PRELIMINARY ASSESSMENT OF MARINE WATER QUALITY IN BATHING, SURFING AND FISHERY AREAS OF ARUGAM BAY

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Abstract
Assessment of recreational water quality is a useful tool in identifying pollution sources, risks to public health and developing appropriate mitigation measures. Present study was undertaken with the view of assessing marine water quality of Arugam bay beach, identifies pollution sources and trends in water quality variation along the surfing, bathing and fishery areas. Research was carried out monthly for a period of 03 months period from February to April, 2015.

Measured average pH ((8.15± 0.1) values are indicated slightly alkaline conditions and pH values gradually increase from fishery site to surfing site due to waste water discharge from nearby hotel area. Turbidity values of bathing site are higher than other sites because of high density of bathers and trampling activities in bathing site. Phosphate concentration gradually decreases along the beach area from fishery site to surfing site whereas nitrate concentration gradually increase from fishery site to bathing site and then decrease from bathing site to surfing site. Total Coliform and Escherichia coli counts were high in bathing site than other 02 sites which may be due to discharges from nearby hotels and high density of bathers. Frequent and long term monitoring is essential to obtain temporal and spatial variation in coastal marine water quality of Arugam bay beach.

Keywords: Marine water quality, recreational site, bathing site, pollution, surfing site

Introduction

Recreational use of inland and marine waters is increasing in many countries. Huge amount of foreign and local tourists together spend their holidays at coastal recreational resorts (Shuval, 2003). Nowadays participation in recreational activities has grown to the extent that it has been linked to declining environmental quality in certain areas (Saunders *et al.,* 2000).

Marine water quality plays an important part in the conservation of marine resources, which contribute to the stability of the marine ecosystem. Pollution from land-based sources as well as from the sea can pose threats to these invaluable resources (DOE, 2010). Maintaining and protecting the quality of the recreational water is an important environmental health and resource management issue (MFE, 2003). The quality of bathing waters is essential not only for the bathers because of public health concerns. It is also a strong indication to the overall health of our coastal zones and inland water bodies (EEA, 2011).
Recreational waters generally contain a mixture of pathogenic and non-pathogenic microbes. These microbes may be derived from sewage effluents, the recreational

population using the water (from defecation and/or shedding), livestock, industrial processes, farming activities and wildlife; in addition, recreational waters may also contain truly indigenous pathogenic micro-organisms (WHO, 2001). Recreational water users are at risk of infection from water-borne pathogens through ingestion or inhalation of contaminated water or through contact with the water (EPA, 1999).

Assessment of the health impacts of recreational water quality is a useful tool in developing appropriate policies. Risk assessment approaches are increasingly being used as a scientific rationale for risk management (Pond, 2005). Managing water resources is also a complex process, which involves many different players, such as different levels of government, different economic actors, and the public. These waters can only be safeguarded if all the countries and regions involved work together and share the responsibility (EU, 2010).

Arugam bay is one of the best places in the world for surfing and favourite tourist destination in Sri Lanka. Since this beach is subjected to tourist visits and fishery activities, it has significant impacts on coastal water quality. Present study was undertaken with the view of assessing marine water quality of Arugam bay beach, identifies pollution sources and trends water quality variation along the surfing, bathing and fishery areas.

Methodology

Location of the study

The study was conducted in the Arugam Bay beach area of Ampara District (Figure 2.1). Arugam Bay is a bay situated on the Indian Ocean in the dry zone of Sri Lanka's southeast coast and the bay is located 320 km east of Colombo. This beach is ideal for bathing and surfing in Sri Lanka. One stretch of the beach is suitable for bathing and other stretch is suitable for surfing. Huge amount of foreign and local tourists visit here and there are lot of hotels located closer to beach area. Further, fishery activities are also found closer to bathing site and lot of boats are parked closer to bathing site. So, water quality monitoring was conducted in fishery boat parking site, bathing site and surfing site.

Water sampling and Analysis

The shallow water depth around chest depthalong the near- shore area was subjected to monitoring. Around 400m stretch of the beach area was subjected to monitoring and samples were collected at 50m gap along the beach area including surfing, bathing and fishery boat parking sites using systematic line sampling method. Study was carried out for a period of 03 months period from 10th of February to 10th of April, 2015 and sampling was done on monthly basis in 09 sampling points along the coastal stretch according to their GPS points. The relative sampling locations are illustrated in Figure 1.

Samples were collected in morning at 9.30am to 10.30am on every month during research period in order to ensure the sample collection at regular interval. Temperature, Electrical Conductivity (EC), Salinity, Total Dissolved Solids (TDS), p^H and Dissolved Oxygen were measured by using multi meter (Orion Star A329 portable pH/ISE/Conductivity/DO meter) and turbidity was measured by using turbidity meter (Hatch 2100Q Portable Turbidimeter). Measurement of nitrate and phosphate concentration was done with the support of National Water Supply and Drainage Board (NWSDB), Sagamam. All the equipments used for the measurements were subjected to calibration before every sampling day.

Microbiological sampling
09 Samples were collected at approximately 15cm below the surface at a point where the depth of the water is approximately 0.5 meters (knee depth) by using sterilized glass bottles in each sampling point. The sample bottles were transported to the laboratory in regifoam box filled with ice. The microbial test was done at National Water Supply and Drainage Board, Sagamam. To enumerate *Escherichia coli* and Total Coliform counts Membrane Filtration (MF) Method was adopted.

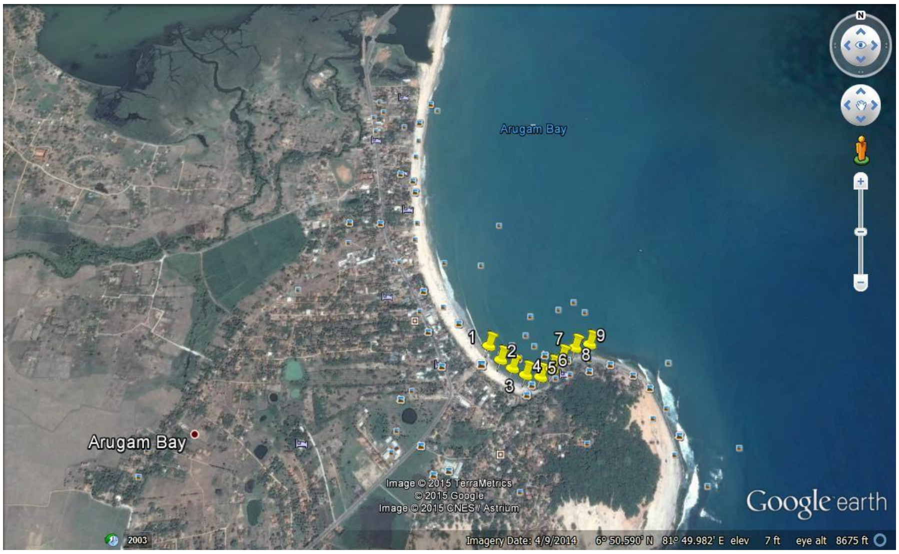

Figure 1: Map showing sampling locations in Arugam bay

Results and Discussion

Recommended marine water quality standard values of some countries for recreational sites and minimum, maximum and standard deviation values of overall results
Water-quality guidelines are necessary to protect human health during recreational activities such as swimming and boating, and to preserve the aesthetic appeal of water bodies. Such guidelines are used in monitoring and managing a range of physical, microbial and chemical characteristics that determine whether a body of water is suitable for recreational use (NHMRC, 2008). In Sri Lanka, there is no ambient marine water quality standard for recreational site until now.

Therefore, I used the recreational marine water quality criteria of some countries for comparison of results. Table 2 outlines the guideline values for the recommended water quality parameters for marine recreational sites in some countries. Table 1 shows the minimum, maximum, mean and standard deviation values of overall results obtained and Table 3 shows the mean value of each parameter in fishery, bathing and surfing site.

Table 1: Minimum, maximum, mean and standard deviation values of results

Parameter	Unit	Minimum	Maximum	Mean	Standard Deviation
P^H	-	7.80	8.26	8.15	0.10
Turbidity	NTU	8.63	10.33	9.52	0.58
Total Dissolved Solids	ppt	25.50	29.64	27.14	1.69
Electrical Conductivity	mS/cm	51.58	60.76	55.32	3.58
Salinity	PSU	31.50	33.13	32.24	0.61
Dissolved Oxygen	mg/l	7.02	8.03	7.51	0.32
Temperature	^0C	28.40	33.50	30.90	1.92
Nitrate	mg/l	0.004	0.270	0.068	0.075
Phosphate	mg/l	0.05	14.30	2.97	4.35
Total Coliform counts	MPN/100ml	0	35	9	9
Escherichia coli counts	MPN/100ml	0	28	6	7

Table 2: Recommended marine water quality standard values for recreational site in different countries

Parameters	India	Malaysia	Japan	Australia
P^H	6.5- 8.5	-	7.8-8.3	6.5-8.5
Turbidity	<30 NTU	-	-	-
Dissolved Oxygen	≥4mg/l	≥5mg/l	≥7.5mg/l	≥6mg/l
Total Dissolved Solids	-	-	-	-
Electrical Conductivity	-	-	-	-
Salinity	-	-	-	-
Temperature	-	≤2°C increase over maximum ambient temperature	-	16-34^{0}C
Nitrate	-	60µg/l	-	-
Phosphate	-	75 µg/l	-	-
Total Coliform counts (per 100ml)	-	-	<1000	-
Escherichia coli counts (per 100ml)	<100	<100	-	**<150**

-: No Guideline Values
(Sources: MEF, 1998; Health Canada, 2012; MONRE *et al*.,2003; DOE, 2010; NHMRC, 2008; EPD, 2008; Snidvongs *et al*., 2002)

Table 3 Mean value of water quality parameter in fishery, bathing and surfing site

Parameter	Mean Value		
	Fishery Site	Bathing Site	Surfing Site
P^H	8.07	8.15	8.20
Turbidity (NTU)	9.30	10.02	9.40
Electrical Conductivity (mS/cm)	55.47	55.08	56.60
Salinity (PSU)	32.22	32.12	32.56
Total Dissolved Solids (ppt)	27.20	27.02	27.76
Dissolved Oxygen (mg/l)	7.47	7.55	7.51
Temperature (^{0}C)	30.73	30.97	31.66
Nitrate (mg/l)	0.049	0.087	0.083
Phosphate (mg/l)	4.32	2.56	1.55
Total Coliform counts (MPN/100ml)	4.22	13.00	9.75
Escherichia coli counts (MPN/100ml)	2.33	8.78	6.58

Comparison of P^H, turbidity and Total Dissolved Solids (TDS) values with the recommended values and its variation along the beach area

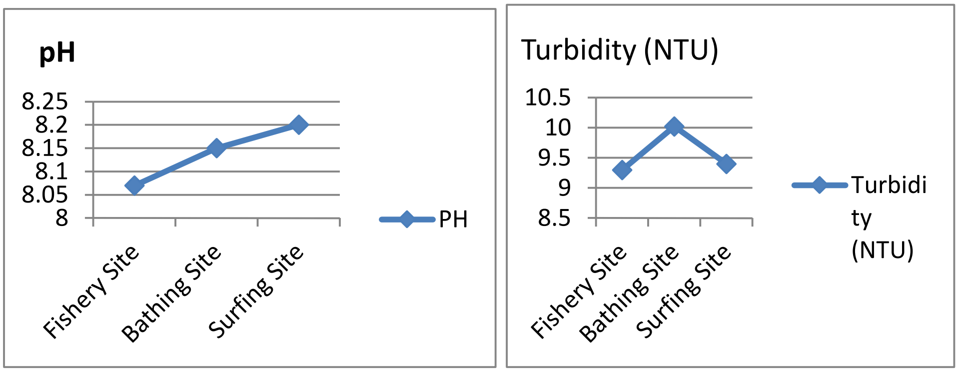

Figure 1: Variation ofpH turbidity along thealong the beach area

Based on table 1, minimum and maximum values of pH were 7.80 and 8.26 with the mean value of 8.15. Recommended Indian water quality criteria for P^H is 6.5-8.5 (Table 2). So, measured values are within the threshold limits. Both alkaline and acidic waters may cause eye irritation. To be protective against the risk of eye irritation, the pH of recreational waters should be in the range of 5.0 to 9.0 (Health Canada, 2012). Recorded average pH values are indicated slightly alkaline conditions. Substances such as fertilizers and detergents and runoff during the rainy season carried by Arugam lagoon from land site may cause increased alkalinity in sea water at the coastal area. Also effluent from the tourist hotels and fishery boating activities could be reason for the recorded alkaline condition of the coastal water. Based on figure 1 pH values gradually increase from fishery site to surfing site. Both bathing and surfing sites have high pH values than fishery site. Waste water discharges from nearby hotel area and detergents are the reason for this variation.

Turbidity in water is caused by suspended and colloidal matter, such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms (APHA *et al*., 2005). This parameter is important for aesthetic, safety and, to a lesser degree, health reasons. High turbidity is aesthetically displeasing and can be a safety concern when it reduces visibility through the water. Lifeguards and other persons near the water must be able to see and distinguish people in distress. In addition, swimmers should be able to see quite well while under water (Health Canada, 2012).

Turbidity values obtained were ranging from 8.63 to 10.33 with mean value of 9.52NTU. Indian water quality standard value for turbidity is 30NTU; so, measured values are within the recommended values. Total dissolved solids obtained were ranging from 25.50 to 29.64ppt. However, there is no specific standard for coastal waters in Sri Lanka and countries mentioned in table 3.2 to compare the present results of TSS. TSS and turbidity are changed due to the watershed hydrologic process, soil sediment characteristics and land use pattern (Amarathunga *et al*., 2010). The high turbidity and TSS values could have been caused either by extensive soil erosion within the watershed and it flow in to the coastal water through river or canal (Hettige *et al*., 2014). Based on figure 1, turbidity values of bathing site were higher than that of other two sites. It may be due to high density of bathers and trampling activities in bathing site. Further, Total dissolved solid values were higher in surfing sites than other two sites.

Comparison of Electrical Conductivity, Salinity, Dissolved Oxygen and Temperature values with recommended values and its variation along the beach area

Measured value range for Electrical Conductivity (EC) and salinity were 51.58-60.76mS/cm and 31.5- 33.13PSU respectively.

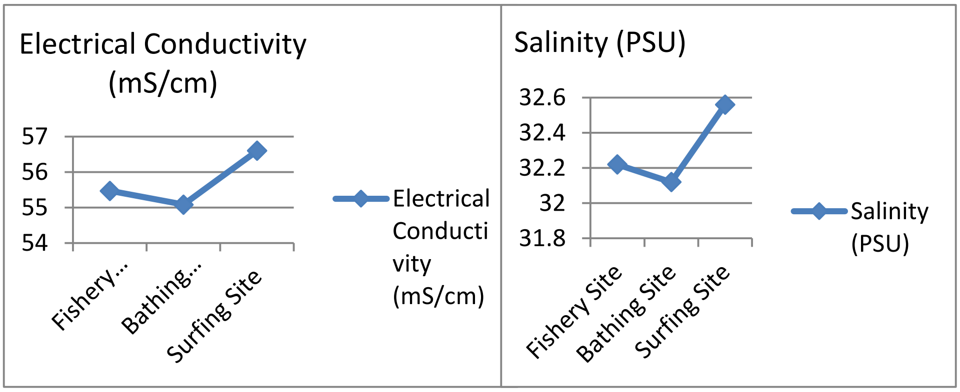

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Figure 2: Variation in Electrical Conductivity and Salinity along the beach area

But, there is no specific standard for coastal waters to compare the present results of EC and salinity. Conductivity is a measure of water's ability to conduct an electrical current (Sawyer and McCarty, 1967). The conductivity of a water sample depends on the water temperature and on the concentration of dissolved salts or other substances that can carry an electrical charge. There is no water quality standard for conductivity, but conductivity can be a useful diagnostic tool for interpreting other water quality information. For example, domesticand industrial wastewater, storm water, and irrigation return water often have higher conductivities than the receiving streams (ODEQ and ODF, 1996).

Generally salinity value for sea water is 35g/kg (or 35PSU). Salinity is an indication of the concentration of dissolved salts in a body of water. In coastal waters, salinity is often used to trace the mixing of freshwater (including sewage outflows) with seawater. Salinity can also be used to find where a sewage outfall is mixing with the sea and the direction of the effluent plume. However, mixing and dilution of the freshwater may be quite rapid. Local variations in salinity caused by evaporation, direct rain precipitation, freshwater discharges from rivers arising from precipitation on surrounding land masses, and the effects of currents (DEFA, 2007). Salinity and conductivity of a system will tend to change depending on the recharge of the system: during wet periods, salinity and conductivity will decline as the concentration of salts becomes more dilute, whereas dry periods will lead to increased salinity and conductivity values (Carr and Neary, 2006). Based on figures 2, average salinity and Electrical conductivity values of surfing sites are higher than other 2 sites. Further, when compare the trend of graphs, EC increases as salinity increases and vice versa.

Measured Dissolved oxygen values (7.02-8.03mg/l) are above recommended value of India (4mg/l). This suggests that the experimental sites were not experiencing any oxygen deficiency at that time. Water can hold more dissolved oxygen (DO saturation) at low temperatures than at high temperatures (ODEQ and ODF, 1996). Dissolved oxygen is vital for aquatic animal life, with differing species requiring differing levels. It is also produced by plants (phytoplankton) during a process known as photosynthesis. The decay of organic matter can consume oxygen; therefore the presence of excessive amounts of decaying organic matter can result in low levels of dissolved oxygen (DEFA, 2007). A large decline in dissolved oxygen in a water body could indicate high levels of organic based pollution such as sewage discharge and warrants further investigation such as sampling for micro-organisms and nutrients.

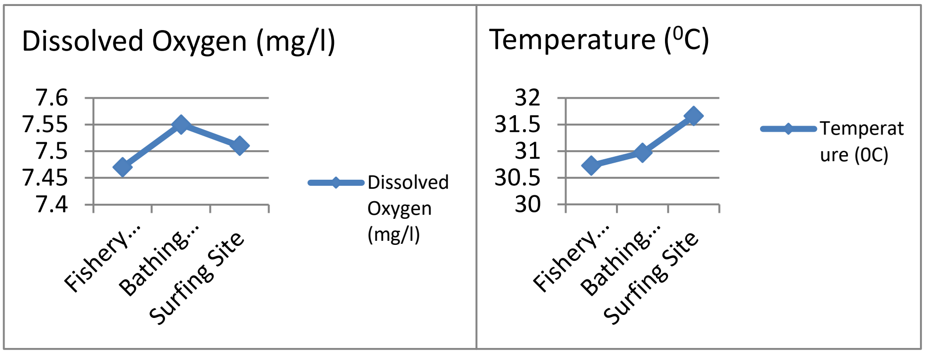

Figure 3: Variation in Dissolved Oxygen and temperature along the beach area

The temperature of recreational water bodies should be in the range of 16–34°C (NHMRC, 2008) and measured values (28.4-33.5^{0}C) were within those limits. Temperature, or changes in temperature, is important in the regulation or triggering of many physiological processes in marine organisms. Anthropogenic sources which may influence water temperature in the marine environment are usually related to the discharge of cooling water from power stations and certain industries (DWAF, 1995).

Recreational water users should be educated to reduce exposure to ultraviolet radiation (UVR), particularly during the middle of the day. Recreational water environments can experience extreme temperature and ultraviolet radiation (UVR) conditions. Exposure to cold water (<16°C) can result in hypothermia (excessive heat loss) or a shock response. Prolonged exposure to waters >34°C may result in hyperthermia (heat exhaustion or heat stress). Levels of UVR vary throughout the day, with a maximum occurring during the 4 hours around noon (NHMRC, 2008). Based on figure 6, temperature values gradually increase from fishery site to surfing site whereas dissolved oxygen values are higher in bathing site than other sites.

Comparison of Nitrate and Phosphate concentration values with the recommended values and its variation along the beach area

Recorded nitrate and phosphate value ranges were 4- 270µg/l and 50- 14300µg/l with the mean value of 68 and 2970µg/l respectively. When compare the mean values with the recommended values of Malaysia (Nitrate-60µg/l and Phosphate-75µg/l); these values exceed the recommended values. Substances carried by Arugam bay lagoon (fertilizers and detergents), sewage and storm water runoff during rainy season from nearby settlement area may be reasons which increases nitrate and phosphate concentrations in water. Also Amarasiri (2007) stated that the large amount of nitrogenous fertilizers has contributed to increased high levels of nitrate in water in many countries. In the marine environment nitrogen pollution (ie nitrate and ammonia), is largely derived from agricultural fertilizers and also from thecombustion of fossil fuels, whilst phosphorus pollution (ie., phosphate) is linked primarily to waste water treatment and detergents (DEFA, 2009).

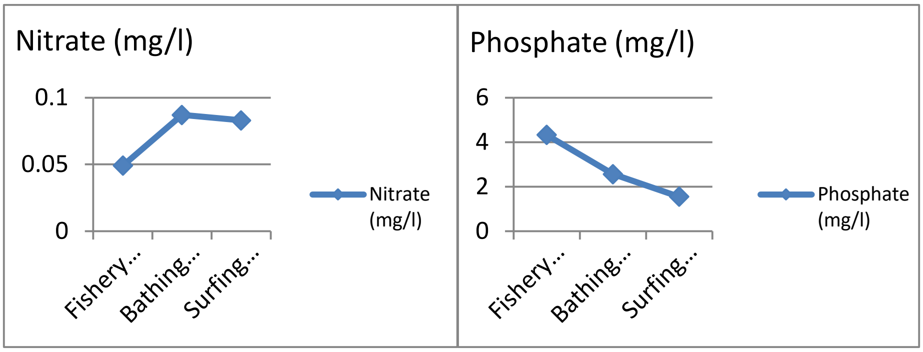

Figure 4: Variation in Nitrate concentration and Phosphate concentration alongthe beach area

Based on figures 7, phosphate concentration gradually decreases along the beach area from fishery site to surfing site whereas nitrate concentration gradually increase and then decrease from fishery site to surfing site. The major sources of elevated nutrients to coastal waters are typically from human waste and chemicals (e.g. detergents, fertilizers). Further, large quantities of nutrients released into the coastal water through the sewage waste water (Danulat *et al.*, 2002). At elevated levels in surface water, nutrients may cause algal outbreaks in rivers, lakes and oceans.

Variation in Total Coliform and *Escherichia coli* counts along the beach area

Total Coliform concentration and *Escherichia coli* counts were ranges between 0-35 and 0-28MPN/100ml with the mean value of 9 and 6MPN/100ml respectively. Measured *Escherichia coli* counts are within recommended values of India (100MPN/100ml) and total Coliform counts are within threshold limit of Japan (1000MPN/100ml). So, based on the results; Arugam bay beach is suitable for the recreational activities. The main sources of *Escherichia coli* are untreated or partially treated animal and domestic wastes and also sewage from coastal premises including hotels and restaurants (DOE, 2010).

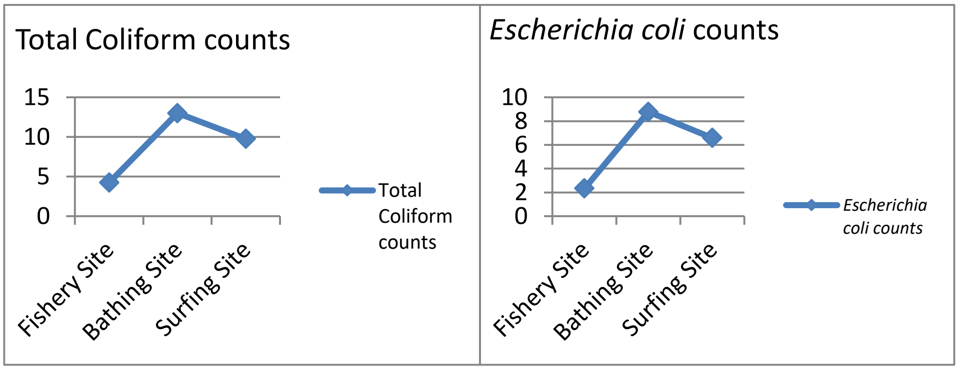

Figure 5: Variation in Total Coliform counts and*Escherichia coli* counts alongthe beach area

According to Figure 9 and 4.0, Total Coliform and *Escherichia coli* counts are high in bathing site than other 02sites.There are a number of factors that can influence the microbiological quality of a recreational water body at any given time. These can include the type and periodicity of contamination events (both point and non-point sources), the time of day, recent weather conditions, the number of users frequenting the swimming area and the physical characteristics of the area itself (Health Canada, 2012). In some instances, the microbial quality of recreational water may be strongly influenced by factors such as rainfall within the catchment, potentially leading to short periods of elevated faecal pollution. There is some evidence that advising against the use of recreational water bodies at times of increased risk has benefits (NHMRC, 2008). Bathers themselves can influence water quality directly. This is most commonly seen as microbial build-up during the day, such that peak levels are reached by the afternoon (WHO, 2001).

Bathing beach waters may contain micro-organisms and beach-goers can be exposed to these micro-organisms through direct body contact or ingestion of beach water. These micro-organisms may, in general, cause infection-type diseases such as gastrointestinal infections or infections of the upper respiratory tract, ears, eyes, nasal cavity and skin. The risk of humans contracting these diseases is positively correlated to the density of these micro-organisms in the water. Beach-goers are informed of the increased health risk under the circumstances of high level of *Escherichia coli* through a beach water quality rating system, based on water quality data obtained from the Environmental Protection Department's (EPD) routine beach water quality monitoring programme (EPD, 2008).

Conclusion and Recommendations

Following conclusions can be obtained from this research study.

- Marine water quality results of Arugam bay beach revealed that, average pH (8.15± 0.1) and temperature (30.9± 1.92 ^{0}C) were within the recommended ranges for recreational sites and turbidity value (9.52± 0.58 NTU) was below the maximum permissible limit. Recorded average pH values are indicated slightly alkaline conditions and pH values gradually increase from fishery site to surfing site. Turbidity values of bathing site are higher than other sites which may be due to high density of bathers and trampling activities in bathing site.
- Mean Dissolved oxygen (7.51± 0.32 mg/l) was above the minimum recommended criteria, suggests that the marine water was well oxygenated and was not experiencing any oxygen deficiency at that time. Dissolved oxygen values were higher in bathing site than surfing and fishery site.
- Average nitrate (0.068± 0.075 mg/l) and phosphate concentrations (2.97± 4.35 mg/l) exceed the recommended values. Substances like fertilizers and detergents, sewage and storm water runoff during rainy season from nearby settlement area may be reasons for higher nitrate and phosphate concentrations in marine water at Arugambay. Further, phosphate concentration gradually decreases along the beach area from fishery site to surfing site whereas nitrate concentration gradually increase from fishery site to bathing site and then decrease from bathing site to surfing site.
- Average values of Total Dissolved Solids, Electrical Conductivity and salinity were 27.14± 1.69ppt, 55.32± 3.58mS/cm and 32.24±0.61PSU respectively. Salinity and Electrical conductivity values of surfing sites were higher than the other 2 sites. Based on the results, EC increases as salinity increases and vice versa.
- Mean Coliform (9± 9MPN/100ml) and *Escherichia coli* concentrations (6± 7MPN/100ml) were within maximum threshold limits. So, based on the results; Arugam bay beach is suitable for the recreational activities. Total Coliform and

Escherichia coli counts were high in bathing site than other 02sites. Number of factors can influence the microbiological quality of a recreational water body at any given time. These can include the type and periodicity of contamination events (both point and non-point sources), time of the day, recent weather conditions, the number of users frequenting the swimming area and the physical characteristics of the area itself (Health Canada, 2012).

Recommendations

- More frequent (daily/weekly/monthly) and long term monitoring is very essential for this important recreational site to identify issues and take remedial actions. In order to ensure that the human health is adequately protected, water should be monitored at a minimum frequency of once per week during the swimming season. A weekly monitoring strategy is useful to alert managers and responsible authorities to more persistent contamination problems that may have developed and allows them to make the necessary decisions within a reasonable time frame.
- Improve the public health through sanitary facilities such as providing latrine facilities and establishment of waste collection bin closer to beach area. Further, waste water discharges (sewage, hotel discharges) should be treated before discharge into marine water.
- Awareness programs about coastal pollution should be conducted among coastal communities including fishermen, school children, hotel owners and tourist association.
- Information on the quality of the water should be communicated to the user through the use of posted signs. Signs should be used to warn users when the water is unsafe for recreational use as well as to communicate when the water is safe for use.
- Proper coordination should be created among government and nongovernmental organizations to minimize the effect of pollution from the land based activities. All stakeholders are expected to become informed about their roles and responsibilities in the safe management of recreational waters. Regulation should be implemented to minimize the pollution from tourism and public activities.
- In Sri Lanka, there are no marine water quality standards for recreational sites until now. Marine water quality standards for recreational sites should be established using coastal water quality monitoring data and expert views and comments.

References

Amarasiri, S. (2007). Declining water quality and its effect on water security. Symposium Proceedings of the Water Professionals' Day, Geo Informatics Society of Sri Lanka (GISSL).

Amarathunaga, A. A. D., Weersasekara, K. A. W. S., Sureshkumar, N., Shirantha, R. R. A. R. and Azmy, S. A. M. (2010). Total Suspended Solids and Turbidity co-relation and its impact on aquatic community in Kotmale sub-catchment in the Upper Mahaweli Watershed in Sri Lanka". Symposium Proceedings of the Water Professionals' Day, Postgraduate Institute of Agriculture and Geo Informatics Society of Sri Lanka (GISSL).

APHA, AWWA and WEF (2005). Standard methods for the examination of water and wastewater. American Public Health Association, American Water Works Association and Water Environment Federation, Washington, DC.

Carr, G.M and Neary, J.P. (2006). Water quality for ecosystem and human Health. United Nations Environment Programme Global Environment Monitoring System/Water Programme, Canada. pp. 1-21.

Danulat, E., Muniz, P., Alonso, G. J. and Yannicelli, B. (2002). Fist assessment of the highly contaminated harbour of Montevideo, Uruguay. Mar Pollut Bull 44(6): 554-565.

Department of Environment (DOE). (2010). Malaysia Environmental Quality Report. Strategic Communications Division, Department of Environment, Malaysia. pp.50-56.

Department of Environment, Food and Agriculture (DEFA) (2007). MARINE MONITORING. Isle of Man Government Laboratory, Douglas, Isle of Man. pp. 8-12.

Department of Environment, Food and Agriculture (DEFA) (2009). MARINE MONITORING. Isle of Man Government Laboratory, Douglas, Isle of Man. pp. 14-16.

Department of Water Affairs and Forestry (DWAF) (1995). South African Water Quality Guidelines for Coastal Marine Waters, Volume 2: Recreational Use. Pretoria, South Africa. pp. 51-91.

European Environment Agency (EEA). (2011). European bathing water quality in 2010. European Environment Agency, Copenhagen, Denmark. pp. 9-10.

Environmental Protection Agency (EPA). (1999). Action Plan for Beaches and Recreational Waters. Office of Research and Development and Office of Water, Washington, USA. pp. 9-22.

Environmental Protection Department (EPD) (2008). Bacteriological Water Quality Objective for Bathing Beach Waters in Hong Kong. Advisory Council on the Environment, Environmental Protection Department, Hong Kong. pp. 1-5

European Union (EU). (2010). Water is for life: how the water framework directive helps safeguard Europe’s resources. European Union, Belgium. pp. 4-9.

Health Canada (2012). Guidelines for Canadian Recreational Water Quality. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. pp. 1-147.

Hettige, N.D., Weerasekara, K.A.W.S., Azmy, S.A,M and Jinadasa, K.B.S.N. (2014). Water Pollution in Selected Coastal Areas in Western Province, Sri Lanka: A Baseline Survey. Journal of Environmental Professionals Sri Lanka, 3(2), pp. 12-24.

Ministry of Environment and Forests (MEF) (1998). Gazette notification, New Delhi, India. pp. 9-10.

Ministry for the Environment (MFE). (2003). Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas. Ministry for the Environment, Wellington, New Zealand. pp. 17-27.

Ministry of Environment and Natural Resources (MONRE), the World Bank and the Danish International Development Assistance (DANIDA) (2003). Vietnam Environment monitor. Hanoi, Vietnam. pp. 68-69.

National Health and Medical Research Council (NHMRC). (2008). Guidelines for Managing Risks in Recreational Water. Canberra, Australia. pp. 4-148.

Oregon Department of Environmental Quality (ODEQ, 1996) and the Oregon Department of Forestry (ODF) (1999). Water quality monitoring: Technical guide book. Pp. 40-61.

Pond, K. (2005). Water Recreation and Disease. World Health Organization, IWA Publishing, Alliance House, United Kingdom. pp.16-74.

Saunders, C., Selwyn, J., Richardson, S., May, V. and Heeps, C. (2000). A review of the effects of recreational interactions within UK European marine sites. UK Marine SACs Project, UK CEED Marine, Bournemouth University and Centre for Coastal Conservation and Education. pp. 9-53.

Sawyer, C.N., and McCarty, P.L. (1967). Chemistry for sanitary engineers. McGraw-Hill Book Company, New York, USA.

Shuval, H. (2003). Estimating the global burden of thalassogenic diseases: human infectious diseases caused by wastewater pollution of the marine environment. Journal of Water and Health. 1(2): 53–64.

Snidvongs, A., Utoomprurkporn, W. and Jarayabhand, S. (2002). Regional Coordination for Integrated Protection and Management of Coastal and Marine Environments in ASEAN: Phase I. Southeast Asia START Regional Center Technical Report No. 11, Southeast Asia Start Regional Center, Bangkok, Thailand. pp. 25-191.

World Health Organization (WHO). (2001). Bathing Water Quality and Human Health. World Health Organization, Geneva. pp. 6-49.