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predictive methodology as a tool for planning water and wastewater processes

It is normal for decision makers to select the most recent, up-to-date and proven methodology. This is true in both developing and developed countries. In selecting water and wastewater treatment processes, the most up-to-date means the process selected to be used may not necessarily be the most recently-developed technology but the modal device being used by some advanced and better informed countries. It is desirable to "look like" one's rich neighbour or to strive to emulate the current and the popular; hence, one majestically arrives at the best solution to one's problem. However, this approach may be far from practical and optimal. For example, what is the correct sewage treatment in Chicago may not be applicable anywhere else, certainly not in Bangkok. In fact, what is selected for Chicago might not be technically optimal but politically optimal.

In general, there is a real urge to be with the advanced and the rich. This is particularly true for developing countries and it results too frequently in the selection of water or wastewater treatments that cannot be managed due to a lack of logistics, a lack of trained personnel and a lack of proper chemicals. That is, the punishment should fit the crime to quote Gilbert and Sullivan.

Therefore it is obvious that there exists a need to develop schemes whereby decision makers will be encouraged to select from an array of water and wastewater treatment processes that will optimise in-country capability, manpower and materials. This need can best be demonstrated by some treatment process selected and used in some developing countries that are not in-country compatible. There are ample examples of chlorinators without chlorine, filters with broken rate controllers, shutdown for lack of parts, poor products because of improper chemicals and chemical dosages.

There are a great variety of processes that are effective in treating water and wastewater. Historically, in developed countries more sophisticated processes were selected as countries grew in size, in industrial capability and wealth. The economies of scale were ever present as were those of advances in technology, all at the expense of safety, energy, education, and costs. Though generally so, industrial development does not necessarily correlate with levels of technology. There are some more suitable technologies available that are highly advanced but not modal (or should one say sufficiently proven) to be acceptable by a developing country. On the other hand, there are well established older technologies that are most suitable.

To bring this problem into focus the authors have developed a technique that enables one to look at the socio-economic and natural resources of a site, as well as the raw water or receiving stream quality, and then to select the most compatible water or wastewater treatment process. This sounds simple, if socio-economic conditions and natural resources are known, and water and waste treatment processes efficiency and costs are established; it is just a matter of bringing them together in an optimal function.

One might ask what social indicators, economic indices and natural resources could one establish as having data at global sites and then whose water quality standards? World Health Organization, U.S. Public Health Services? Where are the global construction, operation and maintenance cost data, particularly in developing countries where process experience is simply not available? Even the task of defining process is bad enough. How shall one group them?

Would one say, in sewage treatment, activated sludge or rated aeration, minimum solids aeration, extended aeration, oxidation ponds, step-aeration, biosorption, etc.; or filters, or standard, acelo, bio, aero, filters, etc. for example?

Therefore the task is to develop a scheme that has as inputs, socio-economically available and forecastable indices, resource capabilities, water quality goals, and detailed efficiency and cost matrices on processes, including capital and manpower needs. Once achieved, this scheme must be tested for technical validity and for user's acceptance.

After considerable effort, a classification of the water and wastewater treatment processes was obtained (Table 1). This classification could be modified. For example, Dr Archeivala and Dr Arboleda, both of WHO, have been and continue to give suggestions for the modification of our classification.

Given the process classification, it is necessary to accumulate costs for construction and operation and maintenance by type and by size, and more important also by socio-economic development. Four socio-economic levels were defined and they are noted in Figure 1. A typical cost matrix is shown in Table 2. The costs were developed first by comparing construction and operation and maintenance costs of developed countries to developing countries by relative labour types and costs; materials were considered as products of labour. For example, unskilled labour is cheaper in developing countries than in developed countries, and it is just the opposite in regard to skilled labour. Similarly, resources classified as mechanical, chemical or electronic, can be evaluated. These data were strengthened by a global cost survey.

Table 1: Water and wastewater treatment process characterization

WATER	
Processes***	Constraints
PW1 No-treatment	
a. Groundwater (not construction, etc.)	Usually limited by size
b. Catchment control	to less than Level IV
PW2 Pre-treatment	
a. Turbidity/sand - plain sedimentation	Level I
b. Algal control - thermocline control**	Level IV
c. Copper sulphate ($CuSO_4$)**	Level III
d. Microscreen**	Level IV
PW3 Slow sand filtration	
a. Conventional, manually cleaned	Usually limited by size
b. Upflow**	to less than level IV
c. Crossflow (dynamic)**	
d. Dual media**	
PW4 Rapid sand filter - conventional*	
a. Conventional	Level III
b. Surface agitation (air, water, mechanical)	Level III
c. Dual media (sand and artificial)	Level III
d. Upflow	Level IV
PW5 Rapid sand filter - advanced	
a. Multi-media (sand, garnet, coal)	Level IV
b. Plate or tube settling	Level III
c. Polelectrolytes (ionic and anionic)	Level IV
d. Biflow**	
e. Dynamic**	
f. Valve-less**	
PW6 Softening	
a. Lime soda	Level III
b. Zeolite	Level IV
PW7 Disinfection	
a. Disinfection-chlorine	Level III
b. Iodine	Level IV
c. Ozone	Level IV
d. Ultra violite	Level IV
e. Lime, $CuSO_4$	Level I
f. Energy** (Pasteurization)	Level II
PW8 Taste odour - Fe, Mn	
a. Aeration	Level II
b. Zeolite	Level IV
c. Chlorine	Level III
d. Adsorbent - Char.	Level III
PW9 Desalting - salt	Level IV
a. Multiple effect	
b. Freezing out	
c. Pressure	
PW10 Desalting - brackish	Level IV
a. Electrodialysis (ED)	
b. Reverse osmosis (RO)	
c. Chemical	
PW11 Containment filters	
a. Dunbar**	
b. Coconut fibre/charred rice**	
c. Asbestos/charred pine needle**	

Cont/........

Table 1 Continued ....

WASTEWATER	
Processes	Constraints
PS1 Primary - conventional	Level I
a. Separate	
b. Combined	
PS2 Primary stabilization pond	Level I
a. Single cell	
b. Multiple cell	
PS3 Sludge - conventional	
a. Conventional	Level III
b. Heated	Level III
c. Thickened	Level IV
d. Staged, including mixing	Level IV
PS4 Sludge - advanced	Level IV
a. Zimpro-Pyrolysis	
b. Incineration	
c. Fertilizer	
PS5 Sludge combined - Imhoff	Level I
PS6 Secondary - standard filter	Level II
PS7 Secondary - high rate filter	Level III
a. Bio-filter	
b. Accelo-filter	
c. Aero-filter	
d. Biosorption-filter	
PS8 Secondary - activated sludge	
a. Min. solids	Level IV
b. Conventional	Level III
PS9 Secondary extended aeration (oxidation pond)	Level III
a. Dutch ditch	
b. INKA	
c. Aerated lagoon	
PS10 Disinfection - Chlorine	Level II
PS11 Aqua - culture	Level I
a. Fish, culture-milkfish, tilapia, bass	
b. Vascular plants - hyacinth, kang kung	
c. Ecological	
d. Irrigation	
PS12 Dilution	Level III
a. Coarse screens	
b. Fine screens	
c. Chemical precipitation, Guggenheim	
PS13 Individual	Level I
a. Septic tank	
b. Clivus multrum	
c. Sanitary pit privy	
PS14 Individual (advanced)	Level III
a. Chemical	
b. Thermal·	

*Includes Fe, CaO, and/or Al for coagulation, mixing and settling.

**Requires more field evaluation at present.

***The classification of the process is presently under another revision.

Figure 1 THE COMPLETE INFORMATION FLOW FOR THE WATER AND WASTEWATER TREATMENT PROCESS SELECTION MODEL

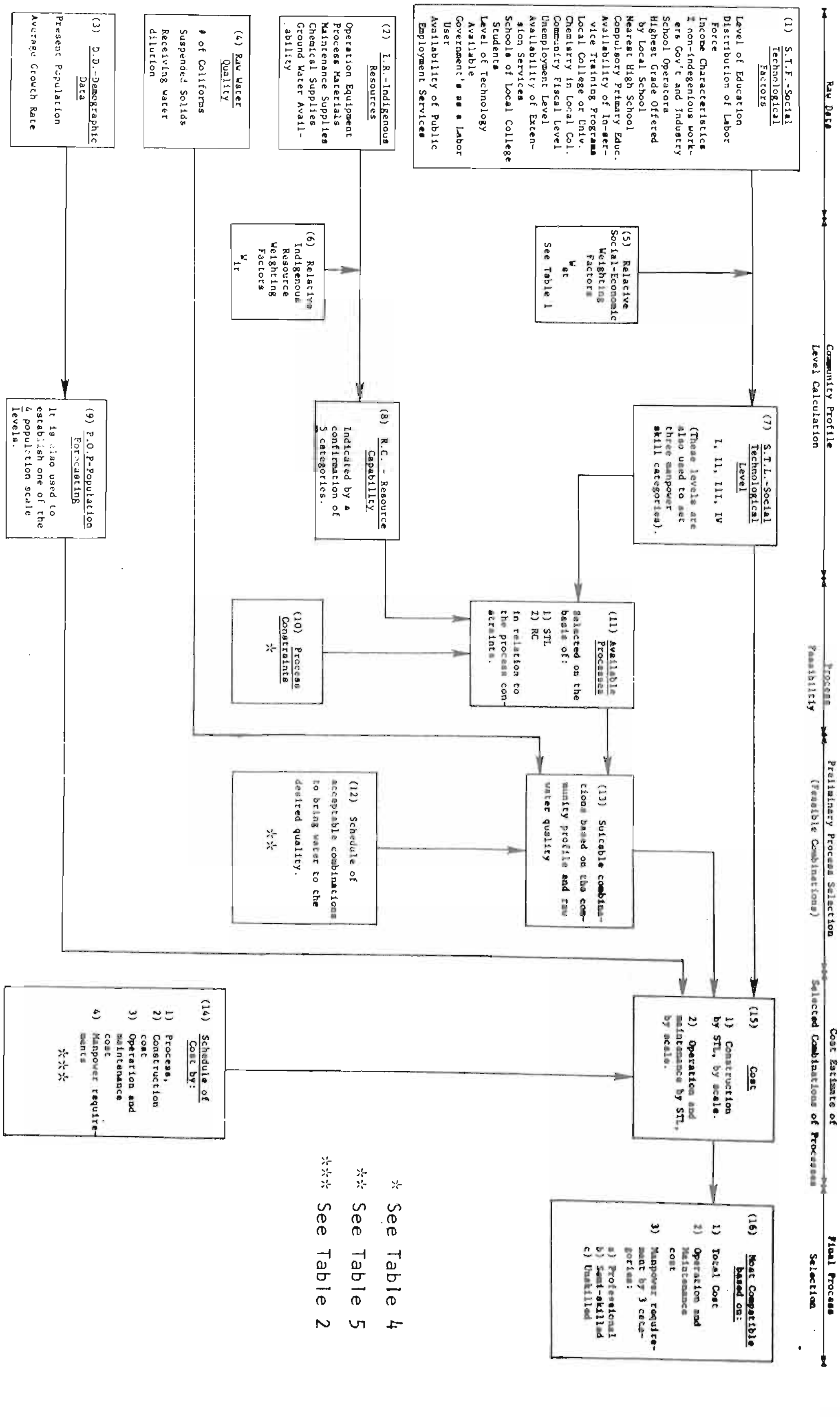

Table 2: Per capita cost parameters in U.S. Dollars and operation and maintenance manpower requirements

Process: Slow sand filter (PW3).

Population scale		Socio-Technological levels*				MANPOWER (no of workers)		
Level	Type of cost	I	II	III	IV	Unskilled	Skilled	Professional
1	Construction	12.65	16.50	16.00	20.00			
(500-2499)	Operation & maintenance	1.33	2.00	2.33	5.00	1		
2	Construction	9.03	11.72	11.85	14.28			
(2500-14 999)	Operation & maintenance	0.60	0.90	1.05	2.25	2		
3	Construction	6.33	7.18	7.68	10.01			
(15 000-49 999)	Operation & maintenance	0.33	0.58	0.73	1.25	5		
4	Construction	3.95	6.98	5.21	6.25			
(50 000-100 000)	Operation & maintenance	0.20	0.35	0.44	0.75	8		

The socio-economic classifications were based on relative availability or development of sixteen parameters, such as level of education, income, etc. The use of sixteen parameters made it possible to have as many as five parameters being voids and one still can set the prospective site into one of the four socio-economic categories. Simple scenario can also be used rather than using the parameters to classify the community levels. Typically for education, the socio-economic levels would be as in Table 3.

Table 3: Percent of population in various educational levels

Level	None	Primary	High school	Technical institute	College
(1)	95%	4%	1%	0%	0%
(2)	70%	19%	7%	3%	1%
(3)	55%	22%	14%	6%	3%
(4)	9%	34%	42%	8%	7%

The other sixteen items are similarly treated. The non-human resources capability of a site was classified in five general categories. These five categories are shown against the treatment processes in Table 4. The human resources requirements are shown as skilled, unskilled and professional; for example, a slow sand filter requires only unskilled labour and maintenance supplies.

Table 4: Water and sewage treatment processes with essential components for operation

	Treatment Methods \ Process Requirements	Process Number	Manpower Operation: Unskilled	Manpower Operation: Skilled	Manpower Operation: Professional	Resources Required: Operation Equipment	Resources Required: Process Materials	Resources Required: Maintenance Supplies	Resources Required: Chemical Supplies	Resources Required: Groundwater Availability
WATER PROCESSES	No Treatment	PW1	●				●			●
	Pre-Treatment	PW2	●					●		
	Slow Sand Filtration	PW3	●					●		
	Rapid Sand Filter-Conv.	PW4		●	●	●	●	●	●	
	Rapid Sand Filter-Adv.	PW5		●	●	●	●	●	●	
	Softening	PW6		●	●	●	●	●	●	
	Disinfection	PW7		●		●	●	●	●	
	Taste-Odor - Fe, Mn	PW8		●		●	●	●	●	
	Desalting-Salt	PW9		●	●	●	●	●	●	
	Desalting-Brackish	PW10		●	●	●	●	●	●	
	Containment Filter	PW11	●					●		
WASTE PROCESSES	Primary-Conventional	PS1	●							
	Primary-Stab. Pond	PS2	●							
	Sludge-Conventional	PS3	●	●			●	●	●	
	Sludge-Advanced	PS4	●	●		●	●	●	●	
	Sludge-Combined (Imhoff)	PS5	●			●		●		
	Secondary - Standard Filter	PS6	●	●		●		●		
	Secondary - High Rate Filter	PS7	●	●	●	●	●	●	●	
	Secondary - Activated Sludge	PS8	●	●	●	●	●	●		
	Secondary - Extended Aeration	PS9	●	●		●		●		
	Disinfection	PS10		●		●	●			
	Aqua Culture	PS11	●							
	Dilution	PS12	●							
	Individual	PS13	●							●
	Individual (adv)	PS14		●		●		●		●

Finally criterion of raw water supply or receiving stream processes must be layered to achieve a desired level of treatment. The acceptable combinations are shown in Table 5. For water, coliform and turbidity levels are generally used as standard for rates; for sewage, dilution is used.

Table 5: Acceptable combination of treatment processes for potable water

	Combination CODE	PROCESS COMBINATIONS	CRITERIA LEVEL: Raw Water Concentration			CRITERIA LEVEL: Receiving Water
			Coli MPN/100 ml	Solids mg/l: Turb	Solids mg/l: Other	Receiving Water Volume (7-day Low Flow Level)/Waste Volume
WATER TREATMENT	W1	PW1	1 - 2	10		
	W2	PW1 + PW7	100	10		
	W3	PW3	100	100		
	W4	PW2 + PW3	300	800		
	W5	PW11	300	800		
	W6	PW4 + PW7	2,000	100		
	W7	PW2 + PW4 + PW7	3,000	1,000		
	W8	PW5 + PW7	2,000	100		
	W9	PW2 + PW5 + PW7	3,000	1,000		
	W10	(any one of W1 to W8) + PW6			300 Hardness	
	W11	(any one of W1 to W8) + PW8			1-3 Fe & Mn	
	W12	PW7 + PW9			>3000 TDS	
	W13	PW7 + PW10			>2000 TDS	
SEWAGE TREATMENT	S1	PS1 + PS5				20 (or 3-4 CFS/1000 PE*)
	S2	PS1 + PS3				20 (")
	S3	PS2				10 (or 1.5-2 ")
	S4	S1 + PS6				6 (or 0.9-1.2 ")
	S5	PS1 + PS9				3 (or 0.45-0.6")
	S6	S2 + PS6				6 (or 0.9-1.2 ")
	S7	S2 + PS7				5 (or 0.75-1 ")
	S8	S2 + PS8				4 (or 0.6-0.8 ")
	S9	(any one of S1 to S7) + PS10	250			2 (or 0.3-o.4 ")
	S10	PS3 (Without water carriage)				- NA
	S11	PS11				10 (or 1.5-2 ")
	S12	PS12				40 (or 6-8 ")
	S13	PS2 + PS12				8 (or 1.2-1.6 ")

* The unit is defined as cubic feet per second of receiving water flow rate/1000 population equivalent. A population equivalent is a waste equivalent to one person per day, normally taken as 0.17 lb.BOD/day

Given these building blocks plus an estimate of scale (community size), the components of the predictive model for the selection of the suitable water and wastewater treatment processes can all be put together (see figure 1). Starting at the left of figure 1 and using four pieces of raw data as follows:

1) socio-technological data

2) resources data

3) population information

4) raw or receiving water quality

one of the four socio-economic levels as a country's profile is selected. These data are used with Table 4, treatment process and manpower requirement, to select the available processes. Next, given the raw water quality or receiving stream quality, the suitable combination of processes are selected by using Table 5. Next, using Table 2, cost data and manpower requirement and the site population level, the most compatible process is selected, and the selected process usually is the least total cost process.

A more detailed discussion of the model is being published by WHO International Reference Centre for Community Water Supply (IRC/NL). There are also two supplements for the model publication. Supplement I is the Manual Computation Method which illustrates a step by step procedure of how to implement the model without using a computer. Supplement II is the computer program technical manual which includes all the programs needed for the implementation of the model by using a computer.

The model really is nothing new. It simply models what a good engineer normally would do in the selection process, and it presents a systematic method of how to select the optimal process by looking at all the alternatives subjected to the constraints of optimizing local resources.