AQUASANITATION:
Alternative Urban Sanitation in Indonesia

Preface The purpose of this concept paper is to introduce the special case of **wastewater-fed duckweed aquaculture**, or "aquasanitation", as a new alternative to urban and periurban water supply and sanitation in developing countries. Aquasanitation is a managed biological process combining the sanitary treatment of human wastes with cultivation of aquatic plants of the *Lemnaceae* family, the common duckweeds. Duckweed biomass and a treated effluent of better than tertiary quality are two products of the system. The final product that drives the system financially is fish. A by-product derived from drying fresh duckweed is a high protein animal feed ingredient competitive with soybean meal.

The agronomics of duckweed production and its use in pond fish nutrition are discussed in "Duckweed Aquaculture: A New Aquatic Farming System for Developing Countries", World Bank (EMTAG) special publication. The context selected for purposes of this discussion to illustrate the benefits and costs of aquasanitation is a World Bank financed urban project in the Jakarta metropolitan area (JUDP III). Assumptions about costs and service levels are based on the JUDP III appraisal report, and those for duckweed and fish production on actual experience in Bangladesh.

Introduction Aquasanitation is an aquatic production system that uses two of the basic constituents of domestic wastewater as its growth medium: organic nutrients from human wastes and the water used to transport the wastes. Coincidentally, the objectives of water and sanitation planners are (a) provision of adequate quantities of good quality water to support a high standard of household and personal hygiene, and (b) collection, concentration and sanitary treatment of the resulting wastewater.

An aquasanitation system represents the "demand" side for wastewater while public hygiene facilities, known in Indonesia as "MCKs" are the "supply" side, combining the private sector's interest in a business opportunity with the public interest in better environmental and personal hygiene. The next step in the cycle, fish production sustained by duckweed farming, creates a demand for duckweed and is substantially more productive than current fish production technologies. This mutual interest can be promoted to the advantage of the community.

Description of Jabotabek Urban Development Project JUDP III is designed to provide basic services, mainly to the urban poor of Jakarta and contiguous urban areas, at an investment cost of $45 per capita. Water will be supplied from standpipes connected to city mains, deep wells or storage tanks at a service level of 60 liters per caput per day (lcd), with 20-50 families sharing one tap. House connections will be given where supplies permit.

The sanitation component consists of financing for solid waste disposal and excreta disposal. Household pit latrines will be provided where settlement densities and soil conditions permit. Public toilet and washing facilities (MCKs) will be provided at the rate of one toilet per 6-12 families. Storm drainage will be improved, and sullage water will go into surface drains at the calculated rate of 45 lcd. Resources are allocated to improve the operation and maintenance of existing infrastructure, and environmental protection and pollution control is planned.

Sector constraints and priorities The urban water and sanitation subsector in Indonesia is characterized by inadequate investment, weak local resource mobilization, low per capita budgets and very limited use of credit for capital investment. Only 24 percent of the metro area population has access to piped water supplies. About 65 percent of low income groups shares toilets, and use of canals is common. Industrial water supply and waste disposal are inadequate, while poor O&M of existing public toilet facilities is the norm.

The Aquasanitation Alternative Three outcomes can be expected from an aquasanitation component in the context of an urban development project:

Improved environmental sanitation Aquasanitation is a lagoon treatment system that allows for pathogen destruction through adequate detention time (20-30 days), while producing 600-1,000 kg/ha/day of fresh duckweed. Simultaneously, duckweed growth removes nutrients (nitrates, phosphates and trace minerals) and suppresses algae production, yielding a final treated effluent higher than tertiary quality.

Additional food production Because the waste treatment process produces large quantities of a complete fish food, it creates new and substantial financial incentives to encourage private sector and government investments in waste collection strategies. Duckweed-fed carp production in Bangladesh yields in excess of 10 ton/ha/year, approximately four times the best average yields in Asia (2.5 ton/ha/year in Indonesia). A by-product of the production system is dried duckweed meal, an adequate substitute for soybean meal in poultry feeds.

Additional employment Aquasanitation is a highly intensive, continuous production system. It is also labor intensive; cultivation of duckweed and feeding the fresh plant material to fish, harvesting fish, and drying excess duckweed are daily and year-round activities.

One hectare of combined wastewater treatment/duckweed production area (one meter deep) will treat the wastewater of a population of 5,000-6,000. One hectare of fish pond will yield 10-15 tons/ha/year of fish and can be sustained by approximately one half ha of duckweed production. Gross revenues on the order of $6-$10/person/year have been generated from human wastes in aquasanitation production systems in Bangladesh. These input/output relationships were derived empirically and are not yet optimized. However, the "environmental particulars" of Indonesia are more moderate and uniform, and prospects for both duckweed and fish production are marginally better than in Bangladesh.

Community Hygiene Facilities (MCK) The alternative community hygiene facilities proposed hypothetically for JUDP III would provide a higher level of service than the conventional MCK. The "improved MCK" would feature bathing, laundry and toilet facilities, as well as taps for household water collection. The rationale for a higher service level is to attract householders to the facility for all their water and waste disposal needs with a combination of **amenities** (convenience, privacy), **higher quality** of service, and **greater quantities** of water. Raw wastewater from several facilities would be conveyed to the treatment facility. The investment in greater utility to the householder may be expected to pay off in a higher standard of personal and environmental hygiene in addition to generating the growth medium to sustain duckweed production. Sullage or "graywater" would also be

collected for sanitary disposal by emptying surface drains into the collection system linking the improved MCKs. The individual improved MCKs would form a "node" for eventual upgrading of the system to house connections for water supply and wastewater collection.

The improved MCK would be managed by employees of the aquasanitation entrepreneur-farmer, who would be responsible to the Community Association for the standard of service and cleanliness of the facilities. Two shifts of work (pre-dawn to mid-afternoon and mid-afternoon to late night) would clean the facility and supervise its use, except during normal sleeping hours. Bath and laundry soap could be sold from a kiosk at the improved MCK through a "concessionaire", the Community Association, or the fish farmer.

Relationship between Community, Entrepreneur, and Government The strategy proposed here recognizes shared interests among the entrepreneur-farmer, the community through the Community Association and individual householders, and government. The entrepreneur would need to secure the use of some land in the community and would depend on the wastewater generated in the community to sustain his production system. The community would receive a high standard of water and waste disposal services and the right to use the MCK facilities in exchange for a small user fee to cover **operation, maintenance** and **management** costs[1]. The government interest is twofold: (a) in health benefits that will follow from improved environmental and personal hygiene, and (b) additional food production.

In addition to mutual interests, reciprocal responsibilities will mediate the relationships among the parties: The entrepreneur should be required (by government) to meet norms for quality of the final treated effluent and minimum hydraulic detention time. The community will demand an acceptable standard of O&M of the public hygiene facilities in exchange for their user fees. The Community Association may receive compensation for the land leased to the entrepreneur and in exchange would guarantee the tenure of the land and a steady supply of a specified quality of wastewater. Options for compensation include a fixed annual fee, a share of fish production for direct consumption, or a percentage of profits to be distributed among the membership.

The total per capita investment planned in JUDP III is $45. Two thirds of than amount, or $30/caput could be reallocated to cover the aquasanitation component, which would include the costs of construction, economic development, and land acquisition, leaving $15/caput for solid waste disposal, social development and management. Annex 1 analyzes the costs and potential benefits of a ten year investment scenario, as if aquasanitation were the selected technology for the sanitation component of JUDP III.

[1] The policy of JUDP III is that the beneficiaries should finance O&M costs and organize management of MCKs through their Community Associations.

Table 1: Aquasanitation Investment Scenario (One hectare of Fish Production)

CAPITAL COSTS (US$)	Year 0
Public Hygiene Facilities (MCK)	(67,500)
Land (1.5 ha)	(7,500)
Earthworks	3,000
Equipment	2,000
Office/Storage building	2,000
Total Fixed Costs	7,000
Working Capital	14,000
Total Working Capital	21,000

ANNUAL RECURRENT COSTS	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cost of Capital	4,184	4,184	4,184	4,184	4,184	4,184	4,184	4,184	4,184	4,184
Fingerlings	500	535	572	613	655	701	750	803	859	919
Pond & Lagoon Maintenance	750	803	859	919	983	1,052	1,126	1,204	1,289	1,379
Labor	2,190	2,343	2,507	2,683	2,871	3,072	3,287	3,517	3,763	4,026
Supplies	700	749	801	858	918	982	1,051	1,124	1,203	1,287
MCK O&M	12,352	13,216	14,141	15,131	16,190	17,324	18,536	19,834	21,222	22,708
TOTAL RECURRENT COSTS	20,676	21,830	23,066	24,387	25,801	27,315	28,934	30,666	32,520	34,503
INCOME										
MCK User Fees	13,140	14,060	15,044	16,097	17,224	18,430	19,720	21,100	22,577	24,157
Fish Sales	20,000	21,400	22,898	24,501	26,216	28,051	30,015	31,116	34,364	36,769
GROSS INCOME	33,140	35,460	37,942	40,598	43,440	46,481	49,734	53,216	56,941	60,927
Net (less recurrent costs)	12,464	13,629	18,876	16,211	17,638	19,166	20,800	22,549	24,421	26,423
Fee to Community Association (10%)	1,246	1,363	1,488	1,621	1,764	1,917	2,080	2,255	2,442	2,642
NET PROFIT TO ENTREPRENEUR	11,218	12,267	13,389	14,590	15,875	17,249	18,720	20,294	21,979	23,781

Table 2: Assumptions for Duckweed and Fish Production

ITEM	UNIT	VALUE
Interest Rate	percent	15
Repayment Term	year	10
Labor	person-day	1095
Labor Cost	$/day	2
Fingerlings	unit	20,000
Fingerlings Cost	$/each	0.25
Fish Production	ton/ha/year	10
Pondside Fish Price	$/kg	2
Annual Inflation	percent	7
Wastewater Treatment Capacity	m^3/day	180
Population Served	persons	3,000
Land	$/ha	5,000
Duckweed Production Area	hectare	0.5
Fish Production Area	hectare	1.0
Fresh Duckweed Production	ton/ha/year	146
Supplies	$/year	700
Pond Maintenance	$/year	750
Fee to Community Association	(percent of net)	10

Table 3: Assumptions for Improved Public Hygiene Facilities (MCKs)

DESIGN PARAMETERS FOR ONE MCK	UNIT	VALUE
Persons Served per MCK	unit	500
Number of MCKs	unit	6
Water Use	LCD	60
Water Cost	$/m^3$	0.01
Electricity Use	KWH/day	3
Electricity Cost	$/KWH	0.03
Staffing Requirements	person-day/day	2
ANNUAL RECURRENT COSTS FOR SIX UNITS		
Labor	$/year	8,760
Cleaning Supplies	$/year	1,643
Water	$/year	657
Electricity	$/year	197
Plant Maintenance	$/year	1,095
TOTAL		12,352
ANNUAL REVENUES		
Daily Use Fee	$/person/day	0.012
Population Served	persons	3,000
TOTAL		13,140