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Bridging the Gap in Resource Mobilization: Avoiding the Crisis in Sustainable Irrigation Management in Sri Lanka[1]

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Abstract

Participatory Irrigation System Management has been the Major Irrigation Management policy in Sri Lanka after 1988. Under this policy, irrigation system below the distributory canals were turned over to farmers/farmer organizations, which aimed to change the traditional farmers' role of passive recipient of irrigation benefits to active partners in the management process. The other objective of this policy is to reduce the government cost in operation and maintenance (O&M) and increase the efficient management of irrigation infrastructure.

The objective of this study is to assess the level of resource mobilization for irrigation management from both farmers and irrigation agency. The study also examines the farmers' willingness to pay (W.T.P.) for sustainable irrigation system maintenance. The research was conducted in two major irrigation schemes namely Rajangana and Mee Oya irrigation system during the wet season of 1995.

The study findings reveals that there exists a deficiency between actual resource requirement and current level of resource mobilization for sustainable irrigation management. The study also expose that there is exists a WTP among farmers for O&M in addition to the current level of resource mobilization which has so far not been captured in the process. The existing WTP will be adequate to overcome the prevailing deficiency in resource mobilization.

1. Background

Irrigation based agricultural development was the primary development approach adopted in Sri Lanka after the independence in 1948. This development approach has taken a large share of the public investment budget for construction of new irrigation infrastructure and rehabilitation of existing water resources. The investment on irrigation development during the period of 1950 -1985 was an average 19 percent per year of the total public investment budget in Sri Lanka. Ninety percent of the irrigation investment has been spent for new construction (Aluwihare and Kikuchi, 1990; IMPSA 1991). The major policy in the irrigation sector during the reference period was supply argumentation rather than demand management.

[1] Paper Presented at the National Conference on the Status and Future Direction of Water Research in Sri Lanka, 4-6 November, BMICH, Colombo.

In addition the irrigation sub-sector claimed a disproportionate share of the public recurrent budget arguably hindering the development of rainfed agriculture and other sectors. Moreover, the return from irrigation investment specifically on new construction was not impressive and the poor performance of irrigation schemes, particularly return to investment was severely criticized by donor agencies. However, Sri Lanka's economy remains dependent on irrigation for much of its agricultural output, particularly rice (paddy) the main staple, and irrigation based agricultural growth has been the primary development strategy (Barker and Herdt 1985).

The combination of fiscal constraints and poor technical and economic performance, led planners to re-think policies and put forward several policy reforms. From the early 1980s emphasis was shifted from supply augmentation to system improvement. Then the policy moved from paddy mono cropping in irrigation systems to crop diversification. It is worthwhile to note that cultivation of non paddy crops (NPC) in irrigation systems was prohibited up to the 1960s by the irrigation ordinance and the paddy land act (Alwis, 1986).

Historically there had been some instruments to collect revenue for the state for provision of irrigation service. The land tax and implicit product tax are two of the main tools used as indirect financing methods in Sri Lanka. These taxes are not linked either to use of irrigation services or the benefits received from the existence of the irrigation facilities and consequentially do not provide any incentive to use the resources efficiently in terms of irrigation investment, operation and maintenance (O&M) and sustainable use of water. All these policy changes, therefore, failed to make the necessary policy and institutional changes required to generate and allocate sufficient funds to properly operate and maintain Sri Lanka's expanded and improved public irrigation systems.

In 1984, the government introduced direct user fee collection for O&M from farmers promising improved irrigation services. The O&M fee collection was started with the 85% of amount due, which is much higher than any other previous indirect irrigation charges. But the collection rate dropped sharply during the subsequent years until less than 10% of the fees for 1985. The major reasons for the failure of the Programme were that: civil unrest which prevailed in the country, failure to take action against defaulters, lack of confidence in officers, political economy and implementation problems such as legal and administrative problems. Legal challenges were raised in courts against the implementation of O&M fee collection and a number of farmers won their cases (Gunasekara 1985; Cabinet Memorandum of GOSL 1989; Small and Carruthers 1991). Beyond these factors one of the primary reason for the sharp decline in fee collection was the centralized financial agency could not link the collected revenue to significantly improved services which was a big disincentive for farmers in making payment.

Failure to collect O&M fees demanded an alternative policy for the sustainable and efficient management of irrigation infrastructure and water resources. The government of Sri Lanka (GOSL) introduced Participatory Irrigation System Management Policy (PISMP) in 1988 as a national irrigation sector policy after series of experiments and pilot projects under different circumstances. The GOSL has invested necessary resources and used all its administrative experience to develop the necessary institutions and appropriate environment for participatory irrigation management.

Under the PISMP, the government launched a management transfer programme from bureaucracy to beneficiaries leading to a system of joint management i.e. the full responsibility for resource mobilization and management from field channel (FC) to distibutory channels (DC) level of the major irrigation systems[2] is turned over to farmer organizations (FOs). In return, farmers are exempted from payment of the irrigation service fee. The government retains responsibility for O&M of the head works and main system, and for major or emergency repairs of turned over distributory systems. The policy aimed to secure farmer participation and contribution of labour and finance to reduce the public cost of system O&M and to improve performance. The policy emphasized the change in the traditional role of farmers from passive recipient of irrigation benefits to active partners in the management process sharing responsibility with the agency staff. (Abeywickrama, 1983).

3. Objectives

The paper examines the reduced involvement of state sector in irrigation management and the current level of resources mobilization for irrigation management from both farmers and the line agency. The study also assess the implications of the existing resource gap on infrastructure and farmers willingness to pay (WTP) to bridge the dearth in existing level of resource mobilization.

4. Research Methods

4.1 Selection of the Study Sites

The research was conducted in two major irrigation schemes under the INMAS[3] program viz. Rajangana irrigation System (RIS) and Mee Oya irrigation system (MIS). Rajangana it has sufficient water to cultivate two paddy crops per year, where as Mee Oya is experience water scarcity. Degree of participation or net benefits from participation in water management are likely to vary with regard to water availability (Uphoff et-al, 1990). Availability of water decides the cropping pattern which will determine the level of farm income and consequently farmers capacity to Mobilize the resources for system maintenance.

RIS is one of the large irrigation schemes compared to MIS. Organizational and physical complexity and resource requirement for the sustainable maintenance also differ with size of scheme and condition of the infrastructure.

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2 Irrigation schemes which have a command area of more than 80 hectares are called major irrigation schemes.

3 Integrated management of major irrigation schemes (INMAS) is a irrigation management programme adopted for selected major irrigation schemes.

4.2 Methods of Data Collection

The study is based on data collected from a rapid appraisal, structured questionnaire survey and direct field observations. Necessary data were also gathered from FO records including meeting minutes, FO account books and maintenance records.

A multi stage stratified random sampling method was adopted for the selection of sample farmers considering head-tail differences of the schemes. Questionnaire survey was aimed to collect information on the farmers involvement in O&M works and performance of agency support. More specifically, the questionnaire aimed at eliciting information on farmers opportunity cost in participation and willingness to pay for operation and maintenance (Kg of paddy per season).

5. Results and Discussions

5.1 Level of Resources Mobilization

Sustainability of infrastructure basically depend on proper maintenance of the system from primary level (head system) to tertiary level (farm gate). The task necessitate the mobilization of labour for group works (Eg. DC maintenance) and individually allocated tasks (Eg: FC maintenance), mobilization of time (Eg: planning, decision making, FO meetings) and mobilization of cash and materials (Eg: masonry works, structural repairs). The mobilization of all above items are equally essential for the sustainable maintenance of infrastructure (Aheeyar, 1997).

Table 1and 2 shows the level of resource mobilization by both farmers and the line agency and the estimated level of resource requirement for the sustainable maintenance. The findings clearly describes that there is a deficiency exists in the level of resource mobilization for channel maintenance in both schemes. The note worthy feature in the farmers resource mobilization is the level of materials mobilized for the system maintenance which is desperately very low.

5.2 Implications of the Situation

As discussed earlier, mere mobilization of labor is not adequate to maintain the infrastructure sustainable. The lower level of resource mobilization is reflected by the existing structural problems from minor level to major level for a considerable period of time. (see table 3 and 4). The sustainable maintenance of these structures needs mobilization of sufficient amount of cash and materials in addition to labor. Further existence of these minor structural problems like lack of field out level and major structural problems such as broken gates for the period of up to 10 years indicates not only the insufficient quality of maintenance by both FOs and agency but also continuation of structural problems as seen before turn over.

5.3 WTP of farmers for Irrigation System Maintenance

A traditional custom which exists in Sri Lanka is the giving of a certain proportion of paddy to irrigation headmen after each harvest for his services, though it is not in practices in new settlement schemes. Farmers chosen for the survey were asked, how many kg. of paddy they are willing to give to their FOs in addition to their current level of volunteer labour, in order to maintain the infrastructure in a good condition. Farmers explained clearly about the existing status of irrigation infrastructure, institutional context in which water resource is to be provided and funding is to be done and farmers responsibilities under turn over agreement etc. before elicit the WTP. The willingness to pay (WTP) in terms of paddy were converted into money value using 1995 paddy prices prevailing in the study area.

The average WTP for both schemes is 12kg. of paddy per acre of land irrigated per year. This is equivalent to the money value of Rs. 90 per acre at the 1995 paddy price (see Table 5). The WTP value obtained is in addition to current labour mobilization by farmers for system O&M.

The amount that farmers WTP to FOs towards system O&M is an impressive point, compared to the past attempt made to collect O&M fee through a centralized financial agency which had a unsuccessful short life of 4 years. The existing WTP for O&M is higher than the current maintenance deficiency of Rs. 60 per acre (in 1995 price). However, the level of WTP is not sufficient for a sustainable O&M if the government stop or drastically reduced its O&M allocation.

6. Concluding Remarks

Since irrigation sub sector in Sri Lanka was heavily subsidized throughout the years, farmers have a mentality of depending on government financial allocations for management of the irrigation system. It was found during the study that all FOs are mainly dependent on external agents for their financial requirement and their first priority in financial allocations from FO fund is for income generating activities. No FO leaders were keen to invest FO money for routine maintenance activities although it is farmers responsibility under the turnover agreement. It is interesting to note that no single FO had a special fund or provision for maintenance activities in their FO accounts.

At the same time the government has not given any guidance to FO leaders on how farmers could generate O&M funds, what is the amount that should be collected and how it should be utilized. As Kloezen (1994) rightly pointed out *"Participatory management programme in Sri Lanka focuses too much on sharing activities without making clear who is responsible for these activities and who can be made accountable if these activities do not take place".* The situation is also evidenced by the above analysis. FO leaders are not keen to invest FO money for operation and maintenance. They strongly believed and expect that maintenance works which need cash and materials will be done by the agency as they were in the recent past while DC's were turned over to FOs. It was observed in Kaudulla irrigation scheme, where farmers have incentives to work harder for their multi-functional FOs to make it financially viable. The financial viability is mainly for cheaper services provision through FOs and merely to improve system maintenance (Kloezen, 1994).

The existing deficiency in the current level of resource mobilization by FOs for O&M is not being properly addressed in current irrigation management policy. The major concern aimed by the PISMP is reduction of government cost on irrigation O&M which rises the doubt about the long term physical sustainability of irrigation infrastructure.

Although there exists a willingness among farmers to pay in kind for sustainable maintenance of the infrastructure toward FOs, FOs in the study schemes have no system to mobilize cash and materials from farmers for system O&M. It is a responsibility of FOs to amass necessary resources under the turn over agreement in order to maintain the sustainability of irrigation infrastructure and to increase the efficiency of resource allocation. Nevertheless, no mechanism has been adopted by farmer organizations (FOs) to capture the farmers WTP towards irrigation system management. The role of government at this juncture is to provide necessary guidance to FOs to mobilize necessary resources and monitoring the financial transparency with proper legal backing in order to maintain the physical sustainability and farmers financial sustainability.

Table 1: The Estimated Value of Level of labour mobilization by Farmers for maintenance (Year 1995/96)

Location	Average labour mobilization for group works per farmer(a)	Average labour mobilization for meetings per farmer (b)	% of participation for group works per farmer ©	% of participation for meetings (d)	Value of mobilized labour[2] (Rs/ac) (e)
H 1	2.3	0.17	85	85	111.00
H 2	2.7	0.26	75	75	183.25
T 1	3.6	0.71	75	75	172.50
T 2	3.2	0.17	60	60	150.00
H 3	1.6	0.15	90	60	82.00
T 3	1.69	0.16	95	80	105.00

Source: Survey data

Note:

1. H1 and H2 - RIS (Head) H3- MIS (Head)
   T1and T2 - RIS (Tail) T3- MIS (Tail)
2. e =[No. farmers in FO x (a) x © x opportunity cost of labour] + [No. of Farmers in FO x (b) x (d) x opportunity cost of labour]

Table 2: Level of Resource Mobilization for Irrigation Maintenance (Year 1995/96)

Scheme	Average value of mobilized labour (Rs/Ac)	Average value of mobilized materials (Rs./Ac)	ID allocation[1] (Rs/Ac)	Actual requirement for proper maintenance[2] (Rs/Ac)	Deficiency in Current resource mobilization (Rs/Ac)
RIS	154.23	0.86	85.00	300.00	60.00
MIS	93.00	0.00	50.00	200.00	57.00

Note:

1). Average amount of money allocated in last 5 years

2). Value estimated by the Irrigation engineer in charge of the system (personal discussion). Lower estimation for MIS is because of Single season cultivation in a year which required proper maintenance only once per year.

Source: Survey Data

TABLE 3: STRUCTURAL PROBLEMS IN SAMPLE FCs

Type of the Problem	Number of Given Problem in FCs		Duration of the Existence of Given Problem	
	RIS	MIS	RIS	MIS
Broken gates	26	02	1-5 years	3-8 years
Broken structures	01	-	02 years	-
Broken Channel bunds	51	17	0.5-5 years	1-6 years
Lack of field out lets	33	11	0.5-6 years	1-10 years

Source: Survey Data

TABLE 4: STRUCTURAL PROBLEMS IN SAMPLE DCs

Type of the Problem	Number of Given Problem in DCS		Duration of the Existence of the Given Problem	
	RIS	MIS	RIS	MIS
Broken gates	10	04	02-04 years	02 years
Lack of water regulators	12	-	04 years	-
Broken channel bunds	13	12	0.5-15 years	02 years
Broken structures	02	-	02 years	-

Source: Survey Data

Table 5 : Willingness to pay for system O&M (Kg of paddy per acre per year)

Location	**WTP (Kg/Ac)**	**Value of paddy (at 1995 price in Rupees)**
Rajangana (Head)	12.45	93.37
Rajangana (Tail)	11.05	82.87
Mee-oya (Head)	13.6	102.00
Mee-Oya (Tail)	11.1	83.25

Source: Survey data

References

Abeywickrama, N. (1983), "Irrigation and Water Management Policies in Sri Lanka". Paper presented at Seminar on Rural Employment policies in Asia, ILO Asian Employment Programme, Bankok.

Aheeyar, M.M.M. (1997), "Participatory Irrigation Management and Sustainability of irrigation Infrastructure: A case of Irrigation Management Turnover in Sri Lanka", *Proceedings of International Conference on Large Scale Water Resources Development In Developing Countries: New dimensions of Problems and Prospects*, Kathmandu Nepal, October 20-23.

Aluwihare, P.B. and M. Kikuchi, (1990), *Irrigation Investment Trend in Sri Lanka: New Construction and Beyond*, Colombo: IIMI.

Alwis J. (1986). "An Analysis of Trends and Perspectives in Policies for Irrigation Water Management and Agricultural Development in Sri Lanka", Paper Presented at the Seminar on Irrigation Water Management and Agricultural Development of Sri Lanka, Agrarian Research and Training Institute, Colombo, Sri Lanka, 20-21 February 1986 (mimeo).

Barker R.& Herdt R.W. (1985). *The Rice Economy of Asia*. Washington, D.C.: Resources for the Future,

Cabinet Memorandum of GOSL (1989). Government of Sri Lanka, Colombo.

Gunasekara, A. (1985). "Recovery of Operation and Maintenance Rates in the Major Irrigation Schemes". In K.P. Wimaladharma (ed.) *Towards Improved Water Management: Some papers Presented at Pase Training Course* ,1983-1985, Pase Publication No:6, Ministry of Land and Land Development , Colombo.

IMPSA, (1991), "Future investment Need in the Irrigated Agricultural Sector", IMPSA Staff Working Paper No. 9.3, Department of Irrigation, Colombo, Sri Lanka.

Small L.E and I.D. Carruthers (1991). *Farmer Financed Irrigation*. Cambridge: Cambridge university Press.

Kloezen, W.H. (1994), "Financing participatory Irrigation Management in Sri Lanka", In Johnso iii, S.H. (et-al), *Irrigation Management Transfer; Selected papers from International Conference on Irrigation Management Transfer*, Wuhan, China, 20-24 September, IIMI and FAO, Rome.

Uphoff, N., M.L. Wickramasinghe and C.M. Wijayarathna. (1990). "Optimum Participation in Irrigation Management: Issues and Evidence from Sri Lanka". *Human Organization, 49:* 01, pp. 26-40.

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IMPACT OF PARTICIPATORY IRRIGATION MANAGEMENT ON THE PERFORMANCE OF IRRIGATION SCHEMES IN SRI LANKA

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Abstract

This paper presents the results of the study on the effects of participatory irrigation management in Sri Lanka. The assessment on impacts is made on basis of a set indicators developed by IIMI to assess the performance of irrigation schemes. Piecewise linear regression models are fitted to analyze changes in performance during the five-year period before transfer and five years after. The main aim was to measure the direction of change, rather than changes in the absolute value of the performance indicators. The results show that there has been a significant drop in government's recurrent expenditure for irrigation. However, this is not confined to schemes that had undergone management transfer, but is common to the non-transferred scheme as well. The analysis shows that management reforms had not resulted in the improvement in yield, the quality of irrigation services and productivity of water. But management transfer combined with improvements to the physical infrastructure has significant improvements in agricultural performance.

INTRODUCTION

This paper reports the results of a study on the impact of the participatory irrigation management program in Sri Lanka. The study was part of a broader effort of the International Irrigation Management Institute (IIMI) to support systematic documentation of international experience with irrigation management reforms and their impact on the performance of irrigated agriculture.

In 1988, following a decade of field experiments, the government of Sri Lanka formally adopted a policy of transferring full responsibility for the operation and maintenance (O&M) of irrigation facilities below the distributary canal head of medium and major schemes to farmer organizations. Government retained its control of the headworks and the main canal system. The program labeled as "Participatory Irrigation System Management" was implemented in a large number of irrigation schemes in the country.[1] Its main objectives are to:

- relieve the financial burden on government of funding recurrent expenditures for irrigation,
- improve the maintenance of irrigation facilities and the irrigation service,
- enhance the productivity of irrigated land and water,

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[1] It has been estimated that participatory management has been introduced in about 85% of the 200 schemes included under these three major government sponsored programs: The Integrated Management of Irrigation Schemes (INMAS), Management of Irrigation Systems (MANIS) and the Mahaweli Development Project (IIMI/HKARTI, 1997).

Cropping intensities, paddy yields, and GVOs per unit of land and water were adjusted for seasonal and location variations and analyzed as annual values.

A common set of explanatory variables was specified in all equations. These includes a *Time* variable (T) to capture the effect of time (in years) on the dependent variable, and a *Dummy* variable (D1) to indicate the periods before and after turnover.

The basic regression equation estimated was as follows:

$$Y_t = \beta_0 + \beta_1 T + \beta_2 (T - T^*) D1 + e \quad \ldots\ldots\ldots\ldots (1)$$

Where: Y_t = Performance measure (O&M costs, yield/ha, CI, GVO/ha, GVO/ m^3) in year t

T = Time in years (1985.............1995)

T* = Threshold period (i.e. 1990 the year of transfer)

D1 = 1 if T, >1990

0 if T<=1990

e = random error

$\beta_0 \ldots\ldots \beta_2$ are parameters to be estimated

Assuming E(e) = 0, parameter β_1 gives the slope of the regression line or the trend during the pre-IMT period (1985-90) and (β_1+ β_2) the trend in the post-IMT period (1991-95). A test of the hypothesis that there is a change in the trend between the two periods is conducted by noting the statistical significance of the estimated differential slope coefficient β_2.

RESULTS

Impact on Government Expenditures for O&M

The government's main interest in transferring management of irrigation at the sub-system level to farmer organizations was to reduce its own costs for irrigation. This section examines the trend in government expenditure for O&M during the period 1985-1995. The hypothesis advanced is: with the transfer of O&M responsibilities to farmer organizations government's recurrent cost for irrigation will be lower in the transferred schemes than in the non-transferred schemes. The regression model (1) was used to analyze trends in government investment in O&M during the period 1985-95.

Estimates of the parameters of the model for O&M costs for the various groups are given in Table 1. The results indicate that in all four groups, there is a statistically significant declining trend ($-\beta_1$) in government expenditure for O&M during the pre-IMT period. In the post-IMT period, there is a slight reversal in the trend ($+\beta_2$) in all categories schemes except the No-IMT and rehabilitated group. However the change trend is not statistically significant.

The conclusion which emerges is that there has been a decline in government's recurrent costs for irrigation during the period 1985-95 across all categories of schemes irrespective whether IMT programs have been introduced or not, and does not fully support the hypothesis that IMT leads to a reduction in government expenditure for O&M.

Impact on Cost of Irrigation to Farmers

This section examines the implications of participatory management for the cost of irrigation to farmers. The hypothesis advanced is that, as farmers did not pay for most of the cost for irrigation before transfer, the adoption of participatory management will increase cash costs and labor contribution for irrigation.

The analysis is based on the sample survey of farmers in Nachchaduwa and Hakwatuna Oya schemes. Three kinds of irrigation costs were assessed: cash payments, payments made in kind, and the number of person days of family labor contributed for canal maintenance. Farmers were also asked about any "unofficial" payments made to obtain irrigation water. Table 2 gives the actual irrigation costs reported by farmers in the post-transfer reference year (1994-95). The total cost of irrigation is about the same (approximately US$ 15-16/ha) for both schemes. Data show that after transfer farmers generally contributed more in the form of unpaid family labor (60 % in Nachchaduwa and 58 % in Hakwatuna Oya) than in cash or kind for canal maintenance.

In the survey, farmers were asked to compare irrigation costs in the post-transfer reference year with costs of irrigation before transfer. About 90% of farmers in both schemes claimed that there was no cash fee on irrigation before turnover. After the transfer of O&M functions to FOs, some organizations charged a modest fee (Rs. 50/acre/season or US$ 2.5/ha) for canal maintenance. The survey results showed that only a minority of farmers (23 % in Hakwatuna Oya and 16 % in Nachchaduwa) paid the maintenance fee. In both schemes, the irrigation cost to farmers is primarily unpaid family labor contributions for canal maintenance and payments in kind (about 27 kgs of paddy per hectare) to the person employed by the FO to distribute water.

Quality of Irrigation Service

It has been argued that as farmers have a vested interest in the irrigation service, involving them directly in irrigation management would lead to improvements in the quality of the service. This section examines the whether the introduction of participatory irrigation management resulted in an improvement in the quality of irrigation service. The analysis is based on data obtained from Nachchaduwa and Hakwatuna Oya schemes. Computing Relative Irrigation Supply (RIS) and Relative Water Supply (RWS), and farmer perceptions about changes in the adequacy, timeliness and fairness of water distribution assessed changes in the quality of irrigation service, and incidence of irrigation related conflicts among farmers before and after turnover.

RIS is the ratio of irrigation supply to demand and can be considered as an indicator of efficiency and adequacy of targeting water delivery at the scheme level. RWS is the ratio of total water supply (irrigation plus rainfall) to demand. RIS and RWS were computed for both wet (first) and dry (second) seasons for a ten -year period. The estimates were based on the norms used by the

Irrigation Department for determining water demand for paddy and other field crops grown in the dry zone irrigation schemes.[2] Figure 1 gives the trend of RIS and RWS for the period 1985-95. In both schemes there is no obvious change in RIS and RWS in the years before and after turnover. An exception is that in Nachchaduwa there appears to be excess irrigation in the wet seasons of 1994 and 1995. This was due to the high rainfall experienced in these years and more water being released into the canals.

Figure 2 displays farmer perceptions about the quality of irrigation service before and after turnover. Most farmers in both schemes consider the water supply to be adequate before and after turnover. However, in Nachchaduwa about one-third of the farmers in the head-reach and about 25 percent of them in the middle and tail-end areas reported that water supply in both seasons had worsened after turnover. Farmers attributed the worsening of water supply to the poor quality of work done during rehabilitation prior to management transfer. The responses of a majority of farmers in both schemes were similar with regard to the timeliness of water supply, fairness of distribution and the frequency of conflicts over water distribution, namely, that these had not changed significantly after transfer. What was negative or positive before remained so afterwards.

Impact on Agricultural Production

Although irrigation schemes contribute about two-thirds of the national rice output, there is growing concern about low cropping intensities and stagnation of rice yield in the schemes. Problems related to irrigation are considered to be a major reason for the stagnation of agriculture in the schemes (National Development Council, 1996). If the shift of primary responsibility for water distribution to farmer organization leads to an improvement in the quality of irrigation service, one could expect cropping intensities to improve and farmers to use more inputs due to greater confidence in the irrigation service, which in turn would lead to higher yields. This proposition is tested by examining the trend in paddy yields and cropping intensities in 50 schemes over a ten-year period 1985-95. The analysis was done separately for rehabilitated and un-rehabilitated schemes with and without IMT.

Trends in Paddy Yields

The trend paddy yield during the period 1985-95 is estimated using equation (1). Table 3 shows the estimated coefficients.

The results indicate that in the pre-IMT period, paddy yields in the rehabilitated schemes, irrespective of whether they have transferred or not, show a declining trend ($-\beta_1$). The decline is statistically significant in the schemes with IMT and rehabilitation. During the same period, yields in the un-rehabilitated scheme show a statistically significant upward trend ($+\beta_1$). In the post-IMT period, there is a statistically significant upward shift in paddy yields in the group showing the

[2] According to the Irrigation Department water demand for paddy and other field crops for major irrigation schemes is 15000 m^3/ha in wet season (*Maha*) and 17000 m^3/ha in the dry season *(Yala)* (Irrigation Dept. personal comm.). RWS was estimated on the basis of 60% effective rainfall in wet season and 80 % in the dry season.

effects of both rehabilitation and management transfer (β_2 = 245.54). There is no statistically significant change in trend in the schemes which had been rehabilitated but not transferred and those which had been transferred but not rehabilitated. In the post-IMT period, paddy yields in the group without the two forms of intervention show a statistically significant declining trend when compared to the pre-IMT period. The conclusion, which emerges from the analysis, is that there has been a significant improvement in yield in the schemes, which have undergone both management transfer and rehabilitation. There is no statistically significant change in yield trends in schemes with only one type of intervention, and those without any of the two forms of intervention show a significant decline in yield. These findings are consistent results from the Gal Oya scheme in Sri Lanka (Amerasinghe *et al,* 1998).[3]

Cropping Intensities[4]

The regression model (1) was used to analyze trends in cropping intensities in the different groups of schemes. The estimated regression coefficients are given in Table 4. The analysis indicates that there are no significant differences in the trends in cropping intensities in all four groups of schemes in the periods before and after transfer.

Economic Returns per Unit of Land and Water

This section examines the value of agricultural production over a ten-year period of five years before transfer and five years after. Gross values of output per unit of land and per cubic meter of water diverted were estimated. Rice is the major crop grown in the irrigation schemes in Sri Lanka. Although, in recent years there has been an increase in cultivation of non-rice crops particularly in the dry season, there is a lack of reliable data on the area and the yield of other crops grown in the schemes. Therefore, an estimate of the gross value of output per unit of land and water is based solely on the output of paddy.

To permit international comparisons, the total value of the crop was standardized in terms the international price of rice, and expressed in terms of constant 1995 US dollars.[5] The trends in the gross value of production were analyzed using the regression model (1). As a standard price is used to value the output of paddy, the trend in the gross value of output per unit of land corresponds closely with the trend in paddy yields noted earlier, with schemes which have been transferred and rehabilitated showing a significant change in the gross value of output in the post-IMT period compared to the pre-IMT period.[6]

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[3] Also see in this issue the article by Murray-Rust *et al.*

[4] cropping intensity = $\frac{\text{area cultivated in first (maha) season + area cultivated in second (yala) season}}{\text{cultivable area x 2}}$ x 100

[5] The method of estimating the standardized gross value of output is explained in Molden *et al*, 1998.

[6] The details of the analysis are reported in Samad *et al* (forthcoming)

Returns per Unit of Water

Returns per unit of water were estimated in terms of gross value of output per unit of water diverted. As most of the un-rehabilitated schemes did not have accurate time-series data on irrigation releases, the analysis is confined to the schemes, which had undergone rehabilitation. Table 5 gives the estimated regression coefficients of the parameters used to estimate trends in the gross value of output per unit of water diverted (GVO/m^3). The results indicate that there is a declining trend in the productivity of water in the pre-IMT period in both categories of schemes. In the post-IMT period there is a significant reversal in the declining trend irrespective of whether the schemes had been transferred or not. The results suggests that rehabilitation rather than IMT may be the major contributing factor for the improvements in the productivity of water experienced in the post-IMT period.

CONCLUSIONS

The purpose of this study was to apply the methodology developed by IIMI to assess the impacts of irrigation management transfer. The methodology was applied to analyze the effects of Sri Lanka's participatory irrigation management program on the performance of irrigation schemes.

The results of the analysis lead to the following conclusions on the impact of the participatory irrigation management program on the performance of irrigation schemes:

- There has been a substantial decline in government expenditure on irrigation, beginning before transfer. The declining trend is not confined to schemes where IMT had occurred but is common to non-IMT schemes as well.
- The reforms have not generated an appreciable increase in the costs of irrigation to farmers. Farmers generally make fewer direct payments (in cash and kind), but contribute more labor for canal maintenance.
- Management transfer alone did not bring about significant changes in the quality of irrigation services.
- Management transfer alone did not result in significant improvements in agricultural production levels or the gross value of agricultural production per unit of land or per unit of water diverted. Neither did rehabilitation alone create significant effects. However, in schemes where both management transfer and rehabilitation occurred, significant effects on agricultural productivity levels and economic returns were observed.

TABLES

Table 1. Estimated regression coefficients for trends government expenditure for O&M - 1985-1995

Variable Description	Coefficients			
	IMT and Rehabilitated	No-IMT and Rehabilitated	IMT and Un-rehabilitated	No-IMT Un-rehabilitated
Constant (β_0)	87.04	80.11	86.80	96.72
Trend in government's O&M cost/ha in the pre-IMT period (β_1)	- 0.879 (-5.684)*	-0.794 (-4.269)*	-0.885 (-8.271)*	- 0.983 (-5.023)*
The change in trend in government's O&M costs in the post-IMT period (β_2)	0.424 (1.373)	-0.2867 (-0.761)	0.346 (1.603)	0.428 (1.078)
Adj. R^2	0.534	0.4439	0.487	0.390
F. stat	43.42*	52.18*	102.47*	37.265*

* significant at or less than 10 % level

Figures in parenthesis are t values

Table 2. Annual irrigation costs to farmers after IMT (1994-95)

Cost Components	Units	Nachchaduwa	Hakwatuna Oya
Cash costs per hectare [a]	US$/ha	6.34 (36) [b]	6.58 (50)
Value of unpaid family labor contributions for canal maintenance	US$/ha	8.18 (67)	9.00 (74)
Total Irrigation Costs [c]	US$/ha	14.52 (47)	15.58 (54)

Source: Farm Survey (July and November 1996)

[a] Irrigation cash costs include cash payments plus the monetary value of payments made in kind.

[b] Figures in parenthesis are the coefficients of variation in percentage terms.

[c] Total irrigation cost = Irrigation cash costs + monetary value of family labor.

Table 3. Estimated regression coefficients explaining trends in paddy yield in the selected schemes, 1985-95

Variable Description	Regression Coefficients			
	IMT and Rehabilitated	No-IMT and Rehabilitated	IMT and Un-rehabilitated	No-IMT Un-rehabilitated
Constant	12941	5163	- 1761.38	-3558.15
Trend in paddy yield in the pre-IMT period (β_1)	-98.79 (-2.875)*	-6.32 (-2.219)	61.14 (2.338)*	89.83 (3.088)*
The change in trend paddy yield in the post-IMT period (β_2)	245.54 (3.799)*	-0.70 (-0.219)	-52.09 (-1.06)	-93.66 (- 1.728)*
Adj. R^2	0.113	- 0.008	0.038	0.076
F. stat	7.81*	0.124	5.18*	7.72*

* significant at or less than 10% confidence level

Figures in parenthesis are t values

Table 4. Estimated regression coefficients explaining trends in cropping intensities in the selected schemes, 1985-95

Variable Description	Regression Coefficients			
	IMT and Rehabilitated	No-IMT and Rehabilitated	IMT and Un-rehabilitated	No-IMT Un-rehabilitated
Constant	-34.16	242.63	372.87	-27.21
Trend in cropping intensities in the pre-IMT period (β_1)	1.797 (0.578)	-1.356 (0.551)	-2.49 (-1.158)	1.57 (0.496)
The change in trend in cropping intensities in the post-IMT period (β_2)	5.878 (0.937)	5.545 (1.133)	7.026 (1.645)	-0.375 (0.058)
Adj. R^2	0.11	0.0001	0.01	0.008
F. stat	4.31	1.041	1.511	0.424

Figures in parenthesis are t values

Table 5. Estimated regression coefficients explaining trends in the productivity of water in the selected schemes, 1985-95

Variable Description	Regression Coefficients			
	IMT and Rehabilitated	No-IMT and Rehabilitated	IMT and Un-rehabilitated	No-IMT Un-rehabilitated
Constant	0.181	0.135	-	-
Trend in GVO/m3 in the pre-IMT period (β_1)	-0.001 (-1.323)	-7.6512 -(0.400)	-	-
The change in trend GVO/m3 in the post-IMT period (β_2)	0.0033 (1.710)**	0.0053 (1.693)**	-	-
Adj. R^2	0.014	0.11	-	-
F. stat	1.54	0.011*	-	-

Figures in parenthesis are t values

* Statistically significant at the 10 % level.

** Statistically significant at 5 % level.

- Promote a sprit of self-reliance among farmers in irrigation schemes (Abeywickrema, 1986; Brewer, 1994).

The aim of this study is to determine what effects participatory irrigation management has had on the performance of irrigation management and irrigated agriculture. Performance is measured from several perspectives:

The principal hypotheses tested are:

- IMT leads to a reduction in government expenditure for operation and maintenance.
- Where farmers did not have to pay for most of the cost for irrigation before transfer, IMT will lead to an increase in the cost of irrigation to farmers.
- IMT will lead to improvements in the quality of irrigation services to farmers.
- IMT will result in higher agricultural productivity per unit of land and water.

METHODLOGY

The assessment is made both in qualitative and quantitative terms. Qualitative assessment is based on farmer perceptions of changes in selected performance indicators before and after turnover. For this purpose a questionnaire survey was conducted in 1996/97 among a sample of farmers in two schemes: one which had which had undergone management transfer and rehabilitation (Nachchaduwa) and other (Hakwatuna Oya) which was considered as transferred but not rehabilitated.

The aim of the quantitative analysis was to determine the annual trends in selected performance indicators during the period 1985-1995, which covered 5 years before IMT (1985-90) and 5 years after (1991-1995).

Piecewise linear regression models were fitted to analyze trends in performance in two time periods: the period before IMT (1985-90) and the period after (1991-95). The aim was to determine whether a performance indicator shows a particular linear trend from 1985 up to 1990 the year of transfer, but follows a different trend thereafter. The following performance indicators were used

- government expenditure for O&M from 1985-1995,
- Paddy yields (yield/ha) 1985-1995,
- cropping intensity(CI), 1985-1995,
- standardized gross value of output per hectare (GVO/ha), 1985-1995,
- GVO per cubic meter of water diverted (GVO/m^3), 1985-1995.

Figure 1 Relative Irrigation Supply and Relative Water Supply 1985-1995 - Nachchaduwa and Hakwatuna Oya Schemes

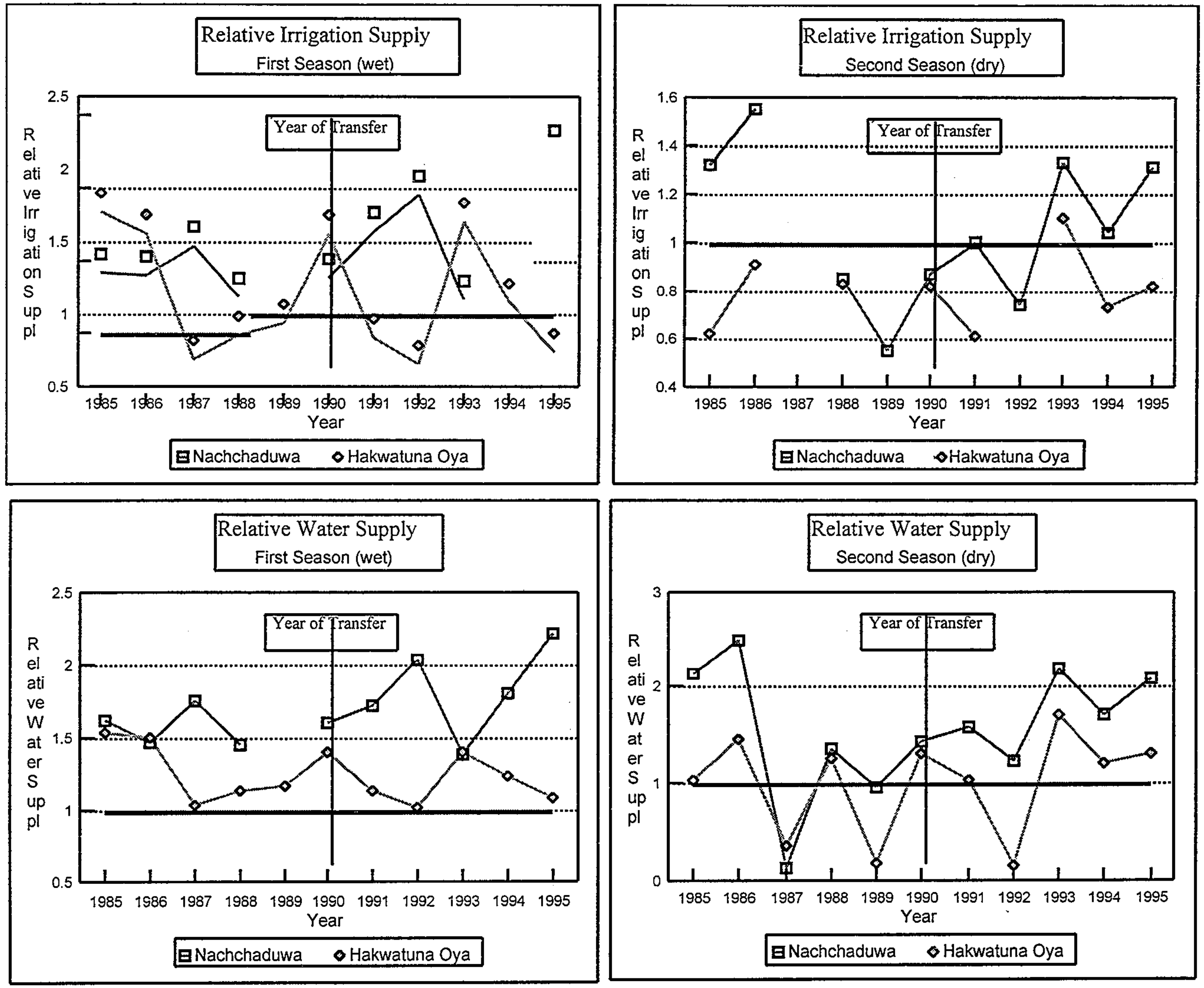
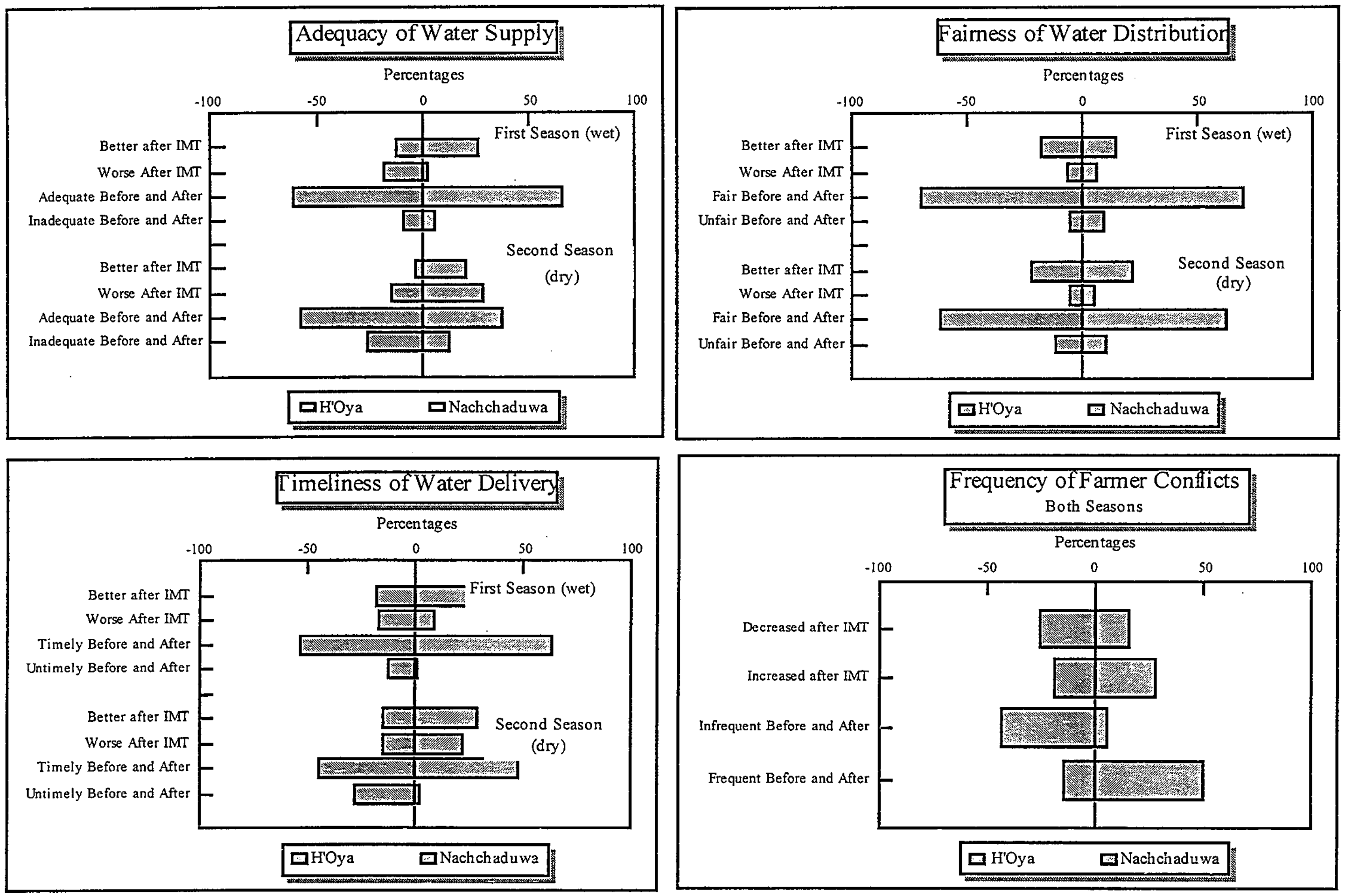


Figure 2 . Farmer perceptions about the quality of irrigation service before and after IM



Literature cited

Abeywickrema, Nanda. 1986, Government policy in participatory irrigation management, in *Participatory Management in Sri Lanka's irrigation schemes,* Colombo, Sri Lanka, IIMI.

Amerasinghe, Upali A., Sakthivadivel, R and Hammond Murray -Rust (1998), Impact Assessment of Rehabilitation Intervention in the Gal Oya Left Bank, Research Report 18, Colombo, Sri Lanka, IIMI

Brewer, Jeffrey D. 1994. The participatory irrigation system management policy, *Economic Review*, Vol. 20, No. 6,

IIMI/HKARTI. 1997, Monitoring and Evaluation of the Participatory Irrigation Management Policy, mimeo.

Johnson III, Sam H., Vermillion, Douglas L. Sargadoy, J.A. 1995 (eds), *Irrigation management transfer: Selected papers from the International Conference on Irrigation Management Transfer*, Wuhan, China, 20-24 September, Rome, IIMI/ FAO.

Kloezen, Wim. 1995, Results of participatory management in two irrigation systems in Sri Lanka, in Vermillion, Douglas L (ed), *The Privatization and self-management of irrigation* , Final Report, Colombo, Sri Lanka, IIMI.

Meinzen-Dick, Ruth., Mendoza, Meyra., Sadoutlet, Loic., Abiad-Shields., Subramaniam, Ashok., 1997, Sustainable water users association; Lessons from a literature review. In Subramaniam, Jaganathan, Meinzen-Dick (Ed), *User organizations for sustainable water services*, World Bank Technical Paper 354. Washington D.C. World Bank.

Molden, David., Sakthivadivel, R.,Perry, Christopher J., de Fraiture, Charlotte., and Kloezen Wim, H. 1998, Indicators for comparing the performance of irrigated agricultural systems, Research Report 20, Colombo, Sri Lanka, IIMI.

National Development Council (1996), Report of the National Development Council Working Group on Agricultural Policy, Colombo, Sri Lanka, duplicated.

Ratnayake, Ranjith. 1995, Irrigation management transfer in Sri Lanka, in J.C.M.A. Geijer (ed) *Irrigation management transfer in Asia,* Papers from the expert consultation on irrigation management transfer in Asia, Bangkok and Chiang Mai, 25-29 September, FAO/IIMI, Bangkok.

Samad, M. and Vermillion, Douglas (forthcoming), Participatory Irrigation Managment in Sri Lanka: Partial Reforms, Partial Benefits, Colombo, Sri Lanka, IIMI.

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Title:

Role of Farmer Organizations in canal irrigation systems: a case study in Udawalawa Irrigation & Settlement Scheme

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Summery:

In canal irrigation systems inefficient water use is a common phenomena and the operation and maintenance of the systems cost the state a large sum of money. Irrigation management Transfer (IMT) is one of the alternatives proposed by authorities to solve the problems of O&M, unfair and inefficient water use . Farmer Organizations are the key elements of the IMT. The idea of social development includes the conception that people would meaningfully participate, individually and collectively.

The impact of IMT in Udawalawa Irrigation Scheme is examined in this paper. The Udawalawa Special Area under controlled of Mahaweli Authority of Sri Lanka (MASL) was selected for the study because a large variation could be seen in operation of Farmer Organizations in the area.

Participatory Rural Appraisal Techniques (PRA) by participating farmer group meetings were administered to collect information about FOs and existing problems with their relative intensities.
Randomly selected 390 farmers were interviewed using a structured questionnaire to find the change of each aspects after the involvement of FOs in irrigation management and related activities using self evaluation method. The farmers' responses were categorized according to intensity and direction of the change. In addition to the above sample survey, two case studies were carried out for in depth information of irrigation management practices in Murawasihena and Embilipitiya Blocks. The paired signed test, Wilcoxon signed rank test and the Spearman's correlation coefficients were used as statistical tools.

Fairness of water distribution, conflict resolution, timeliness, canal maintenance and reduction of misuse of irrigation water have been improved with the activities of Farmer Organizations. Marketing aspects have not been developed simultaneously with the improvement of fairness of distribution of water.

Participation of women in decision making process is at very low level and the environmental aspects have been neglected by the activities of FOs.

Allocation of irrigation water has become fair and efficient after the FOs began its operation with IMT. There is no trade off between the efficiency and the fairness of distribution and they are interdependent in Udawalawa scheme because the system is operating behind the frontier of efficiency and fairness. There is a large space to improve both the efficiency and equity without any trade off.

Background of the study

Agriculture is the largest enterprise in Sri Lanka which provides employment opportunities for 47% of labour force in rural sector and 40% of the total labour force in the country in 1994 (Central Bank,1996). After the independence, 1948, there was a trend to develop irrigation works to fulfil the need of foodstuffs and to provide the employment opportunities for the unemployed youth. In irrigation schemes water is a free resource and therefore, farmers allocate water neglecting its value. On the other hand after the settlement of farm families with equal plots of lands, uneven distribution of income and variation of status of living among farmers could be seen obviously.

Water users neglected the care of canal maintenance, security of the canals, damages of the canals as a result of lack of property right. Further they tend to damage structures in order to get excess amount of water neglecting the other farmers' needs. All together externalities of maintenance of canal irrigation systems have made problems of persistency of the systems. Accordingly, to avoid water allocation problems and the high costs of operation and maintenance of the canal systems, in the 70's and 80's there was a move towards alternative institutional and organizational arrangements based on the principle of ***Participatory Management***. In the system known as the **Irrigation Management Transfer (IMT),** the responsibility of the complete operation and some section of the irrigation works in the field canals and distributary canals except irrigation head works is transferred to the farmers from the irrigation authorities.

However, farmers' group activities and involving farmers in irrigation works are not a something new in Sri Lanka. Collective activities and decision making in irrigation management could be seen in the history and more recently it was evident by the traditional *velvidane* (Irrigation leader in the village) who was elected by the farming community in each village tank systems. The *velvidane* was mainly responsible for water distribution, maintenance of irrigation works and conflict resolution. In 1958, the traditional *velvidane* system was abolished and the Paddy land Act No. 1 of 1958 established cultivation committees replacing traditional system.

After 1958, several steps were taken regarding the irrigation management by the government and Irrigation Ordinance of 1968, Agricultural Productivity act of 1972, Agrarian Service Act of 1979 and amendments of Agrarian Service Act in 1991 and the amendment of Irrigation Ordinance Act in 1994 to grant legal recognition and more power to Farmer Organizations are the important milestones of the path way of management of irrigation systems. Analysing these policy changes in irrigation management, it could be seen that the government and authorities have realized the importance of farmer involvement in irrigation management in major irrigation systems.

Razak and Perera (1995) have used the self evaluation method to evaluate the effect of Water User Associations in the Galoya left bank irrigation system (Razak & Perera,1995). The study reveals that water distribution in the field canals had been more effective and equitable after the establishment of Water User Associations in Galoya Left Bank Area.

Another important aspect of improved with the WUOs is the water distribution. After the establishment of WUOs water distribution was more equitable and effective in the Gal Oya Left Bank Irrigation System (Razak & Perera,1995). According to the Razak and Perera (1995), farmers believe that inadequate water availability at the D- Canals discourage farmers in taking part in WUO activities at the field canal level.

Saving of irrigation water has increased as a result of farmers' participation in WUOs. About 70 % of the members of WUOs was concerned about water requirement of other farmers and therefore, attempt to save water by closing poles once they receive adequate water to their fields. However, in the areas where most of the farmers are not having membership of WUOs and the farmers are mortgagees and tenants water saving is inefficient due to absent of support from mortgagees and tenant farmers for water saving activities (Razak & Perera,1995). Razak and Perera (1995) reveals that physical rehabilitation and group works of farmers are equally important and they mutually strengthened each other. The conflict resolution is another important factor to consider in irrigation settlement schemes. In the Gal Oya System, several factors cause conflicts among water users viz; inadequate and unreliable water supply, damages to control structures, removal of canal flash gates, lack of confidence in water rotation and illegal water tapping. After formation of WUOs these conflicts among farmers have been reduced in considerable amount according to ARTI (1986). Razak and Perera (1995) also reported that conflicts over irrigation water in field canal level have been reduced mainly due to their ability to resolve misunderstandings and settle clashes quickly and in a friendly manner with WUOs. But in the areas where land tenure is complex with tenant farmers and mortgagees, the success of conflict resolution is low compared to other areas (Razak & Perera,1995).

Protection of canal structures are important because damages to canal structures by farmers were common in irrigation schemes (Atapattu,1994; Weerawardene,1988; Murray-rust, 1983; Uphoff,1986; ARTI,1985). With WUOs safe guarding the canals and minimizing the damages to the structures were at a favourable level in Gal Oya Left bank Scheme (Razak & Perera,1995). But selfish motives led some farmers to damage structures as they did not consider themselves to be members of the community (Razak & Perera, 1995).

Style of interaction among farmers were changed and improved with the activities of WUOs in Gal Oya Left Bank area and it improved the performance of the system according to Razak and Perera (1995). Relationship between farmer and irrigation officials also improved with activities of WUOs in irrigation systems (Wijayaratne,1987; Perera,1986; ARTI,1986). Members of WUOs realized the difficulties and constraints of irrigation water management in canal irrigation systems and made effort to solve their irrigation related problems through WUOs without going to irrigation officials (ARTI,1986). Razak and Perera (1995) pointed out that WUOs have played a great roll as a extension agent to communicate effectively for distribution technologies among farmers.

Volunteer activities as a leader of a farmer group is an important issue with IMT and there is no incentive as a compensation for their works to the leader and that is a problem should be considered in promoting farmer groups (Karunanayake, 1980). One reason for the success of traditional velvidane system was the ability to enforce the law backed by the authority to resort to punitive actions. Therefore, there is a need to arm irrigation leaders with some degree of formal authority (Karunanayake,1980). According to Karunanayake (1980) in spite of the organization of farmer groups in irrigation water management, there should be a well conceived training program in water management. Another important issue is the allocation of water among groups and however, in the Mahaweli projects this has become an important imperative of water management at a level of a complex rather than a unitary system (Karunanayake,1980).

Hemaratne (1991) has shown that the poverty level of tail end farmers is three times higher than the poverty level of the head end farmers of the field canals in settlement schemes and the average income of the tail end farmers is equal to half of the average income of head end farmers of field canals. It reveals that the level of income of farmers could be explained by a regression model with several variables including the distance to their land from the field canals (Hemaratne, 1991). Income generated from moderate and large holding sizes (1.6 ha$<$) is sufficient only for their subsistence while farmers with small holding sizes are unable to survive even at the subsistence level in settlement schemes Godaliyadda, 1988). In Mahaweli System-H area the average cultivated area has been decreasing towards the tail ends of field canals and resources are misallocated (Godaliyadda, 1988).

Moragollagama (1990) has shown that there is a significant improvement in farmer participation in irrigation management (O&M) of the irrigation systems in Sri lanka. The distribution of water, input supply and coordination between farmers and agencies have been improved with the activities of FOs. With the farmers' participation in decision making, the yield, cultivated area and especially income of the tail end farmers have been remarkably increased (Moragollagama, 1990).

Objective of the study is to evaluate the impact of Farmer Organizations on several aspects of efficiency of allocation of irrigation water in the canal irrigation systems and the fairness of distribution of water among farmers.

Methodology

For the study, Udawalawa Irrigation Settlement Scheme is selected because of Udawalawa settlement scheme is a good research field for FOs due to existence of several stages of FOs and heterogeneity of the performance of FOs.

Udawalawa project area consists of seven blocks, two in the Left Bank command area and five in the Right Bank command area, and 173 FOs are distributed among above seven administrative blocks in 1995. The number of members of the FOs are varied from 2 to 280 and the levels of the performance are different from each other. However, it was difficult to capture all FOs for the study and number of farmers of the sample represents the proportionate of farmers in each administrative blocks.

Participatory Rural Appraisal techniques were administered to collect the information regarding distribution of water, decision making process, and existing problems related to various aspects of O&M of the system by participating farmer group meetings.

From seven administrative blocks, a sample of 390 farmers was selected proportionately for cross sectional field survey in addition to two case studies carried out in Murawasihena and Embilipitiya Blocks. The sample size of farmers were determined by using the Pagoso Formula.(Pagoso, 1981).

Statistical tools

Paired sign test

Change of the impression of the farmers about the particular criterion before and after the Irrigation Management Transfer is tested through nonparametric statistical test: "the paired sign test". The test based on the signs of differences between two measures before and after. This test is useful and suitable where quantitative measurements is imposable or infeasible (Siegel and Castellan,1988).

Wilcoxon Signed Rank Test

The sign test discussed above utilizes information only about the direction of the differences within pairs of observations. If the relative magnitude as well as the direction of differences is considered, the Wilcoxon Signed Rank Test is more powerful. This test gives more weight to the pairs which shows a larger difference between two conditions than to a pair with small difference. To test the change of the criterion before and after the IMT, each criterion was categorized in to five groups (1 - very bad, 2 - bad, 3 - indifference, 4 - good, 5 - very good) and, therefore, their is a direction and a magnitude for the change of each criterion after IMT (Siegel and Castellan,1988).

Results and discussion

In 1996, majority of the farmers in the area are the members of relevant FOs while some of the farmers have not yet joined with the FOs depending on some reasons. The data shows that a large portion of farmers have taken the membership of FOs in Embilipitiya and Chandrikawewa blocks while in Murawasihene the percentage who having membership is small (53%). The difference of irrigation water availability in the area has influenced the desire of taking membership of FOs. Most of the farmers are not willing to obtain the membership of FOs in Murawasihena due to frequent failure of crops due to irregularity of water availability. Most of the farmers who are not the members of FOs in Murawasihena block responded that they do not want having the membership of such organizations without any assurance of water availability to their lands to reduce the uncertainty of their crops. However, most of the non-members are not reluctant to having membership of FOs after realizing that the FOs are the legal and authorized body of water management in irrigation system.

Decision making regarding the crops and the time of cultivation

According to the farmers' response, the decision making power (40%) is still on the hand of Mahaweli officials. Only 8% of farmers reported that decisions regarding irrigation water distribution are taken by farmer groups while decision making power is on the hands of individual farmer, Farmer Organization, leader of Farmer Group, and Mahaweli Officials as reported by 20%, 2.7%, 13.3%, and 40%, respectively.

Farmer Organization has not a sole authority decide the crops which cultivated in the season or the time which is to be cultivated and other cultural practices. Mahaweli officials are dominant in decision making process about the crops and time to be cultivated. Still some farmers (20%) act on their own decisions neglecting the decisions taken by other authorities and it shows the absence of unanimity among farmers in decision making process and other cultural practices. This situation makes an adverse effect on the performance of Farmer Organizations in the area. On the other hand farmers are not fully satisfied with the decisions taken by bureaucrats. Results reveals that only 13% of the farmers in the sample is completely satisfied with the decisions taken by authorities and 6 % of the farmers totally disagree with the decisions taken by authorities. Results reveals that 44 % of the farmers agree with the 50 % of the decisions taken by the authorities and 36 of the farmers agree with some decisions but not with the most of the important decisions. However, this figures shows an improvement of the decision making process with Farmer Organizations than the totally bureaucratic dominance which were practised earlier.(Murray-Rust,1983).

Benefits of water management through FOs

Farmers were asked to compare their view through their experience after IMT with before IMT conditions. There were positive changes, negative changes and some farmers are indifferent between two options before and after the IMT. Descriptive statistics of the results are shown in the table 1. Amount of water received during the cropping season, fairness of distribution of water, timeliness of water availability, maintenance of distributary and field canals, reduction of conflicts among farmers and the conflicts between farmers and officials are the selected criteria and responses were categorized as;

1 - negative (Worse off with the activities of FOs)
2 - indifferent (No any positive or negative impact of FOs on the criteria
3 - positive (Better off with the activities of FOs).

Data in the table 1 shows that all the aspects regarding water management has been increased in varying degrees after the IMT but the amount of water received to the farmers' field has not been increased considerably. To test whether the increase of each criteria, the "Paired Signed Test" was carried out and the results are shown in the table 1.

Table 1. Parameter estimates of "paired signed test"

Criteria	Mean	Percentage of positive signs	'z' value	Probability level	
1.Amount of water received	2.14	34.7	1.6	0.1096	
2.Timeliness	2.34	58.7	3.2	0.0014	**
3.Fairness	2.67	76.0	6.1	0.0000	**
4.Canal maintenance	2.81	84.0	7.4	0.0000	**
5.Illegal access	2.76	78.7	7.2	0.0000	**
6.Reducing conflicts among farmers	2.70	74.7	6.8	0.0000	**
7.Reducing conflicts between farmers and officials	2.67	69.3	6.7	0.0000	**

(** - Significant at 0.01 level)

Figures in the above table reveals that the amount of water received has not been increased significantly after the IMT while other criteria have been improved remarkably. Timeliness of water receiving to the field has less improved than the canal maintenance and fairness of water distribution. Most of the criteria related to water management show that involvement of Farmer Organizations have created a favourable situation for the farmers. However, Fairness of water distribution has increased a greater extent than the amount of water and it provides an evident to reveal that there is a potential to improve the system performance while the amount of water remaining at the same.

Problems pertaining to the irrigation water management through FOs; Farmer perspectives.

In this section, farmers were asked to mention the existing problems related to water management by the FOs and responses of farmers are summarized in the table 2.

Table 2. Problems of water management through FOs

Problems	Percentage of farmers reported
1. Unfair distribution of water among farmers	17.3
2. Inadequate amount of water	64.0
3. Illegal access corruptions	16.0
4. Political interference	12.0

Source: Field survey, 1997.

Above table shows the existing burning issue related to water management is the inadequate amount of water in farmers' point of view. Other problems have been declined up to certain level with the activities of FOs and unavailability of water is a critical and inherent in the system due to the location of structures and canals and it cannot be corrected by the activities of FOs within a short period of time.

Present situation after IMT

In this section of the analysis, 25 selected criteria were tested to find whether there is an improvement of each criteria with the activities of FOs using "Wilcxon signed Rank Test". For each criteria, farmers' view about the criteria were questioned before and after IMT and magnitude and the sign of change were analyzed after dropping out the tallied pairs. Categories of the change;

1. Very weak
2. Weak
3. Not any change after the IMT
4. Good
5. Very good

Table 3 Shows that decision making aspects and warmth and support among farmer are at higher level compared to the previous management system and 'z' value of Wilcoxon signed rank test shows that above qualities have been increased after introduction of IMT. Participation of various social categories, rich farmers, poor farmer and youth, in water management activities is at a favourable level and the situation has been developed with the activities of FOs. However, women participation in water management activities has not been improved and not at a considerable level.

Political intervention is not a serious problem in water management activities in the area. Input availability, credit facilities, education and training and labour availability are at a low level because FOs have no attempts to organize farmers towards these aspects. Another very poor area is the marketing which is important but neglected or payed less attention. Prices for their products are very unstable and mainly prices are determined by the collusion of traders which were coming from out side areas. There is no bargaining power to the farmers because FOs are not organized to cater a better marketing channels for their products. In Murawasihena Block, FOs have made an arrangement to avoid the exploitation of producers from local traders and it has been functioning well.

FOs have not considered environmental pollution in their activities and awareness about the environmental aspects is at very low level. However, overall satisfaction about water management has been increased with the involvement of FOs and it is a favourable sign with the IMT.

Table 3. Present situation and the change of selected aspects.

Aspects	Mean	Mode	Median	'z'	"P"
1. Listening to the farmers	3.80	4	4	3.06	**
2. Frequent meeting and discussion	3.96	4	4	3.48	**
3. Solutions for farmers' dominant problems	3.63	4	4	4.78	**
4. Farmers contribution in irrigation management	4.03	4	4	6.19	**
5. Contribution of farmers in collective activities (Shramadana)	3.37	4	4	6.80	**
6. Social and cultural aspects	3.72	4	4	5.57	**
7. Fairness of water distribution	3.95	4	4	6.23	**
8. Input availability	2.48	2	2	-3.57	--
9. Participation of women	2.93	3	3	-0.63	--
10.Participation of poor farmers	4.04	4	4	6.58	**
11.Participation of rich farmers	3.91	4	4	6.21	**
12.Participation of youth	3.60	4	4	4.54	**
13.Free from political interferences	3.60	4	4	3.89	**
14.Education & training	2.95	3	3	-0.53	--
15.Labour availability	2.51	2	2	-3.19	--
16.Credit facilities	2.56	2	2	-3.12	--
17.Marketing of products	2.47	2	2	-3.79	--
18.Prices for the products	2.49	2	2	-3.80	--
19.Increase of family income	2.48	2	2	-4.29	--
20.Environmental aspects	2.70	2	2	-2.83	--
21.Mutual relations among farmers	3.71	4	3	3.48	**
22.Mutual relations between farmers and officials	3.65	4	4	5.08	**
23.Collection of water charges	2.24	1	2	-4.88	--
24.Reducing risk	2.64	3	3	-1.72	--
25.Overall satisfaction	3.37	3	3	2.97	**

Key: 5 - very good, 4 - good, 3 - Normal,
2 - weak, 1 - very weak
*** - Significant increase at 0.05 probability level.**
**** - significant increase at 0.01 probability level.**

Source: Field survey, 1997.

Distribution of benefits among farmers in various aspects regarding to water management

This part of the text summarize the selected seven criteria considered to evaluate the effectiveness of FOs in irrigation water management in farmers point of view. Table 4 shows the percentages of farmers responses belonged to each category, viz; percentage of better off farmers, indifferent farmers and worse off farmers.

Table 4. Distribution of benefits among farmers in various aspects

Aspect	Better off	Indifferent	Worse off
1. Amount of water	35	48	17
2. Timeliness	70	6	24
3. Fairness of distribution	88	3	9
4. Canal Maintenance	97	0	3
5. Reduction of damages and misuse	85	12	3
6. Reduction of conflicts among farmers	77	20	3
7. Reduction of conflicts between farmers and officials	85	12	3

Source: Field survey, 1997. (N = 275)

The data in the table 4 shows that all the aspects considered in this analysis regarding the irrigation management after the IMT, except the amount of water has been increased with the involvement of FOs in the activities of irrigation management. The canal maintenance, fairness and timeliness of water distribution and reduction of conflicts have shown a remarkable development with the FOs. The number of worse off farmers are negligible compared to the number of better off farmers. Some farmers, although the number is small, are indifferent with the selected criteria and they do not see any difference after the IMT. Most off the worse off farmers are concentrated in head end area while almost all the farmers are better off in the tail end. However, amount of water availability does not show a significant improvement and it cannot be corrected by the activities of FOs because it is inherent with the irrigation structures.

Conclusion

Through the activities of FOs, both efficiency and the fairness of distribution have been improved in Udawalawa Scheme. There is an opportunity to improve both efficiency of the system and fairness of distribution without any trade of because they are inter-related.

The role played by Mahaweli Official is vital since 1991 to improve the FOs and, for the sustainability of IMT continuity of role of Mahaweli officials is important.

According to the farmer leaders point of view, there are several obstacles of activities of FOs. The main problem is the time limitation of the volunteer officers of FOs to devote to the activities of FOs. The volunteer officers are not paid for the services such as participating meetings and so on. Therefore, they spend a large time period for the activities of FOs without any gain and they could not do their own works in time.

Secondly, there is no continuous program for motivation the farmers and FOs towards the self management of irrigation water. Most of the programs are commenced in large scale with a large publicity and propaganda, but after a short period the motivation is vanished. Thirdly, it is experienced that in some areas, where officers devoted a longer time and effort to improve and to solve problems regarding the irrigation management, FOs are operating very effectively while in the areas where no attention paid by the officers, FOs are inactive. Fourthly, resolution of the problems related to land is essential for effective water management and the absent of this power to the FOs generate an inefficiency of the activities of FOs.

Another serious issue is the lack of incentives for the officials who devoted their time for the improvement of FOs. There is no any incentives for the efficient irrigation officials. On the other hand farmer leaders have a social prestige as a officer or a leader of the farmer group while as a paid employee, irrigation officer has not such a social prestige to be an efficient person. There should be an incentive scheme to promote irrigation officials because the performance of FOs are entirely depend on the efficiency of the irrigation officials who involve in the institutional activities.

There should be organized marketing programs supported by the government authorities for inputs and outputs to improve the importance of the FOs among farmers. Rented lands of the area have become a severe problem for the activities of FOs, because the farmers rent the land for a shorter period and, therefore, they need to cultivate paddy in all the area to pay the rent or to get a highest possible profit. Therefore, they do not agree with the decisions taken by the farmer groups to cultivate the limited extent of paddy. On the other hand they are not members of the FOs but outsiders. There should be a policy to act on this problem to improve the water management through FOs.

REFERENCES

Agrarian Research and Training Institute. 1986. The Gal Oya Water Management Project: End of project impact assesment (Draft), ARTI, Colombo, Sri Lanka.

Aluvihare, P.B. and Masao Kikuchi. 1991. Irrigation Investment Trends in Sri Lanka: New construction and beyond. IIMI, Colombo, Sri Lanka: (1-92)

ARTI,. 1986. Small Farmer Organization Project in Sri Lanka, Colombo

Atapattu, A. 1994. Role of SARVODAYA in Agricultural Development: Agricultural Extension through Farmar Organization and Village Extension Volunteers, Proceedings of the Symposium 1994,SLAAS, Sri Lanka.(pp.60-61)

Godaliyadda, G.A.G., 1988. A Case Study of Farm Level Management and Constraints for Effective Irrigation Management at Gal Oya Irrigation Scheme, Sri Lanka. Unpublished MPhil discertation, PGIA, Sri Lanka.

Hemaratne, H., 1991. Factors Affecting the Income Inequality in Irrigation Schemes of Sri Lanka; The case of Minipe Project. Unpublished MPhil desertation, PGIA, Sri Lanka.

Karunanayake, M.M. 1980. Farmer Organization and Irrigation Leadership in Sri Lanka: Restrspect and Prospect, MARGA Quaterly Journal, Vol.6, No.1, MARGA Institure, Colombo, Sri Lanka. (pp.1-17)

Karunatilaka, H.N.S. 1988. The accelerated Mahaweli Development Programme and its Impact, Centre for Demographic and Socio-Economic Studies, Sri Lanka (pp. 51)

Moore, M.P. 1980. Aproaches to Improving Water Management on Large Scale Irrigation Schemes in Sri Lanka, Occational Publications, ARTI, Sri Lanka.

Murray-Rust, H. and M. Moore. 1983. Formal and Informal Water Management Systems: Cultivation meetings and water deliveries in two Sri Lankan irrigation schemes, Cornel University, Ithaka.(pp34)

Murray-Rust, H. 1983. Irrigation Water Management in Sri Lanka: An evaluation of technical and policy factors affecting operation of the main canal sytems. PhD Thesis, Cornell University, USA.

Nijman, C. 1991. Irrigation Management Processes and Condition: A case study of Sri Lanka's Walawe Irrigation Improvement Project, IIMI, Colombo, Sri Lanka. (7-32)

Pagoso, C. *et al*. 1981. Fundamental Statistics for College Students. Phoenix Publishing House, Quezon City, The Philippines.

Ranatunga, R.S., J.Farington, W.A.T. Abeysekara., (1981) Some Issues Confronting the Rehabilitation of Major Irrigation Schemes in the Dry Zone, Research study series No.44, ARTI, Sri Lanka.

Razak, M. and J.Perera., 1995. Water Use Associations in Irrigation Water Management in the Gal Oya Left Bank Irrigation System; A case study of farmer beneficiaries' evaluation. Research study series No. 95, HARTI, Sri Lanka, 52-80

Sandaratnene, Nimal. 1972. "Sri Lanka's new land reform": South Asian Review, October

1972, Vol. 6, No.1, (pp.122-127)

Siegel, Sidney and N.J. Castellan,. 1988. Nonparametric Statistics for the Behavioral Sciences, Second Edition, McGraw-Hill, New York. (pp.69-185).

Weerawardene J.K. 1988. Land Settlement in Sri Lanka: Review of Farmer Organizations, ARTI, Colombo, Sri Lanka

Wijayaratne, C.M., 1984. Involvement of Farmers in Water Management in Gal Oya, Sri Lanka.Expert Consultation of Water Management, FAO/USAID, Yogyakarta, Indonesia.

Wijayaratne, C.M., 1987. Catalyst Intervention as a Strategy to Promote Popular Prticipation in Rural Development: Lessons from Gal Oya, Sri lanka. CIRDAP, Bangladesh.

Wijayaratne, C.M., 1994. Sustainability of Farmer Organizations. Economic Review, Vol.20, No.6. Peoples Bank Publications, Sri Lanka. (25-28).

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Community Management Model for Irrigation Management Transfer - Moraketiya DC7 in Embilipitiya Block of the Uda Walawe Project

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Community Management Model for Irrigation Management Transfer - Moraketiya DC7 in Embilipitiya Block of the Uda Walawe Project

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ABSTRACT

Irrigation Management Transfer is accepted worldwide today. Though many countries including Sri Lanka have various programs to transfer irrigation management to farmers more failures than successes are reported. One key characteristic of a successful Irrigation Management Transfer is an associated program for community management of irrigation systems. The International Irrigation Management Institute carried out an action research program in the Uda Walawe Project in order to field test a community management model for handing over system management responsibilities at the tertiary level. The model consisted of a 12 step process with three stages of building, strengthening and sustaining the farmer organizations and gradual empowerment of farmers. It was expected that farmer would take over system management responsibilities with this gradual empowerment.

The process followed satisfied the requirements of irrigation management transfer at the tertiary level and it proved to be effective. This paper describes the 12 step process followed and the lessons learned. The community management model tested for Irrigation Management Transfer would be worthwhile replicating in other irrigation schemes.

Introduction

Transfer of management responsibilities of publicly owned irrigation schemes to farmers is widely accepted worldwide today. Many countries implement various projects and programs aiming at improving performance, ensuring the sustainability and reducing government costs (Kloezen and Samad 1995). Both failures and successes are reported in these attempts (Vermillion, ed. 1996; Kloezen 1998). In Sri Lanka this has been tried through different modes of experiments since the 1980s. Irrigation Management Transfer (IMT) is currently accepted in Sri Lanka as a policy and is being implemented in many irrigation systems under special programs called Integrated Management of Agricultural Systems (INMAS), Management of Irrigation Systems (MANIS) and Mahaweli joint management systems. However, expected results have not been achieved from these programs (ARTI 1992; IIMI/ARTI1 1995; Samad and Vermillion - Forthcoming).

The International Irrigation Management Institute (IIMI) carried out an action research program to improve system performance in the Uda Walawe Project during 1988 to 1994 with financial assistance from the Asian Development Bank (ADB) (IIMI 1995). One of the components of this research project was Tertiary System Management, the objective of which was to develop and field test a model for tertiary system management and a process for turning over tertiary system management responsibilities to farmers. This

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paper is based on the lessons learned from implementing the Tertiary System Management component which involved institution building for turning over management responsibilities at distributary and field channel levels to farmers.

Objective of the Paper

The objective of this paper is to analyze the process followed, strategies used, results achieved and impacts observable in implementing the research component of Tertiary System Management; and to suggest its relevance to policies of irrigation management transfer in Sri Lanka.

Tested Hypothesis:

The hypothesis tested was *" if farmers are mobilized through well designed and systematic institution buildirtg strategies and processes they are capable of taking over the full operation and maintenance responsibilities in a tertiary sub system of an irrigation system."*

IIMI Research Program in Uda Walawe

In a diagnostic study carried out by IIMI prior to the action research it was found that system performance below the distributary level was poor because of the absence of an effective management system, either among farmers or on the agency side. Also, the organizational development activities in the project had not achieved the expected results. As a consequence it was found that the existing water user patterns would have serious implications in the achievement of project objectives and the long-term sustainability of the Uda Walawe Scheme which was being rehabilitated under ADB loan funds (IIMI 1990). The study recommended that the Mahaweli Economic Agency (MEA) should commit itself to a joint management approach based on the participatory management policies of the Government of Sri Lanka with the development of an appropriate handing over methodology and process.

The action research phase was designed to contribute to:

- Main System Management: working with MEA to improve its management of the main system.
- Tertiary System Management: working with farmers and MEA to improve the management of distributary channel and below.
- Rehabilitation Process: working with farmers and MEA to improve the ongoing system rehabilitation project (IIMI 1995).

The following four main activities were included in the Tertiary System Management Component:

- Institution building through the formation and strengthening of farmer organizations,
- Pre-seasonal maintenance program,
- Operation planning for the land preparation period, and
- Operation planning for the crop growth period.

The formation of strong and effective farmer organizations was the foremost activity since organizations are a prerequisite for turning over tertiary system management responsibilities to farmers. However, all four activities were implemented through a process of community management.

Location of the Study

The tertiary system management component was first implemented in one distributary canal – Distributory Channel 7 (DC7) under the Moraketiya Branch Canal in the Embilipitiya Block and later expanded to cover all nine distributary channels under Moraketiya Branch Canal.

Moraketiya Branch Canal is the headmost branch canal off the Right Bank Main Canal (Figure 1). DC7 is located at the tail-end of Moraketiya Branch Canal. DC7 was chosen because it was, at the time (1991), one of the few distributary channels where rehabilitation activities had been completed, and it was having many irrigation problems mainly due to poor system management at the DC level and below. DC 7 has 8 field channels (FCs) serving 79 farmers in the command area of 77 hectares (Figure 2).

The study commenced from late Yala 1991 (August 1991) and ended in Maha 1993/1994 (February 1994). Institution building started right from Yala 1991.

Mode of Implementation

The Study was a Participatory Action Research (PAR) program. PAR is a research process in which the community members actively collaborate in the identification of problems, collection of data and analysis of their own situation in order to improve it (Selener 1997). The farmers and the system management unit of the MEA become the implementors of the research program implemented in Uda Walawe (IIMI 1995). Particularly the Tertiary Management Component was a process continued from Yala 1991 with the involvement of farmers, field level MEA officials and IIMI researchers. Collecting information, planning, implementation and feed back of all the activities were done jointly by farmers, MEA officials and the IIMI researchers. The study was implemented by a sub-committee comprised of Block level and field level officers, FC farmer representatives (FRs) and IIMI researchers. The Study Coordinating Committee at the Project level had the responsibility of monitoring the total PAR. The IIMI researchers were expected to assist in collecting data, preparing work plans, providing necessary guidance in implementation and monitoring the work. Particularly one researcher (the first author) played the role of change agent both for field level officials and farmers.

The Community Management Model Tested

The total tertiary system management component was implemented through a twelve step process aimed at institution building and transfer of management responsibilities. These twelve steps can be divided into three stages.

- Building the farmer organization
- Strengthening the farmer organization
- Sustaining the farmer organizations by institutionalizing and stabilizing the activities.

The twelve steps followed under these three stages are shown in Table 1.

Table 1. Steps of the Community Management Model

Stage	Steps
1. Building the FO	1. Evaluating the strengths and weaknesses of existing farmer organizations 2. Developing a model for farmer organization 3. Conducting awareness meetings 4. Forming farmer organizations
2. Strengthening the FO	5. Identifying training needs of farmers, FRs and MEA officials and preparing training modules 6. Providing training for farmers 7. Providing training for FRs 8. Providing training for officers 9. Providing guidance on conducting meetings, systematically keeping records, solving problems and making decisions 10. Formulating rules and getting legal recognition
3. Sustaining the FO	11. Implementing tertiary system management activities with joint management and gradual transfer 12. Implementing other FO activities

The total process was a collaborative and continuous one although given as separate steps as above, and some of them were undertaken out of sequence or simultaneously with others. On the other hand during each step the problems were identified and corrective actions were taken to adapt the process to the changing environment; that is, it was carried out as a learning process. The total process was aimed at gradual empowerment of farmers to take over the system management responsibilities.

The implementation of each step in the process in DC 7 is described below:

Stage 1: Building Farmer Organizations

Evaluating existing farmer organizations was necessary because of previous activities aimed at organizing farmers for irrigation management. However, even where such prior activities had not occurred it is important to undertake this step which will be useful in building new organizations. The survey indicated that the farmer organization built in DC7 in those previous attempts by the MEA was almost non-existing. Therefore, it was decided to build a new farmer organization.

The farmer organization model developed was derived from previous models used in Sri Lanka with several modifications by taking into account what was learned in the initial survey as well as some ideas put forward by farmers. The model proposed two levels of organization, one for each field channel (FC) and one for the DC. At the FC level, a farmer group was to be formed for each FC. The FC group would be headed by a farmer representative (FR) selected by the common consensus of farmers and would be responsible for irrigation management on the FC. The DC level organization was to be comprised of all the farmers of the DC. To manage the DC organization, a DC committee of all the FRs was formed. As suggested by farmers an assistant for each FR was also included in the committee to ensure the representation of the FC committee in every committee meeting and to develop a future group of FRs. In addition to this it was proposed to form a Unit level coordinating committee covering the total Moraketiya BC comprised of all DC FRs and the field level officers and a Block Committee comprised of farmer representatives of the block and MEA officials at the block level.

Conducting awareness meetings was intended to get the farmers to begin discussions on the need of getting organized. These meetings focused primarily on motivating farmers to organize themselves. They were held at field canal level.

Formation of the farmer organization took place after farmers were fully convinced of the need for an organization and decided to create one with a model they thought would be effective. Accordingly, the formation of the organization took place with active farmer participation with over 85 per cent of the total number of farmers in three stages: formation of FC groups, formation of the DC committee, and formation of the general farmer organization.

Stage 2: Strengthening Farmer Organizations

Training for farmers and MEA officials was needed to make necessary behavioral and attitudinal changes and building their capacities to work with the organization. Training needs for farmers and FRs were identified during the initial survey. A separate survey was carried out to identify the training needs of MEA officers.

Training was provided for all the DC 7 farmers under the subjects of development of group consciousness, awareness and advantages of farmer organizations, proposed FO model and objectives, understanding of required leadership qualities, and how to undertake group problem solving and decision making.

The training provided for the FRs was intended to improve their leadership qualities, help them understand their roles and responsibilities, provide knowledge of techniques of leading groups including meeting management and proper record keeping.

MEA officials were not provided with formal training as another agency was given the responsibility to carry out training for all officers. IIMI, however, arranged two programs for officers to facilitate implementation of study:

- A study tour to other schemes in Sri Lanka where participatory management approaches were applied successfully.

- A one-day program on "training skills for training adults" for officers to develop skills needed for transferring irrigation technologies to farmers.

After the initial formation of the FO, farmers needed guidance and assistance in conducting meetings and systematic record keeping. In addition, farmers needed assistance and guidance in participatory decision making and in problem solving as it is a new approach for them. Providing guidance on conducting meetings, keeping records, solving problems and making decisions is very important as they are the key organizational management tasks.

Deciding the roles and responsibilities of farmers, FRs and the office bearers, formulating other rules and regulations, and preparation of a constitution took place as part of the training program prepared for FRs.

Arrangements were made for the farmer organization to fulfill the necessary requirements and obtain legal recognition under clauses 56a and 56b of the Agrarian Services Act.

Stage 3: Sustaining the Farmer Organization

After strengthening, the DC 7 FO gradually took up tertiary level management responsibilities. Gradually these activities were institutionalized. Tertiary system management activities included three categories of activities: pre-seasonal maintenance, operations planning for the land preparation period and operations planning for the crop growth period.

Pre-Seasonal Maintenance

The maintenance program was organized to get maximum farmer involvement in decision making; it included the following steps:

1. Identification and prioritization of DC maintenance work with farmers.
2. Preparation of estimates for DC maintenance.
3. Discussing the DC maintenance program and coming to agreement within the FO.
4. Implementing the DC program by the FO.
5. Planning and implementation of the field channel pre-seasonal maintenance by each FC group.
6. Participatory monitoring and feed back.

Operations

The operation planning was for both the land preparation period and the crop growth period. Operations planning involved six steps:

1. Initial discussion with farmers at FC group level concerning distribution problems and desired operations.
2. Preparation of alternative operations plans by IIMI personnel together with the block Irrigation Engineer.
3. Discussion of the alternative operations plans with the DC committee to devise a plan agreeable to farmers.

4. Discussing the selected plan with the farmers in the FC groups convened by the FRs; with the help of IIMI personnel and the Technical Officer, farmers prepared rotational schedules for each FC.
5. Implementation and preparation of an improved plan after identifying problem areas through experience.
6. Participatory monitoring and feed back.

Both these programs were repeated in the following seasons while farmers gradually took up the responsibilities for the operation and maintenance when they become capable of doing them by themselves.

As it was felt necessary to increase the benefits of the farmer organization by taking up other activities desired by farmers, the DC 7 farmer organization was assisted to organize several activities outside of irrigation management. These included provision of fertilizer and other inputs to farmers, building a community hall, forming a women's organization affiliated to the farmer organization, starting a carpentry school, forming a sports society, starting a library, and organizing religious and social activities for the benefit of the community.

The role played by the FRs, general farmers, MEA officers and IIMI researchers in the total process is given in the Table 2.

Results Achieved

Formation of a Strong and Effective Farmer Organization

The organizational strength was evaluated using specific indicators developed for Sri Lanka to asses farmer organizations (IIMI/ARTI 1995) (Table 3). The conceptual base, performance and outcome was rated as at a very high level.

This organization was able to withstand both the serious consequences of giving up the Yala 1992 cultivation due to lack of water while all other organizations built in the project were severely affected and declined, and some political pressures came from several local politicians to change the FO into a political organization. It became a model for the farmer organizations built in the rest of the 8 DCs in Moraketiya BC. This organization while involved in the DC level operation and maintenance activities gradually took over those responsibilities.

Increase in the Water Management Performance

Prior to the study the operation within the DC was the sole responsibility of the Agency. There was no rotational water distribution and farmers were used to simultaneous irrigation. There were severe irrigation difficulties in the tail-end and as well as frequent farmer disputes. The operation plans developed with farmers under the study were implemented initially with the Agency officials and later by farmers themselves after FRs took over these responsibilities. Rotational water issues were practiced both among and within the FCs with equal distribution of water between head and tail. The irrigation problems were solved and the actual water use was below the target in consecutive seasons (Figure 3). The improvement in water management could be seen in the computation of Delivery Performance Ratio (DPR = actual water issues/target) (Figure 4). The operation plans prepared for the project under the existing rehabilitation and modernization project of the Uda Walawe Project were revised based on the actual water consumption of the DC7 which was lower than those plans (IIMI 1995).

Improvement in System Maintenance

The system maintenance of the DC prior to the study was entirely the responsibility of the MEA and implemented through hired labors. Under the study the maintenance plans were prepared by farmers and Agency officials together and implemented by farmers with part payment from the MEA. Farmers developed routine maintenance practices and implemented them without expecting MEA funds. The total system including roads was maintained at a better quality by farmers.

Creation of Strong Group Consciousness

After the formation of the farmer organization, civic and group consciousness of the farmers was heightened. In DC 7, the whole community including the women and youth were brought together in activities benefiting the entire community. This change of behavior made it possible to solve some long standing boundary disputes and even the contentious cattle grazing problem. Both the FC level and DC level routine maintenance and any repairs to structures were done through group work.

Building a Sense of Responsibility

An additional consequence was a heightened sense of responsibility among individual farmers to fulfill their obligations. This sense of responsibility could be seen in greater effort spent in cleaning the canals and taking measures to protect them including canal roads.

Building Better Farmer-Officer Relations

The usual strained and hostile relations between farmers and many MEA officers, particularly those responsible for irrigation services, were changed especially after the establishment of joint management committees and mutual respect and trust was developed.

Expansion of the Study to the Total Moraketiya BC

With the results achieved in DC7, the Tertiary System Management Study was expanded to the total Moraketiya BC with 9 DCs. The process followed in DC7 was applied in the other DCs and similar results were achieved in organizational development and in operation and maintenance. It was able to build strong and effective FOs in all the 9 DCs. The FOs in the whole BC worked together as one group and became involved in decision making, planning and implementation. A strong Unit Coordinating Committee (UCC) comprised of all the

FOs of the BC was formed and it became the planning and decision making body of the BC and the forum of joint management. The FOs took the responsibility of field level water distribution and implementing the pre-seasonal maintenance. Rotational water sharing was introduced at the field level on operation plans prepared together with farmers instead of simultaneous irrigation which was the existing practice. A sense of responsibility and group consciousness were built among the farmers within the whole BC. The impact of this exercise could be shown in the increase of the water use efficiency of the Moraketiya BC (Figure 5).

Impact of the Study

Gradual Taking over of O&M Responsibilities

Though there was no formal handing over, farmers gradually took over O&M responsibilities with the introduction of joint system management. First, the FRs took over the full responsibility of distributing water within FCs and later took the responsibility of FC head gate operation. The maintenance was done taking it as an obligatory responsibility of farmers. A new practice of mid-seasonal canal maintenance was also followed by farmers.

Impact on the Other DCs of the Branch Canal

The progress made in the DC7 had a positive impact on expanding similar practices to other DCs in the Moraketiya BC. The DC7 FO had become a model for replication. The operation plan tested in DC7 was taken for the development of operation plans for the total Right Bank Main Canal of the Uda Walawe project.

Cost-saving

The agency cost for operation and maintenance was reduced during the study period as the FO shared a part of it. Particularly the maintenance cost was reduced as farmers practiced routine maintenance on their own initiative. For example the total estimated pre-seasonal maintenance cost in Maha 91/92 for the DC was Rs 15,087 ($359 @ $1 = Rs 42 in 1992). In Yala 92 it was reduced to Rs 1576 ($37.50) i.e., just 10 per cent of the previous year's cost (IIMI 1995). The practice followed by the MEA before the study had been to allocate funds according to the length of the DCs without considering the quantity of the work.

Increase in Yield

There was an equitable increase in the yield in both the head and the tail of the DC. The average yield of the DC7 according a crop survey carried out in Maha 92/93 with a sample of 15 farmers was 5.3 tons/ha while the yield distribution among the head middle and tail of the sample was 5.21, 5.47 and 5.26 tons/ha respectively (Table 4). Farmers attributed this to the equitable and reliable distribution of water within the DC (IIMI 1995).

Present Status in DC7 and other DCs in Moraketiya

Strength of the FOs

In a survey done in August 1998 using the same indicators developed to evaluate the performance of farmer organizations in Sri Lanka, it was found that the DC7 FO was functioning at the same high level as at the time it had been formed. All the aspects of membership, conducting meetings, leadership effectiveness and involvement in O&M have been sustained at the level achieved during the study period (Table 5). However, the funding sources of the FO at the time the survey carried out are limited to the membership fee since they receive no maintenance allocations from the MEA.

FOs built in the other DCs of the Moraketiya BC under the expansion of the study were also found to be functioning well in August 1998. The Unit Coordinating Committee formed representing the total 09 FOs is firmly established and functioning well. Meetings of the Unit Coordinating Committee are being held monthly with over 80% attendance. The seasonal planning for Moraketiya BC is taking place at the Unit committee together with FRs and Agency officials. These planning sessions have replaced the typical kana meeting.

Involvement in O&M

The total operation and maintenance within DC7 has been formally handed over based on an agreement signed between the MEA and the FO in 1995. IMT has been therefore completed. The responsibility for total internal water distribution, minor repairs and routine maintenance of the canal structure is with the FO. No O&M allocation has been made by the MEA to the DC7 FO since 1995.

The members of the DC7 FO do the maintenance of the DC, FCs and the roads on a share basis. The chairman of the FO does the distribution of water within the DC while the FRs are responsible for water distribution within the FCs. There no internal water distribution problems. Maintenance of the rehabilitated canal structure is good, there is no evident deterioration of since 1991 except for siltation in one FC.

Based on the precedent of DC7 the total responsibility for operation and maintenance within all the DCs on the branch canal has been formally handed over to the respective FOs. FOs are responsible for the internal water distribution and routine maintenance including minor repairs and earthwork. Maintenance allocations have not been made for these FOs since 1996. The number of MEA gate operated for the branch canal has been reduced from three to just one.

The Unit Coordinating Committee leader who is selected among member FRs is responsible to ensure equal water distribution among the DCs within the BC. He also supervises the water discharge to the BC and to the DCs. Flexible water operation is applied according to field requirements and the gate operator for the main canal makes necessary changes according to the instructions of the Unit Committee leader.

Change of Crop Pattern

The cropping pattern of DC7 has changed dramatically since 1991. About 80% of the total land area is devoted to banana in August 1998. In 1991 when the study commenced the total land area of the DC was cultivated with paddy. Banana was cultivated only in the home gardens but not as a significant commercial crop.

The farmers of the Moraketiya BC are now gradually changing their crop from paddy to banana. Moraketiya BC is gradually becoming the main banana growing area of the Uda Walawe Project. Earlier the tail-end of the Uda Walawe Scheme was regarded as the main banana growing area, mainly due to the water scarcity. Some MEA officials and farmers attributed the new change in the crop pattern in MKDC7 partly to the interventions of the crop diversification program implemented under the study.

Comparison of Changes Before and After Interventions

A summary of the major changes after intervention and at present in MK DC7 as well as in the total branch canal is given in the Table 6. The FOs that had been in name only were re-formed and strengthened under the study and they are still functioning well. The MEA had full responsibility for O&M before the study. Under the study, joint management was introduced. Now, the O&M responsibilities within the DCs have been formally handed over to the FOs. When the study was started the major crop cultivated in the area was paddy. Crop diversification was introduced under the study. The major crop in the Moraketiya BC has changed to banana leading to substantial increase in farmer income.

13. Lessons Learned

The community management model tested in the Uda Walawe Project for irrigation system management transfer offers the following lessons:

Need for a process for institution building over an extended period of time. Institution building and handing over should be a gradual and appropriate process. Each step should be followed with full farmer participation as a way of empowering them. On the other hand the process should be flexible to adapt to a changing environment and implemented as a learning process. Effective process provides four characteristics of formation of farmer organizations, strengthening, sustaining and taking over system responsibilities.

Need for a change agent. In large irrigation systems where government agencies control water source, spontaneous generation of farmer organizations and taking over system management responsibilities is unlikely. The initial leadership is taken by the change agent who induces the farmers to take on leadership tasks so that the catalyst role can be phased out with the gradual empowerment of farmers. In the study this role was played by the researchers which is often one of the roles of those involved in Participatory Action Research (Selener 1997). The study was a training ground for farmers and agency officials as the researchers assisted them in planning, implementing, monitoring and feed back and also in identifying an appropriate process, identifying problems and taking corrective actions. Apart from that they acted in a way to achieve necessary attitudinal and behavioral changes of both farmers and particularly the agency officials.

Time needed for gradual development of organizations and taking over O&M responsibilities. Institution building is a process which needs time for gradual development, strengthening, sustaining and maturing to take over system management responsibilities. The time may vary for different organizations depending on the environment they are built in and the effectiveness of the institution building program and the change agent.

Need for engagement in multi-purpose activities. Depending on the magnitude of the irrigation management benefits to farmers the provision of non-irrigation benefits like a multi-purpose organization may also be necessary to get the initial farmer involvement and make the organizations useful and valuable to them.

Need for empowering farmers. Irrigation Management Transfer becomes effective only if the farmers are empowered to take their own decisions. While there are stories about failures of irrigation management transfer, Moraketiya DC7 and BC show a success story due to this empowerment rather than working on agency timetables.

The application of the community management model in MKDC7 was a complete learning and action process through which a model was applied in such a way that farmers were convinced that continuity and sustenance of the model would bring them benefits. The lessons learned form MKDC7 in Uda Walawe project indicate that the participatory irrigation management policy can be significant in managing major and medium irrigation schemes in the country.

More importantly the experiment discussed in this paper contributes to designing implementation strategies for introducing a participatory management model in irrigation schemes. The twelve steps followed as a continuous process would be worth replicating in other schemes for improving their management.

Reference

ARTI. 1991. *The Integrated Management of Major Irrigation Schemes.* Agrarian Research and Training Institute. Colombo.

Selener D. 1997. *Participatory Action Research and Social Change*. Cornell University. NY.

IIMI. 1990. *Irrigation Management and Crop Diversification (Sri Lanka); Final Report*, 3 volumes. International Irrigation management Institute. Colombo.

IIMI. 1995. *Irrigation Management and Crop Diversification Phase 11; Final Report*, 3 volumes. International Irrigation management Institute. Colombo.

IIMI/ARTI. 1995. *Monitoring and Evaluation of the Participatory Irrigation System Management Policy; Final Report,* draft, 3 volumes. International Irrigation management Institute. Colombo.

Kloezen, W.H., and Samad, M. 1995. *Synthesis of Issues Discussed at the International Conference on Irrigation Transfer.* International Irrigation management Institute. Colombo.

Vermimillion, D.L. (Ed.). 1996. *The Privatization and Self-Management of Irrigation.* International Irrigation Management Institute. Colombo.

Kloezen, W.H., and et al. 1998. *Impact Assessment of Irrigation Management Transfer in the Alto Rio Lerma Irrigation District. Mexico;* Abstract, Research Report 15. International Irrigation Management Institute. Colombo.

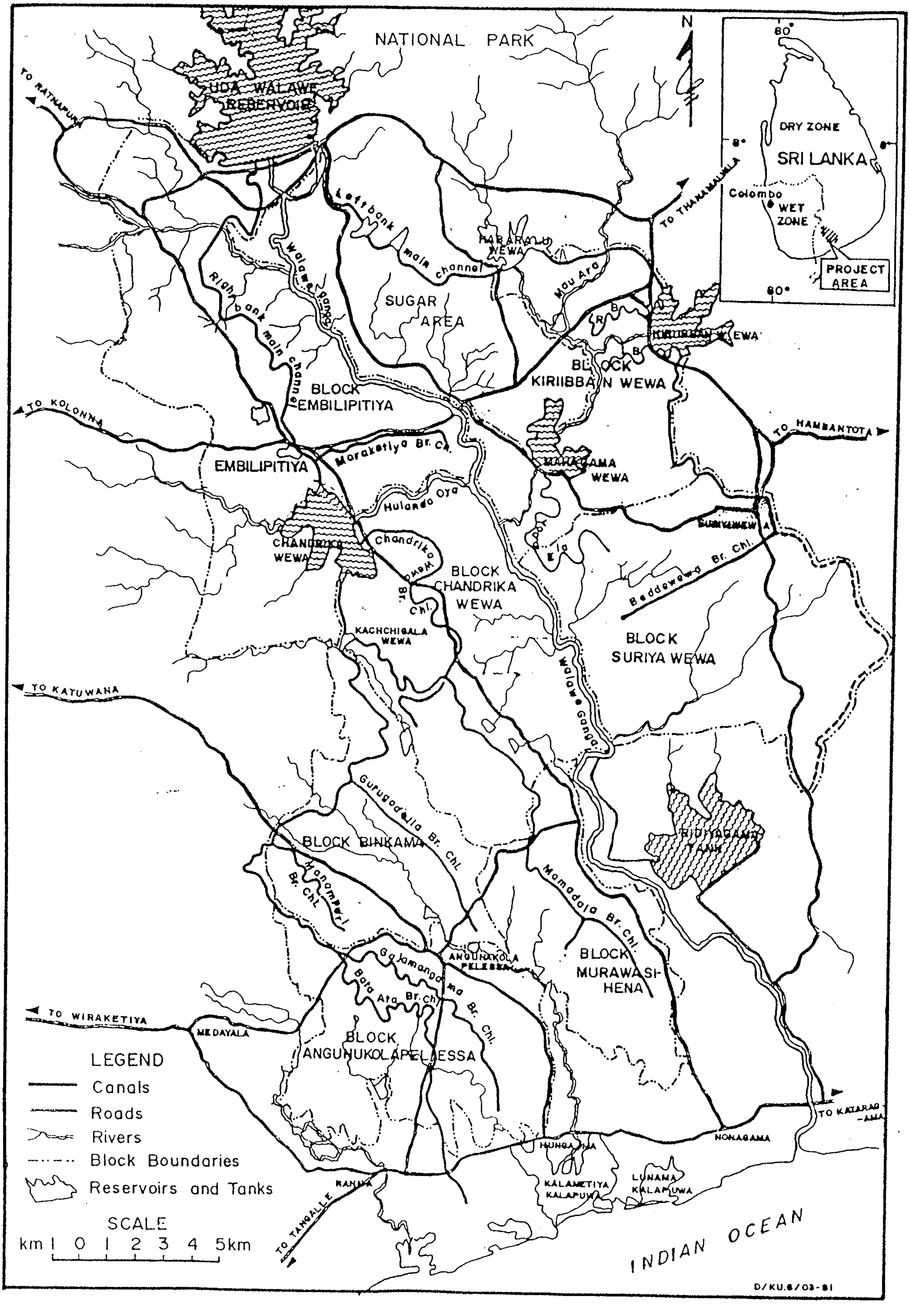


Figure 1. Map of Uda Walawe System

Figure 2

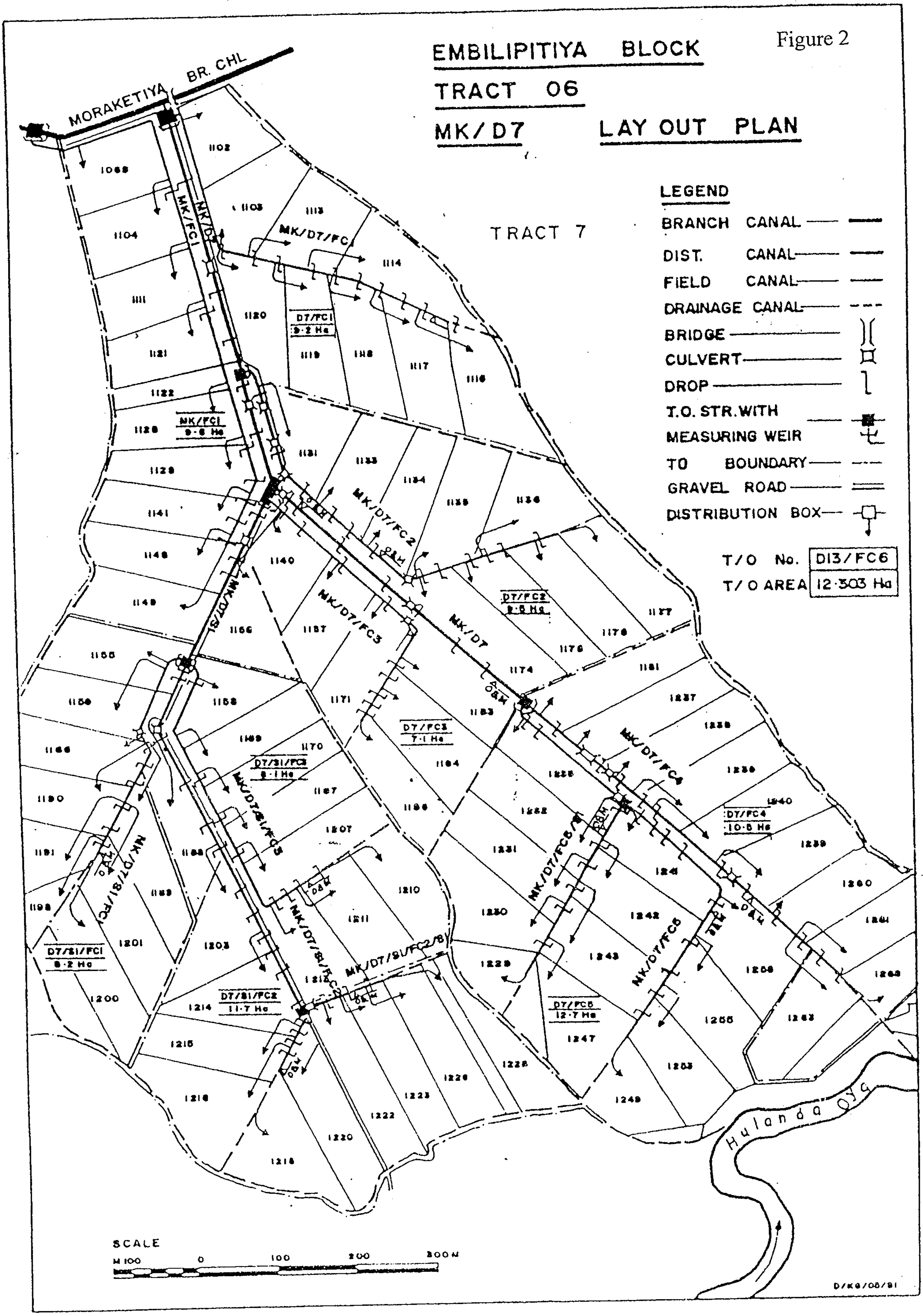
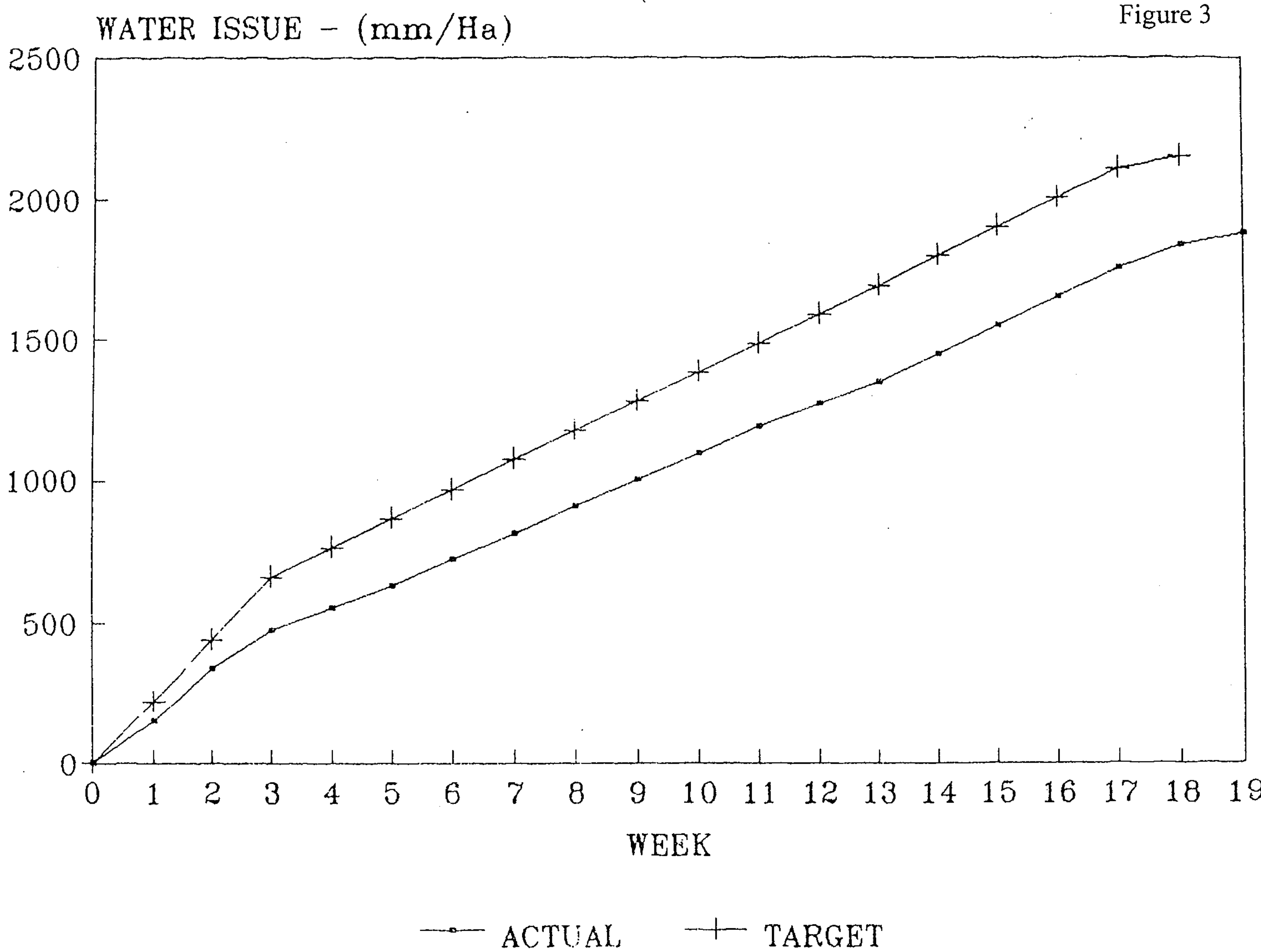

EMBILIPITIYA BLOCK
TRACT 06
MK/D7
LAY OUT PLAN
TRACT 7
MORAKETIYA BR. CHL
LEGEND
BRANCH CANAL
DIST. CANAL
FIELD CANAL
DRAINAGE CANAL
BRIDGE
CULVERT
DROP
T.O. STR. WITH MEASURING WEIR
TO BOUNDARY
GRAVEL ROAD
DISTRIBUTION BOX
T/O No. D13/FC6
T/O AREA 12·303 Ha
MK/D7
MK/FC1
MK/D7/FC1
D7/FC1 9·2 Ha
MK/FC1 9·6 Ha
MK/D7/FC2
D7/FC2 9·5 Ha
MK/D7/FC3
D7/FC3 7·1 Ha
MK/D7/S1
MK/D7/FC4
D7/FC4 10·5 Ha
MK/D7/FC5
D7/FC5 12·7 Ha
D7/S1/FC1 8·2 Ha
D7/S1/FC2 11·7 Ha
D7/S1/FC3 9·1 Ha
MK/D7/S1/FC2/B
Hulanda Oya
SCALE
M 100 0 100 200 300 M
D/K9/08/91

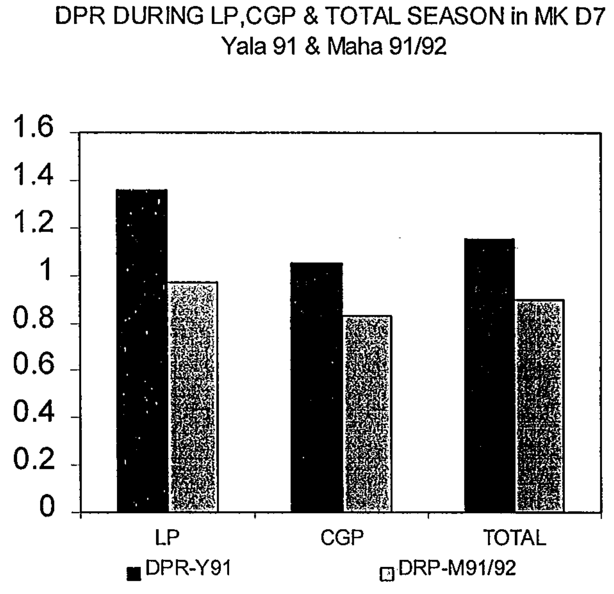
Figure 3



Cumulative Water Use in MK - D7, Maha 1991/92

(IIMI 1995)

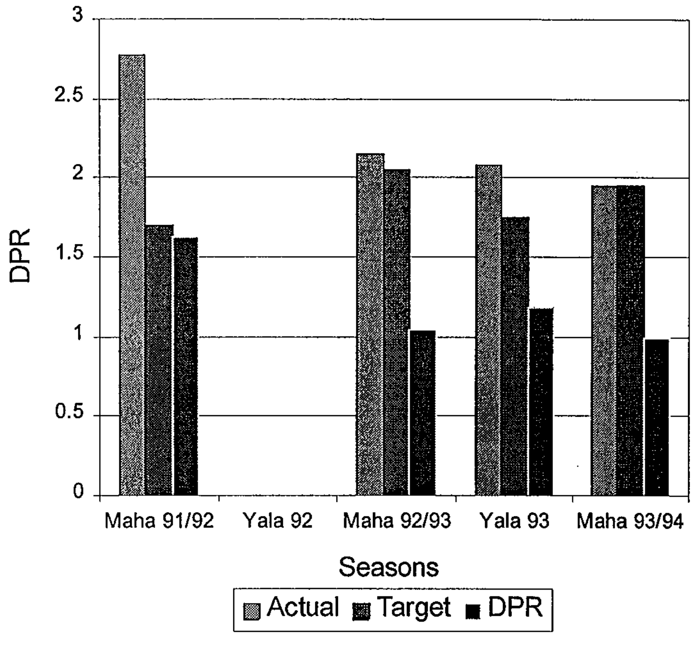
Figure 4



DPR: Delivery Performance Ratio (Actual water issue/Target)
LP: Land Preparation
CGP: Crop Growth Period

(IIMI 1995)

Figure 5. Delivery Performance Ratio - Moraketiya BC



DPR =Actual water issues/Target

(IIMI 1995)

Table 2. Roles Played by Farmers, MEA officers and IIMI Researchers in the Process

Steps	FRs	Farmers	MEA officers	IIMI researchers
1. Evaluating the existing FOs	-	-	-	Conducting the survey
2. Developing the FO model	-	Involved in developing the model	Involved in developing the model	Developing the model
3. Conducting awareness meeting	-	-	Assist in organizing groups, conducting the sessions	Preparing and implementing the program with MEA officers
4. Formation of the FO	-	Involvement in the formation	Organizing the meetings, and implementing	Implement with MEA officers
5. Identifying training needs	-	-	Involved in preparing training modules	Identifying training needs and prepare modules with MEA officers
6. Provision of training	Assist in organizing the groups	-	Conducting training for farmers	Organize the training, assist in conducting training for farmers. Organizing training for officers.
7. Providing necessary guidance in organizational management	-	-	-	Providing of necessary guidance
8. Formulating rules and regulations	Formulated the rules	Assist in formulating rules	Provided necessary guidance	Provided necessary guidance
9. Getting legal recognition	Making preliminary arrangements and fulfilling requirements	-	Assist in getting legal recognition	Assist in fulfilling the requirements and getting legal recognition
10. Implementing tertiary system management activities	Involved in Planning. Implementation	Involved in field level planning Implementation	Involved in planning and implementation	Preparation programs, providing guidance in planning and implementations
11. Implementing social and cultural activities	Planning, Implementing	Assist in planning and implementing	Assist in planning and implementing	Providing guidance
12. Monitoring and evaluation	Provision of data. Monitoring the progress	Discussing the progress	Monitoring the progress	Collection of data. Monitoring and evaluation

Table 3. Evaluation of the Organizational Strength of DC7 FO in 1993

Feature	Conceptual Base (Max = 13)	Performance (Max = 8)	Outcome (Max = 15)
Structure	2	1	2
Membership	1	Na	2
Leadership	2	2	2
Funding	2	1	3
Financial Management	2	1	2
Use of Funds	1	1	1
Communication	2	2	2
	12 (92%)	8 (100%)	14 (93%)

(Values given in Table 3 are calculated using following indicators.)

Feature	Conceptual Base	Performance	Outcome
Structure	0=FO has no constitution or no clear structure 1=FO has a constitution or formal structure 2=FO has both constitution and formal structure	0=FO has no farmer approval for constitution 1=FO has farmer approval for constitution	0=Required characteristics of FO structure are not met 1=Required characteristics are partially met 2=Required characteristics are fully met
Membership	0=No clear definition for eligibility 1=There is a clear definition for membership		0=Less than 50% of potential farmers are active members 1=Between 50% - 75% are active members 2=More than 75% are active members
Leadership	0= No procedure or criteria for selecting leaders 1= There is a procedure but no criteria 2=There are both procedures and criteria	0=Neither procedure nor criteria followed 1= Only procedure is followed 2=Both procedure and criteria are followed	0=Leaders are not selected by farmers 1=Leaders are selected by farmers but not by majority of farmers 2=Leaders are selected by majority of farmers
Funding	0=No planned ways to raise funds 1=Funds are raised in an adhoc manner 2=Funds are raised mostly from agency allocations 3=Funds are raised through a sustainable procedure	0=FO has poor funding position 1=FO has a satisfactory funding position	0=No funds 1=Funds primarily obtained from agency O&M allocations and contributions 2=Funds primarily obtained from membership levies 3=Funds obtained from contracts and other FO business activities
Financial Management	0=FO has no financial reporting or disbursement procedures 1=FO has reporting procedures but no disbursement procedures 2=FO has all needed procedures	0=FO does not follow financial reporting and disbursement procedures 1=FO follows financial reporting and disbursement procedures	0=Funds management and disbursements not reported to membership 1=Funds management and disbursement acceptable to some farmers 2=Funds management and disbursements acceptable to most farmers
Use of Funds	0=No plans prepared to use funds 1=Plans are prepared to use funds	0=Funds are not used 1=Fund are used for FO activities	0=Use of funds brought no benefit to FO 1=FO activities are diversified with the use of funds 2=Stronger financial position through diversified activities
Internal Communication	0=No defined channel of communication 1=Information passed through informal channels 2=Regular channel is established through meetings	0=No FO meetings held 1=Meetings held irregularly 2=Regular meetings are held	0=No systematic information flow between farmers and FRs 1=Information is passed mainly between FRs and DC officers 2=Systematic information flow between farmers and FRs

Note:For purposes of judging membership, "potential members" will be defined as all farmers (including renters, squatters, etc) served by the distributary channel. The number of "active members" will be defined by asking the FO officers to identify the number of "active members" of their organizations.

(IIMI/ARTI 1995)

Table 4. Crop Survey Results DC7 – Maha 92/93

Location	Allotment	Yields tons/ha	Average
Head	1169	4.96	
	1131	6.71	
	1239	4.23	
	1215	5.99	
	1156	4.18	5.21
Middle	1258	7.43	
	1174	5.11	
	1222	4.65	
	1243	5.58	
	1259	4.59	5.47
Tail	1226	4.65	
	1229	6.19	
	1247	5.58	
	1201	4.70	
	1176	5.16	5.26
Total Average			5.31

(IIMI – 1995)

Table 5. Evaluation of the Organizational Strength of DC7 FO in 1998

Feature	Conceptual Base (Max = 13)	Performance (Max = 8)	Outcome (Max = 15)
Structure	2	1	2
Membership	1	Na	2
Leadership	2	2	2
Funding	2	0	2
Financial Management	2	1	2
Use of Funds	1	1	1
Communication	2	2	2
	12 (92%)	7 (88%)	13 (87%)

Table 6. The comparison of the changes before and after interventions in DC 7 and the Moraketiya BC

Activity	Before Intervention	After Intervention	Present Situation
Farmer Organizations	• Namesake, almost non existing • No leadership development • Decision making by Agency • Hostile relations between officers and farmers	• Building strong an effective FOs • Identifying and development of leadership • Joint decision making • Introducing coordinating committees	• Strong and effective FO • Leadership development • Strong UCC • UCC leadership risen up to project and national levels • Empowerment of farmers
Water Management	• Total Agency responsibility • Simultaneous irrigation • No rotational practices • Conflicts with the Agency and among farmers • Severe irrigation problems in the tail-ends	• Joint responsibility • Rotational water distribution • Equal water sharing • FRs taking responsibility of internal distribution • Irrigation problems solved	• Water management responsibility formally handed over to the FO • FO leader is responsible for supply of water to FCs • FRs responsible for internal distribution • No internal irrigation problems • Joint operation planning within BC
System Maintenance	• Total Agency responsibility • Agency personal implemented them • Full cost by the Agency • Farmers were not happy with the quality maintained	• Joint responsibility • Planing together, implemented by the FOs • Part of the cost paid by the Agency • Quality of work maintained	• Responsibility of DC maintenance is formally handed over to the Fos • FOs plan and implement the maintenance work • Agency does not bear any maintenance cost • Quality of work is maintained • Rehabilitated canals are maintained at the same quality
Crop	• Almost all paddy • Yields of tail-end were reduced by irrigation problems	• Equal distribution of high yield • Crop diversification started with growing banana	• 80% banana in DC7 • Substantial increase of farmer income • Moraketiya BC becoming major banana cultivation area
Cost	• Total O&M cost by the Agency	• Part of the O&M cost by the Agency	• No O&M cost within DCs for the Agency
System management	• Total by the Agency	• Joint management	• Formal IMT within the DCs

Table 2: Station Densities Compared with WMO Standards (WRS, 1998)

Organisation	Network Type	Number of Stations	Effective Area SqKm	Station Density SqKm/Station	Respective WMO Standard Density Km^2/Station	WMO Inforhydro 1991 Standard	Satisfactory by WMO standards	Remarks
Department of Irrigation	River Gauging (After 94/95 Water Year)	48	65531	1365	1875 For interior planes and hilly areas	1000	Yes	Very few stations at northern and eastern areas
Meteorology Department	Daily rainfall(Non Recording)	350	65531	187	575 For hilly areas	200	Yes	Very few stations at northern and eastern areas
	Automatic rainfall gauging stations (Recording)	22	65531	2979	5750 For interior planes and hilly areas		Yes	Very few stations at northern and eastern areas
	Evaporation (Agromet)	38	65531	1725	50000 For interior planes and hilly areas		Yes	Very few stations at northern and eastern areas

Table 1: Summary of Sri Lankan Hydrometric Network

ORGANISATION	TYPE OF HYDRO-METRIC STATION	NUMBER OF STATIONS IN THE NETWORK	TYPE OF DATA COLLECTED	FREQUENCY OF DATA COLLECTION
Department of Meteorology	Principal Climatic Station	22	• Rainfall • Evaporation • Humidity • Pressure, temperature, • humidity, cloud cover etc.	• Continuous Pluviographs • Other data every 3 hours
	Agro-Met Stations	38	• Rainfall • Sunshine hours • Evaporation • Humidity • Soil temperature, Pressure, temperature, humidity, cloud cover etc	• Twice Daily
	Daily Rainfall Stations	350	• Rainfall	• Once a day
Department of Irrigation	Streamflow & rainfall gauging stations	48	• Water levels • Flow velocity • Cross section of rivers • Reservoir water Issues • Evaporation	• Water Levels once in an hour where staff gauges are used, continuous where automatic water level recorders are used • Rainfall , once a day in non recording stations, continuous in recording stations • Evaporation etc. once in a day

RESEARCH PAPERS PRESENTED

Session No.5 4 November 1998 *1:30 p.m.*

Water Resource Data

Paper No.80
Galappatti, R.
Data And Modelling: A Symbiotic Relationship

Paper No.91
Gunaratna, P.P.
Ranaweera, R.M.R.P.
Abeysirigunawardena, D.S.
Application Of Mathematical Modelling In Coastal Engineering Investigations

Paper No.102
Wijesekera, N.T.S.
Malone, D.C.
Ranwala, D.A.J.
Mendis, B.P.N.
Recommendations For Water Data Planning And Coordination In Sri Lanka

Paper No.102b
Wijesekera, N.T.S.
Malone, D.C.
Ranwala, D.A.J.
Mendis, B.P.N.
Status Of Water Data Collection, Processing And Management Of Sri Lanka

DATA AND MODELS: A SYMBIOTIC RELATIONSHIP

Ranjit Galappatti & Anura Jayantha Ranwala, *Lanka Hydraulic Institute*

ABSTRACT

The problem of data quality afflicts every developing country. The absence resources prevents adequate supervision or the introduction of new technology. Data is very rarely processed and checked in time to have an impact on data quality. The paper discusses how mathematical modelling could be used to provide a more comprehensive check on data as well as a rapid feedback to the field. It advocates the maintenance of existing mathematical models for this purpose and for other future applications.

1. INTRODUCTION

The importance of collecting and maintaining databases of good water resources data continue to be emphasised whenever hydrologists meet. However, the reality is that the shortcomings of the quality, quantity and coverage of data are discussed only at the time such data is required for an important project and nothing further is done about it. As it is not possible to gather long time series of data within a limited project timetable, consultants such as we have to make use of our verbal and analytical ingenuity to create some useable data out of what is available.

In developing countries, with the exception of the national agency responsible for meteorological data, the other hydrological data collection is usually carried out by a "minor", in the sense of hierarchy and resourcing, division of a leading governmental agency. Such entities, such as the Hydrology Division of the Irrigation Department of Sri Lanka or the two Hydrology Directorates of the Bangladesh Water Development Board, would be expected to provide data (or even justification) for proposed major development programmes, as well for a long list of river diversion projects conceived by politicians and their advisors. Unfortunately, it is not possible to use the political will generated by these opportunities to obtain resources to improve *past* data. Neither is there political to make things easier for the development plans of future governments.

Maintaining quality of data is a major problem faced by hydrology organisations. The supervision of very poorly paid (invariably part-time) staff on a far flung network is never easy. A small poorly funded organisation would find it doubly difficult. As more intensive supervision of field data collection activities is not a realistic option, the only way one could achieve good quality is through better training, motivation and feedback. Feedback is most important because it is very important for the field staff to know that their data is being used and that any errors are rapidly detected.

The limited resources available for hydrological data makes it necessary to optimise and re-design networks to meet present *and future* needs. Some of our network is a legacy from the past when the priorities and the technologies available were different.

All the points mentioned above are under active consideration by the Water Resources Secretariat. Some work has already been done to identify problem areas and to devise a long term strategy. This paper discusses the current status and how mathematical modelling could be used to enhance quality control and the rationalisation of the hydrological network. Upgrading of some measurement techniques in keeping with the current techniques for data storage, analysis and modelling are also discussed.

2. THE PRESENT HYDROLOGICAL NETWORK IN SRI LANKA

2.1 The Network

The hydrological and hydrometeorological network of the country is maintained by two prime organisations. They are

- Department of Irrigation
- Department of Meteorology

The type of hydrometric data , the number of hydrometric stations and frequency of data collection in each station are presented in Table 1.

The density of these stations (see Table 2) were compared with the WMO standards during the study "Institutional Strengthening and Comprehensive Water Resources Management" [WRS,1998]. It in interesting to see that the station densities of rainfall and river gauging sites are satisfactory with respect to WMO standards. It should also be emphasised that these stations alone will not provide the required quantum of data needed for a specific study. Additional measurements will be done according to the need of the specific task in hand.

2.2 Methodology

The methodology employed for data collection is based on primary techniques. The Department of Meteorology collects most of the rainfall data on a daily basis using ordinary raingauges. Majority of these raingauges is located in plantations and tea estates. Recording raingauges, either flip bucket type or siphon type, are maintained in the 22 principal meteorological stations. Evaporation data are collected using evaporation pans in these principal meteorological stations and the other agro-meteorological stations.

Department of Irrigation too maintains some raingauges at their river gauging sites. Some of these raingauges are recording gauges while others are of non-recording type. River water levels are recorded manually using ordinary staff gauges in most of the places. However automatic water level recorders are employed at few sites.

River velocities are not recorded regularly in the gauging stations. However gauging is done according to need. This is about twice a year especially in case of floods and when the rating curve for the gauging station has to be updated. Little emphasis is paid in monitoring low flow conditions which is an essential requirement in terms of water quality etc. River velocities are measured using current meters deployed from boats and cableways.

2.3 Data Processing

It is difficult to say that a regular data processing exists. Rather in most of the occasions it is only a case of data compilation. Some of the data are processed to generate secondary data sets which are required for the day to day needs of these collector organisations.

The position of the Department of Irrigation is that they collect data to satisfy their internal needs rather than aiming at an island-wide hydrological data collection network for use nationally. In the Department of Irrigation still a very large proportion of collected data are in the form of hard copies. Velocity measurements and rating curves have been computerised. Most of the river discharges have been generated from the water level measurements. Water levels and other data are yet to be computerised. Even the computerisation process is *ad hoc* and is limited to the use of spreadsheets and some database software such as Dbase III. Specific water resources data cataloguing and processing software have not been used. Pluviographic data are extracted manually, without the help of a digitizer. Consistency checking and provision of feedback to the field is not a part of the chain. Data are checked in task specific work only.

In the Department of Meteorology, however, a fairly organised data compilation system is in place but yet in its formative stages. The climatic data collection package CLICOM which conforms to WMO standards is used. Most of the daily rainfall figures are computerised. And remaining data are presently being entered to the database, although it is a time consuming process. However pluviograohic data are still extracted manually without making use of a digitiser and ancillary software. No consistency checks are being performed and getting feedback to the gauge readers is not practised to improve the quality of data.

2.4 Preliminary Recommendations of WRS Studies

A review of water resources information in Sri Lanka was done under the ADB funded project " Institutional Strengthening and Comprehensive Water Resource Management" (TA 2242-SRI) where most of the data collection agencies in the country were interviewed to determine the present status of the data collection networks, data processing, dissemination etc. and to identify any constraints faced by these organisations in carrying out their functions.

It was found during this study that there is no nationwide network for water quality data and ground water. However an *ad hoc* network for a groundwater network exists in the form of tube-wells, agro-wells etc., constructed by the National Water Supply and Drainage Board [NSWDB], the Water Resource Board and the Agriculture Development Authority. Nevertheless these wells are not being monitored as elements of a regular groundwater data collection network.

The study has given many recommendations with regard to data ownership, coordination, planning and *inter alia* data collection and processing. Following are some of the salient recommendations given in the study with respect to hydrological data collection and processing:

- Water resources data are identified in four major categories i.e. climate data, surface water data, ground water data and water quality data.
- Four prime organisations will act as the custodians for the foregoing four data categories. These organisations are Department of Meteorology, Department of Irrigation, Water Resources Board & National Water Supply and Drainage Board (collectively) and the Central Environmental Authority respectively.
- Water Resources Secretariat will be the overall co-ordinator.
- Water resources data collection networks coming under each organisation should be reviewed in terms of method of collection, equipment, manpower etc.

- Use of new equipment such as digital data loggers for measuring rainfall water level etc. to be adopted.
- Data compilation and processing should be done using a standard software package used for this purpose such as HYDSYS.
- Chart data should be digitized.
- The management of this database should be on a GIS interface so that the data are easily located and accessed and even easily be used for mathematical models which requires inputs in such formats.

3. USE OF MATHEMATICAL MODELS AS ANALYTICAL TOOLS

3.1 The Traditional Use of Mathematical Models

Mathematical models of hydrological systems are used as predictive tools in planning and less often in system operation and flood forecasting. Such models are usually as good as the basic data on which they are based. Good models have undergone a rigorous procedure of calibration and verification. It is usual that the initial process of setting up and calibration of a model requires the collection of data from a network large number of stations, usually installed specially for this purpose, a network more detailed than one would have for routine operation. If such a model is then verified using a new set of data then it is safe to use it for various planning and operational purposes.

Surface water models are regularly used for planning river engineering projects and for determining environmental impacts of such projects. Rainfall-runoff models form the basis of many water resources studies as well as serve as essential inputs to surface water models. Reliable models however can also be used for a variety of other purposes.

3.2 Other Uses of Mathematical Models

The other uses of mathematical models could be as follows:

a) to assess the quality of new data,

b) to detect changes within the basin and river system and

c) to interpolate and/or generate new time series data*.

a) and b) above require that one runs a model using a new set of data and examines the results for inconsistencies and mismatches. The types of errors that could occur in a river network model are discussed below:

i) Water Level Gauges: It is still very common to use staff gauges to monitor water levels at several stations along a river. It is also common that these gauges are washed away or removed for various reasons and later replaced. This usually results in a datum error which is readily visible in a model run result. However, a similar error can also result if the position of the gauge is shifted either upstream or downstream by a significant distance. An extrteme example of this was in the North Central Region of Bangladesh where the gauge was found to have been re-fixed on an entirely different river!

ii) Rating Curves: The rating curve is an expression of the conveyance factor and the channel resistance of a reach of river. Any change in these properties would show up as an error in the model result. It is sometimes the case that a river gauging station is constrained to be established where backwater effects (or as in the case of Deduru Oya, tidal effects) have a disrupting influence during certain seasons. Examination of the rating curve implied in a model result would reveal very easily any backwater effects which affect a gauging station. The change in a rating curve, other than at the low flow end, must be treated as evidence of major changes within the river, or more usually some change of field measurement methodology.

iii) Low Flows: It is notoriously difficult to estimate low flows in a river. The lower end of a rating curve usually exhibits a great deal of scatter as a result of changes in minor bed topography (bedforms etc). In this instance, a fixed bed model cannot help. Suffice it to say that direct measurements (ie a very recently constructed low flow rating curve) will be the only useful source of information.

There exist many consistency checks that could be applied to detect errors that could occur in field observations. However, such check would nevertheless allow many other errors and inaccuracies to pass muster. A well calibrated model can allow the data to be checked both globally and locally and in space and time. Such models, where they exist, could be used to improve.

The frequent use of mathematical modelling automatically leads on to the need to make data available in digital form. Thus even manually collected data must be entered into the database. This must be done as quickly as possible so that the data could be checked and the necessary feedback provided while the data is still current. Even in a developing country, the value of water resources are such that the need to automate data collection and in some cases even the use of telemetry are becoming viable options.

3.3 Generating Time Series Using Mathematical Models

The use of mathematical models to generate new time series is a frequently used technique. This is best illustrated by an example:

Prior to the 1960s the entrance to the Panadura River (ie the exit of the Bolgoda Basin) was not open all year round. At times of floods, the river mouth had to be excavated to allow the flood waters to subside. A groyne and a sand by-passing culvert which was built by the Irrigation Department in the 1960's was successful in keeping the river mouth open permanently, allowing fishing craft to use the river as an anchorage mainly during the calm season. Due to an increased demand for access around the year, the entrance was to be modified to allow safe navigation for a longer period during the monsoon.

The new design had to satisfy Bruun's criterion for stability of tidal inlets. This criterion is based on the ratio of the volume of longshore sediment transport and the average tidal volume. While information existed that could be used to compute the monthly volume of longshore sediment there was no available record of the variation of tidal exchange at the Panadura River entrance.

It was not practical to try and measure tidal discharges so many times to obtain an estimate of monthly average volumes. Thus it was decided to use the model of the Bolgoda Basin originally developed by the Sri Lanka Land Reclamation and Development Corporation as a part of a research project on the Bolgoda system. The model, which was based on the MIKE 11 modelling system, was adapted for this purpose. Sufficient boundary conditions (rainfall time series and the measured sea levels in Colombo) to run the model for a long period. The model was calibrated against measured water levels and the ten tidal discharge measurements that were carried out. (see Fig 1 and Fig 2). The calibrated model was then used to make a 12 month simulation, which yielded a twelve month tidal discharge time series (at 15 minute time steps) more than sufficient to compute the average

average ebb flood volume. This was repeated for the new entrance geometry where the river mouth was displaced seawards. The changes in tidal flow regime were then estimated.

Mathematical models are now used widely to fill in gaps as well as generate data at places where no measurements have been made. All this however precludes the existence of good models. While, mathematical models have been devised for several river basins in Sri Lanka, they are not all freely available for use when necessary. These models, in order to be useful, must be maintained and kept in good working order by regular verification.

4 CONCLUSIONS

Mathematical models are being used increasingly in water resources management all over the world. These models have the capacity of being used over and over again to support different types of activities. Thus it is necessary to maintain the models in a reasonable state of verification so that they can be conveniently deployed when required. In order to run such models require a moderate amount of hydrometric data as boundary and initial conditions. They also predict/simulate the values of parameters at many other points in the model. Thus they also serve as a diagnostic device for checking data or conversely as a means of checking whether the system itself had changed.

Thus, regular verification of existing models could serve the following purposes:

a) Maintaining the model in good order for future users

b) Serving as a diagnostic tool for data quality maintenance

c) Serving as a diagnostic tool for changes in the system

It is also necessary for the engineering community in Sri Lanka to accept that new tools and methodologies are available and they must be used. While some models are costly to establish, they can be put to many other uses than originally intended. The example of the use of such models for a variety of projects quite unrelated to the original objectives might be found in Bangladesh where the models have been used to assist even highway projects and even to investigate the migration of fish on the flood plain (SWMC, 1993). When the tool already exists it is not necessary to re-invent the wheel as we sometimes do. For this to occur, there should be free exchanges of data and models between agencies. We should also try to repatriate some models (such as Nilwala Ganga, Kalu Ganga etc) that have been set up in the past by foreign consulting firms, so that we could benefit from their re-use.

Widespread use of mathematical models, however, should induce the use of modern data recording techniques, which could also eliminate the drudgery of data entry. The existence of the models might make it possible to optimise the number and location of hydrometric stations.

REFERENCES

WRS (1998), Institutional Strengthening and Comprehensive Water Resources Management: Information System Analysis, Water Resources Secretariat, Colombo

LHI (1997), Investigation for Panadura Anchorage, Final Report, Ceylon Fishery Harbours Corporation, Colombo

SWMC (1993), Surface Water Simulation Modelling Programme: Phase II, Final Report, Surface Water Modelling Centre

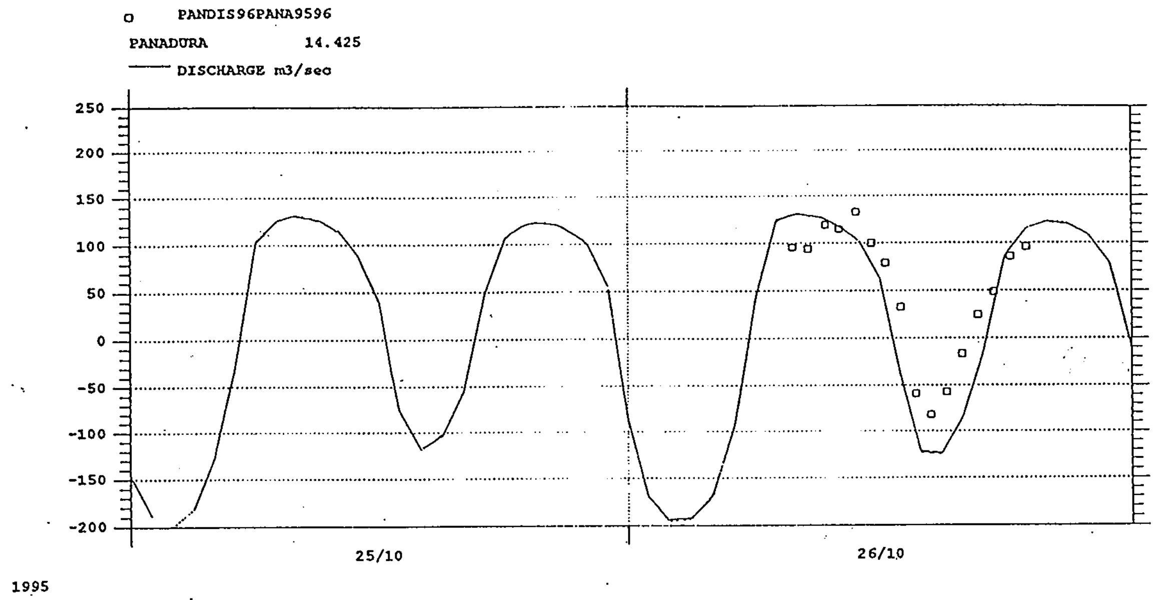


Figure 1: Panadura River: Example of Discharge Calibration

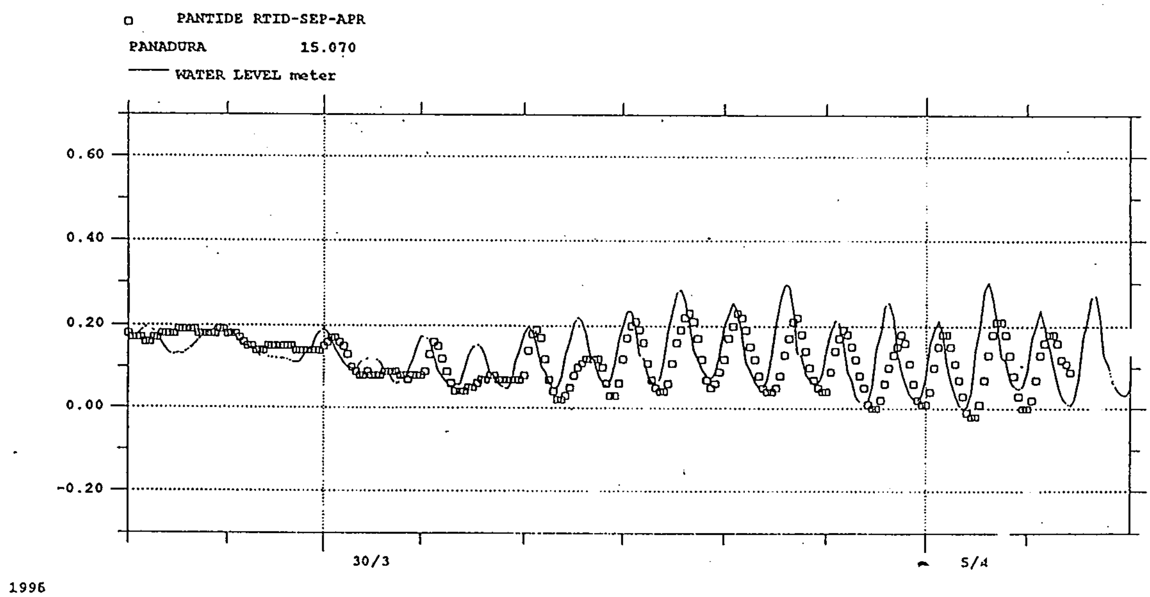


Figure 2: Panadura River: Example of Water Level Calibration

Application of Mathematical Modelling in Coastal Engineering Investigations

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Abstract

Application of mathematical modelling in Coastal Engineering Investigations is discussed referring to examples from recently concluded studies in Sri Lanka. The paper demonstrates how well proven mathematical models in Coastal Engineering, such as, MIKE 21 and LITPACK, could be successfully applied to reproduce the natural conditions and altered conditions due to various man-made implementations in the coastal environment. The paper identifies various phenomena of interest to the Coastal Engineer, such as, wave propagation, hydrodynamics, sediment transport and advection-dispersion. The important processes to be considered in modelling these phenomena are also discussed. The selection of appropriate mathematical modelling tools, setting up of a model, and model calibration and verification processes are outlined.

The reliability of results produced by a mathematical model will increase to the extent to which it is verified against field measurements. Field data are also required in the setting up of models and establishing model boundary conditions. The field data often required in coastal engineering applications include, bathymetry, coastline geometry, wave data, current data, water levels, and sediment and water quality parameters. These data requirements in terms of details and coverage are also discussed.

Introduction

Coastal Engineering investigations are an essential prerequisite in projects which will lead to alteration of existing conditions within the coastal environment. Such projects may include implementation of a harbour, implementation of a coast protection scheme or construction of an outfall structure for effluent disposal. The coastal engineering investigations required in this connection should essentially concentrate on two main aspects: establishment of existing conditions within the project environment; and prediction of impacts due to proposed changes within the environment.

The methodology adopted in a particular coastal engineering investigation may involve exclusively either mathematical modelling or physical modelling or desk calculations or an appropriate combination of all these three approaches. Out of these investigation approaches, mathematical modelling has become increasingly popular over the last decade or so. The main reasons for this can be attributed to the advances made in theoretical description of physical processes, evolution of efficient numerical solution techniques and, most importantly, the development of high speed computers that can handle a large volume of numerical calculations at an unbelievably quick time. Today, more and more well proven mathematical models are becoming available to practicing coastal engineers as computer software packages with user-friendly interfaces.

Prior to the advances made in mathematical modelling, physical modelling was the only available choice in the investigation of complex coastal engineering problems. The main advantages of mathematical models over physical models are the ease and convenience with which structure layouts and bathymetric changes can be incorporated, the possibility of preserving different model set ups used for studying various solution options for future re-use and the absence of scale effects. These advantages make mathematical models highly versatile tools in coastal engineering applications. Any disadvantages in mathematical models arise out of the simplification of physical processes in the theoretical description and numerical discretisation and the inability to provide the user with a physical visualisation of the processes. However, the rapid advances made in theoretical developments and numerical solution techniques, and the ever increasing capability of software packages in providing real-time animations have gone a long way towards nullifying these disadvantages.

The establishment of natural conditions within a particular coastal environment often requires acquisition of various forms of data such as waves, currents, sea bed topographical data (bathymetry), etc. A sound interpretation of these data using good technical judgment will be necessary in establishing existing conditions. The conditions within a coastal environment may vary throughout the year due to varying influence of oceanographic factors such as tides, waves and currents, and meteorological factors such as wind and temperature. However, it is physically not possible to acquire relevant data covering a wide range of sea states. This is where properly set-up mathematical models become useful in establishing natural conditions under different simulation scenarios. Prior to applying a mathematical model it is necessary to verify the validity of its computations using field recordings. This process is known as the "model calibration". A well calibrated mathematical model can then be applied to predict altered conditions due to any man-made implementations.

Modelling Considerations

The primary consideration in a mathematical model application is the identification of physical phenomena of interest. Among the physical phenomena of interest to the coastal engineer are wave dynamics, tidal circulations, storm surges, sediment transport and advection-dispersion processes. The recognition of important processes will lead to the selection of appropriate modelling tools which can be used to simulate these processes. In this paper, the selection of appropriate mathematical modelling tools is described by making references to computational modules available within MIKE 21, two dimensional mathematical modelling system. MIKE 21, developed at Danish Hydraulic Institute (DHI), Denmark is a highly versatile software package, with a wide range of applications in coastal and estuarine waters. Lanka Hydraulic Institute Ltd. (LHI) has successfully applied MIKE 21 in a number of projects carried out locally and overseas.

Having selected the appropriate modelling tools for simulating different phenomena of interest, the model that will be set up need to be first validated against field recordings. It is not possible to generalize the data requirements for a model validation. However, some guidelines on typical data requirements are identified and presented in Table 1.

Coastal Engineering Phenomena Being Investigated	Typical Data Requirements for Model Set up and Validation
Hydrodynamics	Bathymetric data Water Level Recordings : At model boundaries to establish boundary conditions (Alternatively, model boundaries may be located in the vicinity of stations with established tidal information). Within the model for calibration and verification. Typically should cover few spring-neap-spring tidal cycles. Current Data: Two dimensional currents recorded continuously over few spring-neap-spring tidal cycles. Drogue trackings to ascertain nearshore current patterns. Wind Data: Wind speed and direction simultaneously recorded with current and water level data. Wind statistics established from long term recordings. River Flows: Measurements taken across a flood-ebb tidal cycle, at spring/neap tide and at low/flood discharges in the river.
Wave propagation	Bathymetric data Offshore Wave Recordings: A large enough data base (typically few years) to establish representative wave statistics Nearshore Wave Data: over a very short duration to validate model computations
Sediment Transport	Bathymetric, Hydrodynamic and Wave Data Bed Sediment Characteristics: mean grain size, gradation, specific gravity, calcium content determined for a sufficient number of representative samples. Suspended Sediment Characteristics: Sediment concentration measurements over the water column.
Water Quality	Ambient Water Quality Parameters: A sufficient number of samples to ascertain parameters, such as, temperature, salinity, dissolved oxygen, BOD, COD, pH, nutrients (NO_2, NO_3, etc.), bacteria etc. Water Quality Characteristics of Effluent.

Table 1. Typical Data Requirements of Mathematical Models Used for Coastal Engineering Applications

Hydrodynamic Modelling

Hydrodynamic modelling is carried out basically to establish water surface elevations and velocity fields within the area of interest under different simulation scenarios. These simulation scenarios typically consist of different combinations of tidal forcing, wind fields, wave incidences, outfall/intake and river discharges.

The hydrodynamics within the continental shelf off the Sri Lankan coast is typically characterised by weak tidal flows with flow velocities in general less than 0.1 m/s. At times strong intermittent wind influences may enhance velocities beyond 0.25 m/s. The tidal range along the coast is also marginal with about 0.7 m during spring tide and 0.15 m during neap tide. In the very shallow seas close to the beach, strong shore parallel currents due to breaking waves with an angular approach may be generated. These currents are responsible for longshore transport of sediments and are commonly known as "littoral currents". The peak littoral currents are, in general, in the range 1.0 m/s. The existence of nearshore reefs detached from the coastline, at certain localities may give rise to strong currents due to overtopping water masses. Such currents around 0.7 m/s have been measured behind a nearshore reef at Dikkowita about 6 km north of Colombo.

A MIKE 21 based hydrodynamic model covering most of the west coast of Sri Lanka has been developed by LHI, which has been used as the primary basis for establishing local flow fields within any desired location (Fig.1). This model commonly known as the "West Coast Regional Hydrodynamic Model" extends from Galle in the south and beyond Kalpitiya in the north. This model has been well calibrated for tidal flows (Fig. 2) and to a lesser extent for wind driven flows (Ref. /1/). For the purpose of establishing representative tidal boundary conditions, a detailed analysis of tidal wave propagation pattern within the west coast was made.

The coastal engineering projects in which local flow fields were derived from the above mentioned "Regional Model" include, a feasibility study for a proposed industrial fishery harbour, north of Colombo at Dikkowita, a hydraulic study for layout optimization of an outfall improvement structure for the Dehiwala Canal and cooling water dispersion study for a proposed coal power plant at Kalpitiya. On site current, water level and wind recordings made during these studies as well as in previous studies were useful in improving the model calibration. Another hydrodynamic model covering part of the east coast has also been developed by LHI in connection with a proposed harbour at Oluvil.

In Fig. 3, a particular site specific application of hydrodynamic modelling at Dikkowita is shown (Ref. /1/). The area around Dikkowita is protected by two sandstone reefal systems. The outer reef, known as the *"Offshore Reef"*, exists about 1 km from the coast and is submerged at 2.5 to 3 m below mean sea level (MSL). The innermost of these two reefal systems, commonly known as the *"Secondary Reef"*, has got detached from its general existence along the coast over a certain stretch fronting Dikkowita. The maximum distance from the coast to this reef around Dikkowita is about 200m . The reef itself is variable in level consisting of exposed segments and submerged segments as much as 4 m below MSL. In the particular application shown in Fig. 3, wave overtopping currents behind the secondary reef are successfully simulated using an artificial combination of point sources and sinks. In mathematical modelling, such artificial implements are necessary when simulating complex processes.

Wave Propagation Modelling

Wave propagation modelling in the open ocean is carried out to establish nearshore wave fields for design of breakwater structures to withstand wave loads, to establish wave induced radiation stress fields for computing littoral currents and, in turn, sediment transport, and wave agitation within proposed harbour basin layouts. An essential prerequisite for wave propagation modelling is the establishment of directional wave field representative for the study area at a reasonable distance away from the coast. Such wave statistics are available from measurements and wave studies for a more or less continuous coastal stretch along the south western coast (Ref. /2/). Due to their predominantly different characteristics, it is necessary to obtain wave statistics in terms of sea and swell wave systems. Sea waves are those being developed locally under a wind field. Swell waves originate in the deep southern Indian Ocean off Sri Lanka, and have already travelled out of the generating fetches in reaching the Sri Lankan coasts.

Fig. 4 illustrates the propagation pattern of the pre-estimated 100 year return period wave at Dikkowita using a combination of MIKE 21's NSW (Nearshore Spectral Wave) and PMS (Parabolic Mild Slope) wave modules. Both these wave modules are based on an irregular, directional description of wave field considering shoaling, refraction, wave breaking and bed friction. The PMS model can additionally account for diffraction effects due to coastal structures and bathymetric features. The attenuation of wave height over the *"Offshore Reef"* and direct penetration of waves through a gap in this reef are clearly seen from this illustration. The MIKE 21 wave module system set up for this study was extensively calibrated using simultaneously recorded waves within and outside the reefal system (Ref. /3/).

Wave Disturbance Modelling

In the planning of a harbour, it is primarily important to ensure that wave conditions within the basin are within acceptable limits for safe loading and unloading of cargo and safe mooring of vessels. In order to determine wave conditions within a harbour basin it is necessary to consider complex influences of transmission, absorption, reflection of wave energy by harbour structures, in addition to other processes considered in wave propagation modelling.

MIKE 21's BW (Boussinesq Wave) model is a versatile tool that can be applied to compute wave heights within a harbour basin due to penetration of irregular directional waves. The model uses the numerical solution of Boussinesq Equations accounting for wave reflection properties of structures, in terms of a "porosity" and so called sponge layers, to absorb wave energy at natural beaches and at undesirable locations. A numerical wave generator may be placed outside the harbour entrance to generate waves. The model computation is supplemented with service programmes available within MIKE 21 for numerical wave generation, wave disturbance coefficient computation (the ratio of simulated and incoming wave heights) and computation of porosity characteristics to simulate a desired reflective property from a structure. MIKE 21 BW model simulated wave heights for the proposed Dikkowita Fishery Harbour layout for a particular wave incidence is shown in Fig. 5 (Ref. /4/).

Sediment Transport Modelling

Sediment Transport modelling is carried out in coastal engineering investigations in the preliminary phase to assist in the establishment of a sediment budget for an area of interest. For this purpose, LHI has successfully applied LITPACK, a one dimensional Coastal Processes Modelling System, also developed at Danish Hydraulic Institute. LITPACK model is capable of computing longshore current, longshore and cross shore sediment transport for a given bathymetric profile. The model usage may be extended for multiple profiles and multiple wave conditions to compute annual or seasonal sediment transport capacity and determine coastline and beach profile changes due to implementation of coastal and harbour structures.

MIKE 21 in itself is possessed of two dimensional sediment transport modules for computing sediment transport fields for pre-established hydrodynamic and wave fields. These computations can be used to obtain an indication of sediment by-pass capacity at a harbour entrance or an outlet stabilisation structure, or to identify eroding and accreting areas.

Advection-Dispersion Modeling

Advection -dispersion of accidentally or intentionally released effluent matter is of particular importance to coastal engineers and enviornmental planners. These effuluent substances could be sewage, heated water, decaying matter such as coliform bacteria, orgain matter (BOD) , dissolved oxygen and non-toxic and toxic metalic substances. The dispersion in the near-field of effluent matter is governed by its own discharge characteristics such as mass, momentum and buoyancy fluxes, geometry and the ambient velocity of the receiving body. In the far-field, once the effluent substance is well diluted over the receiving water body, further dispersion is governed entirely by the ambient flow conditions. In general, there is however a transition region between these two zones of mixing.

Due to different forcing characteristics involved in the dispersion processes, the near-field and far-field modelling is typically carried out independant of each other. The nearfiled computations can be used to develop appropriate effluent discaharge boundary conditions for far-field modelling. In a recent application in a cooling water study for a proposed Coal Power Plant around Kalpitiya, LHI used mathematical modelling to account for both near and far field mixing. The nearfield modelling was carried out using a semi-empirical CORMIX3 model. The far field dispersion was computed using MIKE21's advection-dispersion module, MIKE 21 AD. A typical simulation result is shown in Fig. 6.

Water Quality Modelling

The large scale environmental pollution mainly resulting from industrial development has affected the coastal environment as well. Therefore, water quality modelling is increasingly becoming an attractive option for studying pollution levels in water bodies. To date, LHI has not engaged in complex water quality modelling except for simplified applications using MIKE 21 AD and CORMIX3 models. However, indications are that it will not be long before such model applications are carried out in Sri Lankan coastal waters.

The MIKE 21 model itself is equipped with three environmental modules that may be used for water quality studies. These are the Water Quality Module (WQ), the Eutrophication Module (EU) and the Heavy Metal Module (ME). MIKE 21 WQ, which is particularly applicable for coastal waters is used for advanced water quality studies considering dissolved oxygen (DO), organic matter (BOD), ammonia, nitrate and phosphorous.

Summary and Conclusions

The paper demonstrates how mathematical modelling can be successfully applied to simulate existing conditions and altered conditions due to implementation of various projects in the coastal environment. The main phenomena of interest to coastal engineers are identified and some guidelines on data requirements in modelling such phenomena are given. Selected simulation results from recent applications of MIKE 21 two dimensional mathematical modelling system in Sri Lankan coastal waters are also presented.

References

1. Gunaratna, P.P., Justesen, P., Abeysirigunawardena, D.S., "Modelling of Hydrodynamics off the Western Coast of Sri Lanka", Proceedings of the Second Indian National Conference on Harbour and Ocean Engineering, Thiruvananthapuram, India, December, 1997.

2. Scheffer, H-J, Fernando, K.R.M.D., and Fittschen, T., "Directional Wave Climate Study - South West Coast of Sri Lanka", A Report prepared by CCD-GTZ Coast Conservation Project, Sri Lanka, May 1994.

3. Gunaratna, P.P., Justesen, P., and Abeysirigunawardena, D.S., "Nearshore Wave Modelling in a Reef Protected Coastal Area", Pacific Coasts and Ports'97 Conference, Christchurch, New Zealand, September 1997.

4. Gunaratna, P.P., Justesen, P., and Abeysirigunawardena, D.S., and Scheffer, H-J, "Application of Mathematical Modelling in Optimizing Layout of a Large Industrial Fishery Harbour", 26th International Conference on Coastal Engineering, Copenhagen, Denmark, June 1998.

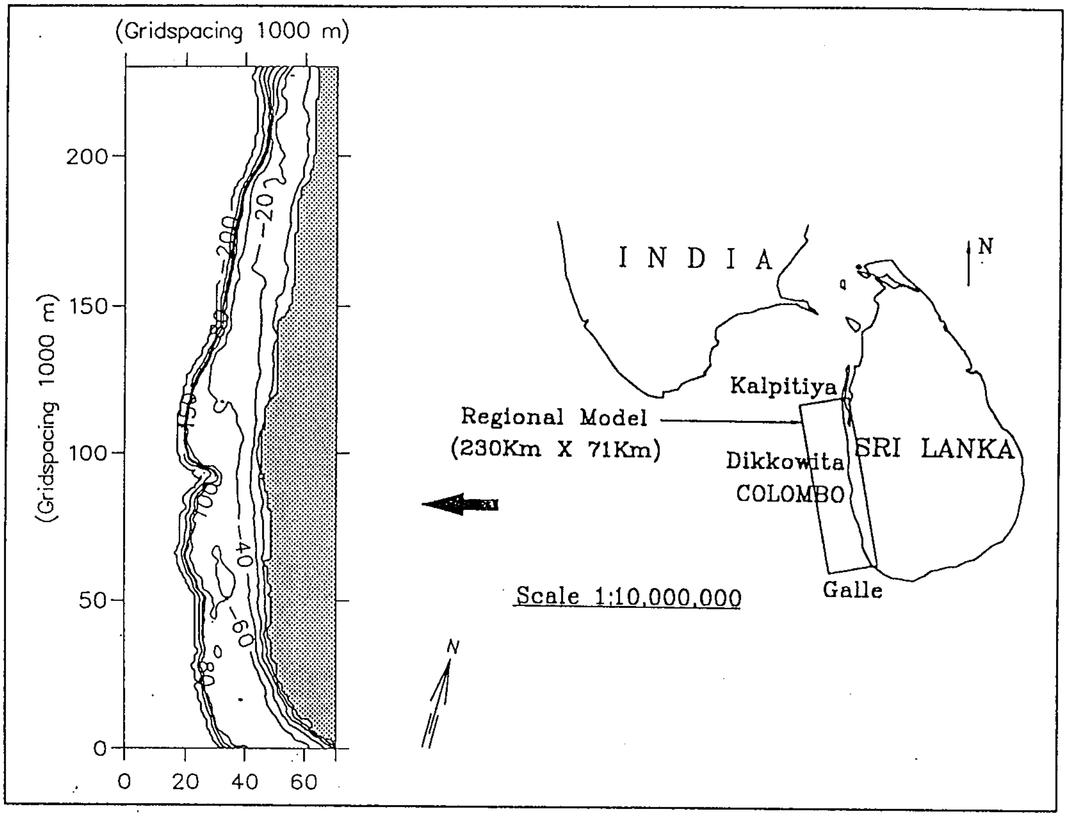

Fig. 1 West Coast Regional Hydrodynamic Model

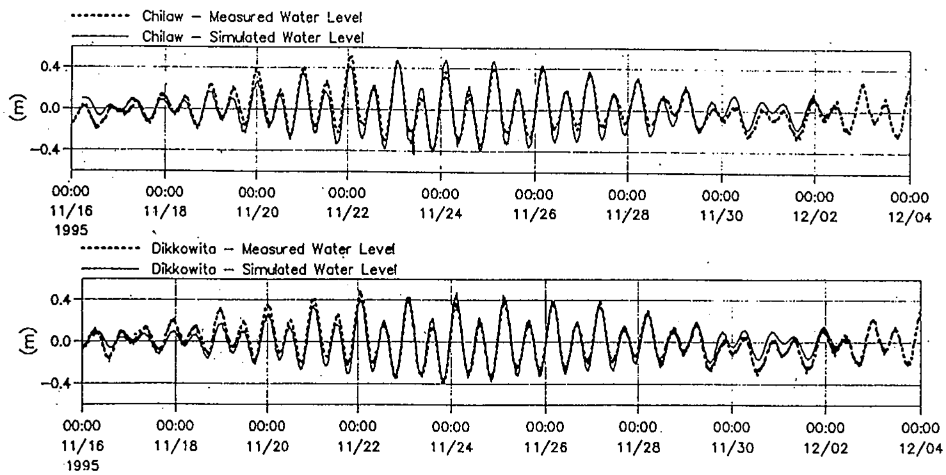

Fig. 2 The Calibration of West Coast Regional Hydrodynamic Model for Tidal Flows

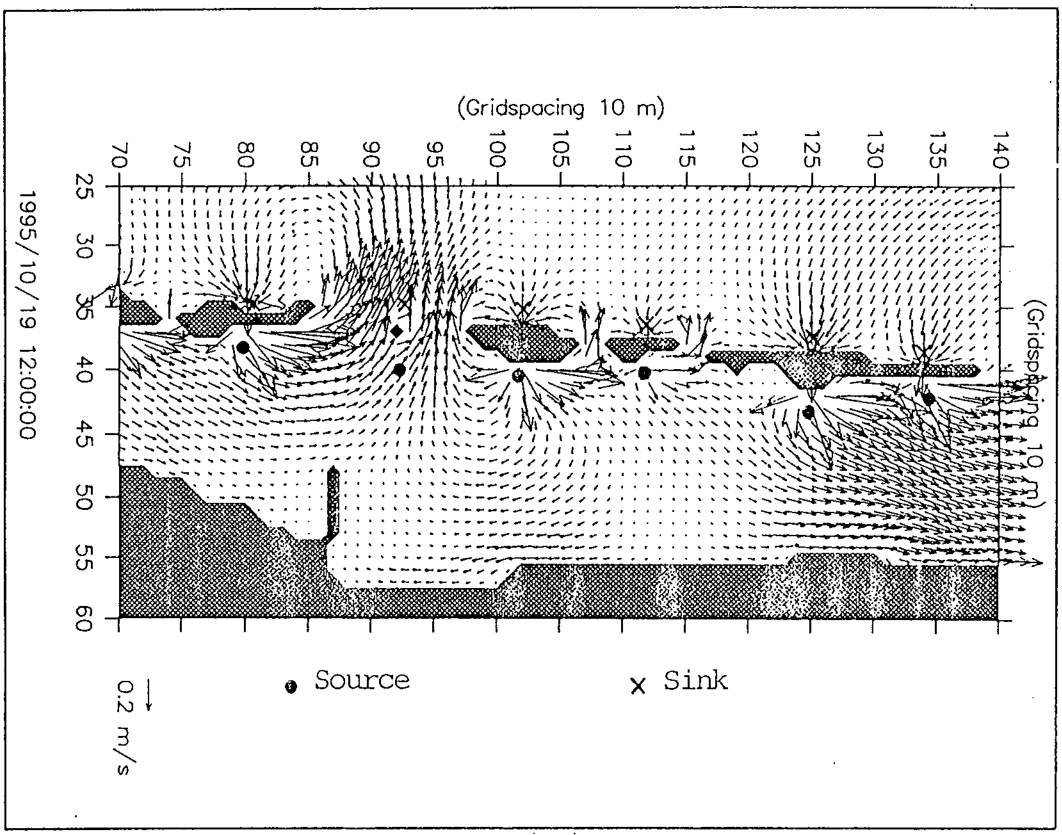

Fig. 3 Simulation of Wave Overtopping Currents Behind the Secondary Reef at Dikkowita

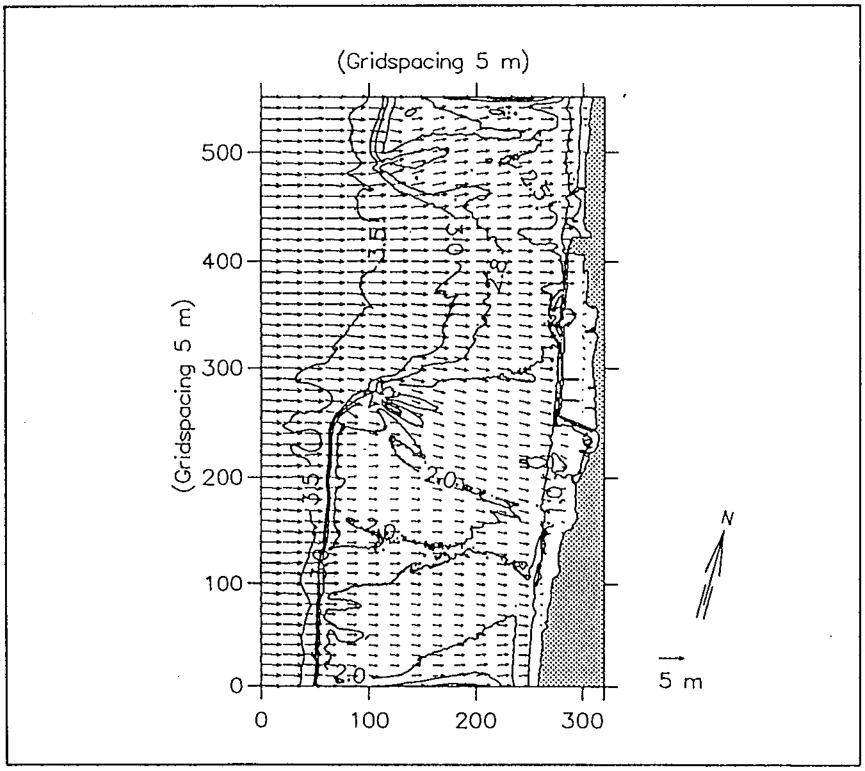

Fig. 4 Simulation of 100 year Return Period Wave at Dikkowita

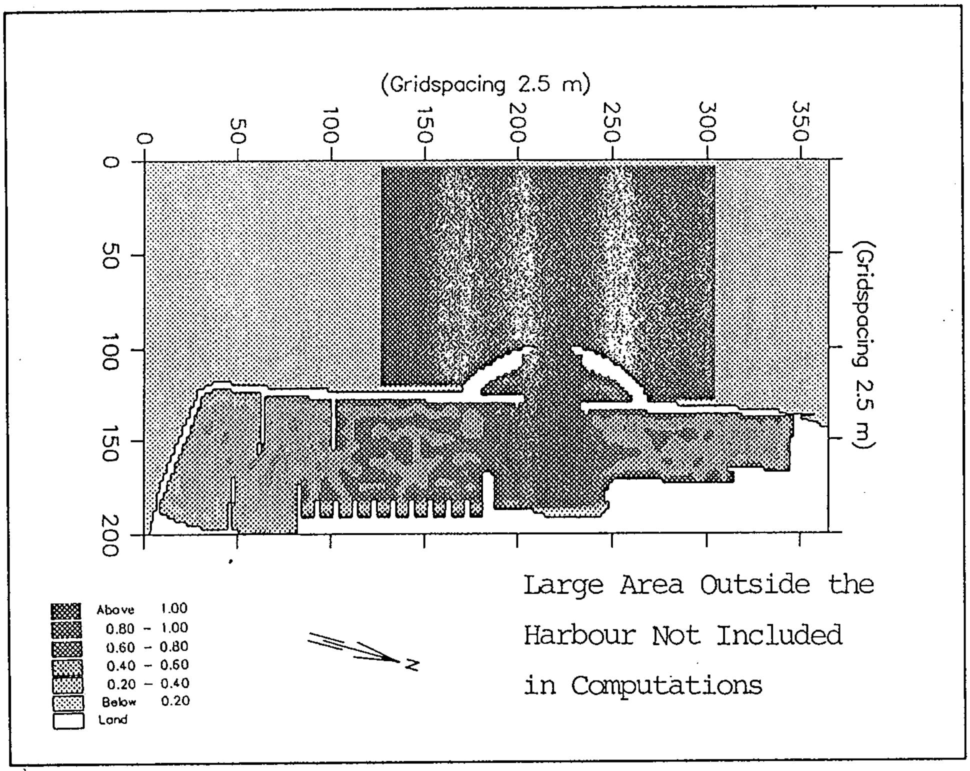

Fig. 5 Simulated Significant Wave Heights Exceeded 1 Week per Year (Proposed Fishery Harbour at Dikkowita)

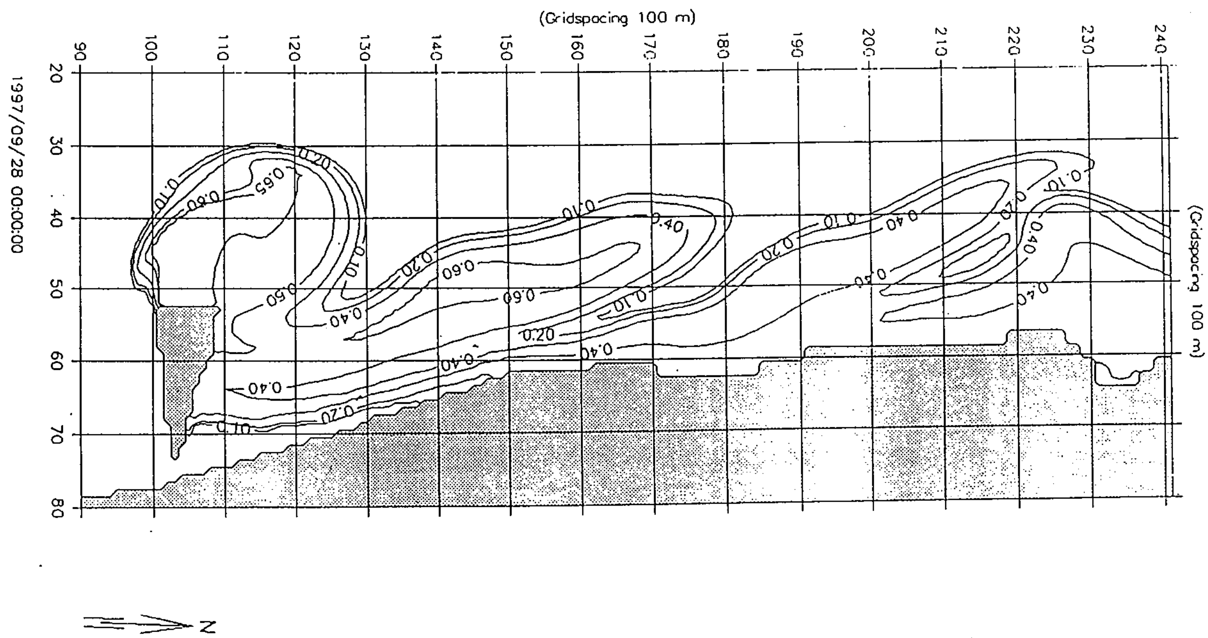

Fig. 6 Simulated Excess Water Temperature Contours (900 MW Power Plant Capacity - Tide + 2 m/s Southern Wind Driven Flow)

RECOMMENDATIONS FOR WATER DATA PLANNING AND CO-ORDINATION IN SRI LANKA

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1. INTRODUCTION

Quantifiable data and information on how much water is available in the country's river basins is required to provide a sound scientific basis for the water resources assessment, planning and management. Knowledge on quality and distribution of the resource in space and time is also an important requirement for rational water resources planning and management.

In Sri Lanka, like many other countries, the rational development and management of water resources depends to considerable degree on the readily available data and information describing the resource. If resource planning and management practices are to have a scientific base, large volumes of data need to be collated, organised and analysed. Sound management decisions depend not just on the amount of water resources data available but rather on the information that the data can yield. The data therefore need to be organised, accessible and comparable.

The collection, collation and management of natural resources data and information in Sri Lanka involves a complex arrangement of projects undertaken by government agencies, semi-government authorities and boards and includes research, consulting and business organisations. The work is being supported directly as government projects and indirectly by donor funded programs in many areas of natural resource management and development including water resources. Recent years have seen a rapid expansion in the amount of water resources data being collected by these government, semi-government and private bodies. This reflects the growing awareness, within the Sri Lankan community, of the need for safeguarding and managing water resources for the future.

It has been determined, that presently there are over 40 industry groups requiring access to water data and information to fulfil their statutory or business objectives. Of these, five are government agencies that undertake major data collection and data management activities. Seventeen others are semi-government, research and consulting groups, that also collect or use data for specific studies.

The Water Resources Council of the Government of Sri Lanka has identified the need to ensure a systematic approach to data collection and improved arrangements for the co-ordination, access and sharing of data between the major data collectors and the data users (GOSL 1994). This also includes a clearer understanding on matters of ownership, pricing policies and the publication of data.

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At present in Sri Lanka, water resources data and information is organised and managed in a traditional manner within the data collection agencies having minimal integration of data archives into a coherent water resources information system. In Sri Lanka there is no water resources database being developed at present, where all the data classes are brought together and integrated. Hydrological data is collected and managed by the Irrigation Department, water quality data by the Central Environment Agency and groundwater data by Water Resources Board and the National Water Supply and Drainage Board. Climate data is collected and managed by the Meteorological Department. Department of Irrigation also collects rainfall data at some selected sites.

This study was undertaken to identify important issues in the existing data collection net works, the present data processing & management, data pricing, data collation, integration and to make appropriate recommendations. This study which falls within the review and upgrading of information systems in the water sector was carried out for the Water Resources Secretariat (WRS) of Sri Lanka which is under the Ministry of Finance and Planning (GOSL 1998).

2. OBJECTIVES

The aim of providing recommendations for water data planning and co-ordination is to detail some of the more important aspects of collection, management, exchange and sale of water resources data in Sri Lanka.

As such the present work:

- Outlines the key issues and reasons for improved co-ordination of water data collection and management.

- Identify issues for improving arrangements for data collection, data storage, data exchange, user awareness and access.

3. WATER DATA PLANNING AND COORDINATION

In making recommendations for water data planning and co-ordination in Sri Lanka for the management of water data and information, it is important to establish an understanding for the responsibilities and accountabilities of the various parties involved in the data management and information processing chain. The parties generally include the data owner, the custodian, the data co-ordinator and the users of the data (information providers). This categorisation referred to as the 'partnership model' is shown in Figure 1. The key members in the partnership model are, 1) the Data Owner, 2) Data Custodians, 3) the Data Co-ordinator, and 4) the Data Users.

The partnership model aims at providing water resources data and information, which is readily available to users, which is of known quality, appropriate to Sri Lanka's water resource planning objectives such as integrated catchment management strategies, and can be incorporated into other natural resource information systems.

The important element of this approach of incorporating a partnership model is the increased emphasis given to access and dissemination of data to users and the public. Modern database software systems provide the tools for the integration of various water data types such as surface water data, water quality data, groundwater data and climate data into one system under the umbrella of a spatial mapping interface. Such a system needs to be introduced, in a co-ordinated and co-operative way, into the various government agencies currently responsible for water data collection and management in Sri Lanka.

The implementation of the partnership model, and the introduction of a suitable water resource information system, are identified as key elements for improved water data management in Sri Lanka.

3.1. Ownership

Key to the establishment of responsibilities and accountabilities for overall management of the water resources data and information, is the principle that water data is a national resource and that effective, efficient and economical data management requires organisations that collect data to share and transfer data to other users.

At the national level, all data collected by government agencies in Sri Lanka is a part of the national data resource. Therefore the agencies that acquire and manage data do not own the data but are custodians on behalf of the people of Sri Lanka. That is, the Government owns the copyright of all data generated by government agencies.

This implies that;

- water resources data is considered a public asset when it exists as a part of public funded or donor funded programs,
- since collection, dissemination and use of water data is essential to sound management decisions, water data ownership require resources to remain with public
- the availability to the public of information on this important resource is a necessary component to the environmental debate, and in this light it is necessary to emphasise that the custodians are for acquisition and management of a public asset.
- Continued government funding ensuring the sense of ownership of water data assessment programs is crucial to sound environmental and water planning.

3.2. Custodianship

The principle of custodianship needs to be adopted in many countries as a means of ensuring accountability for the care and maintenance of water resources information in the public sector. Custodianship is seen as the core to efficient and effective water resources information management.

A custodian of a data set, is an agency having the responsibility to ensure that the data set is collected and maintained according to standards and priorities determined by consultation with the user community. The preferred custodians should be those who have the greatest need to guarantee the accuracy and the integrity of the information.

Custodianship does not require all data to be captured and maintained by the custodian, but the custodian maintains the responsibility for quality and availability of the data that is part of the agency database.

In Sri Lanka, there are five government agencies that are acquiring water data and related information and maintaining databases of this information. In some instances they are not the only collectors of this data but are the principle collectors. It is suggested that these agencies would be the most appropriate national custodians for the data types which they currently collect and manage.

The custodians for the major water data types could be;

- Irrigation Department for hydro-meteorological data,
- Central Environment Agency for water quality data, both surface water and groundwater,
- National Water Supply and Drainage Board and the Water Resources Board for groundwater quantity data,
- Meteorology Department for Climate Data.

The proposed water resources information system in Figure 2 shows the concept of custodian agencies for Sri Lanka. The appointment of custodian agencies need not limit other agencies from collecting data to meet their needs. These other groups have the opportunity to be considered as contributing agencies if they provide data to the custodian agencies that meets agreed standards.

Appointing custodianship would ensure accessibility to data, and provide a recognised contact point for the distribution, transfer and sharing of the data and information. Therefore it is recommended to ensure a Co-operating Agency Agreement between the Custodian Agencies and the Data Users.

3.3. Coordination

For successful implementation of the custodianship policy, a significant level of co-ordination between data collectors and users is required. To ensure this, it is recommended to establish a lead agency responsible for water data co-ordination in the country. Under the present setup WRS appear to be a good choice to appoint as the lead agency.

A Water Data Steering Group within the lead agency is recommended to be established to oversee all activities dealing with co-ordination between collectors and users, custodianship and access to data. The steering group is recommended to be of,

- Database managers from within custodian agencies,
- Data user representatives, and
- A chairperson knowledgeable on data matters who can be external to the lead agency.

It is further recommended that this be maintained as an independent entity.

The Steering Group is expected to address the following and report regularly to the WRS:

- Advise the Water Resources Council on appointment of Custodian Agencies,
- Promote co-operation and sharing of data between custodians and user groups,
- Identify data needs of users such as to ensure that the appropriate long-term data is being collected to meet both project and long-term assessment requirements,
- Review data collection networks to reduce duplication of effort,
- Overview the standards and procedures upon which data is collected to ensure that the data is of acceptable quality,
- Identify ongoing sources of funding for both long-term and short-term data collection networks,
- Assist the lead agency with the collation of data for inclusion in an integrated Water Resources Information System.
- Advise the lead agency on the need for publication of water resources data and information.

4. PRICING AND COST RECOVERY

The *user interviews (Wijesekera et al 1998)* indicated that there was general satisfaction with the pricing of data; the major concern being data availability, data quality and the time it takes to actually satisfy the individual data requests. The exception to this was University groups where student requests for information were often not addressed.

The introduction of modern water resources database software systems into custodian agencies will provide a new opportunity for upgrading data services both in terms of speed of answering requests, and the range of data analyses and presentations that could be provided. Prior to such systems are introduced, it is important that data custodians agree on a consistent pricing philosophy for the sale of water data to users.

The following are stressed as key points for consideration in the pricing of water data;

- The primary aim of the pricing policy is to promote maximum use and dissemination of the data to the water community,
- Water resources data requires to be categorised as either 'basic' or 'interpreted' data;
- Charges for basic data should be levied on the cost of disseminating only and no charges to be made for data collection process. No profit margins should be included.
- Added charges could be made for value added processing. This applies in cases where a user makes a specific requirement for such processing or interpretation,
- No charge should be made for the exchange of basic data between Co-operating Agencies.

While this pricing policy recommends that agencies adopt a common set of principles for the pricing of data, it is understood that the actual charges will vary with individual agency overheads and internal cost factors. This pricing policy will mean that water data users will not have to pay for past or future costs of data collection and processing in it's basic form.

Considering the above it is clear that the government is required to continue with its obligation to fund data collection which provides a public good. An ongoing assessment of quality and quantity of the water resources of Sri Lanka is one of the elements in a series of events in this regard.

5. DATA PUBLICATION

Through the identified water data and information coordinator, the custodian agencies need to work together to achieve higher levels of data access for agencies and the public. This can be achieved by better co-operation and providing advice at the Water Data Steering Group level on the collation and integration of data and the use of new data publishing technologies.

Specifically, custodian agencies and other data collectors and users will need to co-operate to:

- Develop an integrated Water Resources Information System (WRIS) of their various water data archives and information,
- Introduce new database software systems to improve the publication of their water data archives in both hardcopy and on electronic media,
- Advise the water community of the availability of water data information and publications.

As found during the data surveys, with over 40 different groups requiring access to water resources data and information in Sri Lanka, new optical data-storage mediums such as CD-ROM offer vastly improved and cost effective technology for the dissemination of large quantities of data in a microcomputer format. Data in this format, can also be readily distributed to international organizations, such as WMO, who are collating global databases to study such issues as global warming.

6. WATER RESOURCES INFORMATION SYSTEM

A preliminary design of Water Resources Information System is shown at Figure 2. This would involve modules of the individual database systems for time-series data (surface and climate data), water quality data and groundwater data being installed at the various Custodian agencies. An integrated database of all modules could be installed and managed by the Water Resources Secretariat. This would be the integrated Water Resources Information System referred to in this paper.

7. RECOMMENDATIONS

The recommendations outlined were developed after undertaking detailed surveys and interviews with water agencies and data user groups (GOSL 1998). From a total of 22 groups, considered majority of the information was acquired through questionnaire and face to face interview. In addition, the consultants drew on their experience and knowledge of data collection and management arrangements in other countries, such as Australia, New Zealand and United States. (WRCNSW 1991, DISR 1989, WMO 1990, AWRC 1989, USGS 1982).

The summary of recommendations is to;

- Develop a water data policy based on a 'Partnership Model' between the data owners, custodians, co-ordinators and data users,

- Establish a 'Co-operating Agency Agreement' between the custodian agencies and the date users , covering the aspects of Ownership, Custodianship. Co-ordination, pricing and publishing of water data and information.(GOSL 1998).

- Identify the *lead agency* responsible for water data co-ordination activities in Sri Lanka.

- Establish a 'Water Data Steering Group' within the lead agency that would oversee custodianship and the management, exchange and access of data to data users, identify data needs, review networks, over view the standards etc.

- Implement a modern hydrological database system in Custodian agencies for efficient management of water data and information,

- Install or maintain compatible database systems at the co-ordinator agency to facilitate integration of the various data sets into a Water Resources Information System,

- Develop a program of systematic and co-ordinated analysis, dissemination and publication of water data between the WRS and Custodian agencies.

- Develop a system to provide data , in formation and publications to the users at reasonable cost.

8. REFERENCES

AWRC 1989, "Guidelines for the Design and Operation of Surface Water Information Systems" – Australian Water Resources Council, Water Management Series 18-1989.

DISR 1989, "Policy on the Management of the Water Resources Archive in New Zealand" -Department of Industrial and Scientific Research, March 1989.

GOSL 1994, "Comprehensive Water Resources Management in Sri Lanka-Volume I & II", Report prepared under the project TA 1918-SRI with the Asian Development Bank and the USAID, January 1994

GOSL 1998, "Information System Analysis – Final Report", Report prepared by Water Resources Consulting Services(Australia) in association with DHV consultants (The Netherlands), Environment Management Lanka(Pvt) Ltd (Sri Lanka), Resources Development Consultants Ltd. (Sri Lanka), and Lanka Hydraulics Institute Ltd. (Sri Lanka) under the project TA 2422-SRI with the Asian Development Bank, July 1998

USGS 1982, "Water-Data Program of the U.S. Geological Survey" - Geological Survey Circular 863, 1982.

WMO 1990, "Progress in the Implementation of the Mar del Plata Plan and Strategy of the 1990's" – WMO/UNESCO Water Resources Assessment Program –1990.

WRCNSW 1991, "Co-operating Agency Policy on Water Data Management." – Water Resources Council of New South Wales, Australia, July 1991.

Wijesekera et al 1998, Wijesekera NTS, Malone DC, Ranwala DAJ and Mendis BPN, "Status of Water Data Collection, Processing and Management of Sri Lanka", National Conference on Status and Future Directions of Water Resources in Sri Lanka, (To be published), IIMI, Colombo, Sri Lanka, 1998.

PARTNERSHIP MODEL FOR WATER DATA COORDINATION

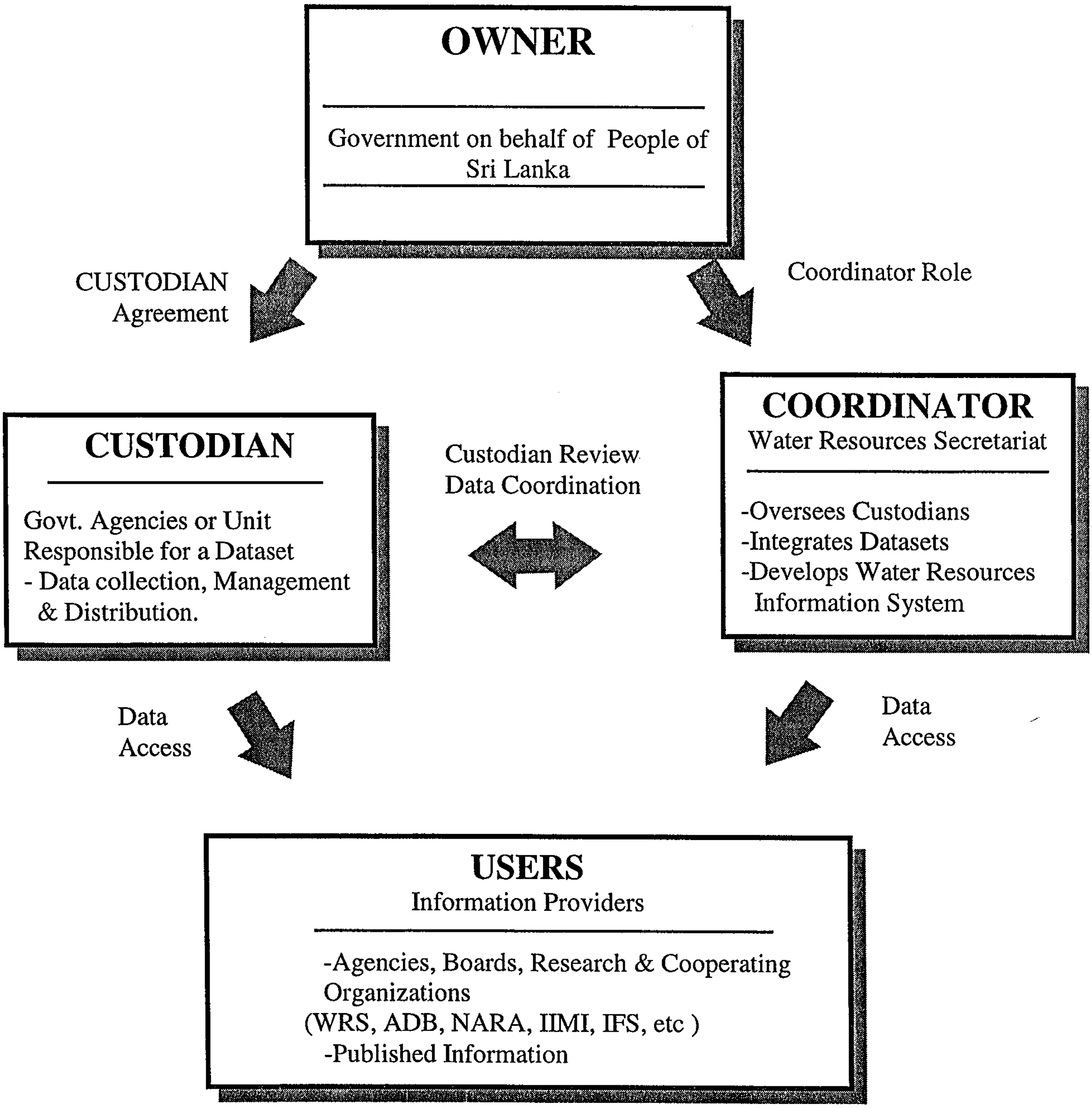
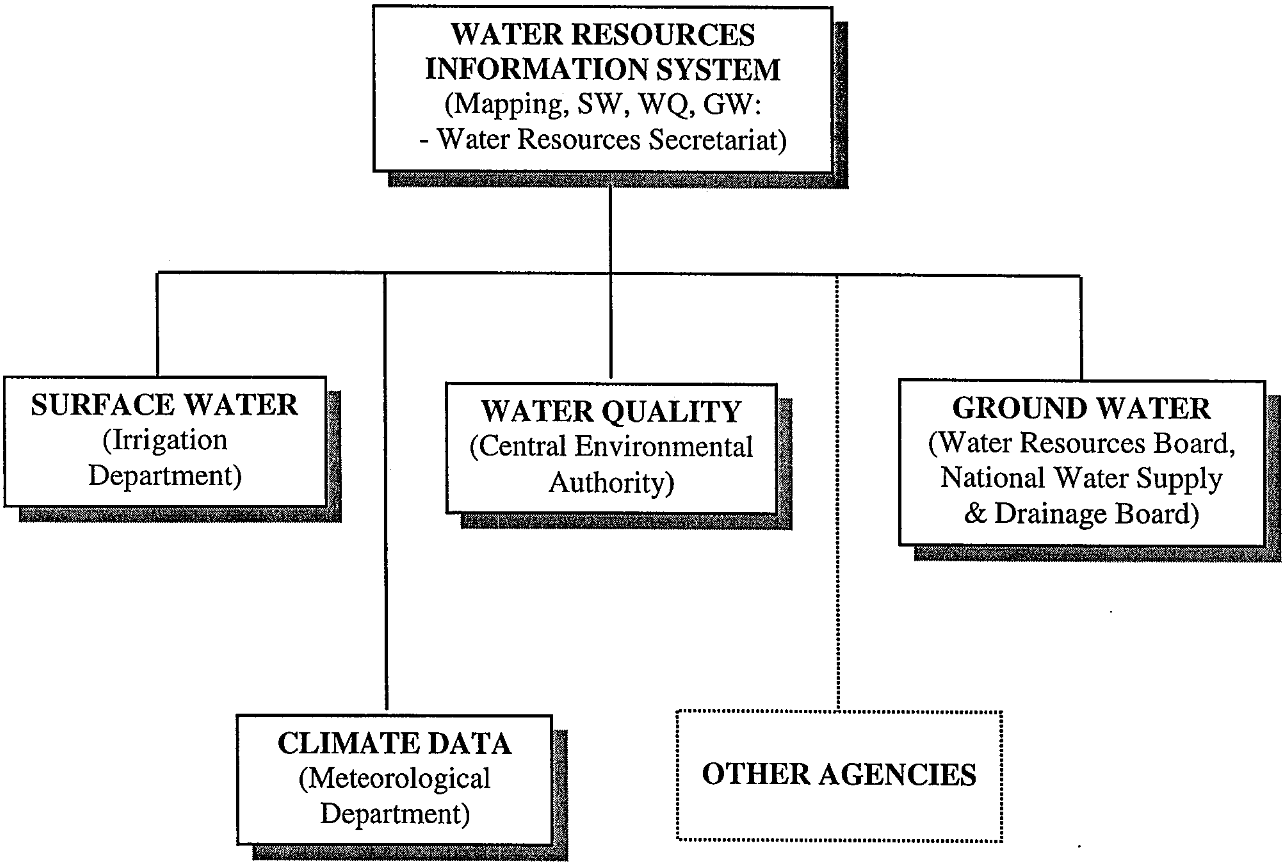


Figure 1: Partnership Model for Water Data Coordination

WATER RESOURCES INFORMATION SYSTEM



Each custodian agency operates a database for its own particular data set. These databases are integrated into a Water Resources Data Information System (WRIS) incorporating a copy of each custodian data set which is upgraded regularly (e.g monthly)

Figure 2 - Water Resources Information System

STATUS OF WATER DATA COLLECTION, PROCESSING AND MANAGEMENT OF SRI LANKA

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1. INTRODUCTION

In common with much of South Asia, economic growth and development needs are exerting pressure on Sri Lanka's natural resources. This growth and development signify increasing demand on water for irrigation and for other uses such as industrial, hydro power generation, domestic, and recreation. In addition, large investments in water management infrastructure have created high and ongoing operation costs for the Sri Lankan Government. The Government of Sri Lanka (GOSL) in its effort to monitor and ensure the exploitation of natural resources within the environmental concerns has recently established requisite environmental legislation. Long term planning of water resources development within a river basin framework also had been identified as a prime need by the GOSL and had developed an action plan (GOSL 1994) to integrate this planning with broader water industry objectives. Two of the more important consequences resulting from the complex issues involved in integrating river basin planning and management, are firstly the need for sound policies and strategies covering major natural resource issues, and secondly the growing need for information on which to base decisions.

Resource managers are demanding more reliable, accessible and timely information together with sound, clearly defined policies to assist their decision making. Recent technological developments in data collection, data processing and information technologies provide opportunities that can dramatically improve data dissemination to decision-makers and to the community. To strengthen water resources sector management it is required to strengthen the water data and information systems. As such it is necessary to acquire adequate information pertaining to the present status of water data collection, processing and management of Sri Lanka.

2. OBJECTIVES

Based on the overall objective of strengthening water resources information systems, a survey of data archives and, user interviews were undertaken to identify the status of data collection, data coordination, sharing, pricing, data gaps and the desirable options for new technology and change.

To achieve this overall objective, following specific objectives were identified:

- Describe the current data collection for the monitoring of hydrometric, groundwater, water quality, and climate data including identification of agencies undertaking such data collection.

- Carryout a survey of existing databases and data collection programs and procedures with a view to identifying strategic gaps in water resources data.

- Review information technologies being used for water resources data collection, management and dissemination in relation to their efficiency, ability to interface with existing water resource information systems and suitability to meet foreseen requirements.

3. WATER DATA SURVEY AND USER INTERVIEWS

The information collection for the study targeted all water data collection programs being undertaken by Government agencies including research organizations, boards, consultants, businesses and universities. This investigation was planned to base on interviews of appropriate staff within each agency dealing with data collection and data management.

In keeping with the objectives the following were undertaken to fulfil the information collection;

- a ***water data survey*** to determine the effectiveness of the data collection programs administered by various agencies, and
- a ***user interview*** to identify issues of access, sharing, utilisation and appropriateness of current collection programs from the data user perspective.

Anticipated outputs from the water data survey and user interviews included;

- the objective of the major data collection programs being conducted,
- a list of data types collected by agencies,
- the amount of data available and how it is stored
- data management; - hardware, software, data dissemination methods, quality coding, pricing policies and services,
- field monitoring procedures, equipment and related issues,
- instrument support facilities, and
- an inspection of typical monitoring sites and discussions with agency field staff.

3.1. Questionnaire

A detailed questionnaire was prepared to cater to both the water data survey and the user interview requirements and these were undertaken simultaneously. In this survey, data is the term given to both measured and derived variables, while the term water resources information looks at both descriptive and analytical information.

The questionnaire focused on the data ownership, collection and standards, the current arrangements for exchanging data including cost recovery, dissemination of data to users and the community, development of information from the data, maintenance of databases on water resources information, overseeing and co-ordination of the integration, sharing and exchange of data.

The questionnaire is also targeted to provide;

- a snap shot view of existing water data information in Sri Lanka,
- recognition of data gaps and deficiencies, and
- opportunity for refinement of strategies for current data collection and data management processes.

3.2. Survey and Interviews

Surveys and interviews were undertaken of staff at 22 different water groups and reports of the interviews were prepared (GOSL 1998). The results have been summarised into tables to provide information on the work being undertaken by each agency and the types of data that are collected for the various water resources activities. The list of agencies and contact personnel are given in Table 1.

Interviews were carried out by the authors and these provided opportunity for comment and discussion on issues that are viewed as important to improving the overall management of water resources data in Sri Lanka.

The survey identified data types currently being collected. These were compared with lists of data, which are known (from industry practice), to be a requirement for future water resources planning and management activities such as integrated river basin planning.

Emphasis was given in the survey to water resources assessment data and information. Comment was made, however, on the importance of related natural resource and environmental information when this was considered necessary. A schedule was developed of these data classes which also includes the data needs for other specified water resources planning activities such as river basin planning.

Agency staff were asked their opinion on the adequacy of the current programs in terms of methods, instruments, frequency, quantity, quality etc. Similar enquires were made of data users such as research organisations and consulting organisations.

4. SURVEY RESULTS

Results of the survey indicate that a high level of data collection is currently taking place. However, the demand for data and information on the resource is extensive with over 40 data user organisations identified. The data collection, storage and management methods require refinement since these activities are mostly adhoc at present. An analysis of the survey and interview material was carriedout in the areas of data collection, data management, data coordination and data sharing and exchange. The following are the key observations made from the survey results.

4.1. Data Collection Networks

(a) Surfacewater Data

The Irrigation Department (ID) and the Meteorological Department (MD) are collecting extensive hydrometric and climate data on a long-term basis. These organisations operate islandwide long term monitoring programs for which records are kept in both computer and hardcopy formats.

The surface water network which is operated by the Irrigation Department was established to meet the project, operational and management needs of that agency. Although these data are being used for overall surface water assessment of the country in general and of different projects in particular, the network was not designed with this as the primary objective. A comparison of the current station densities of both the Irrigation Department and Meteorological Department with WMO guidelines showed as satisfactory (Table 2). However it was observed that only a few stations were in the Nothern and Eastern regions of Sri Lanka.

Data collection is based mostly on manual daily readings with little use of modern digital recording systems. Continuous data, which is recorded on a small number of analogue recording charts by both the ID and Meteorological Department, has to be extracted and processed manually as no 'digitising systems' are available.

(b) Operational Data

Daily operational data on reservoir levels and river levels are used extensively by the Water Management Secretariat (WMS), Ceylon Electricity Board (CEB) and Irrigation Department. The data required for these purposes are viewed, by these agencies, as being satisfactory for current operational requirements. The data are read manually and transmitted by telephone, radio or facsimile to operations centres within the respective agencies, to help water sharing specially in the Mahaweli river reservoir system.

(c) Water Quality Data

There is no nationwide monitoring program for water quality data. Current data collected by the Central Environment Agency (CEA) is undertaken in specific areas to address local needs and for local development projects. Other research and consulting organisations also collect water quality data on a project basis. There is no annual 'state of the rivers' reporting on water quality or environmental health of rivers across the nation, although specific research studies are undertaken by organisations such as the Institute of Fundamental Studies.

(d) Groundwater Data

There is no base line groundwater quantity or quality monitoring program for resource assessment and utilisation. Both the Water Resources Board (WRB) and the National Water Supply and Drainage Board (NWS&DB) collect geological and spatial data on bores, agro-wells and water supply wells which they construct and maintain databases of hydrogeological information. Both organisations carry out drilling programs and there is opportunity for rationalisation of these activities. At the moment there is no monitoring of groundwater level data or groundwater quality data islandwide for long term assessment or for resource planning and management.

4.2. Data Processing and Management

(a) Hydrological Data

The Irrigation Department has the majority of its hydrological records such as river water heights, rating tables, rainfall data and station details stored in hardcopy format at its Head Office in Colombo. There is presently approximately 2400 station years of primary record in this hardcopy format which could be destroyed through fire damage or other forms of loss. Only a small percentage of this data (daily flows) is in computer format. There is currently a 10 year backlog in the entry of flow data into the existing computer system. Software development is undertaken in-house and the whole system is desperate for overhaul and for the introduction of modern hydrological database software.

(b) Climate Data

The Meteorological Department is storing its climatic data on the WMO 'CLICOM' database system. The majority of the records at MD are stored in computer format that is readily available for data processing and analysis. The data can be exchanged with other computer systems. Some upgrading of existing software to the latest release is required, however the data is secure and proper data security and backup procedures are in place. However data are yet to be digitized and included in this database

(c) Water Quality Data

The Central Environment Authority (CEA) collects and analyses water quality data and information to meet the agency's licensing requirements, for project work and for dealing with complaints concerning water quality. There have been earlier suggestions and proposals for a national water quality monitoring program, however, this has not progressed. Laboratory sample data is stored in a laboratory management system. For quantitative modelling and analysis studies, data is output and stored in spreadsheets.
There are other organisations such as universities, IFS, private companies and NGO's who posses project specific water quality data.

(d) Water Usage Data

Significant surface water and groundwater usage in Sri Lanka is for irrigation, hydro-electric, industrial, and domestic purposes (Table 3). In comparison, water resource utilisation for recreation, tourism, transport and fishing could be considered as small. However a recent conflict with respect to an attempt to use water for hydro-electric generation, depleting major waterfalls, reflected the growing concerns of the usage for recreation, tourism and others.

Groundwater usage is mainly for industries and water supply schemes but islandwide there is a heavy reliance on groundwater to fulfil the domestic water requirements. The Agricultural Development Authority is presently executing a significantly large program for the development of Agro-Wells for irrigated agriculture in the dry zone of Sri Lanka. Agro-wells are shallow large diameter dug wells to harness groundwater.

Surface water is mainly tapped for the use of irrigation and hydro-electric generation. Water supply schemes and industries scattered around the country which are mostly located closer to cities extract surface water in significant quantities. National Water Supply and Drainage Board, which is a national organisation, maintains water extraction data from surface and groundwater sources for water supply schemes.

Water release data from the major reservoirs are collected by the Ceylon Electricity Board. Irrigation water extraction data in some schemes are maintained by either the Mahaweli Authority or Department of Irrigation. Water usage data of the smaller irrigation schemes or of the Agro-wells are not being collected.

The data are stored in both digital (spreadsheets), and hard copy formats. General opinion was expressed that this was satisfactory for daily and seasonal operation decisions and for input to operational models.

(e) Geographical Information

The monitoring, collection, collation and management of natural resources data and information in Sri Lanka involves a complex arrangement of projects undertaken by government agencies, authorities and boards and includes research, consulting and business organisations. The work is being supported by several donor funded programs and through direct government projects.

During the interviews undertaken as part of this project, it was noted that many government agencies are developing Geographic Information Systems (GIS). Policy and coordination is vitally important particularly in relation to reducing duplication of effort in data capture and to adopting common standards for digitising and processing. There appears, however, to be no clear strategy to define an overall policy for natural resources information management in Sri Lanka, or to coordinate this work between agencies.

Several projects, such as the GIS project at the Environment and Forestry Division of MASL in Kandy, have made substantial progress and it is understood that a national GIS Working Group has recently be convened to address some of these issues. This would lead to a coordinating body being appointed and custodian agencies undertaking specific areas of work.

4.3. Data Pricing

In general water data in Sri Lanka are not priced by the agencies which collect such data except by the Department of Meteorology and by the Department of Irrigation. The Department of Meteorology has a price structure for the rainfall data extracted from its digital database. The streamflow data of Department of Irrigation are also has a price structure. Price structures at both these institutions have been established by the respective institutions on behalf of the government. It is also noted that these agencies allow either special discounted rates or free of charge access for research, academic purposes and for national projects.

Other than the above two agencies, none of the organisations sell any water data. The water data with these agencies can be accessed, by obtaining an approval from the concerned agency, indicating the purpose of usage. During the water user/collector survey it was revealed that the two holders of the groundwater data, namely the National Water Supplies and Drainage Board and the Water Resources Board did not have a pricing policy.

The Central Environmental Authority and the Agriculture Development Authority was of the opinion that the water data should be made accessible free of charge since data is meant to be used.

Data pricing policies for the dissemination and sale of water data have been set on an agency by agency basis in Sri Lanka. Although the actual cost varies between agencies, data is generally sold at a price which reflects the cost of dissemination only. There does not appear to be any attempt to charge for the cost of data collecting and primary processing or to charge for profit. Data is often made available to other government agencies or research organisations without any cost.

The user interviews indicated that there was general satisfaction with the price of data; the major concern being data availability, data quality and the time it took to actually satisfy the individual data requests. The one exception to this was University groups where student requests for information were often not addressed, by the data collecting organisations.

Most of the user/collector personnel expressed the view that the basic data should be available to the users at a nominal cost but were of the feeling that the processed data should be priced to reflect the additional effort that would go into the data to satisfy specific user requirements.

5. SUMMARY AND RECOMMENDATIONS

5.1. General

At present, in Sri Lanka, water resources data and information is organised and managed in a traditional manner; within various government agencies and with little attempt to integrate the various water data archives into a coherent water resources information system. There is no water database being developed, at present, where all the data classes are brought together and integrated.

Significant gaps in data collection programs such as quality, technology, coverage etc., were identified and recommendations made on how these could best be accounted for with revised monitoring programs. On the broader issue of natural resources data management, at this point in time, there does not appear to be a coherent strategy for the management of natural resources data and information at a government level in Sri Lanka.

There is a need for coordination, planning, improved access, publication, quality assurance and pricing of data, if full benefit is to be gained from the data already collected. The need for a group to undertake the coordination role was raised in many interviews. The user interviews identified concerns regarding the data availability, data quality, and accessibility.

Among the state organisations collecting water data, hydrological data is collected and managed by the Irrigation Department, water quality data by the Central Environment Authority, groundwater data by Water Resources Board and the National Water Supply and Drainage Board, and Climate data is collected and managed by the Meteorological Department.
Other organisations such as universities, corporations, NGO's also contribute to the data collection process.

5.2.Surface Water

Although satisfactory in terms of station numbers, a review of the surface water monitoring network and procedures of the Irrigation Department is overdue and should be undertaken in liaison with the MD and the CEA.

It is observed that a large percentage of the field work for an islandwide water quality monitoring program could be undertaken with minimal cost, through agreement and cooperation with the Irrigation Department. The first stage of such a program would be to collect water samples at river flow monitoring sites that are operated by Irrigation Department staff throughout Sri Lanka for analysis at a suitable organization. This is a practice adopted in many other countries and recommended in the World Meteorological Organisation (WMO 168).

In the case of water quality there is a need to implement a national water quality monitoring program and link this program with other national water data monitoring programs for surfacewater and groundwater. Also there is a need to introduce a compatible modern database system for the storage and management of these data to enable the linking of that data to the archives maintained for other water data.

The nation's hydrological archive at the Irrigation department, most of which is still in hard copies, would require new hardware, software and staff training to successfully undertake the building of the database in computer format and to upgrade the management capabilities. New instruments such as data loggers will be needed for improved data collection.

Regarding the climate data, access to appropriate digitising software would enable the processing of continuous chart data that currently is not taken full advantage of due to the manual processing. Otherwise the MD seems to be well equipped with computers and trained staff capable of undertaking ongoing database management. The computerised data is in a suitable format for integrating into a water resources information system.

5.3.Groundwater Data

In the case of groundwater, there is however, no long-term monitoring of water levels on a seasonal and yearly basis, which is important for assessment and sustainable management decisions. In addition, there does not appear to be any aggradation of data between the NWSDB and the WRB. Currently these agencies operate separate and independent data archives, which are similar in function and purpose.

Two actions are required in the area of groundwater. Firstly, a nationwide groundwater monitoring program of water level and water quality data needs to be implemented. Initially, this would involve designing the appropriate monitoring network and cross reference this with other monitoring programs undertaken by the Irrigation Department, Meteorological Department and Central Environment Agency. Secondly, the database systems of both the WRB and the NWS&DB should be integrated into a single system and link it to a central Water Resources Information System.

5.4. Data Management

As part of the development of a Water Resources Information System, the option of including water usage data should be examined as it is important information for determining the total water budget of the country's river basins since this is prime requirement for planning basin development projects. However, because usage data is presently not collected for smaller irrigation schemes, the total water budget would only in part be estimated.

For a data management policy in Sri Lanka to be successful, it is essential that clear understanding be established for the different roles of the organisations in the management process. In order to achieve this there needs to be a cooperating agreement spelling out the roles and responsibilities for the various groups involved in the collection, processing and management of water resources data and information.

In conclusion, based on the survey results the following are considered fundamental for improved management of water resources data and information in Sri Lanka.

1. Improved coordination between data collectors and data users in the areas of accessibility, quality, publication and pricing.

2. A review of current data collection networks in terms of methodology, frequency, quality etc., to meet future water resources planning needs, and

3. Adoption of new technologies which would include new hardware, software, and staff training for data collecting, processing, dissemination and publication.

The recommendations outlined above have been developed after undertaking detailed surveys and interviews with water agencies and data user groups where information was acquired through discussion. In addition, the experiences and knowledge of data collection and management arrangements in other countries, such as Australia, New Zealand and United States (USA) were incorporated in the study (WRCNSW 1991, DISC 1989, WMO 1990, AWRC 1989, USGS 1982).

6. REFERENCES

AWRC 1989, "Guidelines for the Design and Operation of Surface Water Information Systems" – Australian Water Resources Council, Water Management Series 18-1989.

DISC 1989, "Policy on the Management of the Water Resources Archive in New Zealand" -Department of Industrial and Scientific Research, March 1989.

GOSL 1994, "Comprehensive Water Resources Management in Sri Lanka- Volume I & II", Report prepared under the project TA 1918-SRI with the Asian Development Bank and the USAID, January 1994

GOSL 1998, "Information System Analysis – Final Report", Report prepared by Water Resources Consultanting Services(Australia) in association with DHV consultants (The Netherlands), Environment Management Lanka(Pvt) Ltd (Sri Lanka), Resources Development Consultants Ltd. (Sri Lanka), and Lanka Hydraulics Institute Ltd. (Sri Lanka) under the project TA 2422-SRI with the Asian Development Bank, July 1998

USGS 1982, "Water-Data Program of the U.S. Geological Survey" - Geological Survey Circular 863, 1982.

WMO 168, "Guide to Hydrological Practices", World Meteorological Organisation, WMO No 168, Geneva

WMO 1990, "Progress in the Implementation of the Mar del Plata Plan and Strategy of the 1990's" – WMO/UNESCO Water Resources Assessment Program –1990.

WRCNSW 1991, "Co-operating Agency Policy on Water Data Management." – Water Resources Council of New South Wales, Australia, July 1991.

Table 1 - List of Contacted Agencies

1	Meteorology Department
2	National Aquatic Resources Agency (NARA)
3	International Irrigation Management Institute (IIMI)
4	Natural Resources Energy & Science Authority(NARESA)
5	Water Resources Board (WRB)
6	Irrigation Department (ID)
7	Central Environment Authority (CEA)
8	Water Management Secretariat, Mahaweli Authority of Sri Lanka (WMS - MASL)
9	University of Moratuwa
10	National Water Supplies & Drainage Board (NWS&DB)
11	Ceylon Electricity Board (CEB)
12	E.A.1 Project / Ministry of Environment
13	Sri Lanka Land Reclamation & Development Corporation (SLLRDC)
14	National Building Research Organisation (NBRO)
15	Central Engineering Consultancy Bureau (CECB)
16	University of Colombo
17	Agriculture Development Authority (ADA)
18	Ceylon Institute of Scientific & Industrial Research (CISIR)
19	Department of Agrarian Services (DAS)
20	Institution of Fundamental Studies (IFS)
21	Environment & Forest Conservation Division, Mahaweli Authority of Sri Lanka (EFCD of MASL)
22	Lanka Hydraulic Institute (LHI)

Table 2 – Station Densities Compared with WMO Standards

Organisation	Network Type	Number of Stations	Effective Area (SqKm)	Station Density (SqKm per Station)	Respective WMO Standard Density Km^2/Station	WMO Inforhydro 1991 Standard	Satisfactory by WMO standards	Remarks
Department of Irrigation	River Gauging (After 94/95 Water Year)	48	65531	1365	1875 For interior planes and hilly areas	1000	Yes	Very few stations at northern and eastern areas
Meteorology Department	Daily rainfall (Non Recording)	350	65531	187	575 For hilly areas	200	Yes	Very few stations at northern and eastern areas
	Automatic rainfall gauging stations (Recording)	22	65531	2979	5750 For interior planes and hilly areas		Yes	Very few stations at northern and eastern areas
	Evaporation (Agromet)	38	65531	1725	50000 For interior planes and hilly areas		Yes	Very few stations at northern and eastern areas

Table 3 - Status of Water Usage Data

Purpose	Organisations Involved in Promotion / Management / Administration	Water Source	Water Usage Data Collection
Irrigation	Department of Irrigation	Surface water	Some Schemes
	Department of Agrarian Services	Surface water	None
	Provincial Irrigation Department	Surface water	None
	Mahaweli Authority	Surface water	Some Schemes
	Agricultural Development Authority	Groundwater	None
Hydro-Power Generation	Ceylon Electricity Board	Surface water	Yes
Domestic Water Supply	National Water Supply and Drainage Board	Surface water Groundwater	Yes Yes
Industrial use	Local Government	Surface water Groundwater	Yes None
	National Water Supply and Drainage Board	Surface water	Yes
	Board of Investment	Surface water Groundwater	In Ind. Zones None

NATIONAL WATER CONFERENCE
Nov. 4-6, 1998
BMICH, Colombo Sri Lanka

RESEARCH PAPERS PRESENTED

Session No.6 4 November 1998 *1:30 P.M.*

Managing Water Quality

Paper No.59
Gunesekera, Manisha
Abeygunawardena, S.Indrika.
de Alwis, Ajith
Pathirana, W.
Characterization Of Liquid Effluent From A Pharmaceutical Production Facility

Paper No.78
Ginige, M.P.
Pathiraja, P.M.G.
Abeygunawardena, S.Indrika.
Widanapathirana, G.S.
Isolation And Identification Of Bacteria From Textile Waste Waters And Evaluating Their Biodegradability Of Textile Dyes

Paper No.83
Wijewardena, J.D.H.
Impact Of Intensive Vegetable Cultivation On Drinking Water Quality In The Upcountry Region Of Sri Lanka

Paper No.105
Priyantha, Namal
Tennakoon, D.T.B.
Keerthiratne, Saman
Abeysinghe, Thushara
Removal Of Heavy Metal Ions From Polluted Water Using Environmentally-Friendly Materials

Characterization of liquid effluent from a Pharmaceutical Production Facility.

Ms. Manisha Gunasekera, *Department of Chemical Engineering, University of Moratuwa.*
Dr. Indrika Abeygunawardana, *Department of Microbiology, University of Kelaniya.*
Dr. Ajith De Alwis, *Department of Chemical Engineering, University of Moratuwa.*
Mr. W.Pathirana, *State Pharmaceuticals Manufacturing Corporation, Ratmalana.*

Abstract

Pharmaceutical manufacturing industry is expected to generate effluents having a wide variety of anti microbial substances. The effluent has to meet the Central Environmental Authority's relevant discharge standards. The biological treatment processes should be capable of handling effluents, containing these inhibiting materials without being subjected to inhibitory effects.

A wastewater treatment plant of a Pharmaceutical formulation manufacturing company that produces solid dosage forms was analyzed. This wastewater treatment plant deals with both human waste and factory waste together. The manufacturing process deals with the formulation, filling and packaging of preparations for prescription products.

The wastewater was investigated for its general characteristics such as temperature, pH, turbidity, BOD, COD, TSS and TS. The average BOD_5 and COD removal efficiency of this wastewater treatment plant was 68 and 45% respectively. The TSS removal efficiency was 70%. Different liquid culture media including wastewater from the equalization tank were inoculated with an equal amount of the microorganism *E.coli* and were measured for absorbance in the spectrophotometer after 24 hrs, 48 hrs and 72 hrs. Presence of an anti microbial substance in the wastewater was also determined by determining the sensitivity to the microorganism *E.coli* using the cylinder-plate technique.

Introduction

There are eight major pharmaceutical manufacturers in Sri Lanka presently. The contribution from these local manufacturers is about 35% of the total requirement in this country (WHO Mission 1993). Rest of the pharmaceutical requirement is mainly met through imports. The two main steps in the pharmaceutical manufacturing industry are bulk manufacturing industry and formulation industry. All the pharmaceutical manufacturing industries in Sri Lanka fall under the latter category.

The pharmaceutical production facility of this study produces solid dosage forms of drugs. This facility which is equipped with the most modern machinery has an annual capacity of 550 million units of tablets or capsules and 60000 liters of dry syrup. The organization produces about 42 different drugs presently. The production area of this facility consists of two main sections where penicillin drugs and non-penicillin drugs are manufactured separately. Pipe borne water is used and is entirely supplied by the National Water Supply and Drainage Board. All effluents are collected and treated in a wastewater treatment plant before being discharged. This treated wastewater is then discharged to an open canal, which leads to the Bolgoda Lake.

Water Consumption

The incoming pipe born water is treated before it is used in the facility. The water consumption at this facility is about 1100 m^3 per month. As solid dosage formulation, filling and packing are the main activities, the process water usage is minimal (Table 1). For the preparation of starch as a binder and sugar and film coating blends, water is used in small quantities. However, in these production areas water is extensively used for subsequent cleaning and washing. Processing equipments are washed and cleaned when the manufacturing product is changed. Water is also used for the washing of accessories such as containers and equipment used for preparing paste and film coating materials. The retained process materials adhering on to the surfaces get removed with the wash water.

When considering characteristics of wastewater from a primary manufacturing of pharmaceutical drugs, the BOD_5 of the final effluent strengths in some wastes may be 600 mg/l and some pharmaceutical waste have BOD_5 in excess of 200000mg/l. (Environmental Technology Consultants 1993). In a dry dosage formulation pharmaceutical manufacturing facility, such high strength effluents are not expected to happen (EPA 1991). Since many non-contaminated water is also entering the wastewater treatment plant in this study low strength effluents could be expected.

The Wastewater Treatment Plant

The wastewater treatment plant of this facility consists of a wastewater collection tank. Sewage screened through a bar screen enters the collection tank and the wastewater from production areas enters this tank separately (fig.1). It collects wastewater and transfers it to the equalization tank (fig.2). This wastewater is screened through a fine screen before entering the equalization tank. The contents in the equalization tank are mixed continuously using air diffusers placed at the bottom of the tank. Wastewater is transferred from the Equalization tank to the aeration tank through a flow rate-controlling device. During this transfer wastewater flows through the aeration tank, sedimentation tank, sterilization (Chlorination) tank and to the outlet of the wastewater treatment plant under gravity flow. In aeration tanks aeration is done continuously throughout the day by air diffusers placed at the bottom of the tanks. Sludge collected at the bottom of the sedimentation tank is transferred to a sludge storage tank once a day and during this transfer part of the sludge is sent back to the aeration tank as the return sludge. The rate of return of the activated sludge in a typical activated sludge plant is usually between 50% to 100% times the (volumetric basis) inflow of the wastewater.

Materials and Methods

General Process Analysis

Wastewater samples collected from collection tank, equalization tank, two aeration tanks and from the outlet were analyzed for the parameters shown is table 2.

Samples taken from the equalization tank were analyzed for BOD for six different dilutions. (i.e. 3.33%, 5%, 6.67%, 8.33%, 10% and 13.33%). The purpose of this test was to ascertain the presence of any substance in wastewater, which can cause inhibition in the microbial activity of this test.

Anti microbial effects

Growth characteristics of microorganisms in different media vary depending on the amount of nutrients and anti microbial substances present while keeping other growth factors constant. The growth of the microorganism *E.coli* DMBUK3001 was observed by measuring absorbance (wave length 600 nm) by using different culture materials. Culture media were 5ml samples of 0.1% peptone water, 10 μg/ml amoxycillin solution (1ml of 50 μg/ml amoxycillin solution in 4ml of 0.1% peptone water), distilled water and filtered wastewater collected from equalization tank (filtered through a membrane filter nominal pour size 0.45 μm). The microorganisms *E.coli* grown in 0.5% peptone water was inoculated in these media by aliquots of 0.05 ml, 0.1 ml and 0.15 ml, and were incubated at 37^0C. The turbidity was measured at the time of incubation and after 24 hours, 48 hours and 72 hours. A control sample was also analyzed for each media.

The presence of anti microbial substances could be observed by microbial characteristics such as bioluminescence, oxygen uptake rate, inhibitory effects etc. The inhibition of the growth of a microorganism from a wastewater sample from equalization tank was tested using the cylinder plate technique, and a comparison was done with the sensitivity of Amoxycillin to *E.coli* DMBUK3001. Amoxycillin standard solutions were prepared in distilled water having concentration 500μg/ml, 100μg/ml, 50 μg/ml, 10 μg/ml and 1μg/ml. The organism *E.coli* in the 0.5% peptone water (70% transmittance, 600nm wavelength) was spread (0.08ml) on nutrient agar medium. Quantities 0.08ml from each of the amoxycillin standard solutions and wastewater were tested for inhibition zones. Wastewater was used after filtering through a membrane filter (nominal pore size 0.45μm) and sterilized distilled water was used as the blank solution.

Results and Discussion

General Effluent Characteristics

Wastewater from the collection tank, equalization tank, aeration tanks and from the outlet have temperature in the range 28^0C to 31^0C. The lowest recorded pH was 6.88 from the collection tank and the highest recorded pH value 8.46 was also from the collection tank. Therefore the pH variation was highest in the collection tank. Collection tank holds the wastewater discharged from the factory for approximately 40 minutes. Therefore the wastewater pH vary with the variation of the wastewater discharged at the time of collection. The pH values in the aeration tanks, where the biological treatment takes place, vary between 6.88 and 8.0. The general range of operation of an aeration system is between pH 6.5 and 8.5 (Hammer 1977).

The turbidity observed in the collection tank was within the range 12-48 (NTU) and that of equalization tank was 10-44 (NTU). The turbidity measured in the outlet samples varies in the range 4.5-16 (NTU). For an effluent from a wastewater treatment plant these values could be considered as low (very good quality with regard to this parameter) as even for drinking water, the WHO guidelines give a value of 5 NTU which is generally objectionable to consumers (WHO 1984).

BOD_5 in the collection tank vary between 14 mg/l to 62 mg/l. Of the total number of 12 samples six values were less than 30 mg/l which is the maximum tolerance limit of the general standards given for discharge of effluents into inland surface wasters by Central Environmental Authority. In the aeration tanks the maximum BOD_5 value observed was 29mg/l. The outlet wastewater has BOD_5 values 100% less than the maximum permissible BOD_5, 30 mg/l. The average BOD_5 of the influent in collection tank was 37 mg/l and that of the effluent of the wastewater treatment plant was 12 mg/l. Therefore the BOD_5 removal efficiency of this plant was 68%. The main wastewater treatment process of this wastewater treatment plant is a biological treatment process. In the aeration tank 1, 50% of the F/M ratios were above 0.5 and in the aeration tank 2 about 17% were above 0.5 (fig. 3). The maximum BOD_5 value observed in the aeration tanks was 29mg/l. Therefore, wastewater treated in this process has very low strength effluent.

The COD values in the wastewater of collection tank vary in the ranges 33mg/l to 257mg/l. The average COD value in this tank was 122mg/l. The COD value variation in the equalization tank was between 26mg/l to 161 mg/l. In the outlet wastewater COD values observed varied between 18mg/l to 239 mg/l. The average of these values was 67 mg/l. Therefore the COD removal efficiency was 45%. Although the COD removal efficiency was low the effluent discharged from this wastewater treatment plant complies with the maximum tolerance limit 250 mg/l of COD. When comparing the ratios BOD/COD, 92% of the wastewater in the equalization tank were less than 0.5 (Table 3).

The effluent discharged from the wastewater treatment plant has a maximum TSS of 26 mg/l and the maximum tolerance limit for this parameter is 50mg/l. Therefore this parameter also complies with the standards. Total suspended solids in the inlet to the wastewater treatment plant vary from 12 mg/l to 96 mg/l and the variation in the outlet was from 4 mg/l to 26mg/l. The TSS removal efficiency for these ranges was 70%.

The total viable count of the bacteria were in the ranges 11700 CFU/ml to 67×10^4 CFU/ml in aeration tanks on Nutrient Agar medium and on Plate Count Agar it was observed in the ranges 12500 - 25×10^5 CFU/ml.

BOD_5 variation in various sample dilutions

The variations in the BOD_5 value for the six dilutions of five samples taken from the equalization tank are shown in fig.4. In two of the five days a decrease in the BOD value was observed with the decreasing of dilutions. In lower dilutions high concentration of the inhibition substance is present, consequently the inhibition of biological activity is greater. In samples 1 and 2 a decrease in BOD_5 from 64 mg/l to 44 mg/l and 69 mg/l to 45 mg/l respectively were observed with the decrease in dilution. The average dissolved oxygen in aeration tanks was 6.6 mg/l. This shows that there was adequate aeration for the biological treatment process. The dissolved oxygen level was quit high and this has the tendency to reduce toxic effects.

Inhibitory effect on E.coli

The absorbance variation observed for sample 1 (0.05 ml aliquots of *E.coli*), Sample 2 (0.10ml aliquots of *E.coli*) and Sample 3 (0.15 aliquots of *E.coli*) are shown in fig. 5. During the first 24 hours, highest increase in the absorbence was observed in the culture grown in 0.1% peptone water. During the next 24 hours to 48 hours the increase in absorbance was less. Since there were no inhibitance for the microorganism's growth and the presence of enough nutrients for the microorganism growth, high absorbance values were observed. The next highest increase in absorbance was seen in the wastewater from the equalization tank. Therefore this organism *E.coli* does not grow in wastewater in the same rate as it is in the 0.1% peptone water. In distilled water, during the first 24 hours absorbance of the samples increase but not as much as the increase in wastewater. An inhibitory growth was shown in the 10μg/ml amoxycillin solution.

Determination of presence of an anti-microbial substance in the wastewater

The figure 6 shows the variation in the clear zone diameter with the amoxycillin concentration in a semi-log scale. From the best fit curve the equivalent amoxycillin concentration to the wastewater sample collected from the equalization tank was given as 2.9 μg/ml. Therefore this wastewater contains an anti microbial substance sensitive to *E.coli* micro-organism equivalent to the sensitivity of 2.9μg/ml amoxycillin to the same organism.

Conclusion

The characteristics of the wastewater in this facility show extremely low organic contents. Large quantities of water not contaminated with any contaminants enter and dilute the wastewater stream. The decrease in BOD values with the lowering of dilution shows that the wastewater samples contain substance or substances, which inhibit the biological activity. The effective zone of the wastewater is equivalent to a one where amoxycillin concentration is 2.9μg/ml. Since this factory is planing to meet some foreign demand, an increase in the production capacity is expected in the future. Therefore a vigilant approach to detect any anti microbial substance entering the wastewater treatment plant should be adopted in managing this plant. Anti microbial substances entering the wastewater treatment plant could either kill microorganisms or inhibit their growth and result in low treatment efficiencies. If it is possible to have a detection for anti microbial substance in wastewater streams entering this treatment plant, measures could be taken to reduce the anti microbial concentration to a level that would not affect the biological activity in the activated sludge treatment process.

References

Environmental Technology Consultants Ltd., (ETC) 1993, "Anaerobic Digestion of industrial wastewater, A survey of potential application in the United Kingdom Industry ETSU B 1294, pp52

EPA 1991, Guides to Pollution Prevention, The Pharmaceutical Industry

Hammer M.J. 1977, Water and wastewater Technology, pp 94

Standard Methods, 19th edition 1995, For Examination of water and wastewater, APHA AWWA WEF

WHO 1984, Guidelines for Drinking Water Quality, Volume 2

Table 1 Water Consumption of Different Processes

Water Consumption	Stage
High (>1000 l/day)	Bottle washing, Washing of work personnel uniforms, Oscillating/mixing, Cooling water for Dry Granulator, Fine Mill and Vacuum Pump in the capsule-filling machine.
Medium (1000 l/day to 100 l/day)	Blending and Kneading Machine, Canteen, Quality Control Laboratory, Toilets, Paste Preparation.
Low (<100 l/d)	Sugar coating pans washing General washing

Table 2 Method of analysis of parameters – General Characteristics

Parameter	**Method/Equipment**	**Reference**	**Comment**
Temperature	Thermometer	Standard	on site
PH	pH meter	Methods	measurement
Turbidity	Nephelometry	19th Edition	
BOD_5^{20}	Titrimetry	1995	
COD	Open reflux, Titrimetry		
TSS	Gravimetry		
TS	Gravimetry		
Viable count of bacteria	Pour plate		

Table 3 BOD/COD ratio of the wastewater from Equalization Tank

Sampling Day	BOD/COD
1	0.03
2	0.26
3	0.20
4	0.03
5	0.17
6	0.24
7	0.40
8	0.63
9	0.41
10	0.19
11	0.36
12	0.50

Fig.1 Drain Layout

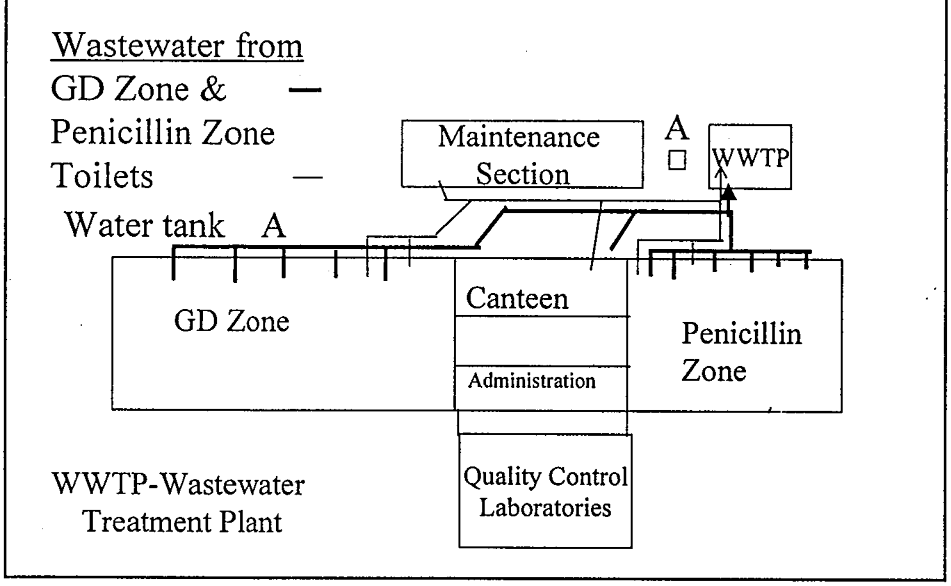
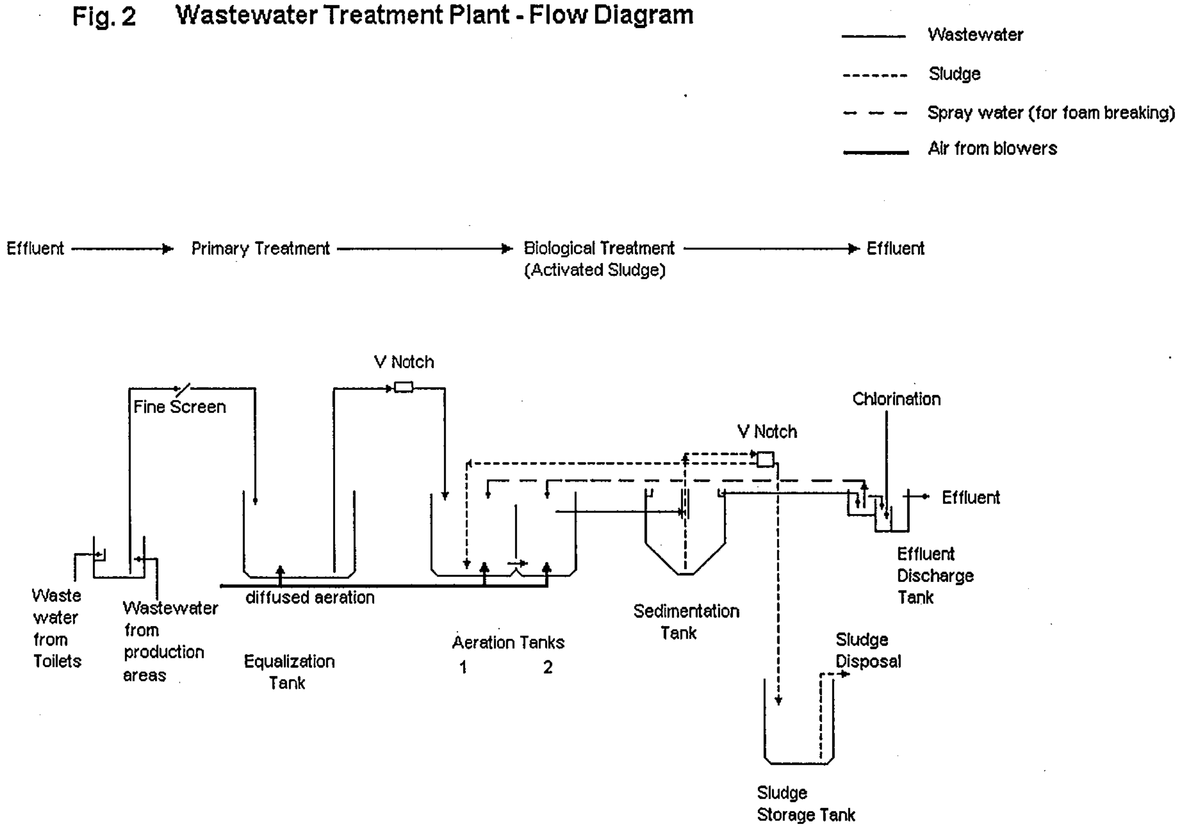


Fig. 2 Wastewater Treatment Plant - Flow Diagram



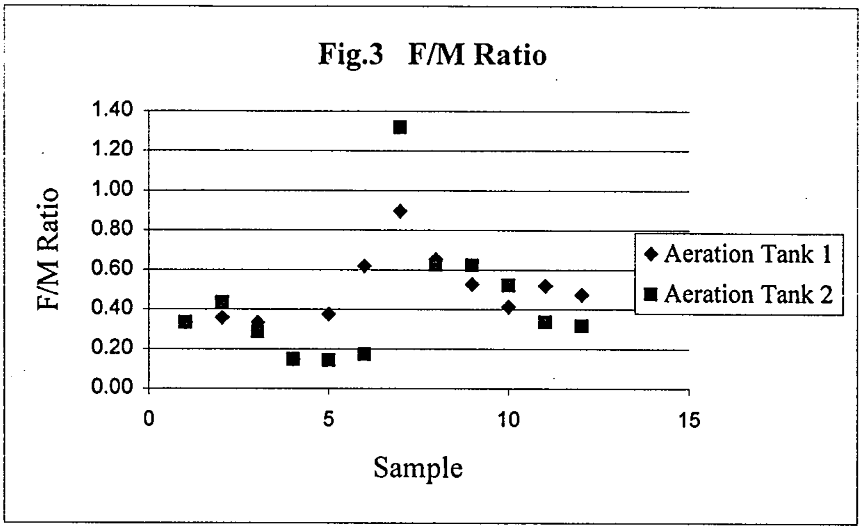


Fig.3 F/M Ratio
F/M Ratio
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
5
10
15
Sample
Aeration Tank 1
Aeration Tank 2

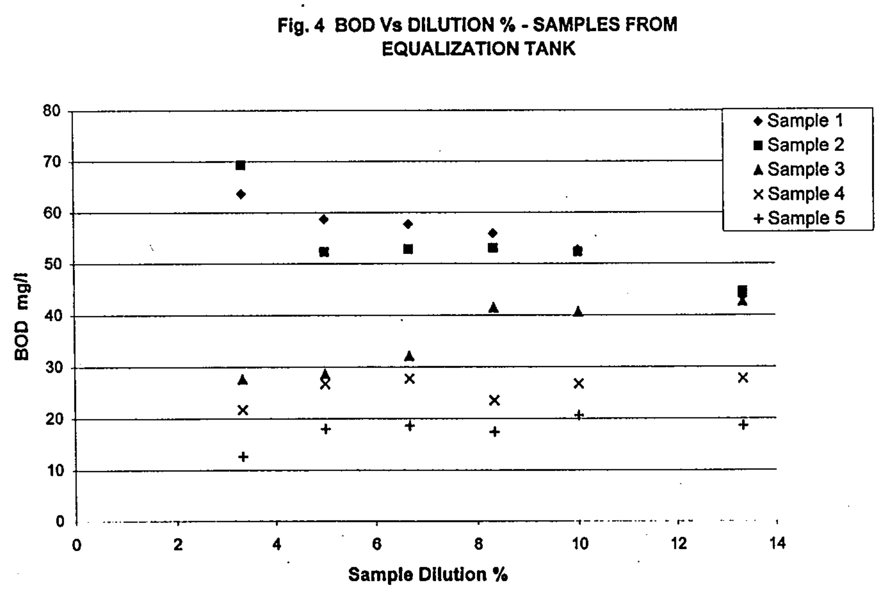
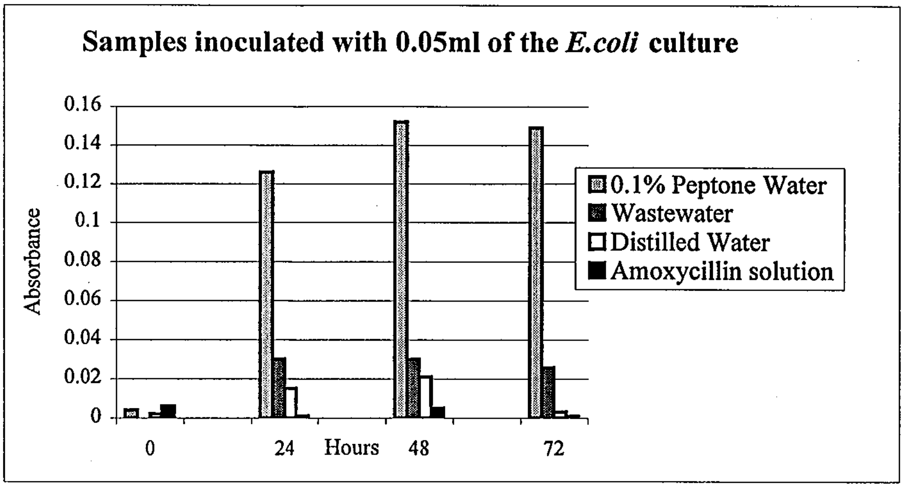
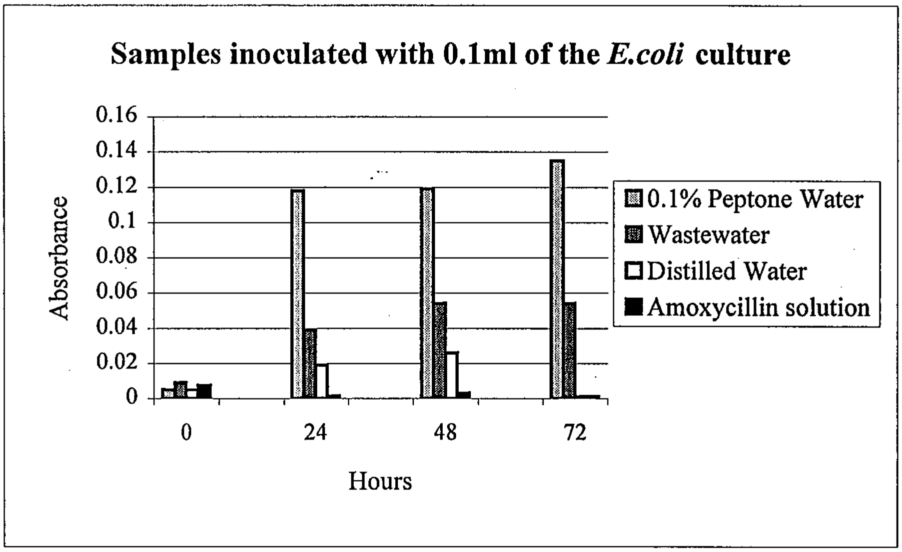


Fig. 4 BOD Vs DILUTION % - SAMPLES FROM EQUALIZATION TANK
BOD mg/l
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
Sample Dilution %
Sample 1
Sample 2
Sample 3
Sample 4
Sample 5

Fig. 5 Absorbance variation Observed





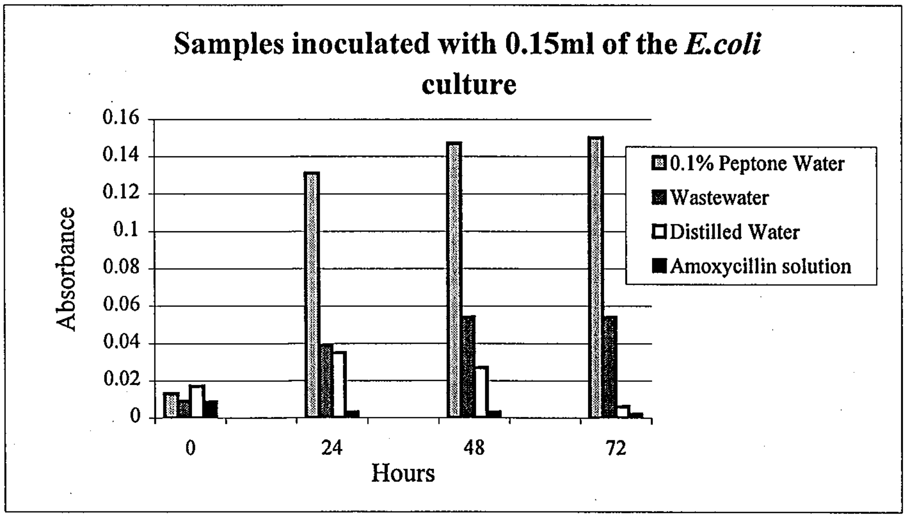


Fig. 6 Cylinder Plate Test

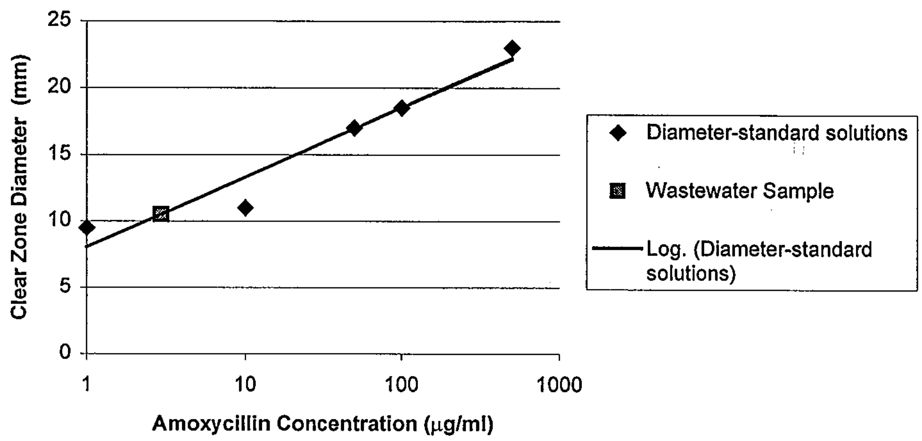


Fig.1 Drain Layout

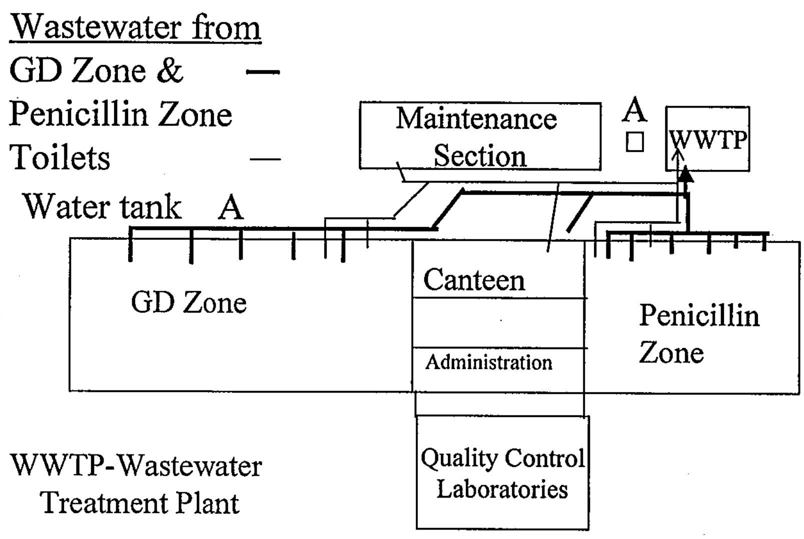
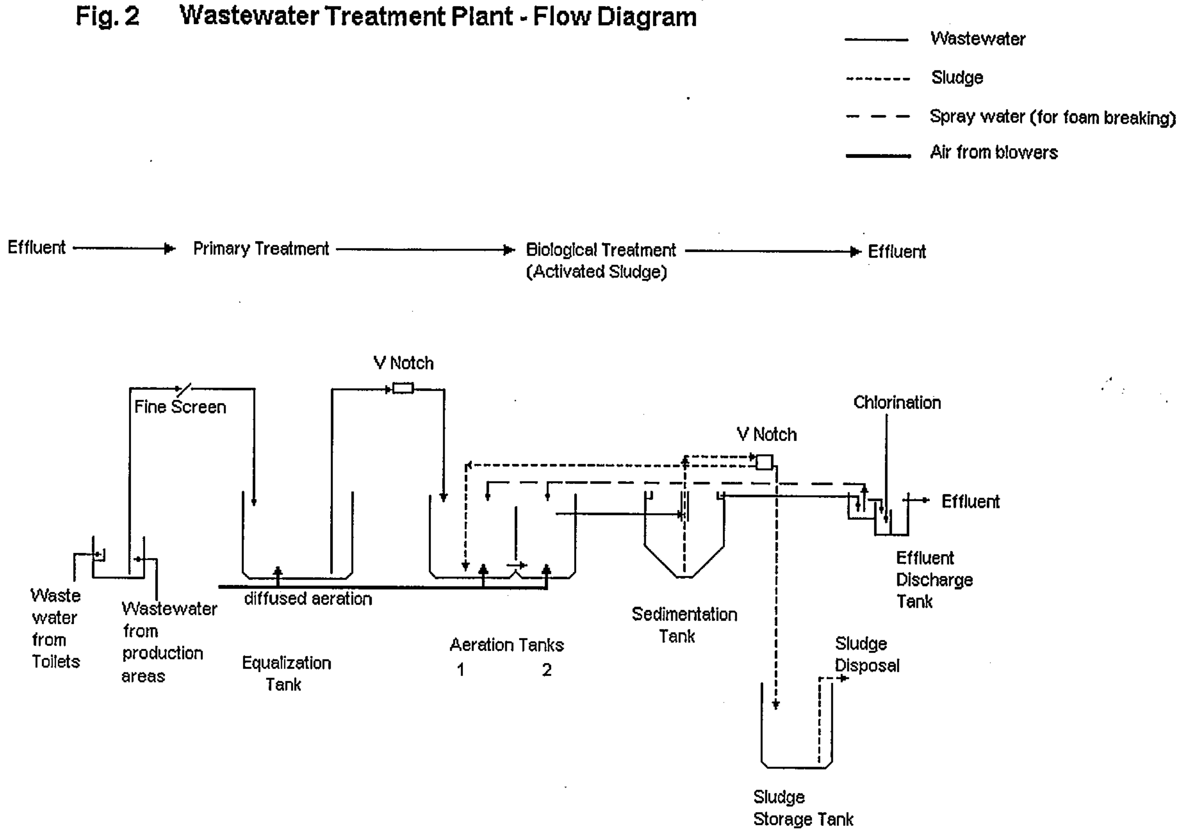


Fig. 2 Wastewater Treatment Plant - Flow Diagram



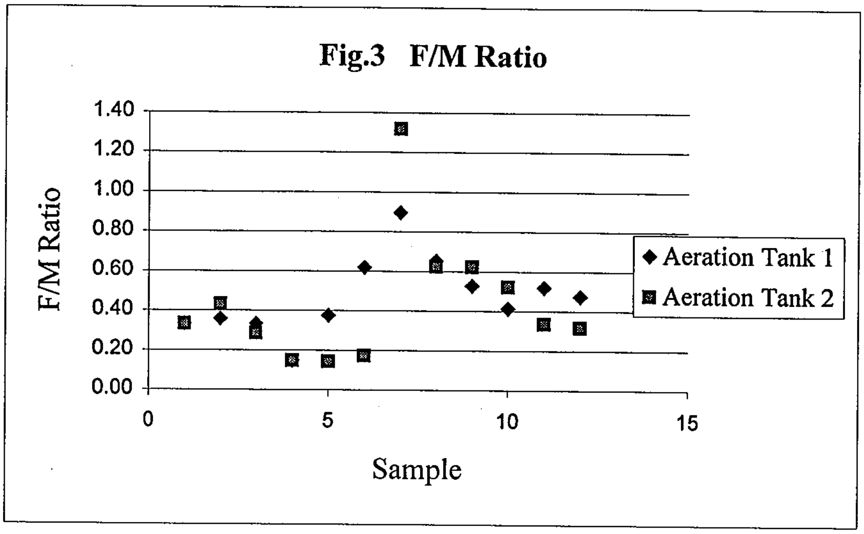
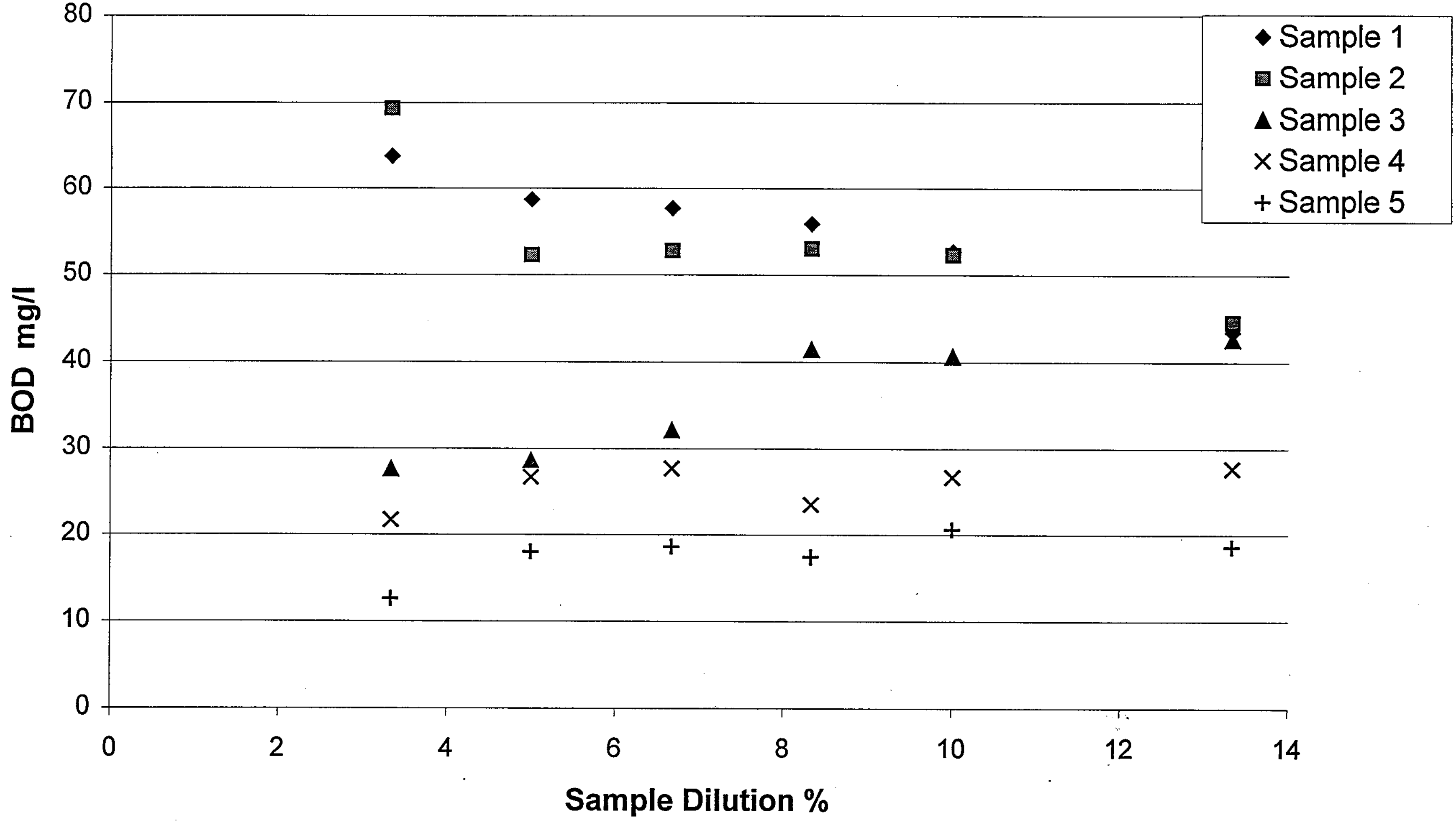


Fig.3 F/M Ratio
F/M Ratio
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
5
10
15
Sample
Aeration Tank 1
Aeration Tank 2

Fig. 4 BOD Vs DILUTION % - SAMPLES FROM EQUALIZATION TANK



Isolation and identification of bacteria from textile waste waters and evaluation of their biodegradability of textile dyes

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The textile industry has been identified as one of the major sources of water pollution in Sri Lanka because individual textile processing operations dispose large quantities of used water to the environment. The waste water from textile manufacturing industries are treated by physical, chemical and biological methods or by using a combination of the three in order to reduce pollution.

The main objective of this study was to isolate and identify different bacterial species from textile wastewater and to determine their ability to degrade textile dyes.

Twelve bacterial species were isolated from the textile wastewater samples. A special medium containing 0.03g / 100ml of a dye concentration was used to isolate the bacteria, and each isolate was identified using morphological and biochemical characters. Using these isolates their ability to reduce the colour of three textile dyes, namely Reactive Red 2, Reactive Blue 21 and Acid Blue 25 was investigated. The colour reduction was monitored by taking spectrophotometric measurements. Organisms such as *Enterobater aerogenes, Bacillus circulans, Bacillus alvei, Pseudomonas putida and Bacillus macerans* had a fair capability to reduce the colours of most of the above three dyes within a very short period of 4 – 6 days.

1. Introduction

The textile industry has made important contributions to many national economies. In Sri Lanka, the textile and garment industry has become one of the most important industrial sectors during the last few years. In 1990, the combined garment, textile and leather goods industries accounted for around 32% of the total value of the industrial production of the country (industrial population control guidelines, 1992). The textile industry manufacture finished cloth from imported raw material. These raw materials usually consist of cotton, wool and synthetics. During the production process the raw material undergo scouring (removal of foreign compounds), desizing (removal of size materials from gray goods to prepare for bleaching, dyeing etc.), mercerizing (a process given to cotton yarns and fabric to increase lustre, strength and dying ability), bleaching, dyeing etc. (UNEP, 1994). Therefore in the textile manufacturing process environmental pollution takes place as a result of the above operations (industrial pollution control guidelines, 1992). The finishing processes consume large quantities of water, resulting in substantial volume of liquid wastes which contributes significantly to water pollution in Sri Lanka.

Much of the textile wastes consist of natural impurities arising from fibre and processing chemicals. However the types of the impurities vary according to the type of raw materials and the processes used (Industrial pollution control guidelines, 1992). In addition chemical companies market a range of products such as dye formulations and colorants to the textile industry, many under trade names rather than by their chemical compositions. The discharge of coloured effluents into water streams makes water inhibitory to aquatic life. This also causes reduction in light penetration and depletion of dissolved oxygen levels in water in addition to visual pollution (Iiorng et al., 1993; Mittal et al., 1989).

Textile effluents are generally grey in colour. It has high biological oxygen demand (BOD) levels & total dissolved solids and an increased temperature. The synthetic finishing effluents which are generally low in volume may contain toxic substances especially when chemical dyes with metallic ions are used (UNEP, 1994).

To depollute these textile wastes, many different techniques have been used. Biological methods together with physical and chemical methods have been employed in many textile waste treatment plants. It has been emphasized that a combination of more than one process is generally necessary to achieve adequate removal of all contaminants rendering adverse effects to receiving water streams. Due to the wide range of dyes in use, each waste will demand a tailored economical method of treatment, making use of a combination of methods (IEC, 1985).

In the case of biological treatment, the eliminating extent (which is a measurement of break down of the dye) of dyes by activated sludge or trickling filter is small (UNEP / IE, 1994). However biological methods are used widely for its simplicity and low cost (Liu and liu, 1991). The decolouration of the textile dyes demonstrates only the transformation of the chromophoric group of a dye and it does not demonstrate the complete degradation of the compound (Spadaro *et al.*, 1992). In activated sludge systems, the degree of elimination of coloured compounds has been attributed to adsorption rather than degradation.

In nature, micro-organisms are known to play a major role in biologically degrading textile effluents (Pathiraja, 1996). The extent to which these dyes are subjected to microbial degradation depends on the solubility, ionic characters and the degree and type of substitutions that are found in the dye molecules (Jinqui & Houtain, 1991). It has been noted that through biodegradation organic loads of the textile effluent could be removed satisfactorily. A substantial reduction of the organic contents results values of pH, BOD and nitrogen to phosphorous ratios in the effluent to be maintained at suitable levels in-accordance to environmental standards. Further artificial introduction of suitable micro-organisms or altering of the environmental factors of the effluent is useful to increase the efficacy of the biological treatment processes.

Therefore the overall objective of this study was to isolate and identify bacteria that have the ability to degrade textile dyes and to asses the efficiency of the isolates towards the breakdown of the dyes under various conditions.

2. Material and Methods

Composite samples were prepared by mixing small aliquots of water samples collected from textile industries such as Vayangoda textile mill and Dial textiles Ltd.

A special medium (Ogawa et al., 1978) with varying concentrations of Reactive Red 2 dye was used to isolate the bacteria from the textile waste water. The isolation was performed under different combinations of the dye and nutrient concentrations. Each isolated organism was identified using its morphological and biochemical characters (De Ley, et al., 1984).

The natural ability of the individual isolates to degrade the dyes were evaluated by using the same medium with a dye concentrations of 0.03g / 100 ml. The textile dyes that were subjected to the test were Reactive Red 2, Acid Blue 25 and Reactive Blue 21. The degradability of the organisms were evaluated by measuring the absorbance of the dyes at their λ_{max} values during a period of 6 days. The experiments were carried out under both aerobic and microaerophilic conditions. An investigation was also performed to evaluate the degradabilty of the isolates, when used as microbial combinations.

Investigations were also done to study the degradation of the intermediate components that are formed during the bio-degradation of Reactive Red 2 dye. Possible formation of the intermediates were studied by measuring the absorbances of the intermediates at their specific λ_{max} values (404 nm, 422 nm, ...564 nm).

Further, the pH variations in the medium that occur during the bio-degradation process were monitored with respect to individual and mixed microbial cultures.

3. Results / Findings

The number of different bacterial species isolated in the presence of Reactive Red 2 textile dye was very small. Twelve species were isolated among which *Enterobacter aerogenes Pseudomonas putida* and *Bacillus circulans* were found to be the most abundant (Table – 1).

Isolates which were allowed to degrade the dyes under aerobic conditions in broth cultures did not significantly reduce the colour of dyes Reactive Red 2, Reactive blue 21 and Acid blue 25. However the organisms showed a dense growth under this condition. Under microaerophilic conditions, a rapid removal of the colours were observed (Fig. 1). Therefore further experiments were carried out under microaerophilic conditions.

During 6 days of incubation, *Enterobater aerogenes, Bacillus circulans, Bacillus alvei, Pseudomonas putida and Bacillus macerans* showed a reduction in the absorbance of the dye Reactive Red 2 (at 580 nm) from around 0.7 to 0.1, indicating an 86% removal of the dye (Fig. 2). When mixed cultures of *Pseudomonas putida, Bacillus pumillus* and other *Bacillus spp.* were used in the presence of Acid Blue 25 dye the absorbance (at 584 nm) of the medium dropped from around 0.7305 to 0.460 indicating a removal of around 35% of the dye. It was also found that when other combinations of mixed microbial cultures were used the degradation of the dye Acid Blue 25 was even lesser than the above (Fig. 3). Mixed microbial combinations when applied on any of the other two dyes, showed a lesser capability than the above to remove the colour of the dyes.

Organisms when grown in a liquid medium containing Reactive Red 2 dye, showed the appearance of various λ_{max} values in the medium during the incubation period, and it was in the range of 484 - 564 nm. The control experiment (the Day 0 in Fig. 4) showed two λ_{max} values 430nm and 580nm. The pure dye gave a maximum absorbance at 580nm while the medium gave at 430nm. The results given in Fig. 4-A for *Serratia liquefaciers* indicates that for Day 0 the maximum absorbances are at 430nm and 580nm. By Day 1, the absorbances had shifted and showed a broad peak in the range of 484 – 564nm, with a maximum at 544nm. The absorbances on Day 4 were very much similar to Day 1. However by Day 6 the overall absorbance values in the medium had become very low.

Enterobacter aerogenes, Klebsiella aerogenes, Bacillus circulans, Bacillus alvei and *Bacillus macerans* showed a similar pattern to the above. However the absorbances showed by other organisms in the range of 484 – 564nm did not show considerable reduction during the course of Day 1 to Day 6, indicating their inability to break down the intermediates efficiently.

Pseudomonas putida showed a specific behavior when grown on solid medium containing Acid Blue 25. It absorbed the dye into the cells from the solid medium and released the absorbed dye when introduced into an aqueous medium. However this feature was not observed when it was grown on a solid media containing either Reactive Red 2 or Reactive Blue 21.

The pure cultures of microorganisms brought about a gradual increase in pH from around 6.4 – 10.4 in the medium containing Reactive Red 2, during a period of 6 days of degradation. However during the same period of time the mixed microbial cultures only brought about a variation from 6.4 – 8.3.

4. Discussion

The soil of the draining channels of textile factories, were considered the most suitable natural substrate to isolate bacteria having the degradability of textile dyes. In the present study, water samples were collected from different sites of the waste water dumping marshes of textile mills. All of these samples showed very minor variations with respect to pH, diversity of organisms (Table - 1), colour (visual observation), odor etc. The major organisms isolated and identified from these samples were *Enterobacter aerogenes, Klebsiella aerogenes, Bacillus circulans, Bacillus anthracis, Bacillus alvei, Pseudomonas putida* and *Bacillus macerans* (Table - 1).

The dyes appeared to be one of the major sources of carbon available to the organisms when they were in the environment. In general natural organisms tends to utilize complex carbon compounds such as the dyes only when other simple carbon sources are limited in the environment (Hollaender, 1982). Therefore it was believed that these isolated organisms possessed alternative pathways to utilize the textile dyes.

A previous research carried out (Pathiraja, 1996) on textile dye effluents revealed that these organisms have the tendency to loose their ability to degrade the dyes when they are exposed to environments rich in glucose or other simple carbon sources. This occurrence was believed to be due to the loosing of a naturally occurring plasmid which would have contained the genetic information leading to the degradation of the dye (Hollaender, 1982). Therefore through out the present study a medium consisting a high concentration (0.03 g / 100 ml) of the Reactive red 2 dye was used to store the organisms, and periodically the ability of the organisms to degrade the dye was tested. The organisms showed a very slow growth on very high concentrations of the dyes. To avoid the slow growth rate of the organisms, initially a small fraction of glucose (0.01 g / 100 ml) was added into the medium and that allowed the organisms to get adapted in to the new environment gradually. The medium was also supplemented with the sterile effluent, as a method to supply the special micronutrients that might be needed by the organisms for their growth and active degradation of the dyes.

At the beginning of the study the degradation process was studied under aerobic conditions, where the organisms were allowed to grow in shake flask cultures. However the degradation of the dye did not occur as expected (Fig. 1). The colour of the dye, more or less remained along with a highly dense growth of the bacterial culture (visual observation). When the degradation of the dye was allowed to take place under microaerophilic conditions, i.e. by only shaking the media every 12 hrs, a very rapid and an effective removal of the dye was observed.

It is presumed that under microaerophilic conditions, the degradation of the dyes begin mainly and simultaneously at the logarithmic phase (Ogawa et al., 1978), but the growth rate of the cells are low. According to Ogawa if the shaking culture method is practically applied the removal of the biomass at the end of the treatment process can be a problem. On the other hand, in the case of the static cultures, the cells get heavily injured affecting their growth due to the localized dye concentrations in the medium.

The biodegradability of the textile dyes by the organisms were assessed by the capability of the organisms to remove the colour of the dyes from the experimental medium. An organism capable of removing the colour of a dye within a very short period of time was considered to be the most efficient organism for that textile dye.

Textile dyes are organic compounds, and many of these are aliphatic or aromatic hydrocarbons substituted by various substitutary groups like nitro, sulpho, -SH etc. (IEC,1985). Most of the microorganisms have the ability to breakdown these hydrocarbons incompletely resulting intermediate products, while using other carbon sources like glucose etc. as their energy source. This was apparent by the appearance of several $\lambda_{max.}$ values in the test medium during the time course of the experiment. However to confirm the formation of intermediates and to elucidate the above results a detailed analysis of the medium is necessary. This can be carried out using the thin layer chromatographic technique. The lack of information on the chemical structures of the textile dyes, and the limited time available for this study, made the task of finding a suitable solvent to carry out the thin layer chromatography difficult.

The natural environment consists of mixed bacterial populations. Therefore it was assumed that mixed bacterial populations could be much efficient than an individual organism in degrading the dyes. However according to results reported in Fig. 2 and Fig. 3 individual bacteria were more capable than the mixed bacterial populations in degrading the textile dyes.

Fig. 4 shows the changes in absorbances that occurred in the test media during 6 days of degradation by individual microorganisms. In this study it was assumed that the sudden appearance of various λ_{max} values in the test medium was associated with the formation of intermediate products in the process of biodegradation. Therefore the breakdown of the textile dye and the formation and break down of the intermediates in the test medium were monitored by measuring the absorbances at their specific λ_{max} values. Some organisms are only capable of breaking down the textile dyes partially, resulting intermediate compounds. However an effective organism(s) should breakdown the textile dye and remove any intermediates that are formed as well. Therefore the most effective organism(s) finally should show very low absorbance values in the test medium, similar to that of the medium without the dye.

In comparison *Serratia liquefaciens, Enerobacter aerogenes, Klebsiella aerogenes, Bacillus circulans, Bacillus alvei,* and *Bacillus macerans* appeared to be effective in degrading the dye, and most other intermediates that are formed in the medium. The literature reveals that *Pseudomonas* sp., *Aeromonas hydrophila* (ogawa et al., 1978), *Bacillus cereus* and *Streptomyces* sp. (Horn et al., 1992) have the ability to degrade the textile dyes. However when considering the isolated organisms only a few had the ability to degrade the dye partially or completely, but all of them were capable of growing in the culture medium containing very high concentrations of all the three dyes.

Furthermore a change of the pH in the medium along with the growth of the organisms was one of the notable features in this study. Here it was very clear that the microbial combinations had a better control over the pH in the medium than the individual microorganisms.

5. References

Cowan, S. T. 1981. Manual for the identification of medical bacteria. Cambridge University Press. U. K.

De Ley, J., Gills, M. and Swings, J. (1984). Bergey's Mannual of Systemic Bacteriology, Volume 2.

Industrial Pollution Control Guidelines (1992 June). No. 6 - Textile Processing Industry. Submitted by Bkh Consulting Engineers for the Central Environmental Authority.

IEC (International Environment Consultants LTD), (1985). Survey of Textile wet processing and Pollution Abatement Technology. Islington, Ontanio.

Jinqi, L & Houtian, L. (1991). Degradation of Azo dyes by Algae. *Environmental Pollution*, 75, 273 - 333.

Mittal, A. K. & Venkobachar, C. (1989). Studies on Sorption of Dyes by Sulfonated Coal and Ganoderma lucidum. *Indian Journal of Environmental Journal of Environrnent and Health*, 31, No. 2, 105 - 111 .

Ogawa, T. Idaka, E. & Yatome, C. (1978). Studies on the Treatment of Waste water Containing Dyestuffs by Microorganisms. *Microbiology for environmental cleaning*, 426 - 437.

Pathiraja, P.M.G. (1996). The Effects of Textile Dyes on Bacteria and Their Biodegradability. University of Kelaniya, Sri Lanka.

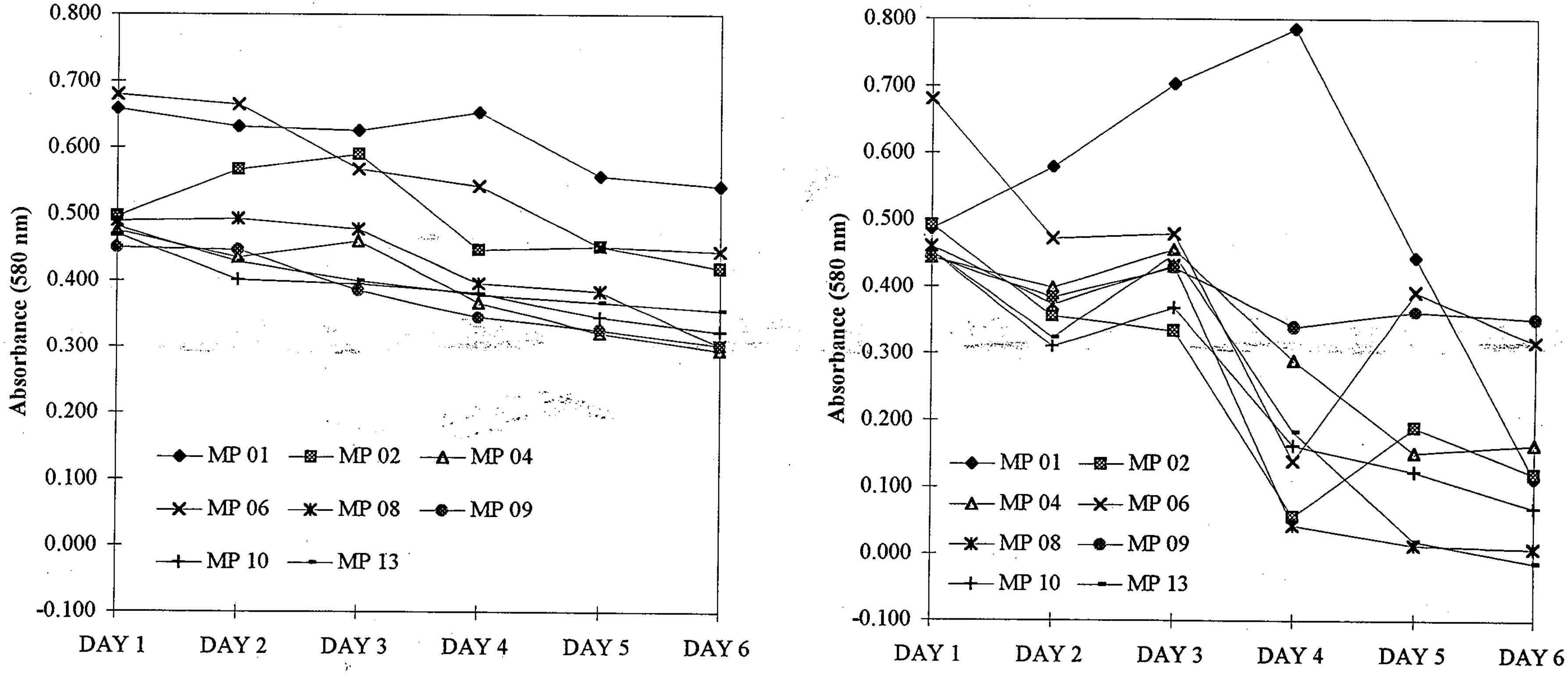
Rao, A. V., Jain, B. L. & Gupta, I. C. (1993). Impact of Textile mill Effluents on Agricultural land - A case study. *Indian Journal of Environment and Health*, 35, No.2, 132 - 138.

Spadaro, J. T., Gold, M. H. & Renganathan, V. (1992). Degradation of Azo dyes by the Lignin - Degrading fungus *Phanerochaete chrysosporium. Applied and Environmental Microbiology*, Aug. 1992, 2397 - 2401.

UNEP (United Nations Environmental Program), (1994). The Textile Industry and the Environment. Technical Report No. 16, Industry and Environment, 33 - 67, Quai Andre-Citroen, 75739 Paris Cedex 15, France.

Table - 1 Different species of bacteria isolated from the textile waste water

Code No	Isolated Species
MP 01	*Serratia liquefaciers*
MP 02	*Enterobacter aerogenes*
MP 03	*Pseudomonas putida*
MP 04	*Klebsiella aerogenes*
MP 05	*Bacillus subtilis*
MP 06	*Bacillus pumilus*
MP 07	*Bacillus megaterium*
MP 08	*Bacillus circulans*
MP 09	Unknown *Bacillus* spp
MP 10	*Bacillus alvei*
MP 11	*Bacillus licheniformis*
MP 13	*Bacillus macerans*



[A]

[B]

Fig : 1 [A] Reactive 2 dye eleminating capability of the isolated microorganisms in shaking cultures

[B] Reactive 2 dye eleminating capability of the isolated microorganisms in stand still culutres

MP01 - *Serratia liquefaciers* ; MP02 - *Enterobacter aerogenes* ; MP04 - *Klebsiella aerogenes*
MP06 - Unknown Bacillus spp ; MP08 - *Bacillus circulans* ; MP09 - Unknown Bacillus spp
MP10 - *Bacillus alvei* ; MP13 - *Bacillus macerans*

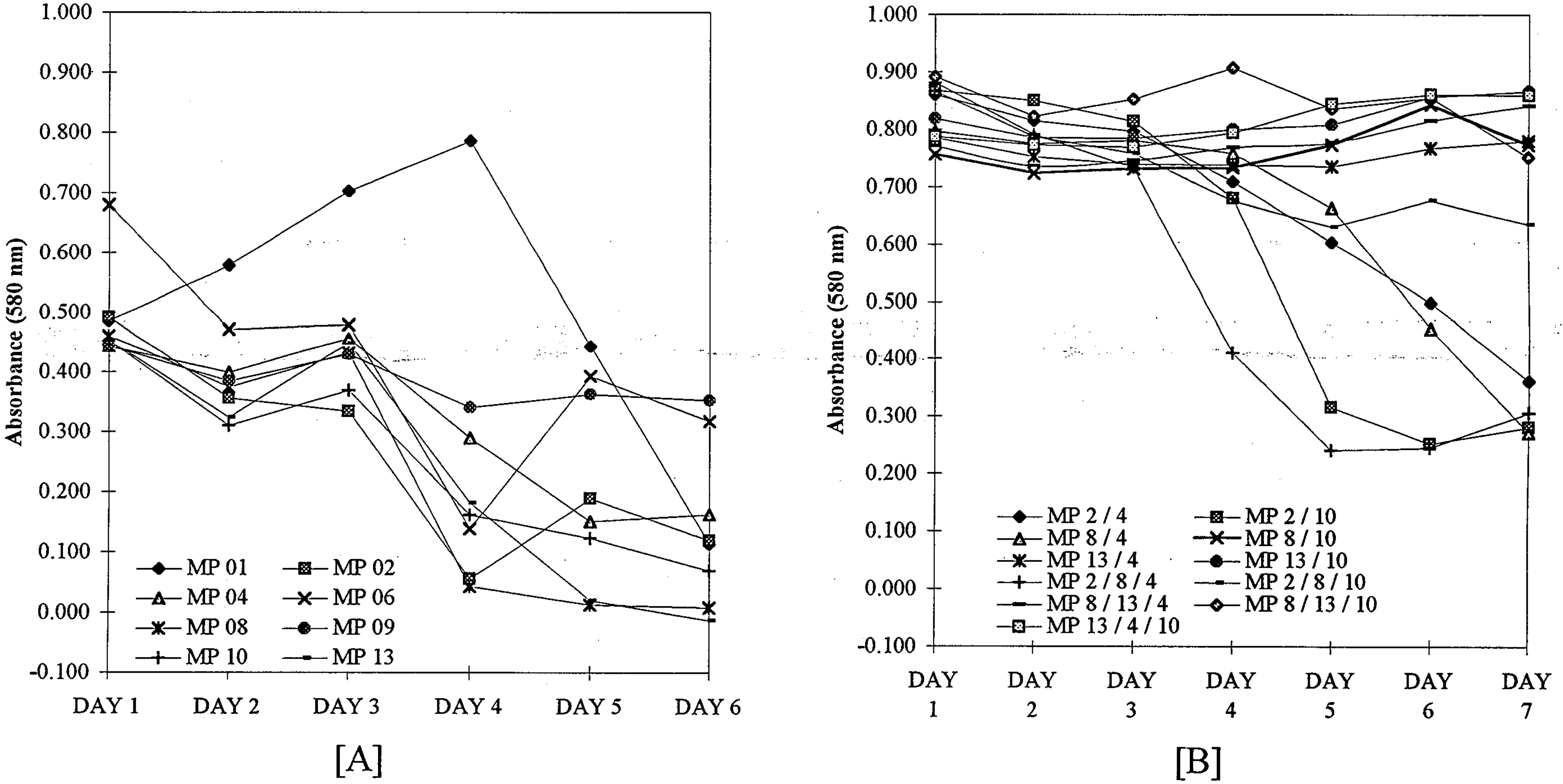


Fig : 2 [A] Reactive Red 2 Dye eleminating capability of the isolated microorganisms in stand still culutres

[B] Reactive Red 2 Dye eleminating capability of the mixed microbial cultures in stand still condition

MP01 - *Serratia liquefaciers* ; MP02 - *Enterobacter aerogenes* ; MP04 - *Klebsiella aerogenes*
MP06 - Unknown Bacillus spp ; MP08 - *Bacillus circulans* ; MP09 - Unknown Bacillus spp
MP10 - *Bacillus alvei* ; MP13 - *Bacillus macerans*

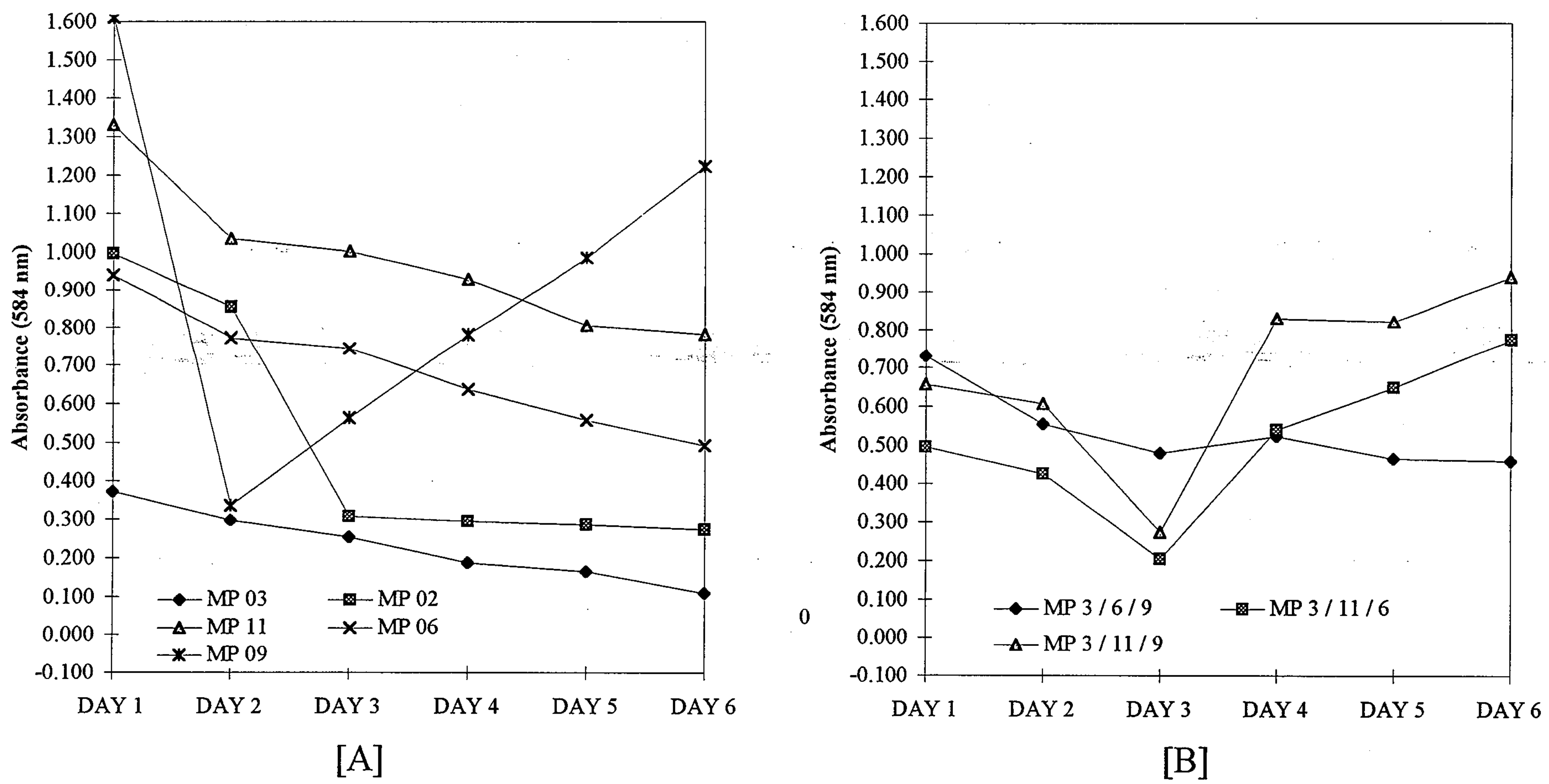


Fig : 3 [A] Acid Blue 25 Dye eleminating capability of the isolated microorganisms in stand still culutres

[B] Acid Blue 25 Dye eleminating capability of the mixed microbial cultures in stand still condition

MP02 - *Enterobacter aerogenes* ; MP03 - *Pseudomonas putida* ; MP06 - *Bacillus pumilus*

MP09 - Unknown Bacillus spp ; MP11 - *Bacillus licheniformis*

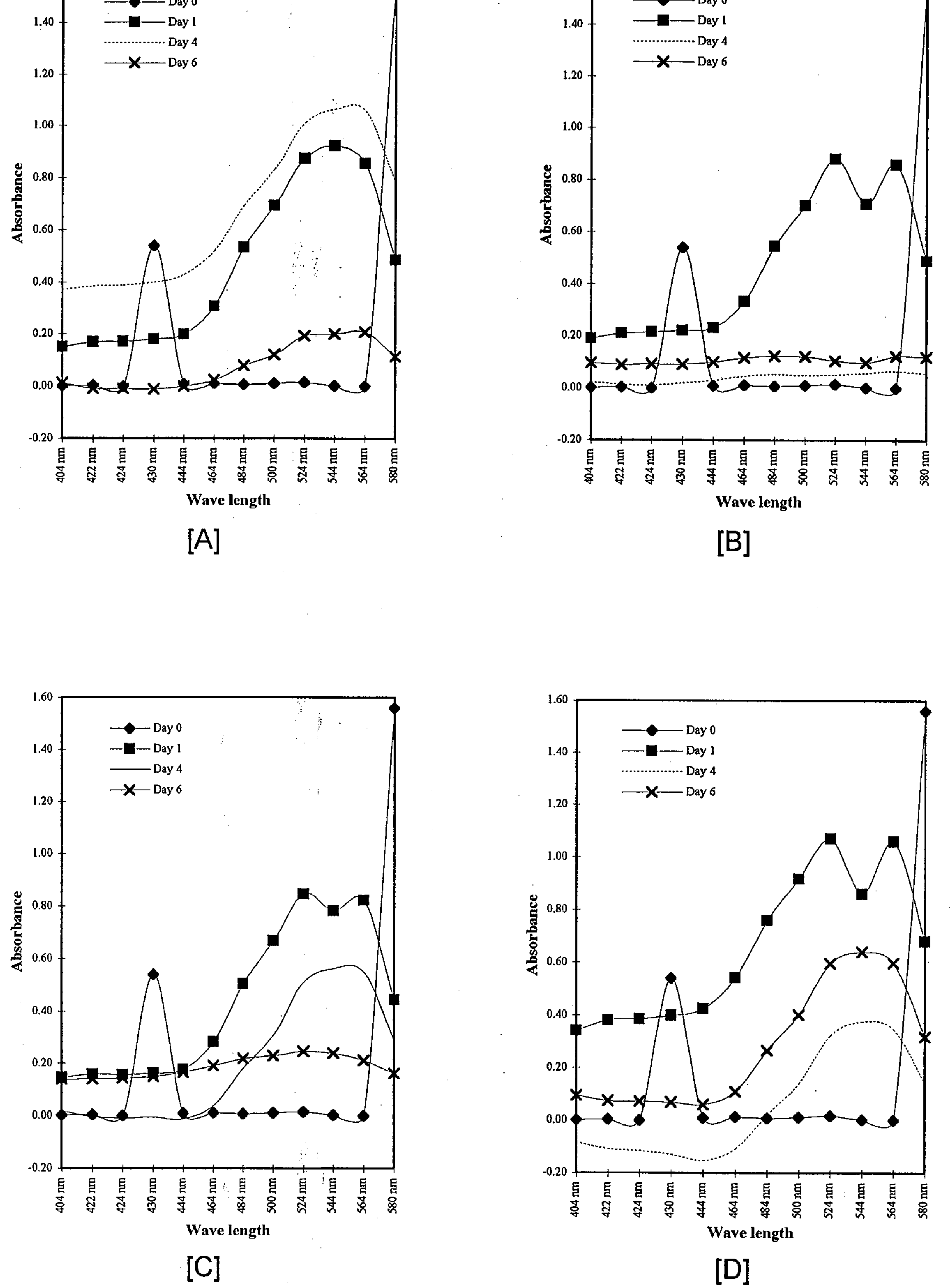


Fig : 4 Relationship between specific wave length's and the absorbance of
[A] MP01 - *Serratia liquefaciers* ; [B] MP02 - *Enterobacter aerogenes*
[C] MP04 - *Klebsiella aerogenes* ; [D] MP06 - Unknown *Bacillus* spp

IMPACT OF INTENSIVE VEGETABLE CULTIVATION ON DRINKING WATER QUALITY IN THE UPCOUNTRY REGION OF SRI LANKA.

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ABSTRACT

An investigation was conducted during the period February 1996 to January 1997 to study the extent of water contamination by plant nutrients due to fertilizer and manure use in 40 drinking water wells, 20 of each were situated in the intensive vegetable growing areas in the upcountry intermediate and upcountry wet zones. Monthly water samples were analyzed for a period of 12 consecutive months for pH, EC, Na, K, Ca, Mg, P and NO_3-N. The pH values of well water in the upcountry intermediate and wet zones ranged from 6.4 to 7.9 and from 4.9 to 7.2 respectively. However, electrical conductivity (EC) of water was low and it ranged from 0.082 to 0.839 dS/m and from 0.036 to 0.461 dS/m respectively. In general, Na content in both zones was high. The highest value in the upcountry intermediate zone was 48.3 mg/l and in the upcountry wet zone was 34.5 mg/l. Potassium levels in well-waters ranged from 1.3 to 22.7 mg/l and from 1.3 to 53.6 mg/l in the upcountry intermediate and wet zones, respectively. In general, Ca content in drinking waters was high in both zones. Calcium content in upcountry intermediate zone ranged from 6.2 to 16.4 mg/l and in upcountry wet zone ranged from 5.6 to 24.5 mg/l. Generally, magnesium content in both zones was high. It ranged from 4.7 to 14.9 mg/l and from 2.7 to 10.5 mg/l in upcountry intermediate and wet zones, respectively. Phosphorus is extremely low in the well-waters. In both zones P in the well waters was below 1 mg/l. In both zones, sampled wells had water with NO_3-N content below 2.5 mg/l, which is an acceptable level of NO_3-N in drinking water according to WHO standards.

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INTRODUCTION

The upcountry intermediate zone of Sri Lanka refers to the region which lies between 600 to 1400m above mean sea level and receives an annual rainfall ranging from 1100 to 1400 mm. The mean minimum and maximum temperatures are 15°C and 27°C respectively. The upcountry wet zone of Sri Lanka refers to the region which lies above 1400 m above mean sea level. The mean air temperature in the up country wet zone ranges from 8°C to 20°C and receives an annual rainfall of 2500 mm. The landscape in both zones varies from undulating, rolling, topography to hilly, steeply dissected mountainous terrain. The Ultisols are the predominant soils of these zones (Panabokke, 1996) with a pH range of 4.0 - 5.5 (Wijewardena *et al.,* 1996).

The agriculture in the upcountry areas of Sri Lanka is intensive and highly commercialized. Potato and exotic vegetables are the predominant crops grown in this region throughout the year. In the upcountry wet zone commonly grown vegetables are cabbage, leek, beet, carrot and radish while, in the upcountry intermediate zone commonly grown vegetables are tomato, bean, cabbage, brinjal and radish. Farm holdings are small ranging from about 0.3 to 0.5 ha. and to make maximum use of available land, farmers often cultivate more than 2 crops per year. In the upcountry wet zone, potato and vegetables are grown in upland conditions while in the upcountry intermediate zone both in upland and lowland rice fields. The lowland cropping system consists of three crops per year: rice during wet season followed by potato and a vegetable crops during the dry season.

In the upcountry potato and vegetables have been cultivated for several decades. Application of fertilizers, both organic and chemicals, are based on this long experience. However, the rates applied by farmers in the upcountry region to each crop are much higher than the quantity recommended by the Department of Agriculture (Rezania *et al.*, 1989; Wijewardena, 1996a). Vegetable produces high biomass in a short time and remove large quantities of plant nutrients in their harvested portions, but yet vegetable growing soils of the upcountry show accumulation of plant nutrients rather than depletion due to the excessive fertilizer usage (Jeevanathan *et al.*, 1995; Wijewardena, 1996a Wijewardena *et al.,* 1996). Reasons for excessive application of both organic and chemical fertilizers are their relatively low cost compared to the profits generated from cultivation of high value vegetable crops (Maraikar *et al.,* 1996).

Use of animal manure in vegetable cultivation is common in the upcountry region. While poultry manure is used in the upcountry intermediate zone, in the upcountry wet zone cattle manure is used. Quantities added range from 10 to 15 t/ha poultry manure and from 20 to 30 t/ha cattle manure. (Wijewardena, 1993; Wijewardena, 1995). In addition to these various types of high concentrated chemical fertilizers are also used in excessive quantities. Besides, inappropriate fertilizer management practices are also prevalent among the upcountry farmers (Wijewardena, 1996a). Due to the hilly nature and high rainfall of the area applied fertilizer could easily get washed out by rain and therefore there is much concern among scientists and public that drinking well waters could be polluted with many plant nutrients in the upcountry region. In addition, many of these wells are situated in the vegetable growing lands and also not properly protected with cement walls. Hence, well water in these areas could easily be polluted even by the run-off water.

However, monitoring of well waters has not been undertaken in the upcountry region of Sri Lanka where intensive vegetable cultivation is common. An investigation was therefore conducted to determine the extent of drinking water contamination due to fertilizer and manure use in 40 wells, 20 each in the upcountry intermediate and upcountry wet zones. This paper reports the results of this study during the period of 12 months from February 1996 to January 1997.

MATERIALS AND METHODS

Monthly water samples were collected approximately at 30 cm depth below the surface of water level for a period of 12 consecutive months from February 1996 to January 1997. Each sample was poured into a 500ml polythene bottle after rinsing it 2 - 3 times with the same water and covered with the lid. Samples were then transported to the laboratory at the Regional Agricultural Research & Development Centre, Bandarawela, for chemical analysis.

Immediately the samples reached the laboratory, water was filtered and the filtrate was used for analysis. In the case of water samples need to be stored for long periods, a few drops of chloroform were added to prevent any algal growth and then stored in the refrigerator.

Immediately, pH measurements were taken using a glass electrode and electrical conductivity using a conductivity meter. Nitrate was determined colorimetrically using the Brucine method (Taras, 1958). Phosphorus was also ascertained colorimetrically by molybdenum blue method using ascorbic acid (Watanabe and Olsen, 1965). Sodium and potassium were determined using a Jenway Flame Photometer while, calcium and magnesium were determined by an Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSION

The analyses of the water samples in 40 wells, 20 each in the upcountry intermediate and upcountry wet zone are given in Table 1 and 2 respectively.

pH

In general, pH values of well water in upcountry intermediate and wet zones ranged from 6.4 to 7.9 and 4.9 to 7.2, respectively. Mean pH value of drinking water in the upcountry intermediate zone was 7.2 while in the upcountry wet zone was 6.4. The low pH in the drinking water specially in the upcountry wet zone may be attributed to the acid nature of the soils in this region. In general, Ultisols which is the main soil group in the upcountry is acidic and pH ranges between 4.0 and 5.5 (Wijewardena, 1996a. Wijewardena *el al.*, 1996).

Generally, rainfall is high in the upcountry wet zone than in upcountry intermediate zone. This may be the reason for low pH in drinking water in the upcountry wet zone compared to that of in the upcountry intermediate zone. Amarasiri (1965; 1973) observed that a close relationship exists between pH of irrigation water and the degree of rainfall in irrigation tanks which are situated in the dry zone of Sri Lanka.

Electrical Conductivity (EC)

Drinking water contains salt in very low quantities (Table 1 and 2) . It ranged from 0.082 to 0.839 dS/m and 0.036 to 0.461 dS/m in upcountry intermediate and upcountry wet zone, respectively. Generally, mean values of electrical conductivity in both zones were almost similar and it was 0.223 and 0.218 dS/m in the upcountry intermediate and upcountry wet zone, respectively. Based on the standards reported by

Nagarajah *et al.,* (1988) the water of majority of wells be categorized as low salinity water having range between 0 and 0.25 dS/m. However, there were few wells which had water with medium salinity that ranged between 0.25 and 0.75 dS/m. Generally, low salinity of the drinking water could be attributed to the low salt concentration in the soil and the low infiltration rates of the Ultisols.

Sodium

In general, Na content in both zones was high. The highest value in the upcountry intermediate zone was 48.3 mg/l (Table 1) while in the upcountry wet zone it was 34.5 mg/l (Table 2). The Na values reported by Amarasiri (1965;1973) and Nagarajah *et al.*, (1988) in irrigation waters were much lower then these values.

Potassium

Potassium levels in well-waters ranged 1.3 to 22.7 mg/l (Table 1) and 1.30 to 53.6 mg/l (Table 2) in the upcountry intermediate and wet zones, respectively. Mean potassium content in well waters was 4.7 and 11.5 mg/l in the upcountry intermediate and upcountry wet zone, respectively. In general, appreciable amount of potassium in drinking water in this area could be attributed to high level of potassium fertilizer used for the crops grown in the upcountry. The level of fertilizer applied by the farmers to the vegetable crops is almost two to three times the quantity recommended by the Department of Agriculture (Rezania *et al.*, 1990; Wijewardena, 1996 b; Wijewardena and Amarasiri, 1997). High potassium content in the drinking water collected from upcountry wet zone may be related to higher rate of organic and chemical fertilizer usage in the upcountry wet zone compared to those in the upcountry intermediate zone. Generally, Ultisols are high in potassium (Wijewardena and Amarasiri, 1993; Wijewardena 1996 b; Wijewardena and Amarasiri, 1997). Hence, high content of soil potassium could also be a reason for the high concentration of K in drinking waters in this region.

Calcium

Calcium content in drinking water was generally high in both zones and ranged 6.2 to 16.4 mg/l (Table 1) and 5.6 to 24.5 mg/l (Table 2) in upcountry intermediate and wet zones, respectively. Appreciable amount of Ca in drinking water may be due to use of liming materials such as dolomite and lime in upcountry farming. The application of lime and dolomite for potato and vegetable cultivation is a common practice in this region (Rezania *et al.*, 1989; Wijewardena 1996a) poultry manure is also a common feature among the farmers in this region. Generally, poultry manure contains a large quantity of Ca (Wijewardena, 1993; Wijewardena 1994; Wijewardena 1997). Green house experiments conducted by Wijewardena(1994) showed that the drainage water from pots treated with poultry manure had high Ca compared to that from untreated pots. Hence, application of poultry manure and other organic manures could also be a reason for the high content of Ca in well waters in both zones.

Magnesium

Magnesium content in the upcountry intermediate zone well waters ranged 4.7 to 14.9 mg/l (Table 1) while in the upcountry wet zone it ranged from 2.7 to 10.5 mg/l (Table 2). Appreciable amount of magnesium in well waters in the upcountry may be attributed to the use of high rate of organic manures. In addition, this could have been also due to the high leaching of Mg in acid soils (Mikkelsen *et al.*, 1963). Long-term field experiments conducted by Wijewardena and Amarasiri (1993) and Wijewardena (1996 b) in upcountry areas of Sri Lanka also revealed the absence of Mg accumulation even in plots treated with kieserite. In addition, use of dolomite for crops grown in this region is a common practice. Generally, dolomite is used in large quantities in this region for plantation crops like tea which may have been washed down to the well waters in this region.

Phosphorus

Phosphorus is extremely low in the well waters of the upcountry (mean < 1 mg/l). It ranged from 0.138 to 0.844 mg/l and 0.166 to 0.772 mg/l in the upcountry intermediate (Table 1) and wet zones (Table 2) respectively. Amarasiri (1965) and Nagarajah *et al.*, (1988) reported very low level of P even in rice irrigation and Jaffna irrigation waters respectively. This could be anticipated because of the movement of any soluble P to ground water is restricted due to ready P fixation by soil minerals. Low pH of the Ultisols would have encouraged the fixation of P in this soil. Infact Vighi *et al.*, (1991) reported that phosphorus losses are independent of fertilizer P application rate, even in intensive cropping systems. Many workers previously reported that in the absence of erosion little P could reach the surface water (Loher,1974; Dillon and Kirchner, 1975; Miller *et al.*, 1982; Heise, 1984). Wijwardena(1994) reported of extremely low P leaching even in soils fertilized with organic manure and phosphorus fertilizers.

Nitrate

Nitrate content in drinking well waters ranged from 0.36 to 1.24 mg/l NO_3-N (Table 1) and 0.48 to 2.13 mg /l NO_3-N (Table 2) in upcountry intermediate and upcountry wet zones, respectively. These values were low compared to the WHO recommended level of 11.3 mg/l NO_3 - N (Olsen, 1978) and USA permissible level of no more than 10 mg/l NO_3 - N (Gervy, 1986). Generally ,nitrate which is considered as the most important plant nutrient could influence human health (Russell 1978; Nagarajah *et al.*, 1988; Kuruppuarachchi, 1995) and in particular the health of babies upto about four months of age. Babies unable to detoxify NO_2 which combines with hemoglobin and reduces the absorption of oxygen into the blood resulting in a clinical condition called "methaemoglobinaemia " (cyanosis) . An infant suffering from this condition is sometimes referred to as a "blue baby". In addition, a high nitrate intake is undesirable for adults because some of the NO_2 produce may be converted to nitrosamine causing gastric cancer and diarrhea (Lehr *et al.*, 1994). However, results of the experiment suggest the low nitrate pollution of the well waters in the upcountry. In contrast, nitrogen fertilizer use has been shown to strongly affect NO_3 concentrations in drainage waters (Baker and Johnson, 1981; Wijewardena 1994). However, Studies conducted by Nagarajah *et al.*, (1988) and Kuruppuarachchi, (1996) reported the high concentration of nitrate in ground waters under different soil conditions in Jaffna and Kalpitiya, respectively. However, low nitrate in the drinking waters of the upcountry may be attributed to heavy textural fraction in Ultisols. This may have restricted the leading of nitrate to the drinking waters. Gamberell *et al.*, (1975) reported the losses of nitrate to ground water were regulated by the amount of infiltration occurring in the soil, being high for a moderately well-drained soil and low for a poorly drained soil. In addition, vegetable crops grown in the upcountry have been considered as high nutrient removers (Greenwood *et al.,* 1980; FAO, 1984). Therefore, nitrate leaching would have been controlled by the high removal of nitrogen from the cultivated fields by vegetable crops. However, it is also reported that vegetables containing high NO_3^- as a result of excessive use of nitrogen fertilizers, could also result in the health problems associated with high NO_3^- in drinking water (White, 1975).

CONCLUSION

Findings of this study demonstrate that there are substantial amounts of some plant nutrients in drinking water are present in wells situated in the upcountry. This indicates that drinking water could be polluted by plant nutrients due to intensive vegetable cultivation. Suitable steps should therefore be undertaken to minimize the build-up of concentration of plant nutrients It is therefore recommended that the Department of Agriculture takes up this matter with the Department of Health, Provincial Council, Local Government Bodies etc., to introduce suitable regulatory measures to minimize contamination of drinking water by plant nutrients and agrochemical. To achieve this the following recommendations are suggested:

(1). Avoid excessive fertilizer application

(2). Use of adequate quantities of fertilizers after testing the soil and plant samples.

(3). Prevent fertilizer application during the heavy rainy seasons.

(4). Avoid over irrigation.

However, long term monitoring of well water in this region is also considered as highly essential to collect information regarding the contamination of drinking water on a long-term basis.

REFERENCES

Amarasiri, S.L. 1965. A study of some rice irrigation waters of Ceylon. **Tropical Agriculturist 121**: 133-140.

Amarasiri, S.L. 1973. Water quality of major irrigation tanks in Sri Lanka. **Tropical Agriculturist 129**: 19-25.

Baker, J.L. and H.P.Jonson. 1981. Nitrate nitrogen in tile drainage as affected by fertilization. **Journal of Environmental Quality 10**: 519-523.

Dillon, P.J. and W.B. Kirchner. 1975. The effect of serology and land use on the export of phosphorus from watersheds. **Water Research 9**: 135-147.

FAO, 1984. Fertilizer and Plant Nutrition Guide. **Fertilizer and Plant Nutrition Bulletin No. 9.** FAO, Rome 172p.

Gamberell, R.P., J.W. Gilliam and S. B. Weed. 1975. Nitrogen losses from soil of the North Carolina Coastal Plain. **Journal of Environmental Quality 4**: 317-323.

Gervy R. 1986. Nitrates in Water. **Fertilizers and Agriculture 92**: 55-58.

Greenwood, D.J., A. Barnes., K. Liu., J. Hunt.,T.J. Cleaver, and S.M.H. Loquens.1980. Relationships between the critical concentrations of nitrogen, phosphorus and potassium in 17 different vegetable crops and duration of growth . **J. Sci. Food Agric. 31** : 1345-1353.

Heise, P. 1984. Gudena. *In*: Ecology of European Rivers. Ed. B.A.Witton. 25p. Blackwell Sci.. Oxford, U.K

Jeevanathana, B., R. Seneviratne and I. Eriyagama. 1995. Phosphorus and potassium status of vegetable growing soils in mid country and upcountry in Sri Lanka. **Krushi 15(1)** : 17-18

Kuruppuarachchi, D.S.P. 1995. Impact of irrigated agriculture on ground water resource of Sri Lanka. **Proceedings 51st Annual Session SLAAS Part II :** 49-66.

Lehr. L.H.., D.M. Nielson and J.J. Montgomery. 1994. U.S. Federal legislation pertaining to ground water protection . In: Ground water pollution Microbiology. Ed G. Bitton and C.P. Gerba. 371p. Krieger Publishing Company, Malabar, Florida .

Loher, R.C. 1974. Characteristics and comparative magnitude of non-point sources. **J.Water Pollut. Control Fed. 46** : 1849 - 1856.

Maraikar, S., J.D.H.Wijayawardena and S.L.Amarasiri 1996. Improving productivity of vegetable cultivation in Ultisols of Sri Lanka. Proceeding of an International Conference on "Managing Soil Fertility for Intensive vegetable Production System in Asia (Ed. R.A.Morris) pp. 370-383 AVRDC, Tainan, Taiwan.

Mikkelsen, D.S., L.M.M. Dreitas and A.C. Muchung. 1963. Effect of liming and fertilizing cotton, corn and soybean on Campo Cerrado soils, State of San Publo, Brazil. **IRRI Bull : 29**, Los Banos, Laguna, Philippines, 43p.

Miller, M.H., J.B. Robinson., D.R. Coote., A.C. Spires. and D.W. Draper. 1982. Agriculture and water quality in the Canadian Great Lakes basin. III Phosphorus. **Journal of Environmental Quality 11**: 487-492.

Nagarajah, S., B.N. Emerson., V. Abeykoon and S. Yogalingam. 1988. Water quality of some wells in Jaffna and Kilinochchi with special reference to nitrate pollution. **Tropical Agriculturist 144**: 61-78.

Olsen, R.A. 1978. Effect of intensive fertilizer use on the human environment A. Summary review. In: Effects on intensive fertilizer use on the human environment. **Soils Bulletin No. 16** pp 15-33 FAO , Rome.

Panabokke, C. R. 1996. Soils and Agro-Ecological Environments of Sri Lanka. Natural Resources Series No.2. Nutural Resources Energy & Science Authority. Colombo, Sri Lanka. 220p

Rezania, M., V. Yogaratnam and J.D.H.Wijewardena. 1989. Fertilizer use on potato in relation to soil productivity in the upcountry areas of Sri Lanka. DOA, Ministry of Agricultural Development and Research , FAO field Document No.3, 35p.

Russell, E.W. 1978. Summary of technical discussions. In : Effect of intensive fertilizer use on the human environment. **Soils Bulletin No. 16.** pp 1-14. FAO, Rome.

Taras, M.J. 1958. Nitrogen . *In*: Chemical Analysis. vol. VIII. Calorimetric Determination of Non Metals. Ed. D.F. Bolts. pp 75-160. Inter Science Publishers, Inc., New York.

Vighi, M., S. Soprani., P. Puzzarini and G. Menghi. 1991. Phosphorus loads from selected watersheds in the drainage areas of the Northern Adriatic Sea. **Journal of Environmental Quality 20**: 439-444

Watanabe, F.S. and S.R. Olsen. 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. **Soil Sci. Amer. Proc. 29**: 677-678.

White, J.W.1975. Relative significance of dietary sources of nitrate and nitrite. **J. Agric. Food Chem. 23:** 886 - 891.

Wijewardena, J.D.H. 1993. Effect of organic and chemical fertilizers on vegetable cultivation in upcountry intermediate zone. **Tropical Agriculturist 149:**1-11.

Wijewardena, J.D.H. and S.L. Amarasiri. 1993. Response of vegetable crops in a cropping sequence to K and Mg fertilizers in the upcountry intermediate zone. **Tropical Agriculturist 149:** 13-22.

Wijewardena, J.D.H. 1994. Effect of poultry manure and its chemical constituents on rock phosphate solubility Ph. D. thesis, Department of Plant and Soil Science, University of Aberdeen, UK 326p.

Wijewardena., J.D.H. 1995. Effect of animal manure and chemical fertilizers on the growth and yield of tomato. **Krushi 15(1)** : 7-10.

Wijewardena, J.D.H. 1996 a. Fertilizer management under intensive cropping systems in Sri Lanka. Paper presented at the FPA - FADINAP Regional Workshop on Fertilizer concepts with special reference to organic fertilizers held in Tagaytay. Philippines, 6-9 May 1996.

Wijewardena, J.D.H. 1996 b. Effect of potassium and Magnesium fertilizers on vegetable cultivation in the upcountry intermediate zone. **Proceedings 52 and Annual Session SLAAS Part 1**: 50-51.

Wijewardena, J.D.H. and U.W.S.P.Yapa. 1996. Effect of animal manure on vegetable cultivation in the upcountry. **Proceedings 52 and Annual Session SLAAS Part 1**: 52.

Wijewardena, J.D.H., U.W.S.P.Yapa and M.K.G.Yatagama. 1996. Status of selected chemical characteristics of vegetable growing lands in the upcountry intermediate zone. **Proceedings 52 and Annual Session, SLAAS Part 1** : 49-50.

Wijewardena. J.D.H. and Amarasiri, S.L. 1997. Long-term use of potassium fertilizer for vegetable crops in the upcountry intermediate zone. **Journal of the National Science Council of Sri Lanka 25(1)** : 59-98.

Wijewardena J.D.H. 1997. Effect of poultry manure and phosphorus on the growth and yield of Capsicum in the upcountry intermediate zone. **Krushi 16(1)** : 8-14.

Table 1. Water analysis in the upcountry intermediate zone.

(Average of 12 monthly samples)

Well No	pH	EC (dS/m)	Na	K	Ca	Mg	P	NO_3-N
			<----------		mg/l			---------->
01	7.3	0.100	6.0	3.1	7.1	4.7	0.329	0.51
02	7.9	0.262	32.8	3.3	10.5	11.6	0.844	0.41
03	7.4	0.126	9.3	1.5	6.2	7.9	0.436	0.96
04	7.6	0.314	25.6	3.8	12.7	7.9	0.262	1.15
05	7.4	0.083	8.5	1.3	6.6	5.0	0.343	0.56
06	7.0	0.174	31.7	5.0	7.2	5.4	0.329	0.70
07	7.0	0.152	8.2	3.2	8.1	8.2	0.393	1.08
08	6.9	0.271	41.0	6.2	8.8	9.5	0.365	0.83
09	6.4	0.141	7.9	5.2	6.7	5.9	0.175	1.24
10	7.5	0.231	8.1	2.9	10.9	14.9	0.381	0.63
11	7.0	0.179	7.6	3.2	10.2	11.1	0.457	0.45
12	7.3	0.839	48.3	22.7	11.2	10.8	0.479	0.84
13	7.2	0.255	9.5	3.1	16.4	11.3	0.243	0.86
14	7.0	0.175	7.5	3.8	13.8	9.3	0.464	1.24
15	6.8	0.082	7.7	2.7	9.7	4.9	0.594	0.77
16	7.0	0.192	9.6	6.0	8.7	9.6	0.608	0.48
17	7.2	0.251	29.7	6.2	10.4	8.3	0.472	0.71
18	7.6	0.350	29.2	1.9	16.2	9.1	0.786	0.36
19	7.1	0.149	7.4	5.5	8.9	6.2	0.138	0.63
20	7.4	0.139	7.7	3.6	7.4	8.4	0.505	0.54
Mean	7.2	0.223	17.2	4.7	9.9	8.5	0.430	0.73

Table 2. Water analysis in the upcountry wet zone.

(Average of 12 monthly samples)

Well No	pH	EC (dS/m)	Na	K	Ca	Mg	P	NO_3-N
				<------------------mg/l				---------------------------->
01	7.3	0.419	8.3	33.5	24.5	10.5	0.472	2.13
02	6.7	0.461	33.4	53.6	18.4	7.8	0.401	1.43
03	6.6	0.116	6.8	4.2	9.7	4.0	0.772	1.36
04	6.9	0.036	3.6	1.3	7.6	3.5	0.348	0.29
05	5.1	0.198	24.5	6.3	12.7	5.2	0.572	1.44
06	6.5	0.393	33.5	38.7	17.4	7.5	0.451	1.91
07	6.4	0.120	7.8	1.4	7.3	5.1	0.522	1.08
08	7.0	0.161	8.8	4.5	12.4	4.0	0.522	0.49
09	6.7	0.100	5.7	3.0	5.9	3.7	0.166	0.60
10	6.4	0.189	8.0	4.2	11.7	5.4	0.593	1.57
11	6.9	0.429	34.5	31.3	15.9	6.5	0.644	1.91
12	5.4	0.307	24.2	8.9	12.7	4.5	0.395	1.93
13	5.7	0.242	8.1	16.6	12.8	5.8	0.472	0.68
14	6.5	0.073	7.6	2.9	6.2	2.7	0.458	0.48
15	7.2	0.171	6.1	2.0	11.8	10.5	0.329	0.60
16	6.6	0.100	8.0	1.7	5.9	4.0	0.200	0.61
17	6.6	0.112	8.3	1.8	5.6	4.3	0.522	1.15
18	5.7	0.230	9.2	7.8	13.3	7.4	0.273	2.12
19	4.9	0.110	6.3	2.0	7.4	4.2	0.548	0.82
20	6.4	0.383	6.5	4.9	7.2	3.6	0.200	0.80
Mean	6.4	0.218	13.0	11.5	11.3	5.5	0.443	1.17

REMOVAL OF HEAVY METAL IONS FROM POLLUTED WATER USING ENVIRONMENTALLY-FRIENDLY MATERIALS

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Abstract

Ions such as Cr, Mn, Fe, Co, Cu, Zn, Cd and Pb can be effectively removed by burnt-brick, saw-dust and ball-clay packed glass columns. The removal efficiency is further enhanced by optimization of experimental parameters such as particle size, length of packing, flow rate, etc. Systematic investigation of standard solutions and mixtures of these metals within the working concentration range shows that brick-clay is the most efficient metal ion remover for many heavy metals.

Detailed investigation on the adsorption of lead ions on burnt brick particles between pH 4 and pH 6 results in the validity of the Fruendlich or Langmuir isotherm models. Ion-exchange phenomenon would also make a contribution to the lead ion removal process.

Key words: heavy metals, treatment, industrial effluent.

INTRODUCTION

Industrial development, urbanization and uncontrolled agricultural practices have resulted in severe environmental problems in Sri Lanka. Consequently, many rivers, water streams and lakes in the country have already been polluted with organic and inorganic pollutants, including coloured substances (azo dyes, anthraquinone, formazan and phthalocyanines), heavy metals, nutrients from sewage or fertilizers, pesticides and solid particles.[1-3] The presence of these contaminants changes physical, chemical as well as biological state of water. Consequently, harmful effects, such as unbalancing solution pH, death of aquatic life, increase in different pathogenic organisms and adverse effects to humans would result. Some specific toxicity problems associated with heavy metals that are found in biological systems include disruption of enzymes by forming metal-sulfur bonds, hindering transport properties by binding to cell membranes, formation of complexes with polysaccharides, bioaccumulation in tissues, and ability to combine or replace compounds which perform important physiological functions.[4-10]

Among many types of pollution, industrial pollution may be more significant. Although many industries require large quantities of water per unit weight of produce, a substantial portion of intake is thrown out as effluent which is contaminated with several substances. Textile industry, for instant, requires 12-65 litres of water for processing one meter of cloth. In Sri Lanka, garment/textile industry has rapidly developed in recent years. It plays an important role in the economy of the country as it is one of the major foreign exchange earners. However, the disposal of effluents of garment industry is posing serious problems as the receiving river or stream may become coloured due to inadequate effluent treatment. Sedimentation of heavy metals by association with organic and inorganic matter present in water body would be another undesirable process of textile effluent.

Industrial effluents usually consist of large amounts of dyes, cations, anions, organic substances, etc. These effluents should therefore be properly treated before discharged into water bodies. Many industries still use chemical procedures for treatment of effluents despite of environmental problems and economical factors. It is recommended that treated effluent should fulfil the specifications laid down by the Central Environmental Authority of Sri Lanka.

Removal of inorganic and organic pollutants from industrial effluents through chemical and biological means are well documented.[10-15] Among various methods available for metal ion removal, coagulation and precipitation, lime treatment, reverse osmosis, ion exchange and adsorption processes have been widely applied.[16-18]

Precipitation process of high metal ion concentrations in waste water are often the most economical. However, some complexing agents present in waste water may decrease the efficiency of the precipitation process. Although chemical precipitation methods have been traditionally used for removal of heavy metals, development of alternative approaches based on naturally occurring substances or their derivatives has become attractive during the past few years. It has been reported recently that many substances of biological origin are effective for removal of metal ions from waste waters; for instant, Salim and coworkers have conclusively demonstrated that several types of decaying leaves have shown an ability for removal of such metals as Al, Ni, Pb and Cd from aqueous solution.[10]

Another significant accomplishment in this area of research is to use immobilized cells including *Pseudomonas sp.*, *Cunninghamelle blakesleeana* and *Aphanocapsa pulchra* for removal of Ni, Cu, Cd, Zn and Co through specific binding processes.[11] Effect of other ions interferents on the removal efficiency, and the extent of recovery of such immobilized species have also been investigated.

Additionally, ion exchange and/or adsorption properties of many other natural substances have been extensively investigated[12]. Modified coconut coir dust has been shown to remove Pb, Cu and Ni successfully from aqueous solution, and it has been suggested that coconut coir has a good potential as an adsorbent of heavy metals present in industrial effluents.[11] Further, activated charcoal has been found to remove not only organic matter, but also heavy metals[13,14]. Metal speciation property of clay-based substances to extract metal ions from aqueous solutions has also been recently reported.[15,21]

High cost of construction, operation and maintenance, and generation of large amounts of unusable sludge have been a problem for effective treatment of industrial effluents, especially in developing countries.[19,20] Lack of environmental friendly attitudes, and poor collaborations between industries and national research institutes may have worsened the situation. As a result, pollution control and management are still at a very low level in developing countries.

It is the goal of this project to develop removal methods for heavy metals using naturally occurring substances which are low cost and readily available such as burnt-brick, different types of clay (ball-clay, kaolin, pot-clay, etc.), dolomite, saw-dust, rice-husk and aquatic plants. Extension of this methodology for removal of heavy metals from industrial effluents collected from various industries is also investigated.

METHODS AND MATERIALS

Materials: Burned brick (brick-clay) samples for all experiments were obtained from a kiln located in Kiribathkumbura, Sri Lanka. Other adsorbents tested; raw dolomite, burnt dolomite, activated charcoal, ball-clay, keolin and coir dust were obtained locally. Saw-dust of *Albizia Odoratissima* ('Mara' in Sinhala) was collected from a saw mill located at Pilimathalawa. All substances were powdered and separated into desired sizes.

Stock solutions of metal ions were prepared by dissolving analytical grade chemicals [NaCl, KCl, MgSO4, CaCO3, K_2CrO_4, $KMnO_4$, Fe(NH4)SO_4, $Co(NO_3)_2$, $CuSO_4$, $ZnSO_4$, $CdSO_4$ and $Pb(NO_3)_2$], purchased from the British Drug Houses Ltd., England, in deionized water. Small amounts of either concentrated HCl or concentrated HNO_3 were used when solubility problems were encountered. Diluted standard solutions of individual metal ions and mixtures of metal ions were prepared using appropriate volumes of each stock solution and deionized water.

Instrumentation: Atomic Absorption Spectrometer (Buck Instruments Model 200-A) was used to record absorbance measurements of each metal ion solution, in triplicate, at a selected wavelength using an appropriate hollow cathode lamp. Pure acetylene and air were used as the fuel and the oxidant, respectively. Brick particles and saw-dust particles were separated into desired sizes using a set of sieves attached to a vibrator.

Research design: Atomic absorption measurements of metal ion solutions before and after treatment with burnt-brick and saw-dust particles were recorded by passing standard solutions of individual metal ions of different concentrations (2.0, 4.0, 6.0, 8.0, and 10.0 mg/L) through burnt-brick/saw-dust packed glass columns (dynamic conditions). The predetermined optimized experimental/column parameters such as length of packing, diameter of column, amount of adsorbent, flow rate and volume of metal ion solution, were kept constant during all experiments. Same packing of adsorbents was used for each metal ion at all concentrations.

Since the working concentration range of a species depends on the linear dynamic range of atomic absorption detection, standard solutions and corresponding treated standards of **Mg, Ca, Mn, Fe, Cu, Zn** and **Cd** ions were diluted by an appropriate volume factor with deionized water until absorbences fell within the linear range. Absorbance measurements of solutions of **Cr, Co and Pb** ions were recorded without any further dilution as the concentration range of 2.0 to 10.0 mg/L is in the linear range of detection.

Further investigation on lead ion removal was performed by passing lead ion solutions of concentration ranging from 0.5 to 256 mg/dm^3 through brick-particle packed glass columns and absorbences were measured before and after treatment. The removal efficiencies and the variation of pH during the treatment process were monitored at many pH values varying from 3 to 9. Further, the eluent was tested for other metal ions. Desorption ability of lead was also tested after treatment process was completed.

RESULTS AND DISCUSSION

Preliminary Screening Experiments

Careful investigation on the efficiency of the removal process indicates that the optimum values for the ion removal process depend on the type of the adsorbent (Table 1). For detailed investigation of ion removal experiments, packed columns (dynamic systems) are preferentially selected over classical methods that use static conditions, as columns packed with suitable adsorbents would be considered as model systems to monitor the extent of ion removal from effluent/polluted water, when it is passed through water treatment plants.

Table 1. Optimum values of experimental parameters for heavy metal removal.

Parameter	burnt-brick	saw-dust
amount of adsorbent	25 g	15 g
volume of solution	100 cm^3	100 cm^3
particle size	0.4 mm	1.25 mm
length of packing	4.5 cm	---
flow rate	25-30 cm^3/min	30 cm^3/min
medium	water	water
pH	neutral	neutral

The percent efficiency of removal for each metal was calculated using the difference in concentrations, which were obtained by conversion of measured absorbencies to concentration units with the aid of calibration curves, before and after treatment with brick/saw-dust particles. Such calculations performed at each concentration lead to the extent of removal of heavy metals from aqueous solution. The series of standard solutions (of 2.00 to 10.00 mg/dm^3) of all metals with the exception of Cr gave a zero absorbance after treatment with brick particles, indicating that the concentration of these species in treated solutions was below the minimum detectable level, which depends on the type of the element and on the sensitivity of atomic absorption detection. Although zero absorbance was recorded only for Cd, Pb, Cu, Mn and Co at 2.00 mg/dm^3 level during the saw-dust treatment, only Pb showed a zero absorbance at 4.00 mg/dm^3 level.

Minimum detectable level of Cr, Mn, Co, Cu, Cd and Pb estimated from a different set of experiments yielded the results of 0.10 mg/dm^3 while that of Fe and Zn showed 0.50 mg/dm^3 and 0.05 mg/dm^3, respectively. Since these concentrations were used to calculate the percent removal of Cr, Mn, Co, Cu, Cd and Pb, actual percentages would be higher than the estimated values. Removal efficiency of Cr is also significant according to atomic absorption measurements although it is less than that of other metals at high concentrations.

The competition of heavy metal ions for adsorption sites depends on the stability of their complexes formed, order of complexing ability, valence of the metal ion, its ionic radius, and the ionization potential. The observed lower affinity of Cr for brick particles suggests that speciation of other metals in brick is stronger than that of Cr.

Columns packed with adsorbents of particle sizes different from what is stated in Table 1 can also be used for treatment of polluted water as the decrease in absorbance of heavy metal ions by many other sizes are not significantly different from that of the preselected value, and consequently, detailed studies of other sizes were not attempted. Nevertheless, sizes below 0.12 mm in diameter are not recommended as they introduce additional turbidity to the effluent. Additionally, experimental/column parameters were always kept constant at the values stated in the experimental section for comparative investigation of different metal ions.

Comparison of absorbance measurements, recorded using mixtures of pairs of metal ions which have close wavelengths of absorption with those of individual ion solutions at 2.0 mg/dm^3 concentration levels indicated that the interelement interferences are minimal with the exception of Zn and Pb which would interfere each other. Analysis of samples consisting of the ions investigated with the same column and experimental parameters, as used for individual ions, was conducted in order to check the possibility of extending the methodology developed in real situations (Table 2). The methodology was then extended for treatment of textile effluent samples obtained from garment industry. Treatment performed under identical conditions in five replicates reveals that levels of heavy metals present in textile effluents can be significantly decreased by brick-particle packed columns (Table 3), although the efficiency of removal is slightly less than that observed with laboratory prepared samples.

Table 2: Concentrations (mg/dm^3) of each metal in a matrix of ion mixtures before and after treatment, percent removal, and corresponding statistical parameters.

Metal	Initial con.(mg/dm^3)	Final con.(mg/dm^3)	% Removal
Cr	2.0	Undetectable	95.0
Mn	2.0	0.4	84.33
Fe	2.0	Undetectable	75.0
Co	2.0	Undetectable	95.0
Cu	2.0	Undetectable	95.0
Zn	2.0	Undetectable	97.0
Cd	2.0	Undetectable	95.0
Pb	2.0	Undetectable	95.0

Table 3: Average concentration values (mg/dm^3) of each metal in textile effluent samples before and after treatment.

Metal	Initial con.(mg/md^3)	Initial con.(mg/dm^3)
Cr	Undetectable	Undetectable
Mn	2.2	0.4
Fe	1.0	Undetectable
Co	Undetectable	Undetectable
Zn	0.7	Undetectable
Cd	Undetectable	Undetectable
Pb	Undetectable	Undetectable

Brick particles show a higher capacity of lead ion removal when compared to the other heavy metals such as Co, Cd, Fe, Mn, Cr and Cu. Mechanism of lead ion removal is complicated, and it is found to be a combination of chemisorption and ion exchange. Further, both the Fruendlich and the Langmuir isotherm models are followed by this removal process depending on experimental conditions. Nevertheless, this methodology, with some modifications, would be suitable for industries to treat their effluent.

CONCLUSIONS

Effective removal of Cr, Mn, Fe, Co, Cu, Zn, Cd and Pb from aqueous solution is achieved using glass columns packed with small burnt brick particles or saw-dust. Main group elements are more difficult to be removed from aqueous solution using these adsorbents. Extension of this methodology for treatment of textile effluents to decrease levels of above stated heavy metals below tolerance limits indicates the possibility of applying this procedure for treatment of industrial effluents. It is proposed that a filter packed with burnt brick particles would have a potential for removal of heavy metal ions present in industrial effluents. Environmental friendliness and cost effectiveness are added advantages of the proposed procedure.

REFERENCES

1. Wong, P.K., Lam, K.C., So, C.M. *Appl. Microbiol. Biotecnol.*, **39**, 127 (1993).

2. Davis, S., Burns, R.G., *Appl. Microbiol. Biotechnol.*, **31(10)**, 2503 (1996).

3. Fytianos, K., Voudrias, E., Raikos, N., *J. Environ. Sci. Health*, **A31(10)**, 2621 (1996).

4. Subramanian, V.V., Sivasubramanian, V., Gowrinathan, K.P., *J. Environ. Sci. Health.*, **A29(9)**, 1723 (1994).

5. Bordons, A., Jofre, J. *Enzyme Microb. Technol.*, **9**, 709 (1987).

6. Dissanayake, C.B., Niwas, J.M., Weerasooriya, V.R. *Environ. Res.*, **42**, 24 (1987).

7. Seneviratne, R.de A. in: Chemistry and the Environment, theme seminar, 21th Annual Sessions, Institute of Chemistry, Ceylon, p.43, Institute of Chemistry, Sri Lanka (1992).

8. Manahan, S.E. Environmental Chemistry, 6th edn., p.181, Lewis Publishers, U.S.A. (1994)

9. Sublette, K.L., Snider, E.H., Sylvester, N.D., *Water Res.* **16**, 1075 (1982).

10. a) Salim, R., Robinson, J.W., *J. Environ. Sci. Health*, **A20**, 721 (1985).
b) Salim, R., *J. Environ. Sci. Health*, **A23**, 183 (1988).
c) Salim, R., Al-Subu, M., Qashoa, S., *J. Environ. Sci. Health*, **A29**, 2087 (1994).
d) Sayrafi, O., Salim, R., Sayrafi, S.A., *J. Environ. Sci. Health*, **A31**, 2503 (1996).

11. Venkateswerlu, G., Stotzky, G., *Appl. Microbiol. Biotechnol.*, **31**, 619 (1989).

12. Baes, A.U., Umali, S.J.P., Mercado, R.L., *Wat. Sci. Tech.*, **34(11)**, 193 (1996).

13. Reed, B.E., Jamil, M., Thomas, B., *Wat. Environ. Res.*, **68(5)**, 877 (1996).

14. Marzal, P., Seco, A., Gabaldon, C., Ferrer, J., *J. Chem. Tech. Biotechnol.*, **66**, 279 (1996).

15. Sergreev, V.I., Shimko, T.G., Kuleshova, M.L., Maximovich, N.G. *Wat. Sci. Tech.*, **34(7-8)**, 383 (1996).

16. Sublette, K.L., Snider, E.H., Sylvester, N.D. *Water Res.* **16**, 1075 (1982).

17. Zhou, W. and Zimmermann, W. *FEMS Microbiol. Lett.*, **107**, 157 (1993).

18. Davis, S., Burns, R.G. *Appl. Microbiol. Biotechnol.*, **37**, 474 (1992).

19. Fettig, J., Stapel, H., Steinert, C., Geiger, M. *Water Science and Technology*, **34**(9), 33 (1996).

20. Asano, T., Levine, D. *Water Science and Technology* **33**(10-11),1 (1996).

21. Qiao, L., Ho, G. *Wat. Sci. Tech.*, **34(7-8)**, 413 (1996).