Geospatial Assessment of Water Quality in Creeks and Coast of Mumbai India

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ABSTRACT - Mumbai, the financial capital of India is generating about 2700 MLD of sewage from seven service areas and discharging into adjoining coast, Malad, Mahim, Marve and Thane Creeks. The coastal and creeks water quality is deteriorating due to disposal of partially treated sewage, wastewater from open drains as well as industrial wastewater. The objective of present paper is to assess and evaluate the water quality during low and high tides. 65 samples from west coast including beaches and seafronts, 44 from creeks and 3 from ocean outfalls were collected as per Standard Method. The samples were analysed for physico-chemical and bacteriological parameters and results were compared with SW II standards as prescribed by Central Pollution Control Board, India. The results were incorporated on the GIS platform for further geospatial analysis and visualization. The spatial distributions of water quality were generated to delineate the areas affected due to sewage discharges and disposal through ocean outfalls. Based on water quality analysis and spatial distribution, creeks were observed to be worst and most of the parameters were above the prescribed standards as compared to west coast. Spatial and temporal assessment of water quality suggests that there is a dire need of improvement in wastewater collection, treatment and disposal facilities to achieve designated standards in creeks and coastal environment.

Keywords: Coast, Creek, GIS, Sewage, SW-II standards, Water Quality

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1.0 Introduction:

About 50% of the world's population lives in coastal areas, a Fig. which will probably rise to 75% during this century (Finkl 1994; Alexander et al., 2008). India has a long coastline of over 8000 km. Indiscriminate releases of untreated or partially treated wastes without considering the assimilative capacity of the waste receiving water body have resulted in pockets of polluted environment with depleted coastal resources, public health risks and loss of biodiversity. Over 300 million people living in the coastal zone of India are considered to generate 1.11 x 10^{10} m^3 of sewage annually, where sewage collection network exists, enters the marine waters (Zingde 1999). The increased human aggression in the form release of sewage and industrial wastes, dumping of solid waste garbage in the creeks caused stress on the ecosystem (Goldin Quadros et al 2004).

Water quality impacts on west coast and Thane creek waters around the city are the most important considerations for future planning of marine environment. Tidal currents which advect, disperse and dilute the effluent in the coastal environment (Indrani Gupta et al, 2004). The objective of the present paper is to assess the water quality of west coast including Mithi River, Malad and Marve creeks as well as Thane creek in east side of Mumbai City. The application of GIS is used to assess the spatial and temporal distribution of water quality during low and high tides and compared with SW II standards (CPCB 1993).

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2.0 Study Area:

Mumbai is the capital of Maharashtra state, located at the west coast of India (Fig. 1). The study area lies between 18^0 52′ to 19^0 20′ N latitude and 72^0 48′ to 73^0 05′ E longitude with an area 438 sq. km and population of over 13 million. Many parts of the city lie just above sea level, with elevations ranging from 10 m to 15 m (Krishnamoorthy Bala 2006). City receives around 3400 MLD water supply from different sources situated 80 km to 160 km away from the city namely Vihar, Tulsi, Tansa, Vaitarna i.e. Modak Sagar, Upper Vaitarna and Bhatsa lake. City generates about 2700 million liters per day (MLD) of sewage from seven service zones namely Colaba, Lovegrove (Worli), Bandra, Malad, Versova, Bhandup and Ghatkopar. Wastewater is collected and transported through various pumping stations to the wastewater treatment facilities and discharges it into the adjoining west coast and creeks namely Malad, Marve and Thane in the Arabian Sea (Lakshmi Vyas and Sapna Vyas 2007).

3.0 Materials and Methods:

Methodology is divided into two phases. Phase I comprises the sampling locations, collection and preservation of samples and analytical techniques. Phase II comprises interface between water quality data and GIS for the assessment of spatio-temporal water quality parameters in west coast and creeks.

Phase I - Sample Collection and Analysis: A well designed program was prepared to generate data on water quality status and impact of sewage/wastewater discharges on marine environment. The water sampling was conducted during winter in January 2007 and monitored at the identified locations using GPS (Trimble 2007). Total 112 water samples were collected, of which 48 samples were from coastal region, 33 from Thane creek, 3 from ocean outfalls, 11 from Marve, Malad creeks, Mithi river and 17 from seafronts and beaches (Fig. 1). Selection of water quality parameters were based on the receiving water body standards. The collected samples were preserved and analysed for various physico-chemical and bacteriological parameters as described by standard methods (APHA 2005).

Phase II - GIS based Analysis: The analytical results were taken on the GIS environment for further analysis. The analytical attributes considered are based on regulatory guidelines and standards for coastal waters. Using ArcGIS 9.3 (ESRI 2008), water quality maps were generated for Turbidity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Fecal Coliform (FC) using Natural Neighbor interpolation technique and classified for spatial analysis (Sibson, 1981).

4.0 Results and Discussion:

The samples were analysed in the laboratory for physical, chemical and bacteriological parameters and the result obtained were compared with the SW II standards (Table 1). The water quality observed at Colaba, Worli and Bandra outfalls are also presented in Table 2.The individual range of water quality parameters in west coast and creeks are presented in Table 3 and Table 4 respectively.

4.1 West Coast

pH was always with in the prescribed limit of SW II standards. The SW II standard for turbidity of 30 NTU exceeded only in limited samples in the impact zone of Marve creek during high tide. The discharge of wastewater with turbidity in the range of 140 to 200 NTU through outfalls at Worli and Bandra gets adequately diluted resulting turbidity of 10 to 30 NTU. DO was observed more than 4 mg/L (SW II standard) in all the samples in coastal waters during low and high tides indicating favourable conditions for aquatic life. The concentration of DO was increasing with the distance from the shoreline. Another indicator of water health is BOD, a measure of pollution due to biodegradable organic matter (S. S. Dhage et. al. 2006). BOD observed at Worli and Bandra outfalls indicated marginal pollution during low and high tides. Though the BOD values were satisfying SW II standard at majority of locations, the impact of sewage discharges was observed upto 3 km seaward distance. Due to non-point discharges in the west coast and discharges from ocean outfalls, it was observed that the bacteriological quality in terms of FC showed non compliance of SW II standards at all locations in west coast and creeks.

4.2 Seafronts and Beaches

Observed pH values were in the range of 7–8 satisfying SW II standards indicating neither pollution threat for biological life nor skin-eye irritation problems during contact water sports. The turbidity was observed to be in the range of 8-95 NTU. About 35 % of total samples were exceeded SW II standard (30 NTU). Rests of the sample were in the prescribed limit. The highest turbidity were observed at Gorai following Manori, Girgaon and Marve beaches having values 95, 75, 65 and 55 NTU respectively. DO was observed more than 4 mg/L (SW II standard) in about 85% samples except Mahim where it was practically zero because of heavy sewage/wastewater discharge in Mithi River which opens near Mahim beach and carries huge load of organic waste. Marginal low DO was observed at Colaba, Manori and Marve beaches. About 60 % of the samples containing BOD were found to be within the prescribed limit of 3 mg/L (SW II standard). Rest of the samples was showing marginal increase and worst at Mahim and Dadar where it was 38 and 18.8 mg/L respectively. The FC count observed in the range 1.2 x 10^2 to 4.1 x 10^7 CFU/100 ml at all beaches and seafronts were exceeding SW II standards because of the non point discharges of sewage/wastewater.

4.3 Thane, Malad, Marve Creeks and Mithi River

pH values were in the range of 7 – 8.2 during low and high tides, satisfying SW II standards. The turbidity was observed in the range of 10 – 150 NTU. Only 20% samples were found above the prescribed SW II standards. Marginal increase in the turbidity at Malad creek during low tide was observed. The highest turbidity was found at upper stretch of Thane creek with 150 NTU during high tide. As per observed DO, the condition of Malad creek is alarming as no DO in the creek during low tide. At Marve creek and Mithi river the alarming condition was also observed as DO was in the range of 0 to 2 mg/L during low tide. During high tide the condition was slightly better as marginal increase in DO than prescribed SW II standards. The condition at Thane creek is not good as about 85% DO samples were below prescribed limit during low and high tides indicating unfavorable conditions for commercial fishing. The BOD was observed higher (above prescribed SW II standards) at all the creeks during low tide. The highest BOD was 22 mg/L observed at Malad during low tide following 18.8 mg/L at upper stretch of Thane creek. Marginal increase in BOD values compared to SW II standards were observed at Marve and Malad creek during high tide. Possible non point discharges of sewage at Thane creek made the condition nastiest. All the creeks were heavily contaminated with FC. Condition at all the creek waters was observed to be vulnerable and not complying with the stipulated SW II standards.

4.4 GIS Based Analysis

The spatial and temporal distribution of Turbidity, DO, BOD and FC for coastal and creeks waters during low and high tides are depicted in Fig. 2 through Fig. 5. Colour coding has been adopted as per SW II standards. Lighter to darker shades of blue represent acceptable water quality and the shades from yellow to red representing higher concentration of pollution exceeding the standards. The distribution of turbidity more than 30 NTU at Gorai beach and lower stretch of Thane Creek indicated with red colour during low and high tides. The orange colour patch showing turbidity not complying with the SW II standards during low and high tides at Dadar, Mahim, Girgaon beaches and some portion of Marve and Malad creeks. Distribution of DO showed Marve, Malad, Mithi and upper stretch of Thane creek with DO 0 to 2 mg/L indicating pollution and not complying with stipulated standards during low tide. The condition improves in Marve and Malad creek during high tide as compared to Mithi river and middle and upper stretches of Thane creek. Like wise BOD distribution indicates poor condition at Marve, Malad creeks, Mithi river and middle portion of Thane creek with BOD upto 15 mg/L during low tide. BOD was increased slightly higher than SW II at impacts zone of Worli and Bandra outfalls due to sewage discharges. Distribution of FC indicates bacterial pollution in west coast, creeks, beaches and seafronts due to point and non point discharge of sewage. Even effect can be visualized up to 7 km seaward distance.

5.0 Conclusions:

Analytical results and spatio temporal distribution of water quality assess the impact of sewage and wastewater in the coast, creeks and beaches. Water quality in terms of DO and BOD satisfies the compliance level in west coast and outer region of Thane creek due to dilution. Water quality in Malad, Marve and upper stretch of Thane creek is worstly affected by influx of domestic and industrial waste in terms of non point pollution. Absence of DO and presence of high BOD warrants urgent mitigation measures in the creeks. Similarly beaches and seafronts are polluted due to non point sources. Mahim is worstly affected beach. Deterioration of environmental quality in the beaches requires remedial measures to improve recreation value. Bacterial water quality in terms of FC was worst and not complying standards at any location. Since, there is no treatment for FC and continuous discharges of sewage in the creeks and through ocean outfalls, water quality of waste coast and creeks is deteriorating.

Spatio temporal study revealed that there is a dire need of suggestive measures to mitigate coastal and creeks water pollution and improvement in water quality. Measures include identification of non point sources and connected through city sewerage system, improvement in existing collection system, appropriate level of treatment and proper disposal may achieve designated water quality standards for the coastal and creek water environment.

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Fig. 1: Details of study area and sampling locations

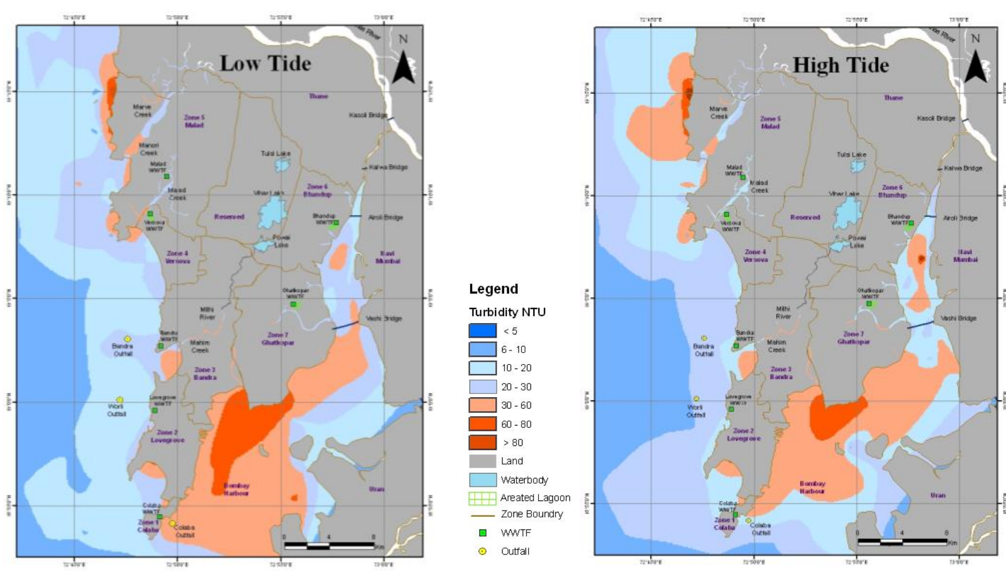

Fig. 2: Spatio-temporal distribution of Turbidity

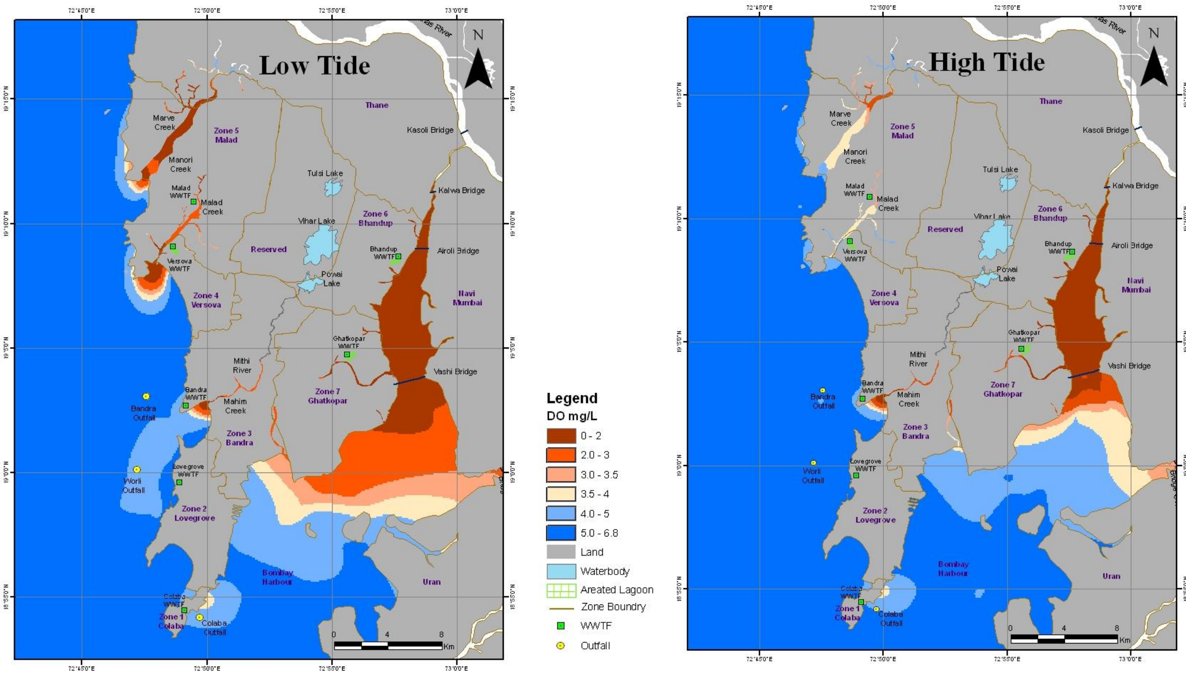

Fig. 3: Spatio-temporal distribution of DO

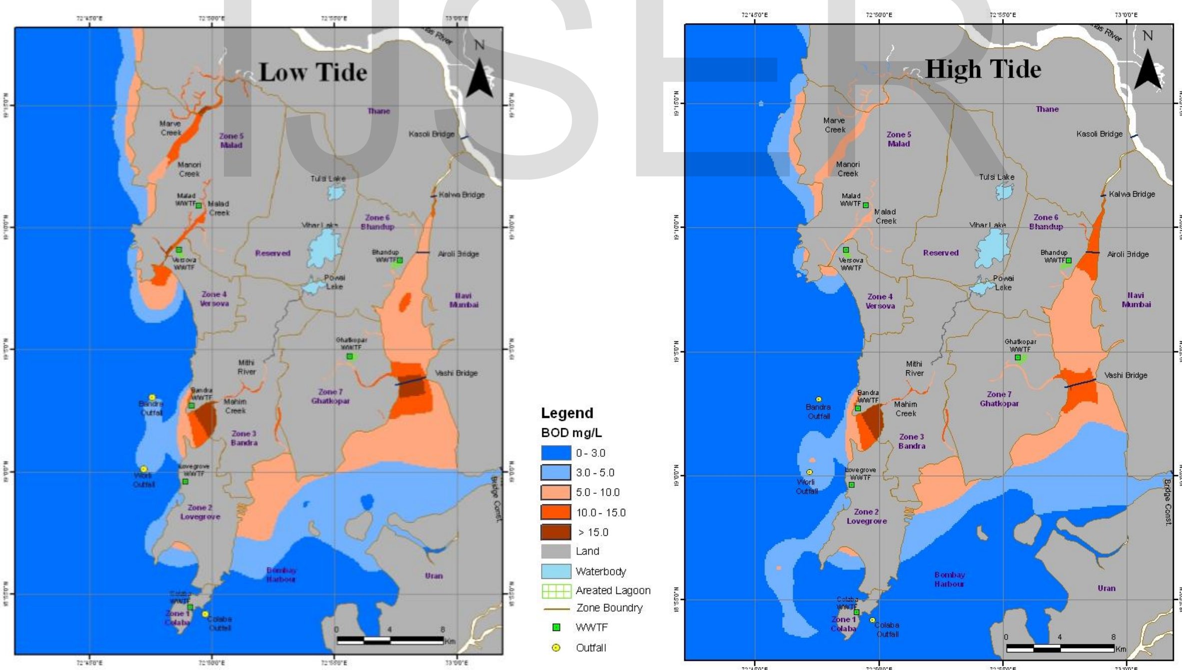

Fig. 4: Spatio-temporal distribution of BOD

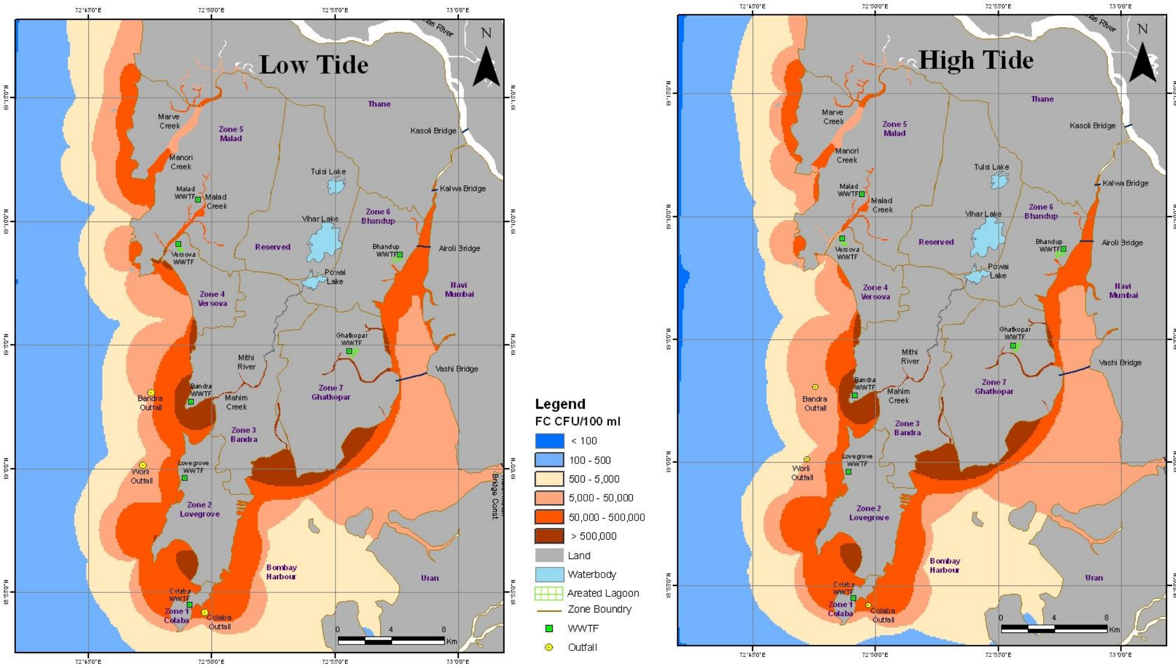

Fig. 5: Spatio-temporal distribution of FC

Table 1: Primary Water Quality Criteria for Class SW-II Waters (For Bathing, Contact Water Sports and Commercial Fishing)

Sr. No	Parameter	Standards
1.	pH range	6.5 - 8.5
2.	Turbidity	30 NTU (Nephelo Turbidity Unit)
3.	DO	4.0 mg/l
4.	BOD (3 days at 27°C)	3 mg/l
5.	Fecal Coliform	100/100 ml (MPN)

Criteria for classification and zoning of coastal waters (sea waters)—A coastal pollution control series: COPOCS/6/, 1993

Table 2: Physico-Chemical and Bacteriological Analysis at Ocean Outfalls

Sr. No	Outfall Locations	pH	Turbidity (NTU)	DO (mg/L)	BOD (mg/L)	FC (CFU/100ml)
1	Colaba	6.5	35	6.5	1.9	1.50×10^4
2	Bandra	7.96	33	5.5	2.5	5.06×10^5
3	Warli	8.04	10.4	5.8	2.8	1.70×10^5

Table 3: Physico-Chemical & Bacteriological Analysis of Coastal Waters

West Coast	pH	Turbidity (NTU)	DO (mg/L)	BOD (mg/L)	FC (CFU/100ml)
1 Km			**Low Tide**		
	7.4 - 7.6	7.9 - 31	4.2 - 6.8	1.2 - 3.4	$2.7 \times 10^3 - 2.6 \times 10^5$
			High Tide		
	7.5 - 7.7	10.9 - 36	4.8 - 6.9	1 - 3.8	$6.7 \times 10^2 - 2.16 \times 10^4$
3 Km			**Low Tide**		

	7.4 - 7.6	10.2 - 30	4.5 - 6.6	1 - 4	1×10^3 - 1.08×10^4
	High Tide				
	7.3 - 7.6	8.6 - 36	4.9 - 6.6	1.2 - 5.4	4.2×10^2 - 1.62×10^4
5 Km	**Low Tide**				
	7.5 - 7.7	8.5 - 31	5.4 - 6.9	1 - 3	1.3×10^2 - 2.1×10^3
	High Tide				
	7.4 - 7.6	9.1 - 37	5.7 - 6.7	1 - 2.8	2.4×10^2 - 1.38×10^3
7 Km	**High Tide**				
	7.5 - 7.7	6.9 - 29	5.9 - 6.8	1 - 3.8	1.2×10^2 - 5.1×10^2
Beaches & Seafronts	7 - 8	8 – 95	0 - 7.5	1 - 38	1.2×10^2 - 4.1×10^7

Table 4: Physico-Chemical & Bacteriological Analysis of Creek Waters

Creek Locations	**pH**	**Turbidity (NTU)**	**DO (mg/L)**	**BOD (mg/L)**	**FC (CFU/100ml)**
Malad Creek	**Low Tide**				
	7.6 - 8	35 – 45	0	14 - 22	4.6×10^4 – 4.2×10^6
	High Tide				
	7.7 - 8	12.5 - 23	3.6 – 5.3	4 – 8	1.7×10^3 – 3.6×10^3
Marve Creek	**Low Tide**				
	7.7 – 7.9	22.6 – 26.4	0 – 0.8	6 – 16	6.9×10^3 – 3.1×10^5
	High Tide				
	7.9 – 8.2	8.3 – 19.6	2 – 5.2	6 – 7.6	4.7×10^3 – 1.2×10^5
Mithi River	7.1 – 7.5	10 – 32	0.9 - 2	7 - 14	1.4×10^7 – 3.7×10^7
Thane Creek	**Low Tide**				
	7 - 8.2	4.7 - 77	0 - 6.2	1 - 18.8	7.5×10^2 - 2.2×10^5
	High Tide				
	7 - 8.2	5.1 - 150	0 - 6	1 - 15.6	5.2×10^2 - 1.25×10^5

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