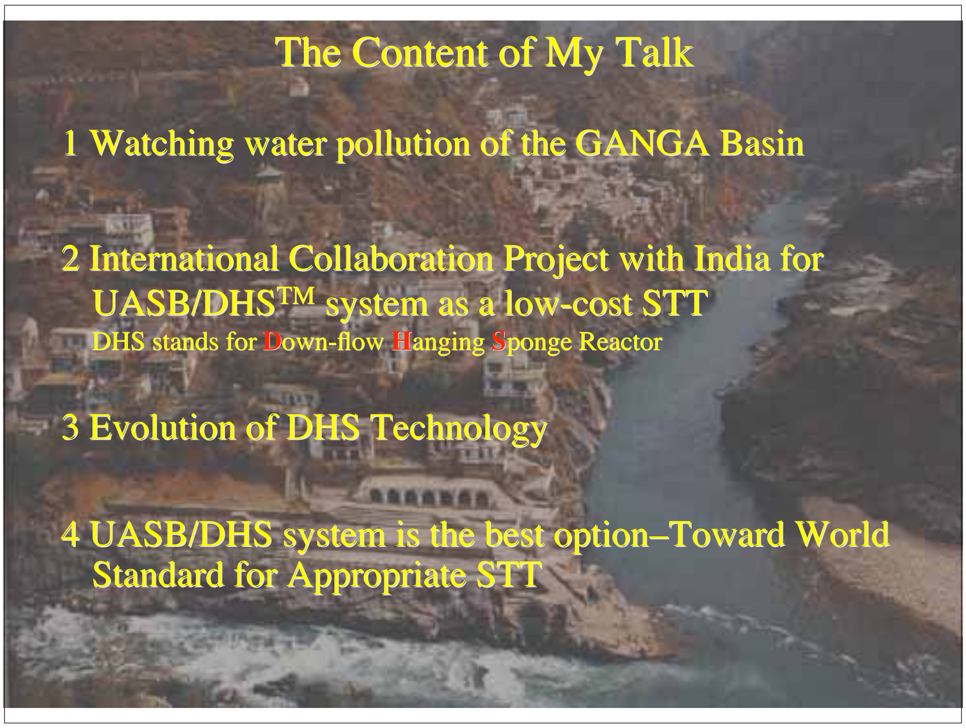
India-Japan International Collaboration for an Innovative Sewage Treatment Technology with Cost-effective and Minimum Energy Requirement

Hideki HARADA
Dept. of Civil & Environ. Eng., Tohoku University, Japan
Previously Nagaoka Univ. of Technology


Asian Science and Technology Seminar (ASTS) in Thailand, 9-11 March, 2008



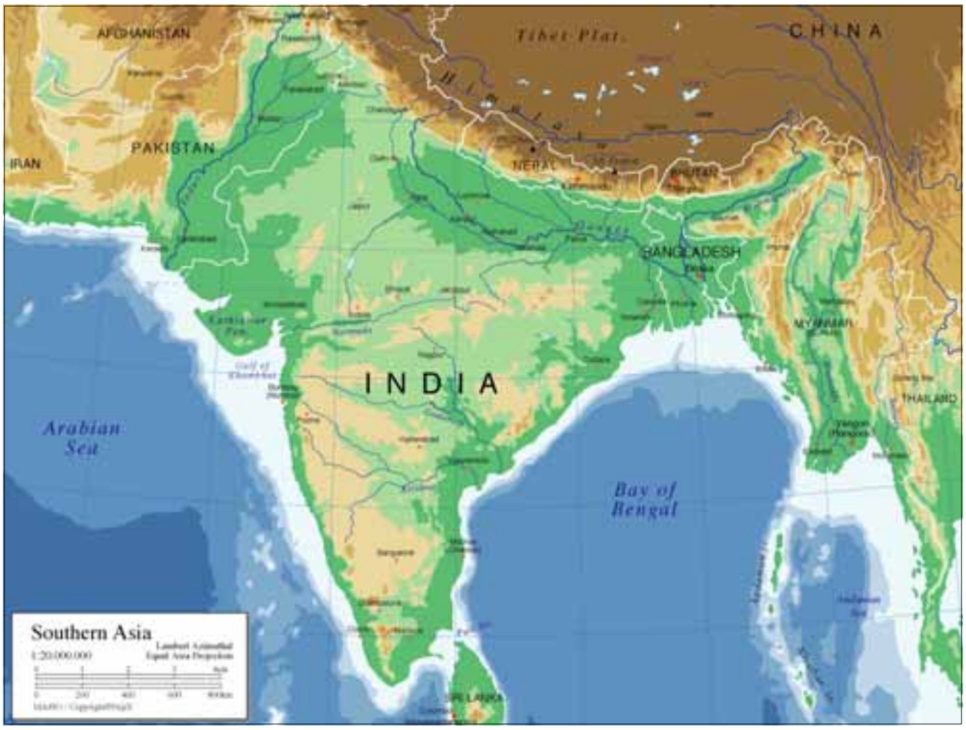
The Content of My Talk

1 Watching water pollution of the GANGA Basin

2 International Collaboration Project with India for UASB/DHS^{TM} system as a low-cost STT
DHS stands for Down-flow Hanging Sponge Reactor

3 Evolution of DHS Technology

4 UASB/DHS system is the best option–Toward World Standard for Appropriate STT


AFGHANISTAN
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Bay of Bengal
SRI LANKA
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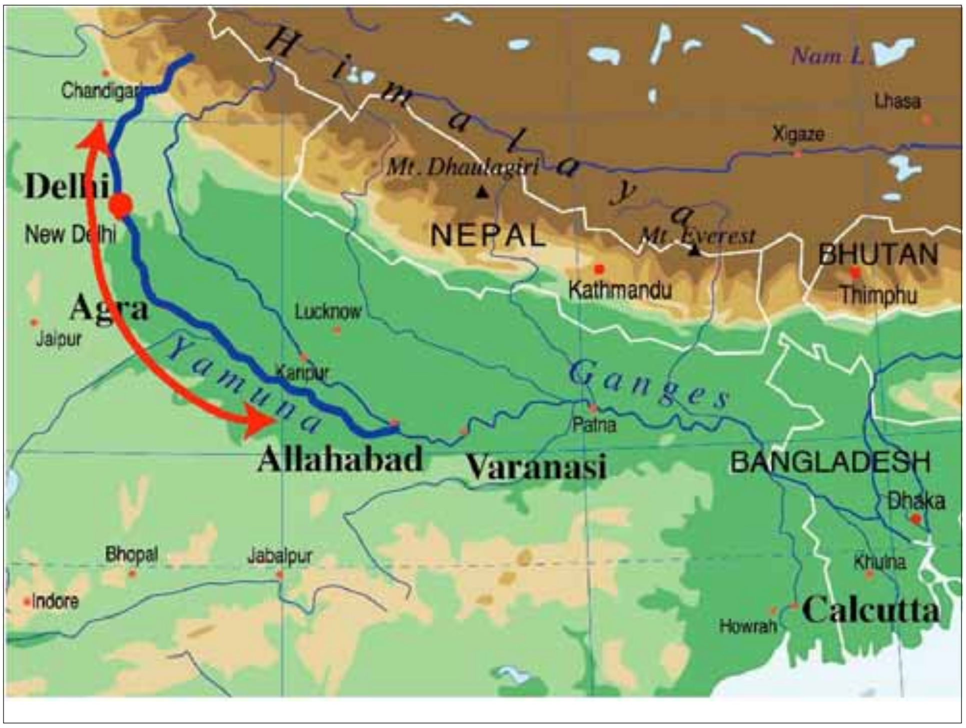
Himalaya
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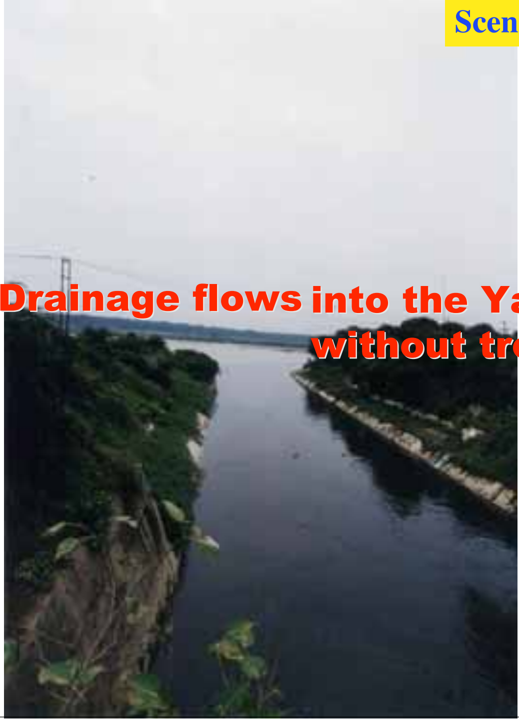
Thimphu
Agra
Jaipur
Lucknow
Yamuna
Kanpur
Ganges
Patna
Allahabad
Varanasi
BANGLADESH
Dhaka
Bhopal
Jabalpur
Khulna
Indore
Howrah
Calcutta


Scene 3: Delhi, India
Urban Drainage

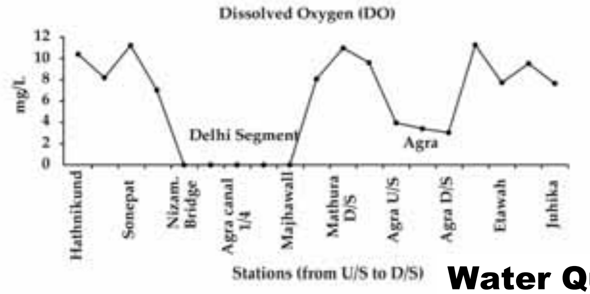

Scene 3: Delhi, India
Urban Drainage flows

Scene 4: Delhi, India



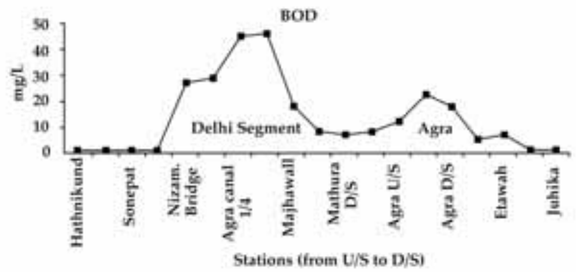
Urban Drainage flows into the Yamuna without treatment

Pollution of the YAMUNA RIVER, DO and BOD

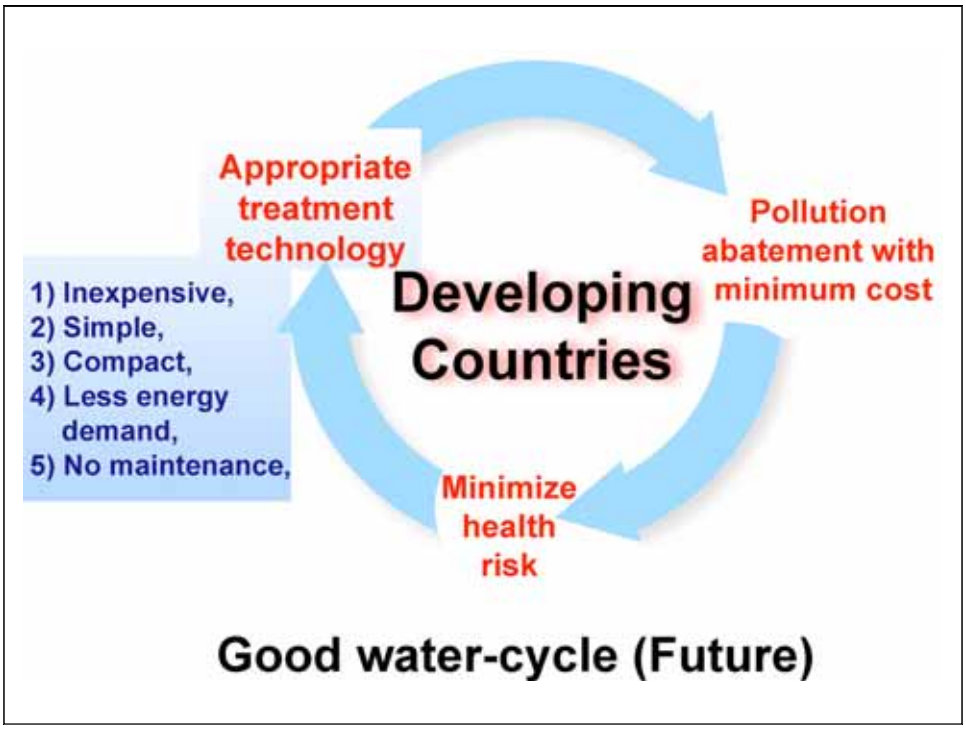


DO>5mg/L

Water Quality Standard for Bathing



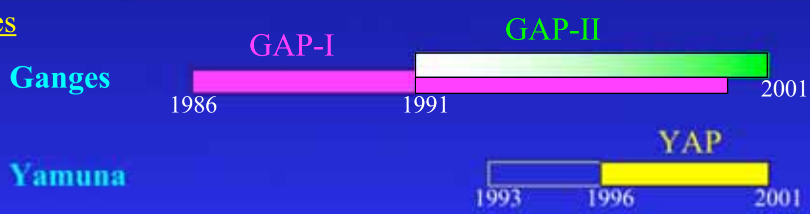
BOD<3mg/L



Ganga Action Plan (GAP), then Yamuna Action Plan (YAP)

Started : 1986 (5 year plan, later extended)

Phases



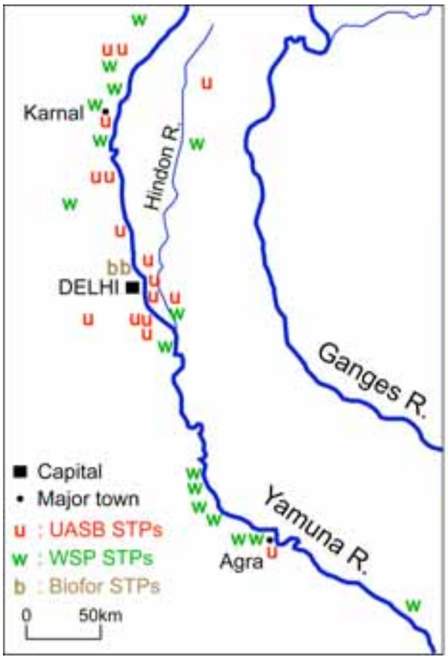
Actions

- Construction of sewage treatment plants (STP)
- Public Toilets
- Crematoria
- River Front Facility (Bathing ghats)
- Industrial pollution- Control by existing environmental law
- Agricultural source- by concerned ministry (reduce pesticides)
- Biological Regeneration

From GAP to YAP, from ASP to UASB

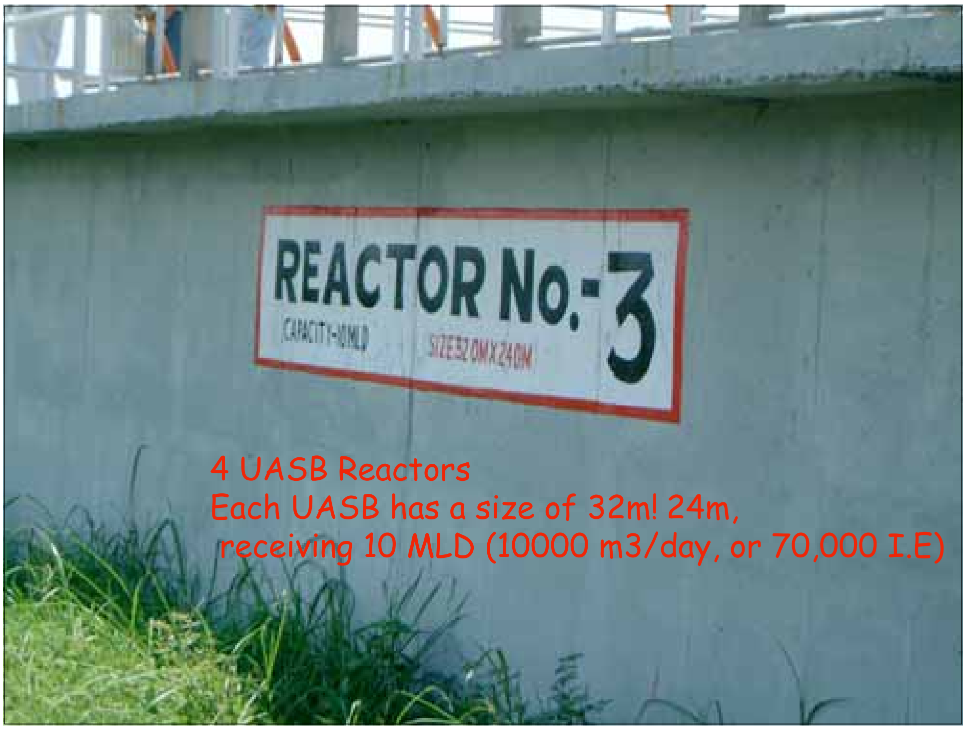
Type of Treatment Systems	GAP-1 No. of Plants constructed	YAP No. of Plants constructed
Activated Sludge Process (ASP)	17 →	0
Oxidation Pond (OP) (Stabilization Pond)	14	9
Upflow Anaerobic Sludge Blanket (UASB)	3 →	16

Abandoned Activated Sludge Plant

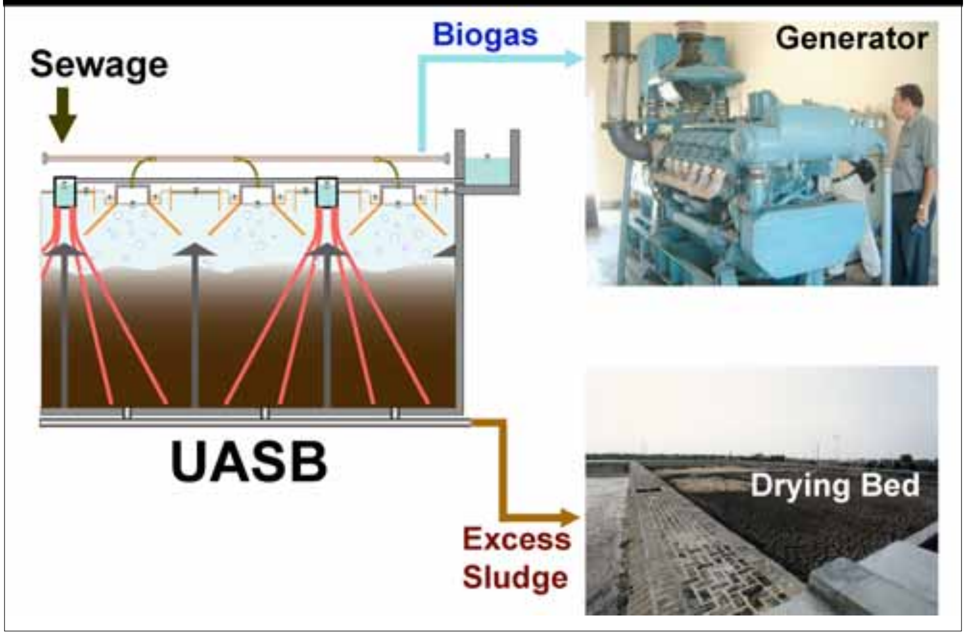


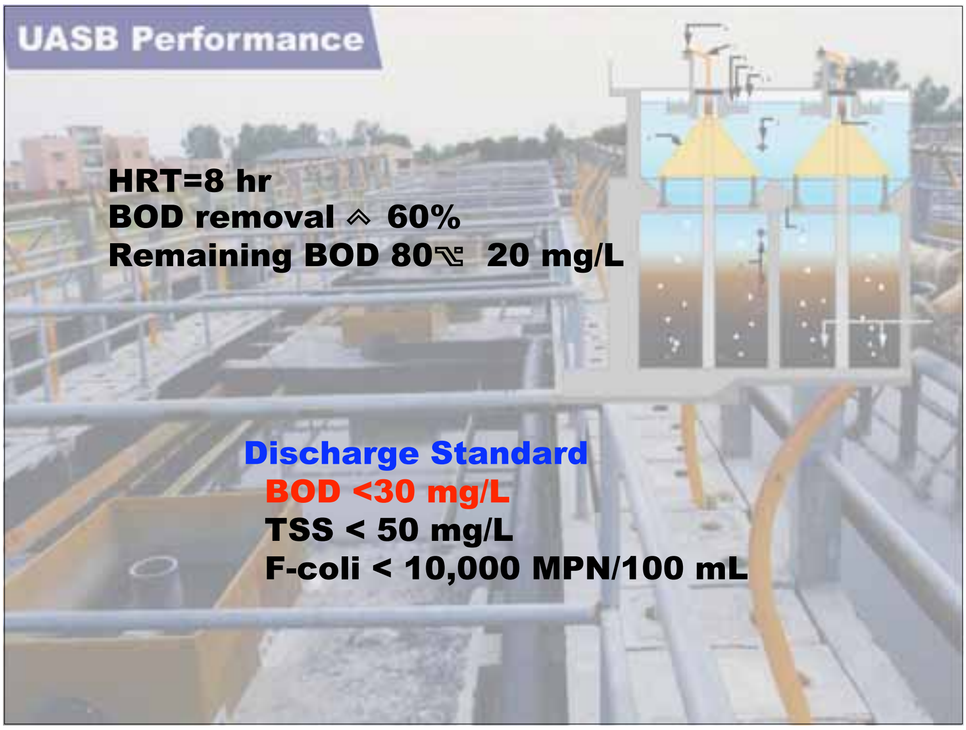
UASB and Waste Stabilization Pond constructed under Yamuna Action Plan

Process	No of STPs	Capasity (m^3/d)
UASB	16	598,000
WSP	9	103,000
Biofor	2	20,000
Total	27	721,000



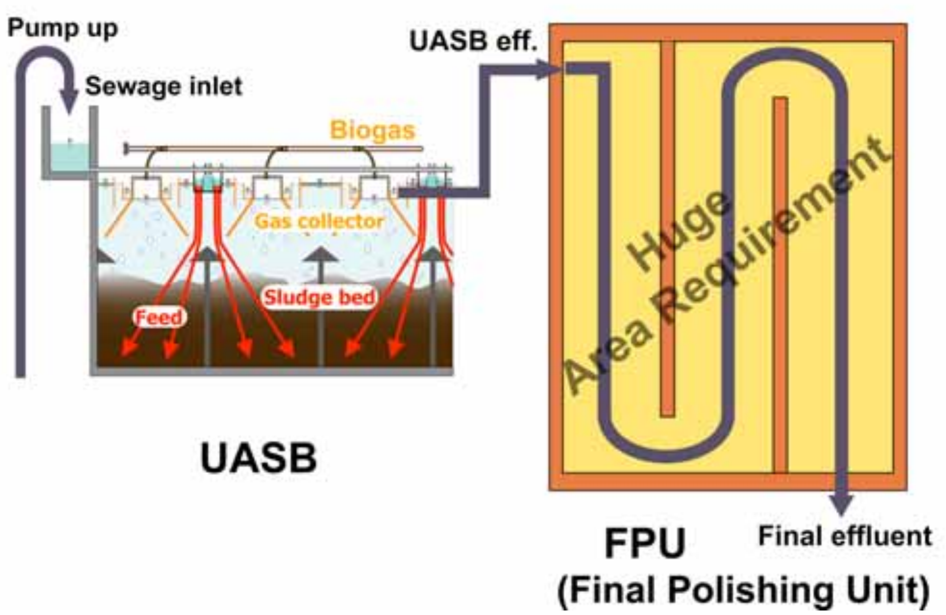
Fate of Byproduct, Biogas and Excess Sludge




UASB Performance
HRT=8 hr
BOD removal ≈ 60%
Remaining BOD 80→ 20 mg/L
Discharge Standard
BOD <30 mg/L
TSS < 50 mg/L
F-coli < 10,000 MPN/100 mL

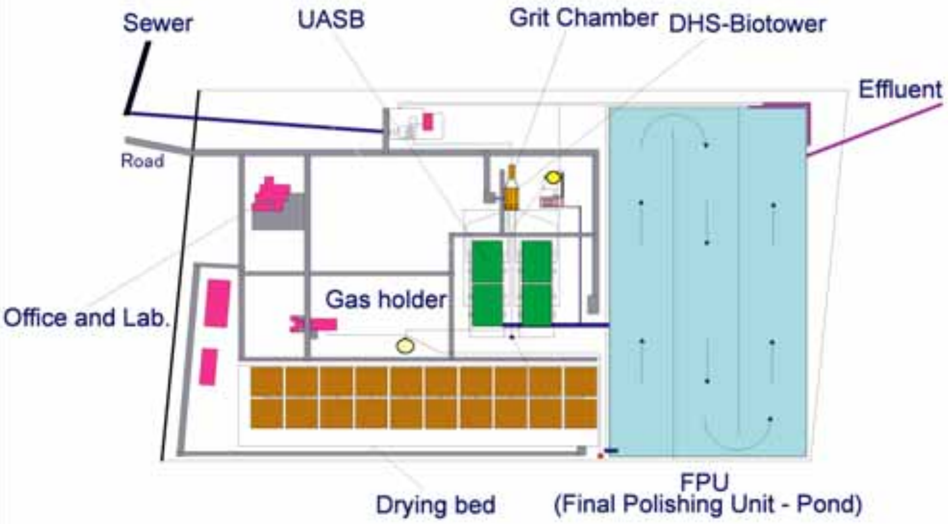

UASB effluent is introduced to 1 day HRT of Final Polishing Unit FPU (stabilization pond).
Polishing pond is working as an algae growth pond.

Indian existing system

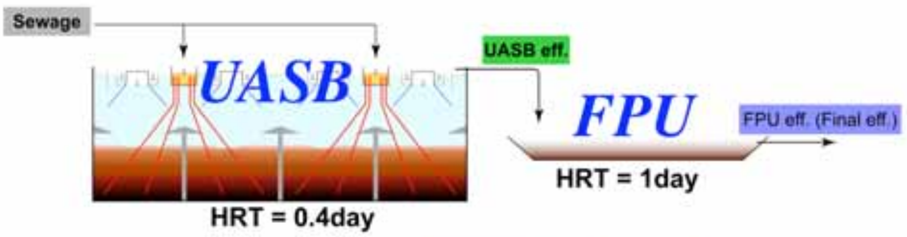


Karnal STP layout

40 MLD Capacity



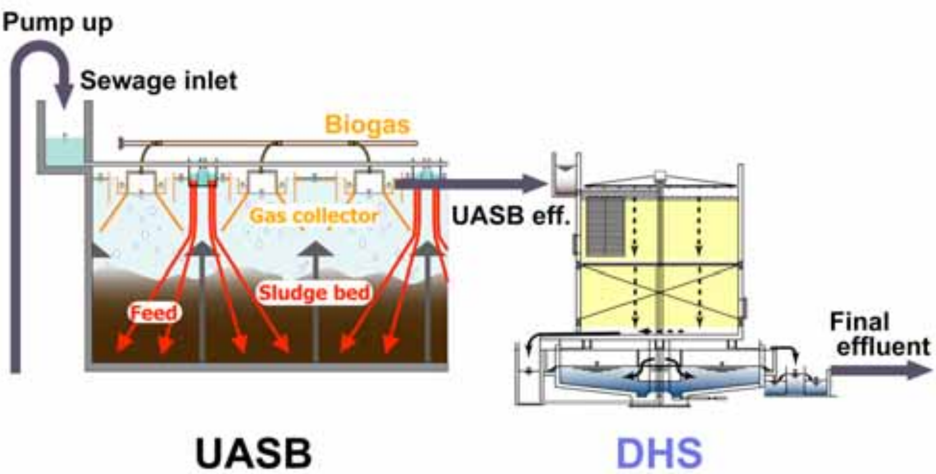
UASB + FPU Performance



BOD (mg/L)	Sewage	UASB eff.	FPU eff.	BODt. rem. (%)
Panipat 35MLD	196	131	116	41
Faridabad 45MLD	318	111	98	69
Faridabad 50MLD	365	179	154	58
Gurgaon 30MLD	318	154	104	67
Ghaziabad 70MLD	293	151	85	71
Agra 78MLD	264	126	64	76

Harada et al (2005), Jour. of Environ. Management

Our proposed system



Combination of UASB and DHS

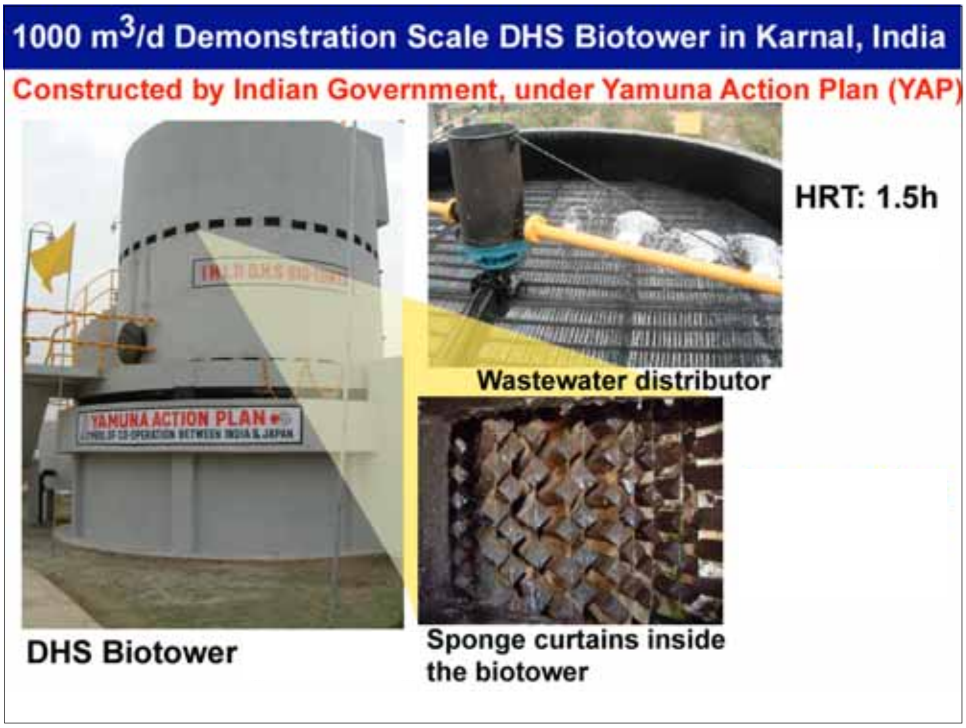
Proposed system

(1) Low-cost,
(2) Simple,
(3) compact,
(4) Energy Thrifty,
(5) Easy O & M,
(6) techno-economically feasible

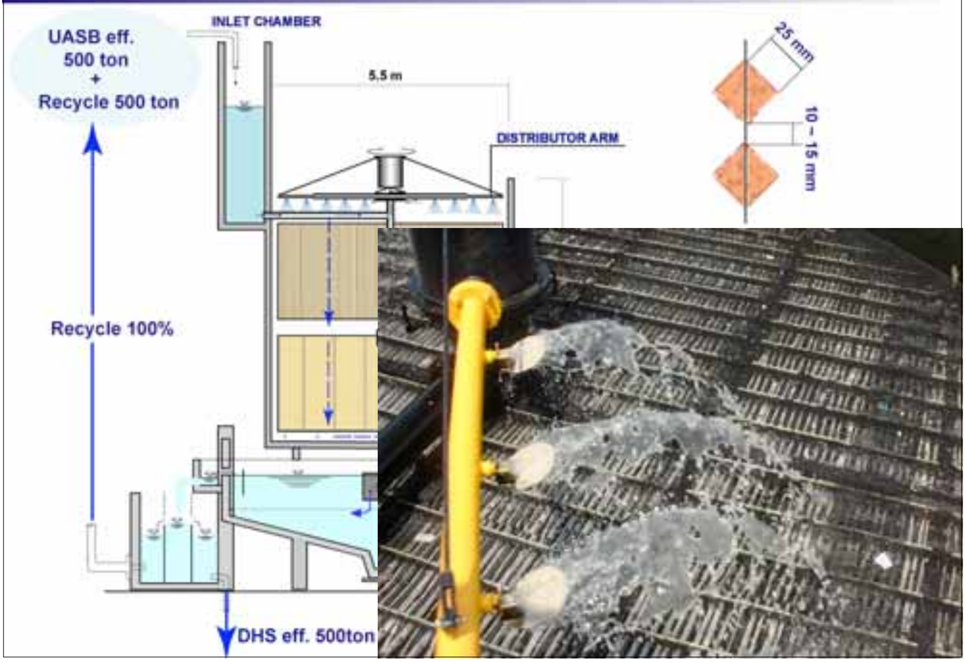
(Down-flow Hanging Sponge- reactor)

DHS reactor under construction, December 2001,
at Karnal, India


LONG LIVE INDO JAPANESE FRIENDSHIP
INAUGURATION
OF
1 MLD D.H.S. BIO-TOWER KARNAL
CONSTRUCTED UNDER YAMUNA ACTION PLAN
BY
PUBLIC HEALTH DEPARTMENT HARYANA
PERFORMED BY
Prof. Dr. H. HARADA
IN THE PRESENCE OF
Sh. KAZUTO TSUJI
(CHIEF REPRESENTATIVE, J.B.I.C.)
ON 24th APRIL 2002


1000 m3/d Demonstration Scale DHS Biotower in Karnal, India
Constructed by Indian Government, under Yamuna Action Plan (YAP)
HRT: 1.5h
Wastewater distributor
YAMUNA ACTION PLAN
DHS Biotower
Sponge curtains inside the biotower

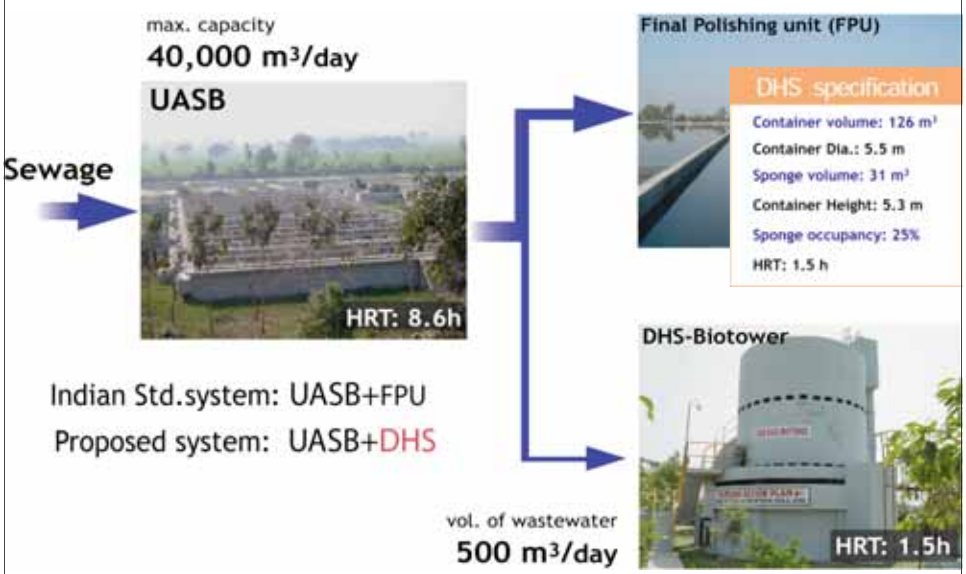
DHS - Biotower



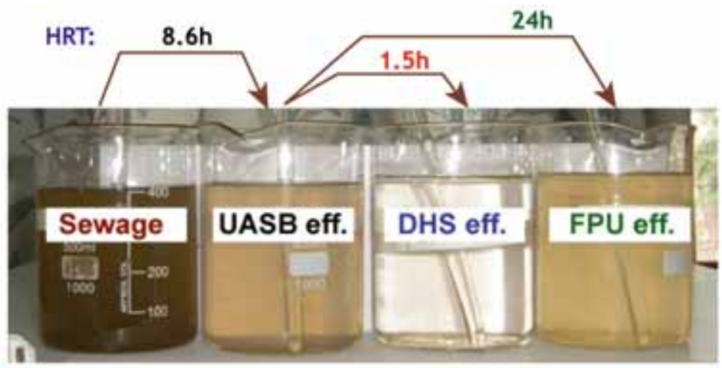
Sending Graduate-students to Karnal STP site since Oct. 2002

Fuel is, of course, cow-dung

Put into curry-pot

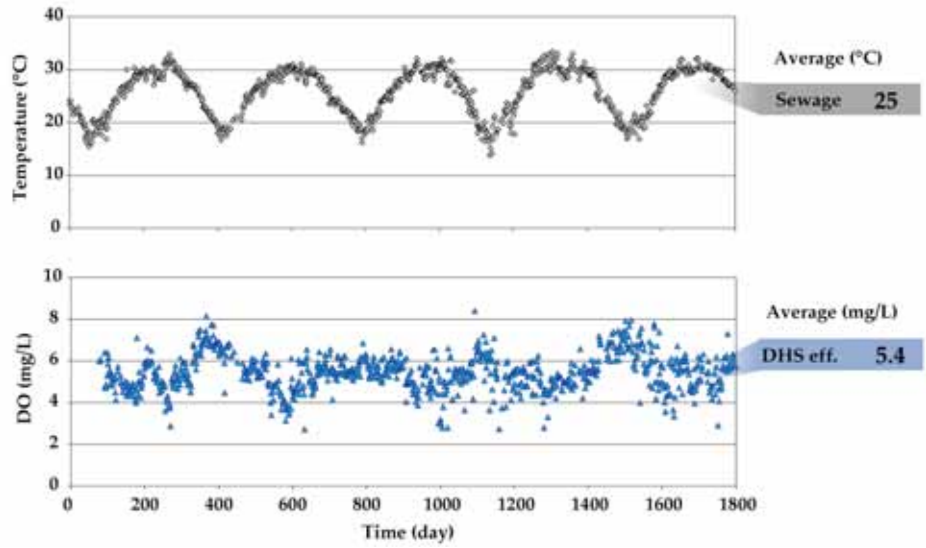


Overall Summary Result of 5-ys non-stop operation

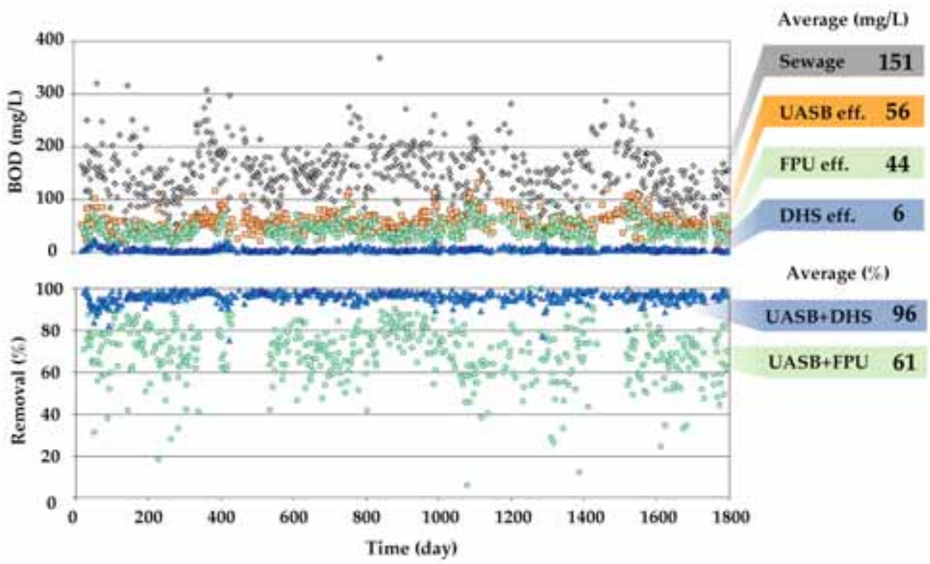


	Sewage	UASB	UASB+DHS	UASB+FPU
Total BOD (mg/L)	152	53	6 (96%)	41
Total COD (mg/L)	436	172	31 (92%)	137
SS (mg/L)	235	50	13 (94%)	47
F.coli (MPN/100ml)	8.9×10^6	5.6×10^6	1.6×10^5 (2log10)	1.8×10^6
NH4-N (mg/L)	24	25	5 (79%)	24
DO	0	0	5.4	-

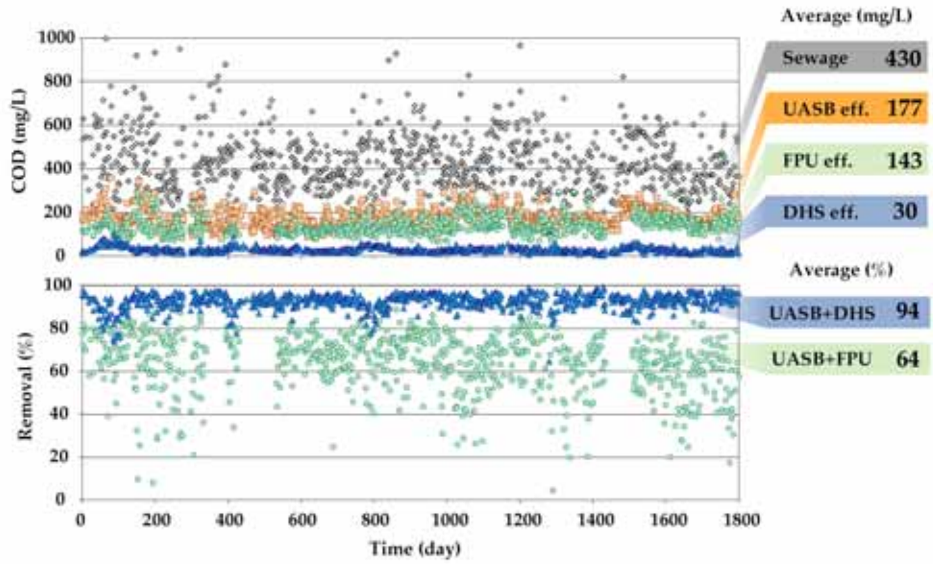
Time course of temperature and DO



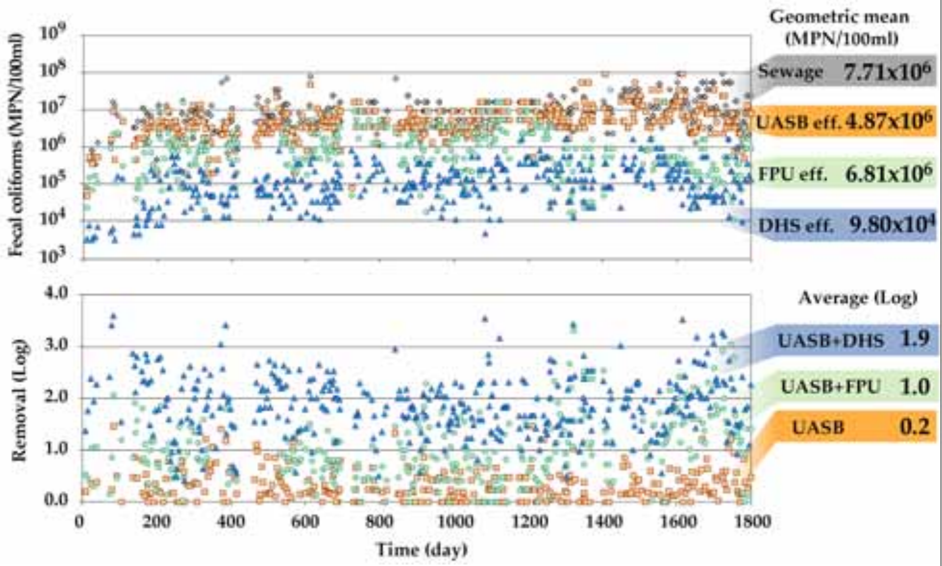
Time course of BOD



Time course of COD



Time course of Fecal coliforms

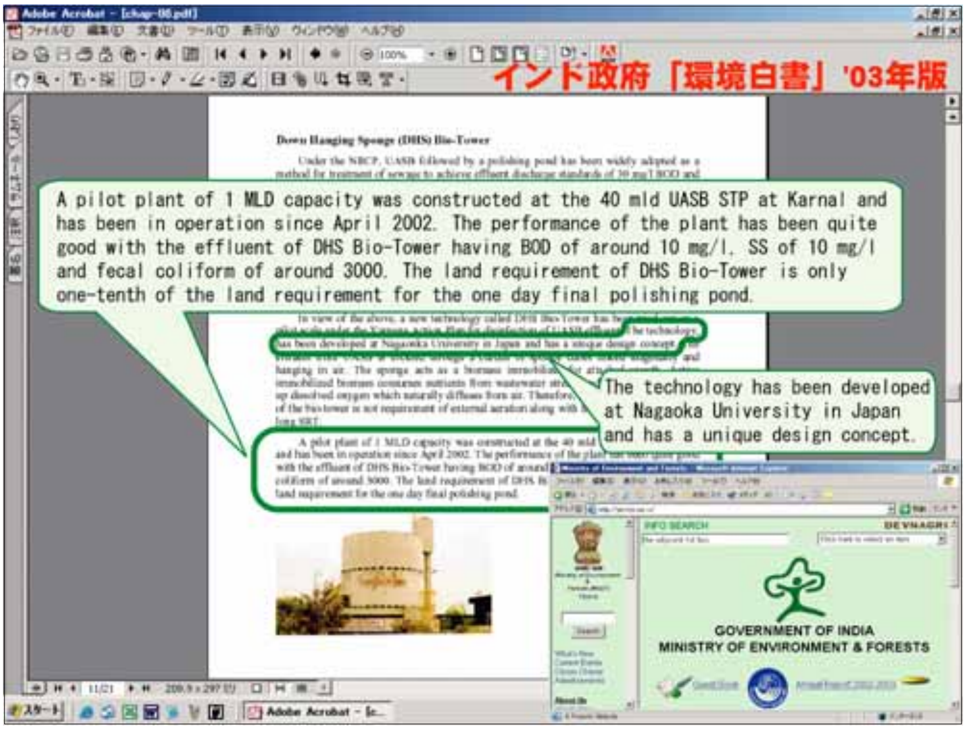


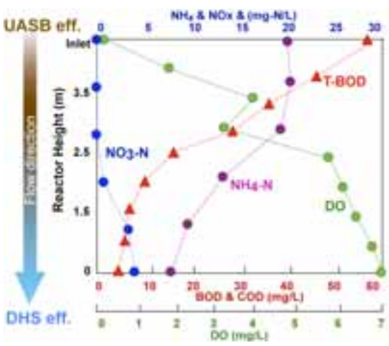
Summary

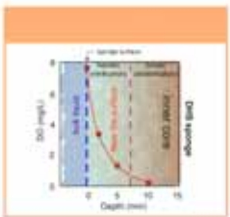
	Raw sewage influent	UASB effluent	DHS effluent	Polishing pond effluent
	average	average	average	average
pH	7.20 (0.17)	7.04 (0.14)	7.87 (0.15)	7.32 (0.28)
DO, mg/L	-	-	5.2 (1.1)	0.5 (1.6)
BOD-total, mg/L	151 (48)	56 (19)	6 (4)	44 (16)
COD_{Cr}-total, mg/L	430 (129)	177 (44)	30 (13)	143 (41)
COD_{Cr}-soluble, mg/L	143 (45)	86 (20)	19 (10)	64 (22)
Fecal coli., MPN/100mL	7.71 x 10[illegible]	4.87 x 10[illegible]	9.80 x 10[illegible]	6.81 x 10[illegible]
NH_4-N, mg/L	25 (7)	26 (8)	6 (5)	25 (9)
NO_3-N, mg/L	ND	ND	5 (3)	ND
SS, mg/L	228 (91)	53 (20)	13 (5)	48 (26)
Temperature, °C	15-33			
Flow rate, MLD	26.3			
Removal		UASB	UASB + DHS	UASB + FPU
BOD-total, %		63 (13)	96 (3)	69 (13)
COD_{Cr}-total, %		58 (14)	94 (4)	64 (15)
Fecal coli., log_{10}		0.2	1.9	1.0
NH_4-N, %			79 (15)	9 (25)
SS, %		74 (12)	93 (6)	75 (23)

General Advantages of DHS post-treatment System

- No need of External Aeration, much less energy requirement
- No clogging, no back-washing, no laborious maintenance
- Much less amount of Excess Sludge
- Less Area Requirement
- High Performance at equivalent HRT to Activated Sludge Process

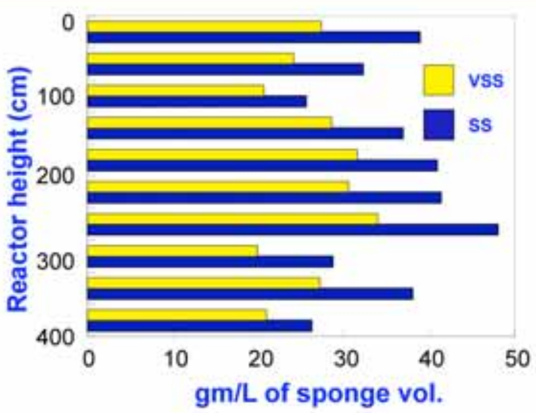

インド政府「環境白書」'03年版
Down Hanging Sponge (DHS) Bio-Tower
A pilot plant of 1 MLD capacity was constructed at the 40 mld UASB STP at Karnal and has been in operation since April 2002. The performance of the plant has been quite good with the effluent of DHS Bio-Tower having BOD of around 10 mg/l, SS of 10 mg/l and fecal coliform of around 3000. The land requirement of DHS Bio-Tower is only one-tenth of the land requirement for the one day final polishing pond.
The technology has been developed at Nagaoka University in Japan and has a unique design concept.
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT & FORESTS

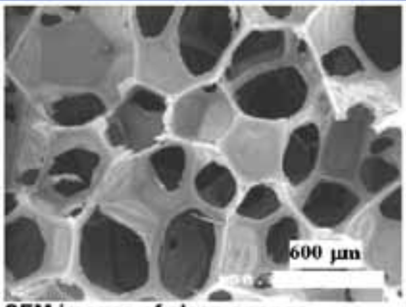

UASB eff.
DHS eff.
Inlet
Reactor Height (m)
NH4 & NOx & (mg-N/L)
BOD & COD (mg/L)
DO (mg/L)
T-BOD
NO3-N
NH4-N
DO




Sludge in DHS sponge

Retained Sludge in DHS Sponge



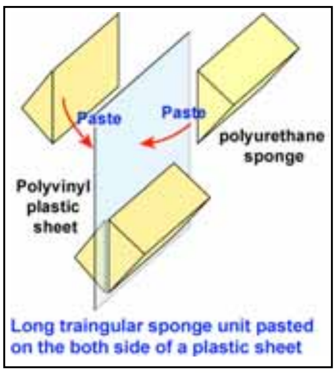


SEM images of clean sponge

SEM images of entrapped sludge

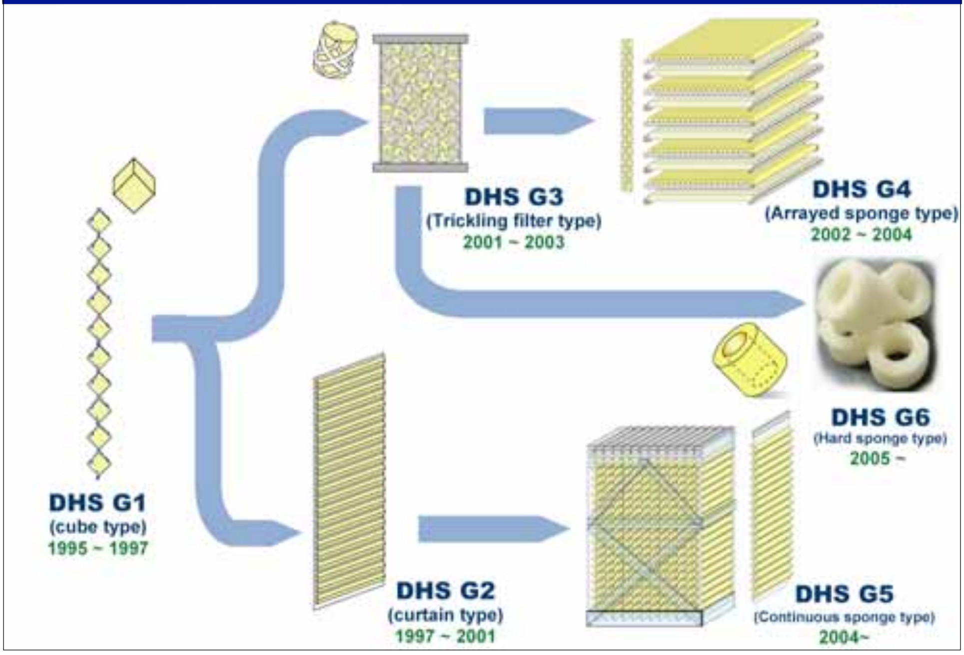
Average retained sludge in the reactor:
26 gm-VSS/lit. of sponge vol.
Calculated SRT:
76 days.
Negligible amount of excess sludge

DHS concept



No need of
External aeration input

Evolution of DHS Process



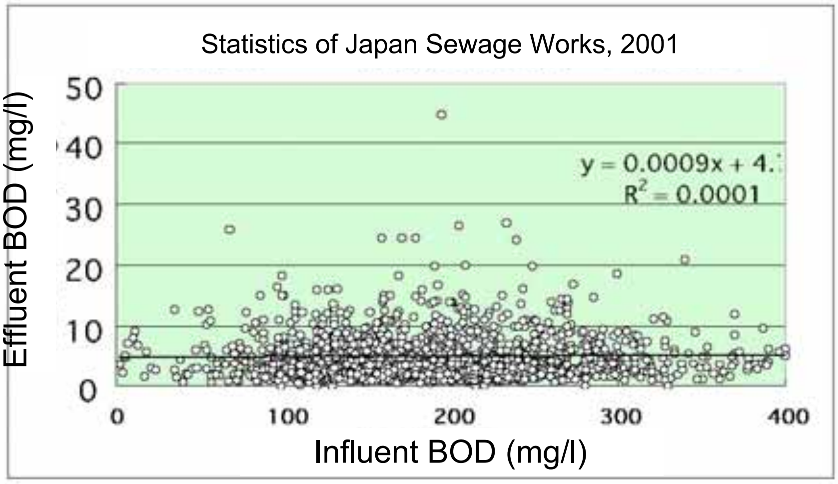
Process Performance of DHS variants in Nagaoka

	DHS G1	DHS G2	DHS G5	DHS G3	DHS G4	DHS G6
HRT (h)	2.3	2	2.5	2.7	2	2
BOD removal(%)	97	96	95	98	96	96
COD removal(%)	94	84	90	93	91	93
SS removal(%)	98	68	95	92	93	95
NH4-N removal(%)	75	64	60	86	28	75
F. coli removal (log 10)		2.7	4.0	2.6	3.5	2.8
SRT (d)	-	90~100	90~125	-	100~125	~100
Sponge occupancy(%)	-	25	55~57	38	38	34

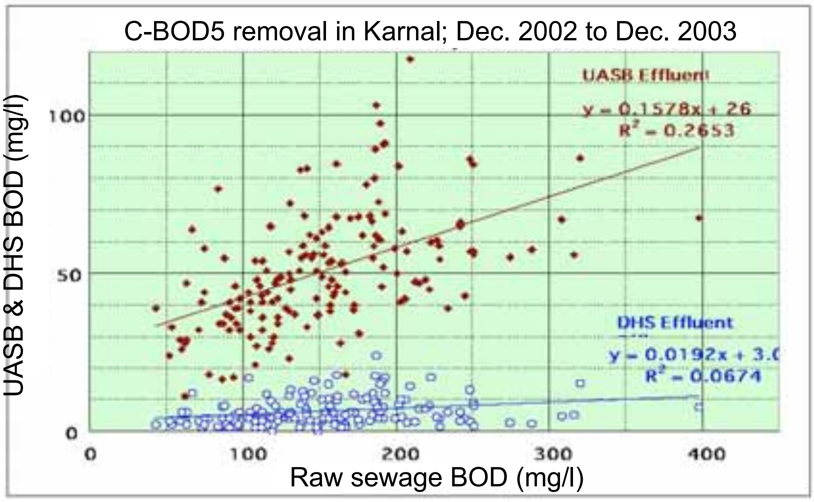
Cross-sectional view of DHS sponge

	UASB + DHS	ASP
BOD removal (%)	94%	98%
SS removal (%)	95%	98%
F. coli removal	4.0 log	3.9 log
SRT	90~130 d	3~5 d
Excess sludge	0.06~0.11 kg-SS/kg BOD rem	1.77 kg-SS/kg BOD rem
Energy required	no aeration	2~3 KWh/kg-BOD rem
O/M	easy	complicated

BOD removal by Activated Sludge process throughout Japan

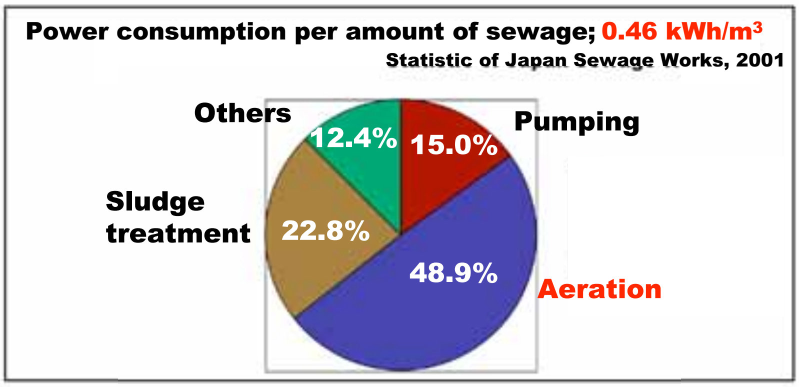


BOD removal by (UASB+DHS) system (Karnal, India)



Power consumption for sewage treatment

	Total power consumption	Pumping	Water treatment	Sludge treatment	Others
Total; x10^3 kWh/yr	5,956,000	896,000	2,913,000	1,359,000	739,000
Percentage	100.0	15.0	48.9	22.8	12.4
per WW amount treated; kWh/m^3	0.46	0.07	0.22	0.1	0.06
per capita; kWh/capita/yr	73.5	Amount of treated water; m^3		13,019,790,000	
		Population; capital		81,076,000	



How much power should be required for Sewage Treatment, if Activated Sludge Process is employed?

Per capita Annual Sewage Amount $=175\ liter \cdot day^{-1} = 63.4\ m^3 \cdot capita^{-1} \cdot yr^{-1}$

Per capita Annual Power Requirement for Sewage Treatment$=63.4\ m^3 \cdot capita^{-1} \cdot yr^{-1} \times 0.46\ kwh \cdot m^{-3} = 29.2\ kwh \cdot capita^{-1} \cdot yr^{-1}$

Country	Annual Power Consumption (kWh/capita·year)	Annual Power Requirement for Sewage Treatment (Per Capita) / Annual Power Consumption (%)
Nepal	66	44.0
Bangladesh	103	28.3
Myanmar	130	21.7
Laos	140	20.9
Sri Lanka	301	9.7
Vietnam	333	8.8
Indonesia	379	7.7
Pakistan	413	7.1
India	473	6.2
Philippines	497	5.9
Columbia	954	3.1
Mexico	1778	1.6
Brazil	1846	1.6
World	2206	1.3
Japan	7230	0.4
UAE	14153	0.2

CIA World Fact Book (2003)

Conclusive Remarks

1. Our Proposed UASB-DHS combined system exhibited an excellent performance, producing Effluent BOD less than 10 mg/L with a HRT of only 8 h (UASB 6 h and DHS 2h) that is equivalent to that of conventional ASP.

2. The UASB-DHS combined system requires
   - no external forced aeration,
   - no laborious maintenance,
   - less sludge production,
   - less land area,
   - resulting in reducing running cost into only 1/5-1/10 of conventional ASP.

3. The UASB-DHS combined system may offer the best option for low-cost and low-energy treatment of municipal wastewater under tropical/sub-tropical climate.