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STUDY OF IMPACTS OF OIL SPILL ON THE SUNDARBANS MANGROVE FOREST OF BANGLADESH

ABDULLAH HARUN CHOWDHURY[1] AND MD ALI AKBER
Environmental Science Discipline, Khulna University, Bangladesh

Abstract

Studies were carried out on the recent oil spill in the Sundarbans of Bangladesh to find out the immediate impacts on the ecosystem of the Sundarbans after oil spilling. More than 500 km^2 areas out of the total study area have been affected seriously by the oil spill contamination on 9 December 2014. Recorded data of the physico-chemical conditions, oil content, productivity, diversity and abundance of phyto-zooplankton and benthos of water, and oil content in soil indicate that the water and soil of the Eastern part of the Sundarbans were polluted by the oil contamination. Results also indicate that seedlings, mangrove algae, eggs and hatchlings of commercially valuable fishes, mudskippers, mud crabs, snails, monitor lizards were affected due to oil spill. Regeneration of the *Sundri* trees; intertidal zone bird - 'Masked finfoot', common birds, fishing cat, otter, dolphins, crocodile would be affected due to the oil spill. Long term monitoring, in depth research and proper implementation of all rules and regulations are necessary to save the fragile ecosystem of the Sundarbans-the UNESCO declared world heritage site.

Key words: Oil spill, Sundarbans, Mangrove ecosystems, Impact

Introduction

The Sundarbans - the single largest tract mangrove forest is located in the South-West area of Bangladesh. Officially it is known as the 'Sundarbans Reserve Forest (SRF) and divided in West and East zones', whole forest covered an area of 3956 km^2 mangrove forest lands and more than 1800 km^2 water bodies (Hussain and Acharya 1994 and IUCN 2001). It is intersected by a network of tidal canals, creeks and rivers. This tidal forest is very rich with natural ecological resources especially floral and faunal diversity (IUCN 2001 and Chowdhury 2003). More than 500 thousand peoples are directly and indirectly depending on the Sundarbans for their livelihoods as well as socio-economic purposes (Biswas *et al.* 2007, Giri *et al.* 2007 and Uddin *et al.* 2013).

Considering the ecosystem functions and services of the SRF in both regional and global extent, it was declared as 'Ramsar site' in 1992 and 'World Heritage Site' in 1997 by UNESCO (FAO 2007). In 1999, the Department of Environment (DoE) of Bangladesh declared the SRF as 'Ecological Critical Area (ECA)'(DoE 2010) including 10 km buffer zone surrounding of the forest. The plant populations of the ecologically sensitive forest-Sundarbans area are being changed due to some environmental threats like macro and micro climatic changes, increasing of salinity in soil and water, natural calamity,

[1]Corresponding Author: aharunc_ku@yahoo.com

land erosion, siltation of the river beds, decreasing of up streams fresh water flows etc. (Mannan 2010, Chowdhury 2011, Mannan *et al.* 2012 and Hossain 2014).

On 9 December 2014, an oil tanker carrying about 75000 gallons (350000 liters) of black-furnace oil was passing through the *Shela* river (inside the SRF east zone) while it slammed on another vessel and spilled the oil into the river. According to the authority of the Sundarbans forest department, floating black-furnace oil was being spread to the small creeks, canals and forest floors within twenty four hours due to tidal action; as a result black-furnace oil was deposited on the soil of inter tidal zones, forests floors, plants leaves, stems, floating fruits, roots and pneumatophores (breathing roots of mangrove plants) etc. The surfaces of the rivers, creeks and canals of that part of the SRF were being covered gradually by the black oil spills. Kingston (2002) observed that oil contamination in mangroves poses long-term impacts which can be measureable for decades after the event. According to Chowdhury and Zaman (2001 and 2002) and Bhuiyan (1983) oil contamination in the water body is responsible for changing the water quality and for decreasing the productivity, abundance of phytoplankton and zooplankton of a water body.

Under the circumstances, it was imperative to institute an investigation on the estimation of oil spill hazards and their impacts on the flora, fauna, soil, water and ecosystems of the Sundarbans. This study was conducted to find out the possible immediate impacts of oil spill on the ecological and biological conditions of the Sudarbans i.e. physico-chemical conditions of water and soil, population of plankton and benthos, status of flora and fauna.

Materials and Methods

Selection of study area: The study was conducted from 11 December 2014 to 25 December 2014 in 15 different locations (22º 22′ 15.47′′ N 89º 39′ 23.78′′ E, 22º 21′ 51.23′′ N 89º 39′ 59.10′′ E, 22º 20′ 16.71′′ N 89º 40′ 47.55′′ E, 22º 20' 46.93′′ N 89º 42′ 43.19′′ E, 22º 17′ 35.66′′ N 89º 31′ 14.27′′ E, 22°17′47.49′′ N 89°36′55.83′′E, 22°18′13.32′′ N 89°33′17.11′′E, 22°19′49.42′′ N 89°32′24.41′′E, 22º 00′ 40.38′′ N 89º 44′ 38.75′′ E, 22º 01′ 29.89′′ N 89º 44′ 48.62′′ E, 22º 02′ 32.22′′ N 89º 45′ 00.73′′ E, 22º 07′ 52.91′′ N 89º 49′ 09.75′′ E, 22º 07′ 50.66′′ N 89º 47′ 17.67′′ E, 22º 08′ 14.09′′ N 89º 46′ 02.49′′ E and 22º 13′ 28.54′′ N 89º 44′ 22.62′′ E) of the eastern part of Sundarbans where the spilled oil was spread (Plate 1). Total study area was more than 1200 square kilometer. Samples were also collected from 3 different locations of uncontaminated areas - Gharilal (22º 11′ 54.80′′ N 89º 20′ 04.52′′ E), Jorshing (22º 14′ 38.97′′ N 89º 21′ 34.70′′ E) and Kalagachia (22º 12′ 22.78′′ N 89º 14′ 37.58′′ E) of the western part of Sundarbans. The investigation tools used were site observations, spot and laboratory analyses. Samples were collected on 11, 13, 15, 17, 19, 21, 23 and 25 December 2014(48 hours interval sampling). The samples of the study were collected by using a country boat.

Collection of water sample and analysis: Water samples were collected from 10-25 cm depth by using a scale (Trivedy 1993) for physico-chemical analysis. A standard Secchi disc was used to measure the transparency of water while for water temperature a digital thermometer was used (Model No. 950). In situ measurements of total suspended solids

(TSS), total dissolved solids (TDS), conductivity, salinity, pH and dissolved oxygen (DO) were carried out with the help of respective portable field meters. Titrimetric methods were used to determine free CO_2, CO_3 and HCO_3 alkalinities (Welch 1948). BOD_5, COD, NO_3-N and other chemical parameters were measured following APHA (1989). Calcium and magnesium were estimated following Mishra *et al*. (1992). Phosphate and silicate were measured following Gautam (1990). Primary productivity was measured by using dark-light bottle procedure (APHA 1989).

Soil sample collection and analysis: Oil contents of water and soil were measured by sulphuric acid, Petroleum ether and separating funnel procedure (APHA 1989 and Mishra *et al*. 1992). Shovels and large ladders were used to collect the soil samples according to Trivedy (1993). Soil quality was determined in the laboratory by following Jackson (1973) and Page *et al*. (1982). Plankton population was collected by using No. 20 silk bolting cloth (mesh size 0.076 mm) and after collecting the plankton materials were transferred into the glass bottle and preserved permanently in Transeau's solution (Transeau 1951). Plankton abundance was counted by using Sedge-Wick Rafter Counting Chamber (APHA 1989) and expressed in unit/l whether it is an individual or a cell or a filament or part thereof. Plankton were identified by the help of relevant literatures (Edmondson 1966 and Tonapi 1980). Benthic macroinvertebrate samples were collected and studied by following SWAMP (2007) and APHA (1989). The populations of plants in field were measured by following quadrat method (Ambasht 1974). Standard observations and monitoring methods (Foot/Pug marks per quadrate area/ a standard area curve) were followed for different faunal study. Latitude and longitude were measured by using a hand GPS meter (model GARMIN GPSMAP® 78s). Statistical analysis among the different parameters was done by following Hoshmand (1998).

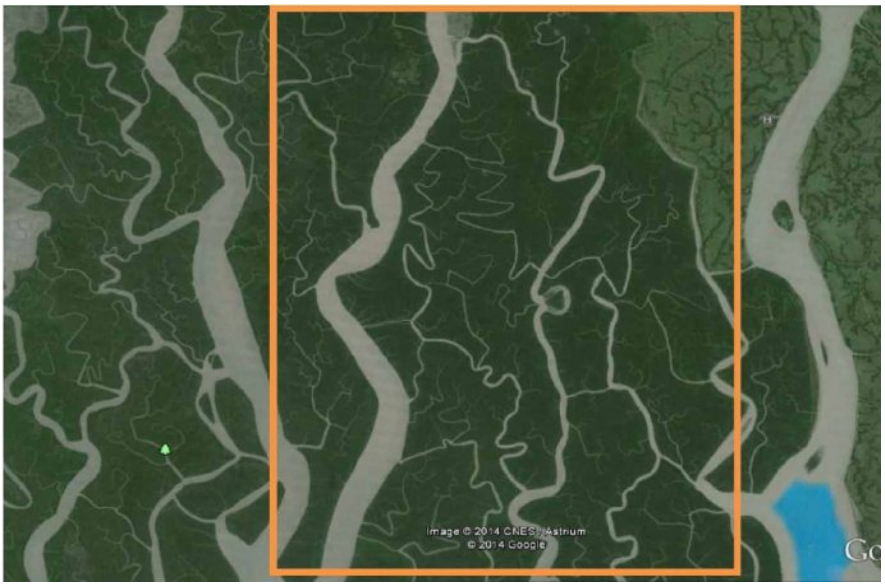

Plate 1. Oil contaminated study areas of the eastern SRF.

Results and Discussion

Physico-chemical attributes of water and soil: Physico-chemical parameters and plankton abundance of water of oil contaminated and uncontaminated areas of the Sundarbans mangrove forest have been presented in Table 1 and physico-chemical conditions of soil of oil contaminated and uncontaminated areas have been presented in Table 2.

The recorded data indicate that high content of oil (995±429 mg/l), total suspended solids (999±447 mg/l) and total hardness value (2156±132 mg/l) along with higher chemical oxygen demand (COD) value (377±104 mg/l) were present in the oil contaminated areas during study period. On the other hand, low transparency (12±2 cm) and productivity (12±2 mg/l) values, and poor abundance of phytoplankton (32±19 units/l) and zooplankton (7±1.5 units/l) were recorded in the oil contaminated areas of the Sundarbans (Eastern part of SRF). Whereas, the recoded data of the same study period of the uncontaminated areas of the Sundarbans (Western part of SRF) indicate that oil content was very poor (8.4±0.9 mg/l) than that of contaminated areas. The values of total suspended solids (9.5±1.8 mg/l), chemical oxygen demand (69±8) and total hardness (965±41 mg/l) of uncontaminated areas were also very lower than those of contaminated areas of SRF. Similarly the values of transparency (26±5 cm) and productivity (14±0.5 mg/l), and abundance of phytoplankton (324±65 units/l) and zooplankton (52±13 units/l) of the uncontaminated areas were much higher than those of oil contaminated areas of SRF. Oil content (1080±420 mg/ kg of 2 inch surface soil) of soil of intertidal zones of the oil contaminated areas was very high than oil content (5.5±0.6 mg/kg of 2 inch surface soil) of uncontaminated areas. High values of oil, total suspended solids, chemical oxygen demand and total hardness; poor values of productivity and transparency; poor abundance of phytoplankton and zooplankton of water, and high content oil of soil indicate that the study areas of the eastern part of the Sundarbans reserve forest (SRF) had been affected by the oil spill. This finding has been supported by the studies of Chowdhury (2009 and 2011), Hossain and Chowdhury (2008), Rahaman *et al.* (2013) and Rahman *et al.* (2006, 2013 and 2014). They had recorded good transparency (27±5 cm), productivity (17±0.8 mg/l), phytoplankton (407±53 units/l) and zooplankton (59±14 units/l) abundance but low values of total suspended solids (9.2±1.4 mg/l), chemical oxygen demands (63±5 mg/l), total hardness (946±53 mg/l) and oil (7.26±0.4 mg/l in water, 3.0±0.2 mg/kg of 2 inch surface soil) in their studies in the Sundarbans.

Table 1. Physico-chemical and biological attributes of water of continental and un-continental areas.

Parameter	Unit	Oil contaminated areas				Uncontaminated areas			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Air temperature	°C	22.1	1.8	19.4	25	22.2	1.8	19.6	26
Water temperature	°C	22	0.5	20.1	23.5	24.8	0.8	22.2	26.6
Transparency	cm	12	2	09	17	26	5	19	33
Total suspended solid	mg/l	999	447	317	1681	9.5	1.8	8.9	15.8
pH		7.4	0.2	7.4	7.7	8.0	0.5	7.8	8.8
Dissolved oxygen	mg/l	5.4	0.3	4.1	6.1	6.5	0.8	6.3	8.0
Total dissolved solid	g/l	21	1.3	17	25	16	5	10.8	23
Salinity	ppt	12.9	1.5	12.7	14.3	13	1.1	12.8	14.5
Total hardness	mg/l	2156	132	1974	2232	965	41	940	1185
Biological oxygen demand (BOD_5)	mg/l	2.8	0.5	2.5	3.9	1.9	0.3	1.4	2.4
Chemical oxygen demand	mg/l	377	104	275	598	69	8	56	81
Carbon dioxide (CO_2 alk.)	mg/l	25	6	16	36	-	-	-	-
Carbonate (CO_3 alk.)	mg/l	-	-	-	-	29	10	24	39
Bicarbonate (HCO_3)	mg/l	131	23	115	157	112	16	97	132
Nitrate as nitrogen (NO_3-N)	mg/l	3.42	0.60	2.79	4.26	2.80	0.48	2.34	3.64
Inorganic phosphate (PO_3)	mg/l	1.93	0.09	1.84	2.08	1.72	0.07	1.69	1.81
Silicate	mg/l	5.71	0.56	4.96	6.97	5.63	0.77	5.04	6.89
Calcium	mg/l	769	72	746	861	575	51	492	684
Magnesium	mg/l	489	63	477	585	315	75	230	426
Oil content	mg/l	995	429	295	1650	8.4	0.9	6.68	11.3
Productivity	mg/l	2.4	0.3	1.7	3.1	14	0.5	12.5	16.9
Phytoplankton	units/l	32	19	24	67	324	65	171	349
Zooplankton	units/l	7	1.5	6	10	52	13	45	71

- = Not detected.

Table 2. Chemical attributes of soil of continental and un-continental areas.

Parameter	Unit	Oil contaminated areas				Uncontaminated areas			
		Mean	SD	Min	Max	Mean	SD	Min	Max
pH		7.7	0.1	7.6	7.9	8.0	0.2	7.8	8.4
Salinity	ppt	13.2	0.7	12.2	14.1	13.4	0.4	12.3	14.5
Total Nitrogen	%	0.24	0.019	0.21	0.28	0.17	0.006	0.14	0.19
Phosphorus	µg/g soil	179	91	72	285	16	0.9	15	19
Sulfur	µg/g soil	104	9	98	115	94	4	85	105
Calcium	meq/ 100g soil	14.2	1.1	13.5	15.5	15	0.6	13.6	15.9
Magnesium	meq/ 100g soil	10.3	0.3	10	10.9	11.5	1.6	10.4	12.7
Potassium	meq/ 100g soil	1.53	0.10	1.45	1.69	1.62	0.39	1.45	1.98
Oil content	mg/ kg of 2 inch surface soil	1080	420	370	1690	5.5	0.6	4	8

Chowdhury and Zaman (2001 and 2002) and Bhuiyan (1983) recorded in their studies that oil contamination in the water body was responsible for increasing of total suspended solids, COD and total hardness values of water and for decreasing of transparency, productivity and abundance of phytoplankton and zooplankton of water. The recorded data of the oil contaminated areas of the Sundarbans has been supported by the observations made by Chowdhury and Zaman (2001 and 2002) and Bhuiyan (1983).

More than 10 mg/l of oil in aquatic habitat can be lethal for the aquatic lives (APHA 1989). Higher content of oil was observed in the water and soil of intertidal zones of the oil contaminated areas of the Sundarbans (Tables 1 and 2). Therefore, the water and soil of the study areas of the eastern part of Sundarbans were polluted and affected by oil spilled on that time.

Status of Phytoplankton, zooplankton and benthos: Diversity and abundance of phytoplankton, zooplankton and benthos of oil contaminated and uncontaminated areas of the Sundarbans have been presented in Tables 3, 4 and 5 respectively. During the period of study total 45 phytoplankton (primary producer) species were recorded in uncontaminated areas of the Sundarbans (Western part of the SRF) and their abundance was found to vary from 171 to 349 units/l. Whereas, in the oil contaminated areas (Eastern part of the SRF), only 18 phytoplankton species were recorded and their abundance was found to vary from 24 to 67 units/l, which is very poor compared to that of the uncontaminated areas. Besides, the presence of *Euglena* sp. and *Phacus* sp. (pollution indicator) in oil contaminated areas also indicates pollution of the aquatic habitat of Sundarbans by spilled oil. Poor productivity values of the oil contaminated areas (Table 1) also indicate significant pollution of the water body by oil spill. Islam (1973), Chowdhury (2003 and 2011), Hossain and Chowdhury (2008) reported 44 phytoplankton species with 226 to 456 units/l abundance in different seasons from the aquatic ecosystems of the Sundarbans before oil contamination inside the Sundarbans. So it may be concluded that the different types of species and abundance of the phytoplankton (primary producer) were affected by the oil spill in aquatic ecosystems of the eastern side of Sundarbans. This result has been supported by the findings of Chowdhury and Zaman (2001) as they observed phytoplankton (primary producer) species diversity and abundance always being decreased by the oil pollution in the aquatic ecosystems. Phytoplankton abundance of the oil contaminated areas of the Sundarbans showed statistically significant negative correlation with oil content (-0.803), TSS (-0.787), COD (-0.695) and total hardness (-0.848) values.

Table 3. Abundance of phytoplankton (units/l) in the water of the Surndarbans.

Phytoplankton	Oil contaminated areas		Uncontaminated areas		Reference data	
	Min	Max	Min	Max	Min	Max
Class: *Cyanophyceae*						
Calothrix castellii	-	-	1	4	3	7
Calothrix fusca	-	-	5	10	6	12
Lyngbya corticicola	-	-	2	4	5	9
Lyngbya confervoides	-	-	3	5	4	10
Lyngbya lutea	-	1	2	6	5	10
Oscillatoria amoena	-	-	7	12	8	14
Oscillatoria limosa	3	4	3	6	5	8
Oscillatoria princes	-	-	1	3	3	5
Oscillatoria subbrevis	-	-	7	11	7	14
Oscillatoria tenuis	2	5	9	15	11	17
Schizothrix lamyi	-	-	1	3	2	4
Spirulina major	2	4	6	10	6	11
Spirulina subsalsa	-	-	3	4	7	10
Microcoleus chthonoplastes	-	-	2	5	3	7
Class: *Chlorophyceae*						
Chlorella vulgaris	2	4	4	9	5	8
Closterium costatum	-	-	6	12	7	14
Closterium lagoense	-	-	8	14	9	18
Class: *Bacillariophyceae*						
Chaetoceros pendulus	-	-	10	16	11	20
Chaetoceros socialis	-	-	6	15	7	22
Coscinodiscus excentricus	-	-	8	12	9	15
Coscinodiscus granii	-	-	9	13	10	16
Coscinodiscus lineatus	-	-	3	9	6	14
Coscinodiscus marginatus	1	2	1	6	3	8
Coscinodiscus	-	-	2	8	4	10

Contd.

Phytoplankton	Oil contaminated areas		Uncontaminated areas		Reference data	
	Min	Max	Min	Max	Min	Max
stellaris						
Coscinodiscus tumidus	-	-	3	7	4	9
Cyclotella bodanica	-	-	1	7	3	8
Cymbella gracilis	-	-	2	6	4	8
Gyrsigma distortum	1	2	2	4	3	7
Melosira arenaria	-	-	8	13	9	16
Melosira granulate	1	2	5	11	7	13
Melosira varians	-	-	2	5	2	6
Melosira moniliformis	1	3	3	8	3	10
Melosira sol	-	-	2	3	3	5
Melosira undulate	1	4	5	12	6	14
Navicula bacillum	1	2	2	4	3	6
Navicula brekkaensis	-	-	3	6	4	9
Navicula grimmei	-	1	1	3	3	6
Nitzschia acicularis	-	-	2	5	3	6
Nitzschia sigma	2	3	4	7	4	8
Surirella fastuosa	-	-	2	5	4	7
Surirell arobusta	1	3	7	10	7	14
Synedra ulna	-	-	2	8	3	10
Class: *Euglenophyceae*						
Euglenea sp. *(2 sps.)*	4	10	-	-	-	-
Phacus sp.	1	2	-	-	-	-
Class: *Xanthophyceae*						
Centritractus belanophorus	-	-	3	6	4	8
Class: *Dinophyceae*						
Ceratium dens	0	2	1	2	1	3
Ceratium extensum	1	2	1	5	-	-
Total	24	67	171	349	226	456

- = Not detected.

Table 4. Abundance of zooplankton (units/l) in the water of Sundarbans.

Zooplankton	Oil contaminated areas		Uncontaminated areas		Reference data	
	Min	Max	Min	Max	Min	Max
Protozoa						
Favella taraikaensis	3	5	-	-	-	-
Cladocera						
Evadne tergestina	-	-	2	5	4	6
Copepoda						
Calanus helgolandicus	-	-	6	8	7	9
Calanopia thompsoni	-	-	6	10	8	11
Corycaeus flaccus	-	-	7	13	9	12
Lucifer typus	-	-	8	11	7	11
Microsetella rosea	2	3	6	9	7	10
Oithona rigida	1	2	8	12	9	14
Oncaea venusta	-	-	2	3	2	4
Total	6	10	45	71	53	77

- = Not detected.

In the period of study only 2 zooplankton (primary consumer) species were recorded in the oil contaminated areas (eastern part of the SRF) and their abundance varied from 6 to 10 units/l, whereas 8 zooplankton species with 45 to 71 units/l abundance were recorded in the uncontaminated areas of the Sundarbans (western part of the SRF). Presence of Protozoa (pollution indicator) in oil contaminated areas of the Sundarbans also indicates the pollution of water by oil spill (Chowdhury and Zaman 2002). Islam (1974) and Chowdhury (2003 and 2011) recorded 8 zooplankton species in the aquatic ecosystems of the Sundarbans in different seasons and their abundance was found to vary from 53 to 77 units/l. So, it is clear that the zooplankton (primary consumer of water) diversity and abundance of the Sundarbans were decreased by the oil pollution. Chowdhury and Zaman (2002) also had recorded that most of the zooplankton species couldn't survive in the aquatic ecosystem except protozoa when oil content of water became more than 20 mg/l. Zooplankton abundance of the oil contaminated areas of the Sundarbans showed statistically significant negative correlation with oil content (-0.772), TSS (-0.772), COD (-0.931) and total hardness (-0.951) values.

Table 5. Abundance of benthos in the water of Sundarbans.

Benthos	Oil contaminated areas	Uncontaminated areas	Reference data
Order: Coleoptera			
Dubiraphia vittata	-	++	++
Promoresia tardella	-	+	++
Order: Crustacea			
Gammarus fasciatus	+	+++	+++
Palaemonetes paludosus	-	++	++
Order: Diptera			
Ablabesmyia mallochi	+	+++	+++
Cricotopus vierriensis	+	++	+++
Cryptochironomus fulvus	-	++	+++
Microtendipes pedellus	-	-	++
Orthocladius dorenus	-	++	++
Tribelos jucundum	-	-	++
Order: Ephemeroptera			
Acentrella alachua	-	-	++
Baetis pluto	+	+	++
Drunella lata	-	+	++
Iswaeon anoka	+	++	+++
Order: Gastropoda			
Cerithidea cingulata	-	++	++
Helisoma anceps	-	+	++
Laevapex fuscus	-	++	+++
Micromenetus dilatatus	-	++	+++
Plicarcularia leptospera	-	++	++
Valvata cristata	-	++	+++
Order: Hemiptera			
Belostoma sp.	-	+++	+++
Order: Megaloptera			
Corydalus cornutus	-	++	++
Order: Odonata			
Boyeria grafiana	+	++	++
Epicordulia princeps	-	+++	+++
Order: Oligochaeta			
Limnodrilu shoffmeisteri	-	+++	+++
Limnodrilus profundicola	-	+	+++
Tubifex heterochaetus	-	++	++
Tubifex tubifex	-	+++	+++
Order: Bivalvia			
Corbicula fluminea	-	++	+++
Elliptio complanata	-	++	++
Order: Plecoptera			
Eccoptura xanthenes	-	++	++
Haploperla brevis	-	-	++
Order: Trichoptera			
Micrasema bennetti	+	+	+++
Molanna blenda	-	++	++
Total number of species present	7	30	34

'+++' Very Common; '++' Common; '+' Rare; '-' Not detected

Status of Flora and fauna: The recorded floral and faunal conditions of the oil contaminated areas and uncontaminated areas have been presented in Table 6.

During the period of study it was observed that some flora and fauna were affected by oil pollution in many different ways (Table 6). Most of the seedlings of mangrove plants and 'saline water lily' of the intertidal zones were covered by oil and they were being decomposed (Table 6). Pneumatophores and most of the seeds of the Sundri plant were found to be oil covered; more than 90% embryos of the seeds were decomposed resulting the inhibition of their germination. Whereas, almost 100% embryos of the Sundri seeds were found in good condition in the uncontaminated areas (west SRF). In the Sundarbans, three species of macro red algae (*Catenella* sp.) were found to be attached with plant root and pneumatophores, and two species of a brown macro algae (*Colpomenia* sp.) were found to grow in small creeks as benthic form (Islam 1973 and Chowdhury 2003). Almost all of these algal flora were found in decomposed conditions in the oil affected area (Table 6).

Table 6. Floral and Faunal status of the oil contaminated and other areas of the Sundarbans.

Name of the flora and Fauna	Units	Oil Contaminated areas	Uncontaminated areas	Previous study Before Contamination	Comments
Seedling of Plants on intertidal zones	no./m^2	2-3 Most of the seedlings were covered by black oil and going to be decomposed.	9-12	12-18	
Saline water lily on intertidal zones	no./m^2	- Plant bodies were being decomposed due to oil spills.	10-14	12-22	
Fruits/Seeds of Sundri plants	no./m^2	9-14 95% seeds were covered by black oil.	10-18	10-19	Embryo of oil coated seeds were decomposed as a result seed would not be germinated

Contd.

Name of the flora and Fauna	Units	Oil Contaminated areas	Uncontaminated areas	Previous study Before Contamination	Comments
Pneumatophores (Breathing roots) of plants	no./m^2	>90% Pneumatophores were covered by black oil.	-	-	Physiological activities of these plants were affected by the oil spills
Catenella sp. (3sps.)- a red algae attached with plant roots	no./m^2	>95% were decomposed due to oil spills.	Present in good conditions	Present in good conditions	Worked as primary producer; Source of food and nutrient of the many aquatic animals
Colpomenia sp. (2sps.)- a brown macro algae grows in small creeks as benthic form	no./m^2	All were decomposed due to oil spills.	Present in good conditions	Present in good conditions	Worked as primary producer; Source of food and nutrient of the many aquatic animals
Eggs & hatchlings of different fishes i.e. Parshe, Khursula, Bagda, Harina etc.	units/l	- Totally absent (But that was the breeding season of these fishes)	1500 to 2000	2100 to 2400	Source of natural and cultivated fish production in the South-west coastal areas of Bangladesh
Mudskippers – a common intertidal zone fish	no./m^2	- Totally absent	2-4	3-7	Indicator of mangrove ecosystem and used as food by the birds, fishing cat, otter, snake and other animals.

Contd.

Name of the flora and Fauna	Units	Oil Contaminated areas	Uncontaminated areas	Previous study Before Contamination	Comments
Mud Crabs (Kakra) (4sps.) – a common intertidal zone Crustacea	no./m^2	- Totally absent (Found dead and decomposed bodies)	2-4	3-7	Indicator of mangrove ecosystem and used as food by the birds, crocodiles and other animals.
Snails (Shamuk) (10 sps.) – a common intertidal zone Mollusk	no./m^2	- Totally absent (Found dead and decomposed bodies)	8-14	9-17	Indicator of mangrove ecosystem and used as food by the fishes, birds, crocodiles and other animals.
Fishes – common fishes of the river Shela, canals, creeks etc.	No of species	10-14 species	27-33 species	31 - 43 species	Major aquatic resource of the Sundarbans
Frogs (2sps.) – intertidal zone of the river Shela & canals are the habitats	Study period	Six dead and five black oil covered Frogs were observed in the study period	Many Frogs were observed in the intertidal zones	Unlimited Frogs were observed in the study area	Common Amphibian of the Sundarbans
Snakes	Study period	4 dead snakes were observed in the study period	Two Snakes were observed due to winter season	Different types of Snakes were observed in the Sundarbans	Vey Common Reptile of the Sundarbans
Monitor Lizards (3 sps.) –	Study period	One dead and two black oil	16 Monitor Lizards of 3	21- 27 Monitor	Common reptiles of

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Name of the flora and Fauna	Units	Oil Contaminated areas	Uncontaminated areas	Previous study Before Contamination	Comments
intertidal zone of the Shela river & canals are the habitats		covered monitor lizards were observed in the study period	different species were observed	lizards of 3 different species were observed in the study area	the Sundarbans
Crocodile – common animal of the Shela river and connected canals	Per day/ study period	Only oil coated two crocodiles were observed in the study period	2-4 crocodiles were observed in a day	3-6 crocodiles were observed in a day	Threatened species and Indicator of the mangrove ecosystem
Intertidal Bird (Masked finfoot) - intertidal zone of the Shela river & canals are habitat	Study period	No Masked finfoot bird was observed in the study period	No Masked finfoot was observed	21 Masked finfoot birds were observed in the study area	Worldwide Threatened species and only the mangrove bird
Common Birds (Heron, Kingfisher etc. - common animal of the Shela river and connected canals	Study period	Only 17 oil affected birds (Heron) were observed in the study period	34 types Birds were observed	56 types of Birds were observed	Common animals of the mangrove ecosystem
Ban Morog (Birds) - common beside the Shela river and connected canals	Study period	No Ban Morog was observed in the study period	7 Ban Morog were observed	Ban Morog was available	Common bird of the mangrove ecosystem
Migratory Birds – intertidal zone of the Shela river & canals are habitats	Study period	No Migratory bird was observed in the study period	Few migratory birds was observed	Many Migratory birds were observed in the study area	The Sundarbans is the habitat of the Migratory birds; It was the

Contd.

Name of the flora and Fauna	Units	Oil Contaminated areas	Uncontaminated areas	Previous study Before Contamination	Comments
					time of migratory birds
Fishing cat	Study period	Only one dead Fishing cat was observed in the study period	Foot mark of fishing cat were observed in the intertidal zones	Many foot marks of fishing cat were observed in the study area	Common animal of the Sundarbans
Otter – intertidal zone of the Shela river & canals are the habitats	Study period	2 dead and 1 black oil covered Otter were observed in the study period	Foot/ Pug Marks of Otter were observed in the intertidal zones	Unlimited Foot Marks of Otter were observed in the study area	Threatened animal in the main land but a common animal of the Sundarbans
Dolphins - common animal of the Shela river and connected canals	no./hour	No dolphin observed in the oil contaminated areas	5-10 times movements were observed in a hour	7-12 times movements were observed in a hour	Threatened species and indicator of the mangrove ecosystem
Deer – beside the Shela river & connected canals	Study period	No deer was observed in the study period	Deer was Available in the study area	Unlimited deer were observed in the study area	Common Animal of the Sundarbans
Wild Boar – beside the Shela river & connected canals	Study period	No Wild Boar was observed in the study period	Wild Boars were observed in the study area	Unlimited Wild Boars were observed	A Common Animal of the Sundarbans

'-' Not detected

During study period 10 to 14 species of fishes were recorded in the oil contaminated areas, but 27 to 33 fish species were recorded in the unpolluted areas (Table 6). No eggs and hatchlings of commercially valuable fishes like Parshe (*Liza* spp.), Khorsula (*Mugli*

spp.), Bagda shrimp (*Penaeus monodon)* etc. were found in the oil polluted areas, although the time of the study was the breeding season for those fishes, whereas 1500 to 2000 units/l of eggs and hatchlings of those fishes were recorded in the unpolluted areas (West SRF). Chowdhury (2011) had recorded 2001 to 2400 units/l of eggs and hatchlings of these fishes in the Sundarbans. Present study indicates that the oil spill posed profound threat for the eggs and hatchlings of different fishes. During the period of study it was found that mudskippers, mud crabs, and snails were totally absent on the intertidal zones of oil polluted areas; frogs, snakes, monitor lizards, otter and fishing cat were found dead and oil coated in the oil contaminated areas, whereas these faunal species were in normal conditions in the unpolluted areas of the Sundarbans (Table 6). Seventeen oil affected birds (Heron) were observed in the oil affected areas in the study period but no migratory bird was seen in that time. In the period of study any dolphin, crocodile, Maskedfinfoot (worldwide vulnerable mangrove bird), wild boar and deer were not recorded in the oil contaminated river, canals, creeks etc. and their intertidal zones and *char Islands*. Chowdhury (2003, 2011) and IUCN (2001) had recorded dolphins, crocodile, Maskedfinfoot, migratory birds, wild boar, deer etc. in and around the river Shela and its connected canals and creeks.

The mangrove communities show striking zonation pattern as their spatial distribution is highly correlated with physico-chemical factors (Alongi 2002). Lewis (1983) and Kingston (2002) had mentioned that the fine grained aerobic sediments reduce the rate of microbial breakdown rate of oil. In addition, the burrowing activities of crustaceans can lead to persistent and high level contamination in the root zone (Lewis 1983). As a result, the long-term impacts are generally confined to community structure anomalies (Kingston 2002). Thus, it is evident that the oil spill in the Sundarbans mangrove has potential threat on its ecosystem.

Based on the data of the present investigation and conditions of the study areas like physico-chemical attributes of water and soil it may be concluded that floral and faunal status of the intertidal zones and the forest floor besides the river Shela and connected canals, creeks of the Sundarbans had been contaminated by the furnace oil. According to Islam (1982 and Islam 1997), Karim (1988), Hussain and Acharya (1994), Nazrul-Islam (1995), Jahan *et al*. (2000), IUCN (2001), Chowdhury (2003) and Hossain (2014) this areas were free from this type of oil pollution. Floral and faunal status indicate that primary producer, consumer and some aquatic animals and some plants and their habitats had been affected by the oil pollution. It is a natural habit of crocodile to prepare their hatchling house besides the rivers, canals and creeks during the month of April- May (IUCN 2001). But due to oil contamination besides the river, canals and creeks crocodiles may not be able to prepare their hatchling house in these areas to lay and hatch their eggs. As a result crocodile may migrate from their own habitats and face territory conflict and ultimately crocodile's population would be affected.

More than 500 km^2 areas out of the total study area (more than 1200 km^2) had been affected seriously by the oil spills contamination (Plate 2). Regeneration of the Sundri trees, population, habit and habitats of mudskippers, mud crabs, snails, monitor lizards, intertidal zone birds (world endangered bird 'Masked finfoot'), common birds, fishing cat, otter, dolphins and crocodile were affected due to contamination of the oil spills hazards of 9th December 2014.

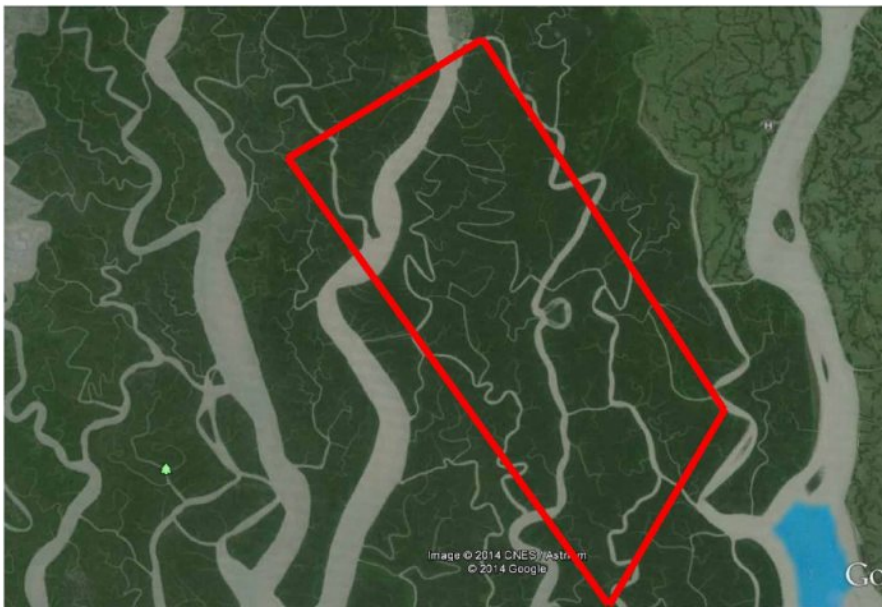

Plate 2. More oil contaminated areas of the eastern SRF.

So oil spill contention is a matter to be concerned and long term monitoring and in depth and multidimensional research are necessary to find out the detail information on the long term impact of oil pollution and self recovery capacity of ecosystem of the Sundarbans. Similarly the rules and regulations of international conventions like Ramsar, UNESCO Natural Heritage Site, Convention of Biological Diversity etc. must be implemented properly and a national and international commitment is necessary to stop all kinds of activities which may create this type of the problem for the fragile ecosystem of the Sundarbans.

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