

Table of Contents

1	What is a tidal flat?	1
1.1	Introduction	1
1.2	Function and structure of natural and man-made tidal flats	2
1.2.1	Pysico-chemical characteristics	2
1.2.2	Hydraulic characteristics	5
1.2.3	Biomass of bacteria and macrobenthos	5
1.2.4	Respiration rates of microorganisms	8
1.2.5	Discussion	8
1.3	Key factors to determine a tidal flat characteristic	10
1.3.1	Transfer experiments	10
1.3.2	Relationship between silt content and bacterial population	12
1.4	Fluid flow on a tidal flat	15
1.4.1	Outline of study sites	15
1.4.2	Shear stress	16
1.4.3	Sedimentation of sand	18
1.4.4	Discussion	20
2	Effects of waves and tide on tidal flat ecosystems	23
2.1	Introduction	23
2.2	Method of experiments on internal flow in seabed	24
2.2.1	Flow visualization inside sandy beach	24
2.2.2	Wave and tide control	25
2.2.3	Quantification of seawater infiltration in sandy beach	25
2.3	Role of wave and tide on seawater infiltration in sandy beach	26
2.3.1	Fresh seawater infiltration	26
2.3.2	Silt movement by wave action	28
2.4	Role of wave and tide on ecosystems in tidal flats	29
2.4.1	Measurement of seawater infiltration in tidal flat	29
2.4.2	Observation of benthic organisms in tidal flat simulators	32
2.5	Concluding remarks	38

3	Unified model for wave breaking action	41
3.1	Introduction	41
3.2	Mathematical model	42
3.2.1	Notations and geometry	42
3.2.2	Conservation of mass for total flow system	44
3.2.3	Conservation of momentum for total flow system	44
3.2.4	Surface blocking effect to seawater due to accumulated materials on the beach	45
3.3	Unified model for two-phase flow with surface blocking effect	46
3.4	Numerical results	47
3.4.1	Correlation between wave breaking action on a sloping beach and internal flow of a sandy beach	47
3.4.2	Flow pattern and infiltration area of seawater in sandy beach	48
3.4.3	Time averaged flow under the beach	50
3.4.4	Surface blocking effect to seawater	51
4	Oil pollution: human damages on hydraulic regime in sandy beach ecosystems	53
4.1	Introduction	53
4.2	Infiltration of stranded oils into sandy beach sediments by waves and tides	54
4.2.1	Waves and Tides	54
4.2.2	Volume of stranded oils	57
4.2.3	Tidal Cycles and temperature	57
4.2.4	Viscosity of oil	58
4.2.5	Weathered and dispersed oils	60
4.3	Effects of the penetrated oils into sandy beach sediments on seawater infiltration by waves	65
5	Theoretical study of oil pollution	71
5.1	Introduction	71
5.2	Behavior of spilled oil in the surfzone	71
5.3	Mathematical model	72
5.3.1	Notations and geometry	72
5.3.2	Conservation of mass for a total flow system	73
5.3.3	Conservation of momentum for a total flow system	74
5.3.4	Unified equations of motion for a three-phase flow	75
5.3.5	Adhesive phenomena of oil on a sandy beach	76
5.4	Unified model for three-phase flow with adhesion	76
5.5	Numerical results	78
5.5.1	Process of drifting ashore of spilled oil	78
5.5.2	Deformation of oil	81
5.5.3	Adhesion and sliding phenomena between oil and water in a sandy beach	81

5.5.4	Infiltration phenomena of oil into a tidal flat or sea bed due to the tidal motion	86
5.5.5	Blocking effect by penetrated oil on the internal flow in sand	86
6	Oil pollution: human damage on hydraulic regime and benthic communities in tidal flat ecosystems	93
6.1	Introduction	93
6.2	Penetration of stranded oils into tidal flat sediments by tides ..	95
6.3	Effects of the penetrated oils into tidal flat sediments on seawater infiltration by tides	97
6.4	Effects of oil spill on seawater infiltration and macrobenthic community in tidal flats	100
6.4.1	introduction	100
6.4.2	The tidal flat simulator	101
6.4.3	Effects of oil spill on tidal flat ecosystem	105
6.4.4	Macrobenthic community	106
7	Decomposition mechanism of spilled oil by bacteria	109
7.1	Introduction	109
7.2	Notations	109
7.3	Characteristics of oil decomposition into water	110
7.3.1	Reactivity condition	111
7.4	Incompressibility condition for a total flow system	111
7.5	Biological contribution to satisfy reactivity condition	112
7.6	Unified model for three-phase flow with decomposition	113
7.7	Numerical results	114
8	Breaking waves and ecosystem dynamics	117
8.1	Introduction	117
8.2	Mathematical modeling	117
8.2.1	Mathematical description of aeration due to breaking waves	117
8.2.2	Modeling for ecosystem dynamics	120
8.3	Coupling scheme between waves and ecosystem dynamics ..	121
8.4	Numerical results	122
8.4.1	Aeration due to breaking waves	122
8.4.2	Simulation of ecosystem dynamics	122
9	Methodologies for theoretical studies	127
9.1	Introduction	127
9.2	Mathematical methodologies	127
9.2.1	Distribution theoretic approach to multi-phase flow	127
9.2.2	Anti-smearing device for numerical free surface	134
9.3	Numerical methodologies	135

9.3.1	Discretized model for the total system	135
9.3.2	Two-phase free surface flow with large density difference	137