namely: Mer Rouge (having geographical coordinates 20.137583°S, 57.498429°E), Pointe aux Sables (20.167365°S and 57.472153°E) and Tombeau Bay (20.123753°S and 57.496476°E) were selected according to their proximity to the harbour.

Figure 1: Sites under investigation in Mauritius

Sampling method

Samples were taken in such a way so as to ensure coverage of the plot and uniformity. As described by Mungla and Chooneea [14], the samples were collected in a 'W' shape.

Experimental design

A completely randomised design (CRD) was used throughout the experiment to statistically compare the results. All analysis had three replicates.

Sediment lab analysis

The following tests were done: pH and Electrical conductivity (using probe), Organic matter content, TPH analysis using GC-FID, Microbial respiration rate and microbial biomass C.

RESULTS AND DISCUSSIONS

pH and Electrical conductivity (EC)

pH measures the degree of acidity and alkalinity of a growing medium. Ions present play an important role in determining the degree of acidity and alkalinity of a solution. The most acidic coastal sediment was at C-BDT, 7.37± 0.14, followed by C-PAS, 7.5± 0.08 and C-MER, 8.10± 0.14. It has been reported that salinity [15], pH and oxygen availability [16] were important parameters for controlling the biodegradation of toxic organics in sediment. Jenkins *et al.,* [17] stated that the diversity of microbial communities was connected to the soil pH. Rousk *et al.,* [18] found that the most abundant biodiverisity of bacteria fall between pH ranged from 4 to 8, which is in line with the present experiment.

The level of salinity can be defined by the electrical conductivity of the substance. Higher concentration of soluble salts indicates that the sediments have high electrical conductivities. The highest EC recorded was at C-BDT, followed by C-MER and lastly C-PAS with 1726.5± 0.5 µS/cm, 304.5± 0.5 µS/cm and 2.81± 0.1 µS/cm respectively. It has also been reported that in general, soils below 200 µS/cm means that possibly soils have little microbial activity while an EC above 1200 µS/cm might indicate too much high salt fertiliser or salinity problems [24]. The deduced results for the experimental sites were quite close to the lower reported value which could probably signify low salt level except for C-BDT which had a high EC.

Organic matter content

The organic matter content affects the physical, biological and chemical properties of soils, that is, the ability of the soil to supply nutrients for plants and contributes to the soil quality [19, 20] and soil microbial respiration rate. It also helps in maintaining elementary ecological functions including decomposition of organic residues [19,20]. Statistical analysis using a completely randomised design showed significant difference in the mean organic matter level for the different sites ($P<0.05$). Tombeau Bay had the highest level of organic matter (5.28 ppm) which might be explained by the fact that there was tree plantation near the coast and the decaying leaves contributed to the relatively higher concentration of orgniac matter as compared to the other sites. An increase in soil organic matter increases the carbon content which the organisms rely on, hence favoring the bacterial growth [21].

Total petroleum hydrocarbon (TPH)

The present results showed that the most contaminated sediment was at C-PAS, 451 mg/kg, followed by C-MER and C-BDT which were <66 mg/kg equally. Despite the fact that C-MER was nearer to the harbour compared to C-BDT and C-PAS, as shown in figure 1, it was noted that the level of TPH quantified was higher at C-PAS. This might be explained by the fact that the direction of the tidal waves carried the hydrocarbons to this shore and was deposited there. In addition, the Grand River North West (GRNW), might carry TPH from various other anthropogenic sources, such as industrial wastes etc... Given that the toxicity of TPH in soil was established at range greater than 1000 mg/kg [13], it was noted that despite the C-PAS site was the most polluted, it did not reach the permissible limit. However, due to the urbanisation and intensive use of the sea for ship activities, the concentration of the level of pollution due to TPH is expected to increase in the forthcoming years.

Previous studies conducted on the relationship between pollution of petroleum hydrocarbons in aquatic environments and aquatic animals showed that these organisms which were esposed to the petroleum were able to bioaccumulate some TPH fractions [22]. Hence the risk of having fractions of TPH in the food chain exists but further studies are needed to determine the biomagnification potential of the TPH fractions, up the food chain within aquatic and terrestrial ecosystems.

Microbial respiration rate and bacterial count

Soil/ sediment microbial respiration is a key ecosystem process that releases carbon from the soil in the form of CO_2. Statistical results showed significant difference in mean for both microbial respiration rate and microbial count, among the sites ($p< 0.05$). C-PAS had the highest respiration rate (0.658 mg CO_2/hour), followed by C-BDT then C-MER. But C-MER had the highest number of bacterial count (27.7 x 10^7). Pearson correlation between bacterial count and microbial respiration rate showed a negative relationship which implied that as pollution increases, number of bacteria present in sediment dreceases which might be attributted to the fact that only the bacteria that developed resistance were unable to adapt to the high concentration of TPH at C-PAS.

On the other hand, despite the fact that C-PAS were the most contaminated sample, it had the highest respiration rate. This might be explained by the fact that the microorganisms upon exposure to the high concentration of TPH were able to utilise and breakdown the carbon chain as a source of energy, which stimulated the rate of reactions. The result was in line with that of Boopathy and Manning [23], who deduced an increasing trend of rate of breakdown of contaminants with increasing energy sources of microorganisms. Hence, the rate of microbial activity was proportional to the bioavailability of the TPH contaminant.

Table-1: Analysis of various parameters in coastal sediment samples

Sites	pH	EC (µS/cm)	Organic matter (ppm)	TPH (mg/kg)	Respiration rate (mg CO2/hour)	Microbial count
C-MER	8.10± 0.14	304.5± 0.5	2.36	<66	0.070	27.7
C-BDT	7.37± 0.14	1726.5± 0.5	5.28	<66	0.237	2.6
C-PAS	7.5± 0.08	2.81± 0.1	2.64	451	0.658	19

CONCLUSION

The review provides a scientifically-estimated data on the extent of TPH contamination in the coastal sediments near the harbour of Port-Louis in Mauritius. It also provides an evidence-based knowledge on the effects of TPH contaminants on the biological parameters of the coastal sediments. The study showed much richer microbial biodiversity in less contaminated sediments while greater microbial activity (respiration rate) in a contaminated environment. Therefore, in the light of the above experiment, it was concluded that despite the level of TPH contaminants in the sites under investigation did not reach the threshold permissible level, the fewer number of microbes detected at the contaminated sites indicated that there was a probable loss of certain species of microorganisms in the ecosystem. In the near future, urbanization and intensive use of the sea for ship activities, will contribute to the increase of TPH in the sediments and the risk of having fractions of TPH in the food chain remains a fact of great concern.

ACKNOWLEDGMENT

I would like to thank the Mauritius Research Council (MRC) for funding part of the research through its Post Graduate Award (PGA) Scheme. Also my sincere thanks goes to the UIS Organic Laboratory, S.A, for supporting the TPH analysis.

REFERENCES

1. Schabert, P. T. (1990). Ecological evaluation of surfactants. Tenside. *Surfactants deterg*, 33, pp.120-124.
2. Prakash, B., & Irfan, M. (2011). Pseudomonas aeruginosa is present in crude oil contaminated sites of Barmer region (India). *J. Bioremed. Biodegrad*, *2*(5).
3. Muniz, P., Danulat, E., Yannicelli, B., Garcıa-Alonso, J., Medina, G., & Bıcego, M. C. (2004). Assessment of contamination by heavy metals and petroleum hydrocarbons in sediments of Montevideo Harbour (Uruguay). *Environment International*, *29*(8), 1019-1028.
4. Fine, P., Graber, E. R., & Yaron, B. (1997). Soil interactions with petroleum hydrocarbons: abiotic processes. *Soil Technology*, *10*(2), 133-153.
5. Jarsjö, J., Destouni, G., & Yaron, B. (1994). Retention and volatilisation of kerosene: Laboratory experiments on glacial and post-glacial soils. *Journal of contaminant hydrology*, *17*(2), 167-185.
6. Pichtel, J., & Liskanen, P. (2001). Degradation of diesel fuel in rhizosphere soil. *Environmental Engineering Science*, *18*(3), 145-157.
7. Pew Oceans Commission. (2003). America's living oceans: charting a course for sea change.
8. USCOP (US Commission on Ocean Policy), 2004. An ocean blueprint for the 21st century: final report of the US Commission on Ocean Policy. Washington, DC: US Commission on Ocean Policy.
9. McLeod, K. L., Lubchenco, J., Palumbi, S. R., & Rosenberg, A. A. (2005). Communication Partnership for Science and the Sea scientific consensus statement on marine ecosystem-based management.
10. Paine, R. T., Tegner, M. J., & Johnson, E. A. (1998). Compounded perturbations yield ecological surprises. *Ecosystems*, *1*(6), 535-545.
11. Steneck, R. S., Vavrinec, J., & Leland, A. V. (2004). Accelerating trophic-level dysfunction in kelp forest ecosystems of the western North Atlantic. *Ecosystems*, *7*(4), 323-332.
12. Hughes, T. P., Bellwood, D. R., Folke, C., Steneck, R. S., & Wilson, J. (2005). New paradigms for supporting the resilience of marine ecosystems. *Trends in ecology & evolution*, *20*(7), 380-386.
13. E Ite, U. (2004). Multinationals and corporate social responsibility in developing countries: a case study of Nigeria. *Corporate Social Responsibility and Environmental Management*, *11*(1), 1-11.
14. Mungla, G., and Chooneea, M., (2016). A study on the effect of different irrigation methods and fertilizer regimes on groundnut. *Scholars Journal of Agriculture and veterinary Sciences*, 3(1), pp.9-19.
15. Bourquin, A. W., & Przybyszewski, V. A. (1977). Distribution of bacteria with nitrilotriacetate-degrading potential in an estuarine environment. *Applied and environmental microbiology*, *34*(4), 411-418.
16. Hambrick, G. A., DeLaune, R. D., & Patrick, W. H. (1980). Effect of estuarine sediment pH and oxidation-reduction potential on microbial hydrocarbon degradation. *Applied and Environmental Microbiology*, *40*(2), 365-369.
17. Jenkins, S. N., Waite, I. S., Blackburn, A., Husband, R., Rushton, S. P., Manning, D. C., & O'Donnell, A. G. (2009). Actinobacterial community dynamics in long term managed grasslands. *Antonie Van Leeuwenhoek*, *95*(4), 319-334.
18. Rousk, J., Bååth, E., Brookes, P. C., Lauber, C. L., Lozupone, C., Caporaso, J. G., ... & Fierer, N. (2010). Soil bacterial and fungal communities across a pH gradient in an arable soil. *The ISME journal*, *4*(10), 1340.
19. Craswell, E. T., & Lefroy, R. D. B. (2001). The role and function of organic matter in tropical soils. In *Managing Organic Matter in Tropical Soils: Scope and Limitations* (pp. 7-18). Springer, Dordrecht.
20. Cerri, C. E. P., Piccolo, M. C., Feigl, B. J., Paustian, K., Cerri, C. C., Victoria, R. L., & Melillo, J. M. (2006). Interrelationships among soil total C and N, microbial biomass, trace gas fluxes, and internal N-cycling in soils under pasture of the

Amazon region. *Journal of sustainable agriculture*, *27*(4), 45-69.

21. Delgado, J. A., Groffman, P. M., Nearing, M. A., Goddard, T., Reicosky, D., Lal, R., ... & Salon, P. (2011). Conservation practices to mitigate and adapt to climate change. *Journal of soil and water conservation*, *66*(4), 118A-129A.
22. Farrington, J. W., Davis, A. C., Frew, N. M., & Rabin, K. S. (1982). No. 2 fuel oil compounds in Mytilus edulis. *Marine Biology*, *66*(1), 15-26.
23. Boopathy, R., Manning, J., & Kulpa, C. F. (1998). A laboratory study of the bioremediation of 2, 4, 6-trinitrotoluene-contaminated soil using aerobic/anoxic soil slurry reactor. *Water environment research*, *70*(1), 80-86.
24. Agriculture solutions, nd, available at: https://www.agriculturesolutions.com/resources/92-the-why-and-how-to-testing-the-electrical-conductivity-of-soils.