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Plastic Debris along the Beaches of Karnataka, Southwest Coast of India

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Abstract: This study deals with accumulation of plastic debris on five sandy beaches of the southwest coast of India. Sand from five quadrats (1 m^2) of mid and hind dunes at each beach was assessed for the accumulation of plastic debris. Plastics were sorted, enumerated, weighed and classified based on their use (food, fishing, domestic and miscellaneous). Qualitative and quantitative variations in plastic debris were recorded between the mid and hind dunes. Quantity of plastic debris was more on mid dunes, while the number on hind dunes. Quantity and number of plastic debris between hind and mid dunes did not differ significantly. A total of 22 types of plastic debris were recovered in the quadrats, while visual observation revealed 15 additional types on beaches. Low-density polyethylene and polystyrene were most common on beaches. Accumulation of food-based plastic debris was highest (43%), followed by domestic (28%), fishing (18%) and others (11%). This study revealed that the beaches of southwest coast of India mainly consist of plastics used for food and fishing purposes. As most of the debris accumulated is of local origin, its prevention can be achieved by public education and employing safe disposal practices.

Key words: Beaches, sand dunes, pollution, plastic debris.

Introduction

Marine and marine influenced ecosystems are facing severe threat of pollution due to human interference. Among them, one of the most dangerous marine pollutants of global concern is accumulation of plastic debris. Many investigators have reviewed nature of marine plastic pollution from the tropics and temperate regions (e.g. Day and Shaw, 1987; Claereboudt, 2004). Plastic debris find their entry into marine ecosystem by land (storm water, wind blow and beach users) and ocean (recreational, shipping and offshore petroleum rigs) (Cunningham, 2003). Distribution of plastic debris in marine environs depends on wind, ocean currents and the proximity of sources. Plastic debris are harmful to marine ecosystem as they float in coastal or off shore waters and accumulate on the beaches or on sediments (Derraik, 2002). Seabirds, fish and many planktivores ingest plastics mistakenly and succumb for death (Carpenter et al., 1972; Robards et al., 1997; Laist, 1997). Plastic ingestion in marine fauna leads to decline in food consumption, blockage of intestine, internal injury, starvation and death (Redford et al., 1997; Derraik, 2002). Plastic debris are also known to transfer polychlorinated biphenyls (PCBs), dichloro-chlorophenylethylene (DDE) and nonylphenols (NP) to food chain (AGTSDR, 1995a, 1995b). Inventoring and monitoring of plastic debris in marine ecosystem is one of the means to assess the magnitude of plastic accumulation and helps to mitigate possible measures to reduce the menace. Alarming increase in the production of synthetic polymers worldwide (~140 million tonnes/annum) (Shimao, 2001) and their possible impact on the environment is assuming importance in the recent past. The current study has been

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aimed to evaluate the abundance and composition of plastic debris on selected sandy beaches of southwest coast of India. Plastic debris has been compared qualitatively and quantitatively between the mid dunes and hind dunes.

Materials and Methods

Study Sites and Sampling

Five sandy beaches on 300 km stretch of Karnataka (Figure 1) of the southwest coast of India were selected for the survey of plastic debris during October-December 2005. Major portion of Karwar beaches are used for fish drying and sawmills; canning factories and cold storage facilities are located in the vicinity. As a natural harbour, shipping activities and ship breaking has a major impact on the quality of beach. The beach Honnavar is very wide with profuse strand vegetation in backshore. Sawmills, seafood and tile factories are situated in the vicinity. The Maravanthe beach is prone for erosion without consistent strand vegetation and the vicinity of beach consists of rice mills and fishing industries. Malpe has undulating

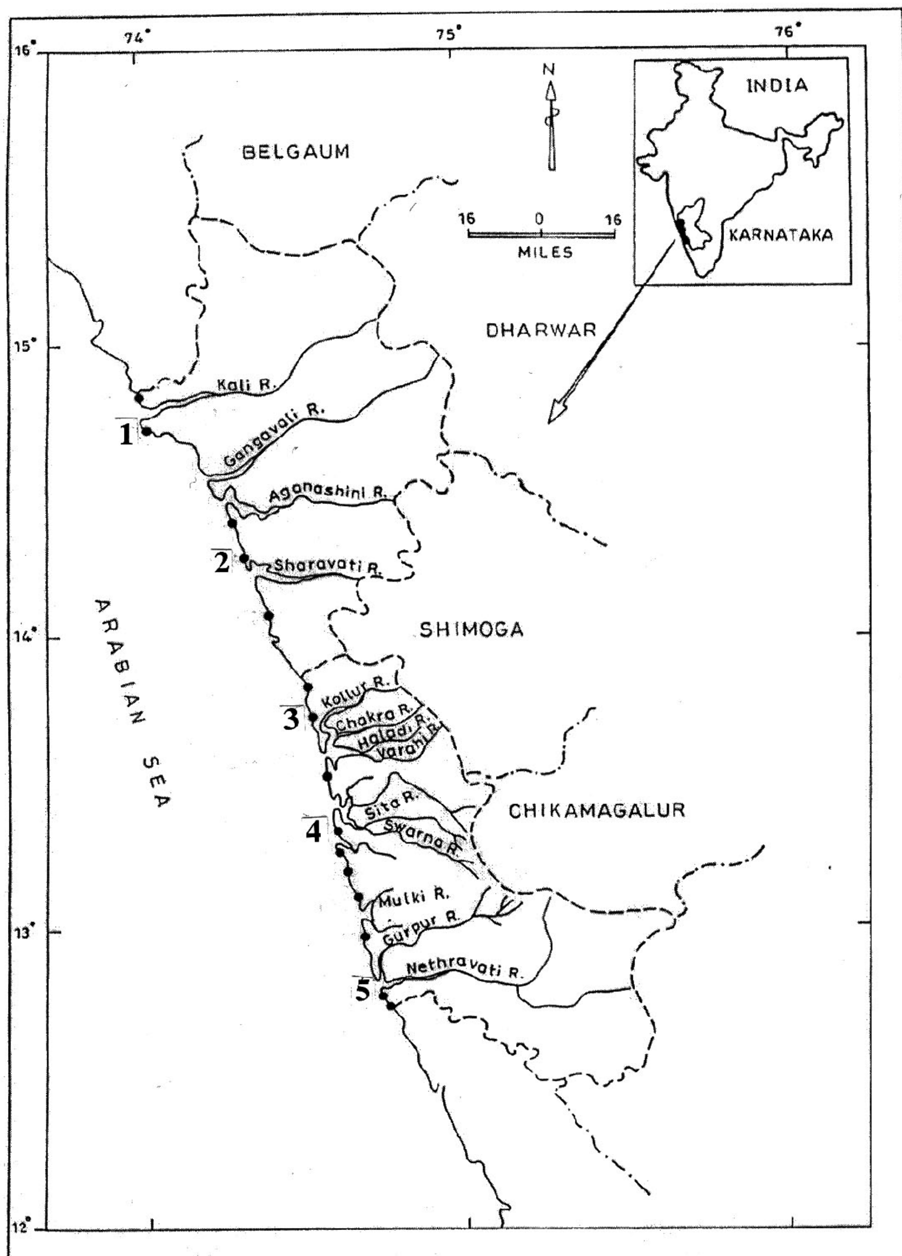

Figure 1: Sampling locations along the southwest coast of India (1, Karwar; 2, Honnavar; 3, Maravanthe; 4, Malpe and 5, Someshwara).

beach topography and backshore covered with discontinuous strand of vegetation. It is one of the major fish landing and recreational centres. Tile factories and canning factories are located around. The Someshwara beach has scattered rocks with moderate strand vegetation.

Beaches were longitudinally divided into two zones, high tide and mid tide to compare the extent of accumulation of plastic debris. Transects of 100 m on each beach, parallel to the shoreline were marked. At every 20 m interval, 1 m^2 quadrat was marked for sampling. Biodegradable surface debris except for plastics of each quadrat was removed, visible plastic materials on the surface collected and later each quadrat was dug up to 30 cm depth and the buried plastics were collected. Besides collection of plastic debris in hind and mid dunes, accumulation of types of plastic debris on the seashore was visually examined.

Classification and Quantification

Plastic items were classified based on their composition and type (e.g. fabrics, rexins, ropes, medical, carry bags, thermocol). Each plastic item was surface cleaned with brush to eliminate adhered materials, counted, grouped and weighed (Analytical Precision Balance, Denver Instruments, Germany; accuracy up to ±0.001 g). For comparison, plastic debris was categorized into four main groups (food, fishing, domestic and miscellaneous). Paired t-test was employed to compare the overall quantity, number and specific type of plastic debris between hind dunes and mid dunes (Stat Soft Inc., 1995).

Results and Discussion

About 60-80% of marine debris consist of plastics and 90% of them are floating (Derraik, 2002; www.gpa.unep.org;http://marine-waste.gpa.unep.org/facts/what-where.htm). Overall results of our study revealed higher quantity of plastic accumulation in mid dunes than hind dunes (121.4 vs. 78/m^2), while high number of plastics in hind dunes (13.3 vs. 0.15/m^2) (Figure 2). Quantity as well as number of plastic debris between hind and mid dunes did not differ significantly ($p = 0.16$ and $p = 0.2$). The quantity of plastic debris was highest in hind dunes of Someshwara and lowest in Karwar hind dunes (37.9 vs. 6.9 g/m^2). The number of plastic debris was highest in hind dunes of Someshwara, whereas lowest in mid dunes of Honnavar (7.3 vs. 0.6 g/m^2). This suggests differential accumulation of plastic debris on marine habitats and dependence on sand erosion or accretion. Bowman et al. (1998) attributed the distribution

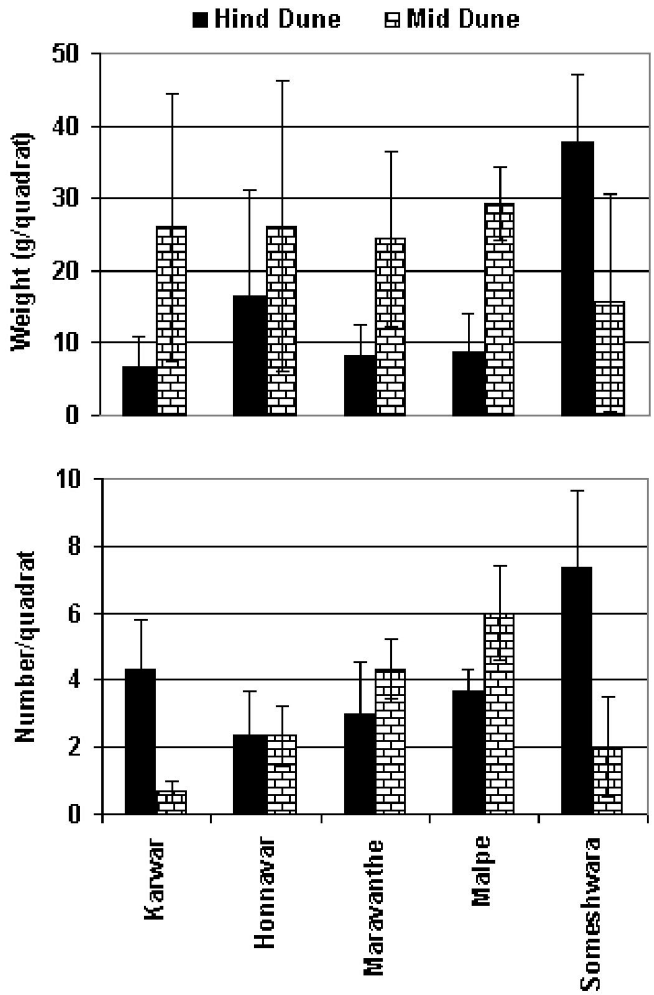

Figure 2: Abundance of plastic debris on the hind dunes and mid dunes per metre quadrat of beaches of southwest coast of India (*n* = 5, mean ± SE).

of plastic debris in beaches caused by the wind and pushing of the debris to the beach face until it becomes trapped by the fore-dune or strand vegetation.

In addition to movement of plastic debris to long distances, ocean currents and winds concentrate them in certain oceanic regions (Moore, 2003). Both land-based (e.g. storms, landfills, garbage transport, open trash containers, industries, riverine flow, beach-users) and ocean-based (e.g. fishing, ballast water exchange, shipping activities) sources contribute for plastic debris in marine environment. According to US Department of Commerce and Navy (1999), 80% of the marine debris mainly originates from land-based sources as seen in the current study.

A wide variety of plastic debris (22 types) was collected and identified in the present study (Table 1). Food-based plastic debris was dominant (food packets, chocolate covers and packages of bakery goods),

Table 1: Classification of plastic debris recovered on the beaches of southwest coast of India

Type of plastic debris	*Recovered in the quadrats*	*Recovered on the beaches**
Bakelite	-	Electrical material
Biaxially oriented polypropylene (BOPP)	Biscuit cover	-
Cellophane	Tapes	-
High density polyethylene (HDPE)	Bottle cap	Garbage bag
HDPE + Nylon		Cement bag
Low density polyethylene (LDPE)	Cigarette pack, palm oil packet, carry bags, chips packet	Duracell cover
LDPE + Additives	Palm oil cover	-
Nylon 6, 6	Fishing net	Mesh
Nylon 6, 10	-	Tooth brush
Nylon (recycled)	Rope	-
Polybutadiene	-	Balloon
Polychloropene	-	Foot wear
Polyethylene	Milk packet, chocolate cover, beverage straw, arrack packet, coated paper plates, butter pack	-
Polyester	Fabric	-
Polyester + mixture	-	Clothing
Polyethylene (recycled)	-	Carry bags, glue bottle
Polyethylene + Polypropylene blend	Cosmetic sachet	-
Phenol-formaldehyde (bakelite/textolite)	-	Bottle caps
Polyethylene + PVC	Ice cream spoon	-
Polyethylene terphthalate	PET bottle	-
Polyester + Aluminium + Polypropylene	Food packet	-
Polyester (Mylar film)	-	Magnetic recording tape
Polyethylene + Colour additives	Oil bottle	-
Polyisoprenes	-	Rubber
Polymethyl methacrylate	-	Automobile glass piece
Polypropylene	Milk chocolate cover, areca/tobacco sachet	-
Polypropylene + Rexin	-	Seat cover
Polypropylene + Polyester blend	Tobacco sachet (mixture of areca nut + tobacco)	-
Polystyrene	Ice cream cup, tea cup, bubble wrapper, bread cover	-
Polystyrene + Copolymer	Ice cream cup	-
Polystyrene	Thermocol	-
Polystyrene/polyester	PET bottle	-
Polystyrene/Cellulose acetate	-	Chips packet
Polyurethane	Hard sponge	-
PVC (hard)	-	Pipe, fishing net float
PVC (flexible)	Pen cap, small box	Bucket piece, cleansing ear bud, comb
Terylene	-	Hat

*Plastic debris not found in the quadrats.

followed by domestic (carry bags, oil bottles and thermocol), fishing (nylon ropes, polyurethane and rubber) and miscellaneous items (bubble wrappers, cellophane tapes, laminated cosmetic packs, pen caps and cement bags). In addition, several plastic debris not recovered in quadrats were accumulated on the beaches (e.g. balloon, toothbrush, electrical materials, fishing net float, foot wear, automobile glass blend with plastic, medical debris). Majority of the debris recovered belongs to domestic and recreational activities which indicates the anthropogenic pressure on these beaches. Most of the plastic debris accumulated are of local origin and indicate their input due to human activities and through storm than the ocean deposition. Fishing related debris were up to 5.12% worldwide, 5-15% in US coastlines as reported by Ocean Conservancy, USA (Anonymous, 2003) and 25-35% in Gulf of Oman (Claereboudt, 2004). Fishing-based plastic debris were observed in the current study and they were dominant in the beaches of Karwar followed by Maravanthe (17-65%). Recovery of high quantity of fishing-related plastic debris in Karwar might be attributed to mechanized fishing in and around the region. Karwar is known for cargo loading docks, shipping lanes and ship-breaking activities, which might dump plastics on beaches. However, food-based plastics were low in Karwar beaches. Highest amount of food-based plastics was found at Malpe followed by Honnavar and Someshwara beaches (46-80%) indicating that these beaches are main recreational zones.

Classification based on the quality of plastic debris in marine habitats projects the problems posed by them in long run. Several studies documented the quality of plastic debris accumulated in maritime habitats (Cunningham, 2003; Claereboudt, 2004; McDermid and McMullen, 2004). Percentage of different types of plastics between hind dunes as well as mid dunes did not differ significantly ($p = 0.5$) (Table 2). Number and types of plastic debris was highest in Malpe and Someshwara beaches (11), while lowest in Karwar beach (5). In hind dunes and mid dunes flexible PVC (74%) and nylon 6, 6 (79%); polystyrene (45%) and polyester (50%); LDPE (44%) and LDPE (40%); polystyrene + copolymer (70%) and polyester (50%); and LDPE (52%) and LDPE (61%) were the major plastic debris in Karwar, Honnavar, Maravanthe, Malpe and Someshwara respectively. Malpe showed the highest amount of food-related plastic debris (80%) followed by Honnavar (47%) and Someshwara (46%) (Figure 3). Karwar beach showed the dominance of fishing-related debris (65%). Domestic plastic debris was high in Someshwara (43%) and Maraventhe (41%) and Honnavar (32%). Plastic debris categorized under miscellaneous group was dominant in Honnavar (20%), Maravanthe (16%) and Karwar (15%). It has been predicted that the southwest Indian beaches mainly consist of plastic debris belonging to food and fishing. Based on this, further strategies have to be planned and executed to prevent or recycle such debris to restore the quality of marine habitats.

Table 2: Percent plastic debris recovered on beaches of southwest coast of India (HD, hind dune; MD, mid dune)

Type of plastic debris	*Karwar HD (MD)*	*Honnavar HD (MD)*	*Maravanthe HD (MD)*	*Malpe HD (MD)*	*Someshwara HD (MD)*
Cellophane			20	6	1
Biaxially oriented polypropylene (BOPP)	0.9				
High density polythene (HDPE)		(31)			
Low density polyethylene (LDPE)	10	12 (14)	44 (40)	8 (7)	52 (61)
LDPE + additives					(0.1)
Nylon 6, 6	10 (79)	(2)	9 (0.1)	6 (17)	
Nylon (recycled)				(0.1)	
Nylon + Polyethylene					0.7
Polyester		21 (50)	(5)	(50)	23 (3)
Polyester + mixture		17			
Polyethylene	1 (21)	(2)		(3)	0.1
Polyethylene + Polypropylene blend			22		
Polyethylene + PVC				(1)	
Polypropylene	4			0.1 (10)	11
Polypropylene + Polyester blend				(2)	1
Polystyrene	0.1	45 (1)	5 (27)	6 (7)	
Polystyrene (thermocol)			(7)		
Polystyrene + Copolymer				70	(30)
Polystyrene + PVC					(6)
Polyurethane			(19)		
PVC (hard)		5			7
PVC (flexible)	74		(2)	4 (3)	5

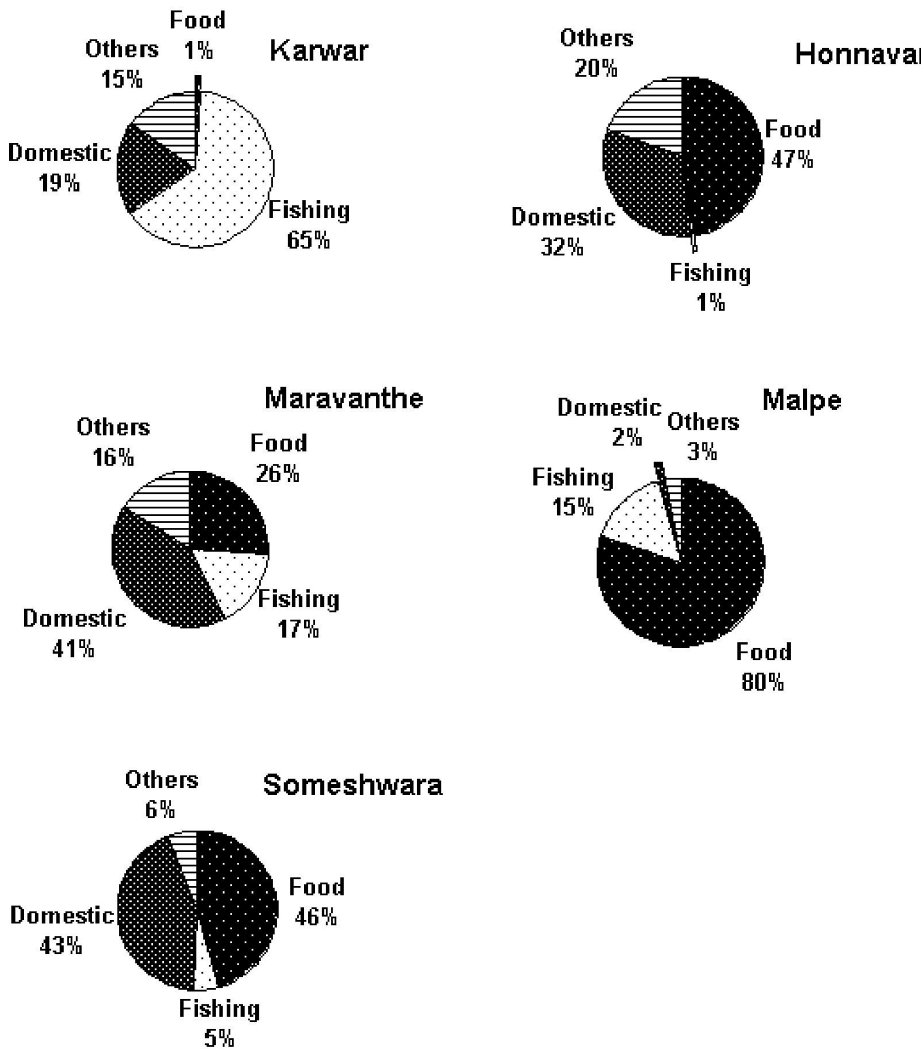

Figure 3: Percent occurrence of different groups of plastics in five beaches of southwest coast of India.

Impacts of ingestion of plastics by seabirds due to anthropogenic activities in North Pacific have been discussed by some investigators (Robards, 1997; Vlietstra et al., 2002). Floating plastics can magnify hydrophobic compounds (e.g. PCB and DDT) up to one million times of the background levels, which increase the risk of biomagnification (Dharani, 2003). Most of the LDPE plastics found in the present study were used as carry bags and usually made up of recycled plastics with colour additives. Colouring pigments incorporated to plastics possess toxic constituents like titanium dioxide, cadmium and lead (Azeez, 2002). Diffusion of such toxic materials into food or environment will intensify the toxicity.

Plastic debris accumulation in southwest coast of India assumes importance due to many factors. For instance, beaches of Karnataka are known for the activities of egg-laying olive ridley turtles (Madhyastha et al., 1986). Mat-forming creepers on southwest coast India (e.g. *Alysicarpus*, *Canavalia*, *Ipomoea*, and *Launaea*) involve in dune stabilization and improve the soil structure. Some important microorganisms (e.g. arbuscular mycorrhizae, *Frankia*, and rhizobia) also support the dune vegetation (Beena et al., 2000; Arun, 2002). Many intertidal organisms are dependent on the supply and dissemination of nutrients through tidal activities (e.g. organic matter, phosphate and nitrate). Seashores and mangroves of southwest coast of India are in the proximity of Western Ghat forests and support the activities of migratory birds. Thus, plastic accumulation or burial may upset the delicate physicochemical and ecological balance of the fragile coastal ecosystem.

Out of 300 km of coastline of Karnataka, currently, 70 km are vulnerable for severe sand erosion during southwest monsoon (June-September) and may result in transport of dune-deposited plastic debris by oceanic currents to off shores. Further studies are essential to understand the quantity and quality of small plastic debris on intertidal zones for appropriate steps to degrade such plastics through suitable methods. Photo-degradation of plastic debris takes longer duration in ocean than on land due to the cooling capacity of ocean (Dharani, 2003). However, exposure of plastic debris in warm tropical beaches (e.g. southwest coast of India) for long duration may lead to formation of small pieces by photo-degradation, which complicate clearing the plastic debris if delayed. Monitoring through remote sensing and marking of specific plastics (e.g. floats, and LDPE) to understand their origin, transport and deposition are the essential future tasks. Public education on the damages caused by the plastic debris in marine ecosystem, suggestion for possible alternatives to prevent plastic menace through use of biodegradable plastics, safe disposal practices and periodical monitoring of accumulation of plastics in beaches and coastal waters is the need of the hour.

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Calendar of Events

2nd European Water Conference
2 to 3 April 2009
Brussels, Belgium
Website: http://www.ewc2009.eu
Contact name: Euro Keys
Organized by: European Commission - DG Environment

2009 Asia Pacific Water and Sewer Systems Modelling Seminar
27 to 28 April 2009
Gold Coast, Queensland, Australia
Website: http://www.asiapacificwater.com/
Contact name: Shankar Ram

WaterTech 2009
3 to 6 May 2009
Dubai, United Arab Emirates
Website: http://www.watertechme.com
Contact name: Stacey Cross
Organized by: IQPC

International Seminar on Water Resources and Coastal Management in Developing Countries
11 to 13 May 2009
Manado, North Sulawesi, Indonesia
Website: http://www.hathi-manado.org
Contact name: Peter Assa
Organized by: Indonesian Association of Hydraulic Engineers (HATHI)

International Conference on Water Resources (ICWR) 2009
26 to 27 May 2009
Langkawi, Kedah, Malaysia
Website: http://seminar.spaceutm.edu.my/icwr2009
Contact name: Ms. Shafinaz/Ms. Raihana
Organized by: Universiti Teknologi Malaysia

Seminar: Synergies between River Restoration and River Management focussing on Natura2000 and Ramsar sites
28 to 29 May 2009
Lelystad, Netherlands
Website: http://www.ecrr.org/lelystad_09.htm
Contact name: Francesco Pra Levis
Organized by: European Centre for River Restoration (ECRR) and Rijkswaterstaat

International Forum on Integrated Water Management
1 to 3 June 2009
Sherbrooke, Quebec, Canada
Website: http://www.cogesaf.qc.ca/rv-eau
Contact name: Jacinthe Caron
Organized by: COGESAF and Universite de Sherbrooke

China Wastewater Treatment 2009
11 to 12 June 2009
Beijing, China
Website: http://www.wastewaterchina.com
Contact name: Tina Tian
Organized by: IGVision International Corporation

Sustainable Ocean Summit
16 to 17 June 2009
Belfast, United Kingdom
Website: http://www.oceancouncil.org
Contact name: Paul Holthus
Organized by: World Ocean Council

Singapore International Water Week
22 to 26 June 2009
Singapore
Website: http://www.siww.com.sg/
Contact name: Michael Toh
Organized by: Singapore International Water Week Pte Ltd

ISA-RC-24- International Conference on Water, Environment, Energy and Society
28 to 30 June 2009
Firozabad, Agra, India
Website: http://www.environment-societyisa.org
Contact name: Dr Ugrasen Pandey
Organized by: S.R.K. (P.G.) College, Firozabad, Agra University, India

Advances in Wastewater Treatment and Reuse
30 June to 2 July 2009
Tehran, Iran
Website: http://awtr.ut.ac.ir
Contact name: M.H. Sarrafzadeh
Organized by: University of Tehran

ICME 2009 Dhaka
26 to 28 December 2009
Website: http://www.buet.ac.bd
Contact name: Prof. R. Sarkar, BUET, Bangladesh
ICME2009@me.buet.ac.bd