Surface Waters, Their Status and Management

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Abstract

Sri Lanka is rich in its water resources, but there are water scarcity problems based on seasonal and spatial variations in rainfall. There are 103 rivers flowing from a central mountainous massif in a radial pattern through various directions of the country, and 18387 tanks are distributed within the river basins and in the Jaffna peninsula and in Taleimannar. The stagnant waters of Sri Lanka are threatened by eutrophication and blooming due to nutrient loading from their catchments. The rivers also receive pollutants from catchments via surface runoff. Proper water resources management criteria focused on river basins is needed with proper coordination among relevant organisations in order to achieve the management goals.

1.0 Introduction

"Water is the most critical resource issue of our lifetime and our children's lifetime. The health of our waters is the principal measure of how we live on the land" - Luna Leopold. (*This statement indicates the value of the water resources.)*

Sri Lanka is a tropical country[1] located between 5^{0} 54′ N and 9^{0} 52′ E and 79^{0} 39′ N and 81^{0} 53′ E with a surface area of 65,525 sq km, and it is rich in its water resources. It consists of one of the highest densities of the water resources of the world, with rivers, reservoirs, lakes, ponds and ground water resources (SOE, 2001). However, this picture of richness in water resources is misleading to a certain extent as there are water scarcity problems due to variations in seasonal and spatial distribution patterns of the rainfall.

The only source of fresh water in Sri Lanka is the rainfall received from monsoonal rains[2]. Nearly two-thirds of the country gets less than 1,500mm of rainfall in a year, and almost all of it comes during the short northeast monsoon season. The mean annual rainfall ranges between 900mm to 6000mm, with an island wide average of about 1,900 mm, which is about two and a half times more than the world annual mean of 750mm. The country can be divided into wet and dry zones with a mean annual rainfall of 2424 mm and 1450 mm respectively.

1.1 The objectives

The objectives of the present paper is to discuss; (i) the types of surface waters, (ii) their status using a multidisciplinary approach to analyse the effect of human interventions on deterioration, and (iii) to discuss the management strategies to protect the surface waters as a response.

2.0 The Types of Surface Waters

Inland waters of Sri Lanka could be categorised into surface and ground water. Out of the total, land area of Sri Lanka, 4.43% (2905 sq Km) is covered by the surface water (Census and statistics data & SOE 2001).

There are two major categories of surface waters, namely, the stagnant waters or lentic waters (The reservoirs, lakes and tanks) and the running waters or lotic waters ("Oya"s and "Gangas"). Present paper deals only with the surface waters of Sri Lanka, Table 1 illustrates the statistics of the rivers, their basin areas and the number of stagnant waters located within each river basin of Sri Lanka.

The stars indicate the river basins greater than 1000 km^2. As indicated by Ranaviraja (2000), the river basins could be categorized into five classes (Table 1 & Figure 1) based on their geographical location; (i) Northern river basin region, (ii) Mahaweli inter basin region, (iii) Western river basin region, (iv) South eastern river basin region and (v) Southern river basin

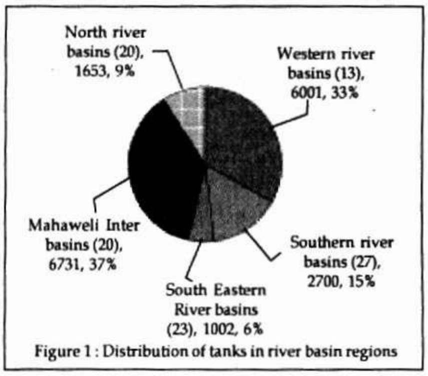


Figure 1 : Distribution of tanks in river basin regions

Figure 1: Number of rivers and distribution of tanks within each river basin region, their number and percentage

region. Table 1 illustrates the river basin included under each region. This type of a classification will be useful to describe issues in groups of river basins based on their geographic location.

2.1 Running waters

The Origin

The water which enters via rainfall into groundwater (the recharge water) drains down through the soil, and in some places, may seep out as a spring thus forming a stream[3]. Such a series of streams degrades the land, and when it flows downhill, other streams or the tributaries join the major stream forming a river. There are 103 such rivers in Sri Lanka flowing from a central mountainous massif in a radial pattern through various directions of the country (see Table 1 for statistics). During rainfall, these rivers receive waters from respective catchments or basins, bounded by ridges located at their highest elevations.

Such basins are referred to as "drainage basins" "river basins" or "watersheds" (defined as the area drained by a river and all its tributaries). They differ in their sizes, shapes and elevation.

Table 1: Statistic of Surface waters of Sri Lanka

River No.	Name of River Basin	Area (sq. km)	No. of TANKS	
1	Kelani Ganga*	2292	20	Western River Basins
2	Bolgoda Ganga	378	12	
3	Kalu Ganga*	2719	6	
94	Moongil Aru	44	0	
95	Mi Oya*	1533	1556	
96	Madurankuli Aru	73	105	
97	Kalagamuna Oya	153	189	
98	Rathambala Oya	218	291	
99	Deduru Oya*	2647	3274	
100	Karambala Oya	596	483	
101	Ratmal Oya	218	15	
102	Maha Oya*	1528	33	
103	Attanagalla Oya	736	17	
4	Bentara Ganga	629	2	Southern River Basins
5	Madu Ganga	60	1	
6	Madampe Lake	91	1	
7	Telwatta Ganga	52	42	
8	Ratgama Lake	10	1	
9	Gin Ganga	932	2	
10	Koggala Lake	65	1	
11	Polwatta Ganga	236	2	
12	Nilwala Ganga	971	16	
13	Sinimodera Oya	39	9	
14	Kirama Oya	225	206	
15	Rekawa Oya	76	113	
16	Urubokka Oya	352	182	
17	Kachchigala	223	150	
18	Walawe Ganga*	2471	777	
19	Karagan Oya	58	28	
20	Malala Oya	404	378	
21	Embilikala Oya	60	20	
22	Kirindi Oya*	1178	334	
23	Bambawe Ara	80	27	
24	Mahasiliwa Oya	13	5	
25	Batawa Oya	39	18	
26	Menik Ganga*	1287	294	
27	Katupila Ara	87	45	
28	Kurundu Ara	132	35	
29	Nabadagas Ara	109	9	
30	Karambe Ara	47	2	
31	Kubukkan Oya*	1233	81	South Eastern River Basins
32	Bagura Oya	93	19	
34	Helawa Ara	52	7	
35	Wila Oya	490	65	
36	Heda Oya	611	55	
37	Karanda Oya	427	95	
38	Semana Aru	52	17	
39	Tandiadi Aru	22	15	
40	Kangikadichchi Aru	57	10	
41	Rufus Kulam	35	7	
42	Pannel Oya	106	21	
43	Ambalam Oya	117	11	
44	Gal Oya*	1813	191	
45	Andella Oya	528	47	
46	Tumpan Keni	9	35	
47	Namakada Aru	12	25	
48	Mandipattu Aru	101	29	
49	Pathantoppu Aru	101	46	
50	Vett Aru	26	9	
51	Unichchai Aru	350	52	
52	Mundeni Aru*	1295	138	
53	Miyangolla Ella	228	27	

River No.	Name of River Basin	Area (sq. km)	No. of TANKS	
54	Maduru Oya	1559	231	Mahaweli nter Basins
55	Puliyanpotha Aru	53	11	
56	Kirimechchi Odai	78	24	
57	Bodigolla Aru	166	45	
58	Mandan Aru	13	1	
59	Makarachchi Aru	38	8	
60	Mahaweli Ganga*	10448	1003	
61	Kantalai Aru	451	120	
62	Palampotta Aru	70	101	
63	Panna Oya	145	12	
64	Pankulam Aru	381	164	
65	Kunchikumban Aru	207	95	
66	Palakutta Aru	21	4	
67	Yan Oya*	1538	832	
68	Mee Oya	91	40	
69	Ma Oya*	1036	366	
90	Aruvi Aru*	3284	1726	
91	Kal Aru	212	14	
92	Moderagam Aru	943	509	
93	Kala Oya*	2805	1425	
70	Churian Aru	75	15	North River Basins
71	Chavar Aru	31	24	
72	Palladi Aru	62	14	
73	Manal Aru	189	88	
74	Kodalikallu Aru	75	59	
75	Per Aru	378	156	
76	Pali Aru	85	9	
77	Maruthapillay Aru	41	8	
78	Theravil Aru	91	15	
79	Piramenthal Aru	83	14	
80	Methali Aru	122	22	
81	Kanakarayan Aru	906	202	
82	Kalawalappu Aru	57	4	
83	Akkarayan Aru	194	70	
84	Mandakal Aru	300	50	
85	Pallavarayan Kaddu	161	39	
86	Pali Aru	456	142	
87	Chappi Aru	67	15	
88	Parangi Aru	842	425	
89	Nay Aru	567	282	
	Jaffna Peninsula and Islands	1200	293	
	Talaimannar	126	7	
	TOTAL	65525	18377	

Source : Survey Department

Perennial, ephemeral and intermittent rivers

Out of the 103 rivers of Sri Lanka, some are perennial having their flows throughout the year, with a base flow even during non-rainy seasons, which depends on the water generated from the movement of ground water into the river channel.

According to the ancient nomenclature, perennial rivers are termed as "Gangas" and non-perennials as "Oya" or "Aru". The non-perennial[4] rivers are of two types, namely, ephemeral and intermittent. This classification is based on the flow regime of the rivers.

Some of the perennial rivers of Sri Lanka are river Mahaweli, Kalu, Kelani and Walawe. Most of them are located within the wet zone. However, the river Mahaweli is the only river which flows through both wet and dry zones of the country, and due to its perennial nature, many hydropower and irrigation projects have been focused on it.

2.2 The stagnant waters

There are no natural lakes in Sri Lanka, and our stagnant waters are mainly man-made other than the flood-plain lakes. As illustrated in Table 1, there are 18,387 tanks distributed within the 103 river basins including the Tanks in Jaffna peninsula and islands and in Taleimannar. Out of that, there are 309 major irrigation reservoirs (serving over 80 hectares each), and nearly 18,000 minor irrigation reservoirs, of which, around 12,000 are presently operational. The major hydropower reservoirs; Kotmale, Victoria, Randenigala and Rantambe and the recent Maduruoya reservoirs store waters of the river Mahaweli. Apart from that, many systems within dry zone reservoir waters of the Mahaweli River are used for cultivation.

Figure 1 illustrates the distribution of tanks within five geographic river basin regions of Sri Lanka. Number of river basins in each "river basin region category" is indicated within brackets. The Mahaweli inter-basin region contains the highest number (6, 731) of tanks. The lowest number (1, 002) of tanks is located within the South-eastern river basin region.

Coastal lagoons and estuaries also act as inland surface waters which also get

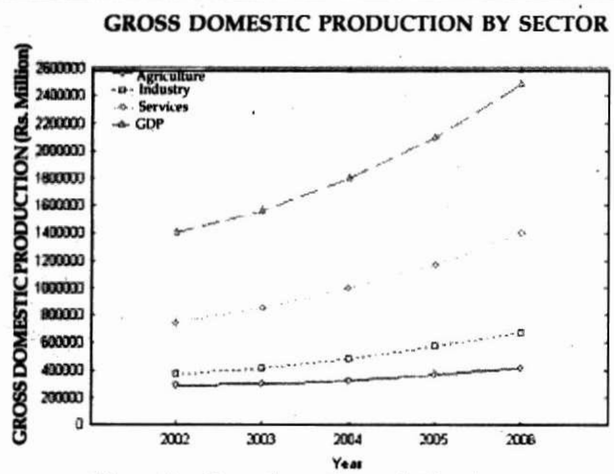


Figure 2 : Gross domestic production by sector
Source : Central Bank of Sri Lanka

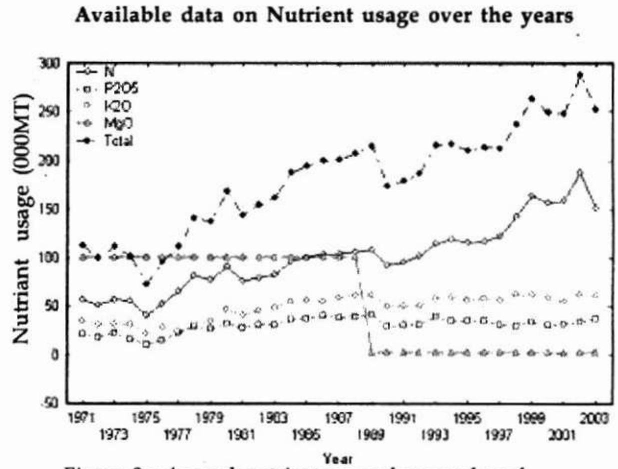


Figure 3 : Annual nutrient usage by year based on available data
Source : National Fertilizer Secretariat

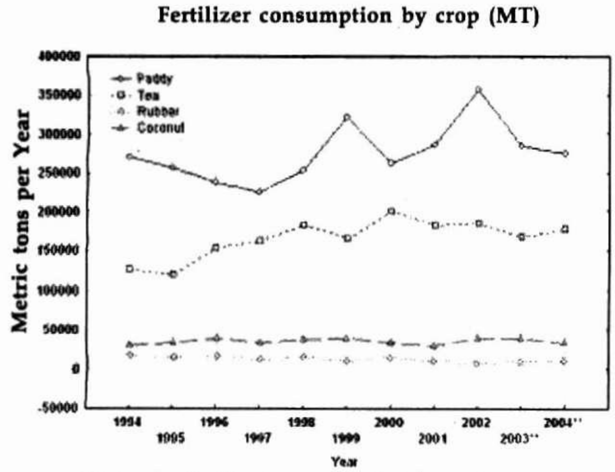


Figure 4 : Fertilizer consumption by major crops
Source : National Fertilizer Secretariat

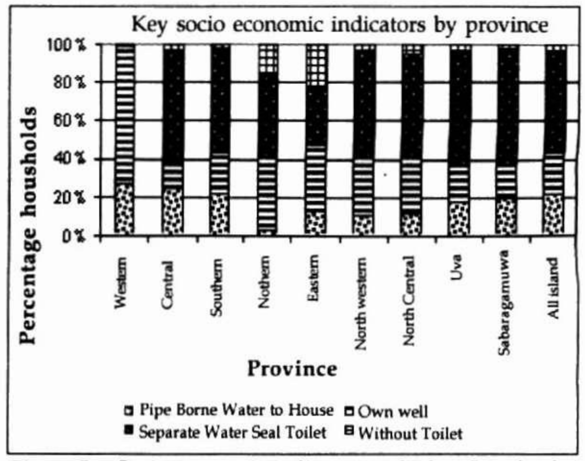


Figure 5 : Socio economic indicators which reflect fecal pollution

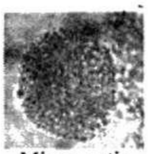
affected due to human interventions on running waters, which release their outflow at their down stream stretch.

3.0 Indicators of Pollution

Figure 2 illustrates the gross domestic product (GDP) of the country by sector. At present, Sri Lanka is not an industrialised country, but the GDP component is greater from industrial sector over the years and its contribution to GDP is greater than that of Agriculture indicating the trend towards industrial development of the country. Therefore, care has to be taken in management practices to avoid or minimise the water pollution due to industrial activities.

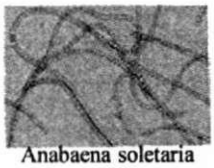
Figure 3 illustrates the annual use of nutrients by crops, and Figure 4 illustrates the consumption of fertiliser by major crops of Sri Lanka based on available data from National Fertiliser Secretariat of Sri Lanka and Dept. of Census and statistics. The excessive use of fertiliser by agriculture is responsible for the elevated levels of nutrients in surface waters in agricultural areas. Paddy and tea are the major crops which consume highest amounts of fertiliser, and therefore, the catchments of the tanks and river basins dense with paddy or tea have threats of loading nutrients into the water bodies and rivers driving them towards nutrient pollution.

Over the years facilities for access to toilets for people was upgraded. However Figure 5 illustrates still there is a minor percentage (less than 1%) of the population without access to proper toilet facilities which is highly significant as a contributor to microbial pollution of water resources. As a result there will be a threat on water resources due to release of sewer into water ways which ends up in stagnant waters. Recent study conducted by North East Coastal Community Development Project (Anon 2009 a & 2009 b) found high quantities over 2500 Colony Forming Units/100ml of E coli (Fecal coliforms) in Arugam Lagoon and in Batticaloa lagoon exceeding the threshold values of 50 CFU/100ml indicating similar threats due to poor sanitary facilities in the area. Therefore Figure 5 is a socio-economic indicator which indicates the fecal pollution threats to our waters and based on their geographical location, it has to be adequately addressed in water resources management by providing proper sanitary facilities for the community who lives mainly in shanties.



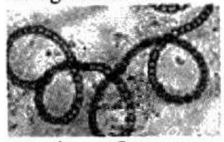
Microcyctis incerta x 400

Microcystis aeruginosa x 400



Anabaena soletaria x 100

Aphanizomenon



Anabaena flosaquae x 400

Anabaena Spiroides x 100

Nodularia x 100

Toxic bloom forming algae in Sri Lanka. Excessive nutrients in waters often leads to prolific growth of some toxic algae

Plate 1 Fish kills observed in Batticaloa lagoon in 2003 due to Anabena bloom

Figure 6 : Toxic Bloom forming algae in Sri Lanka

4.0 Status of the Water Resources

The urbanisation, irrigated agriculture, and the industrial development are the factors which initiate pressures on inland water resources, driving them towards pollution and water scarcity. Such threats stem from the respective catchments of the water resources rather than within the water resource itself.

The major water pollution issues could be categorised as (1) stagnant water pollution (reservoirs and lagoons) and (2) running water pollution.

4.1 Stagnant water pollution

Eutrophication

The common water pollution problem in stagnant water bodies of Sri Lanka is the eutrophication and blooming due to nutrient enrichments. High amounts of Nitrates and phosphates released from fertiliser applications of the relevant catchments in the agricultural zones or from wastes released from the urbanised areas cause the nutrient enrichments in stagnant waters. Status of such waters is referred to as "eutrophic" and the nutrient enrichment process is refereed to as the "eutrophication". This condition occurs only in stagnant waters of Sri Lanka as our running waters move fast due to high elevation gradients.

Eutrophication accelerates growth of nuisance algae (See Figure 6). These algal types release toxic substances to water during their degeneration which causes health problems to human beings.

Most of the stagnant waters in the dry zone are threatened of nutrient and pesticide pollution due to agricultural practices whereas the water bodies of western province are threatened due to urbanisation and industrial activities. Some published information exists on waters threatened of eutrophication and blooming; Kotmale (1991), Victoria (2003), Maussakele, Castlereigh, Rajangana, Kandalama, Nachchaduwa, Nuwarawewa, Tisawewa, Venderasan, Parakrama Samudraya, Kantale, (1997), Girithale (1997) and Maduruoya (1997) reservoirs (Anon 2003a and 2003b, Silva and Schiemer 2001). Kotmale reservoir reached a severe blooming situation in 1991 and high densities later in 1994 (Piyasiri, 1995; Piyasiri, 2001).

The important stagnant water bodies of the western province; the Beira Lake (80 ha), Parliament Lake (95 ha), and the Bolgoda Lake also have indicated eutrophication. The Beira Lake suffers from high eutrophication and elevated levels of fecal coliform. Kandy lake underwent a severe bloom of *Microcystis aeruginosa* due to high nutrients from urbanisation.

Apart from that, many lagoons also are threatened of eutrophication and blooming or fecal pollution such as Batticaloa (NECCDEP 2009a), Arugam (NECCDEP 2009b), Negombo, Rekawa, Galle and Dondra. Batticaloa lagoon in 2001 and 2003 underwent a severe bloom of Anabaena, and fish kills also were recorded (Plate 1).

Bloom formation

In developed countries, nuisance algal counts are monitored in order to warn the general public about the suitability of waters for users. Three alerts levels[5] are declared by Australian water authorities for *Microsystis aeruginosa* cell numbers. It is advisable to introduce such a practice even in Sri Lanka as there are many water bodies in Sri Lanka subjected to blooms. Such blooms cause severe health problems due to algal toxins. Algal densities of *Microcystis aeruginosa* exceeding 15000 cells per ml was observed even in Kotmale reservoir in 1991 (Piyasiri 1995; Piyasiri, 2001).

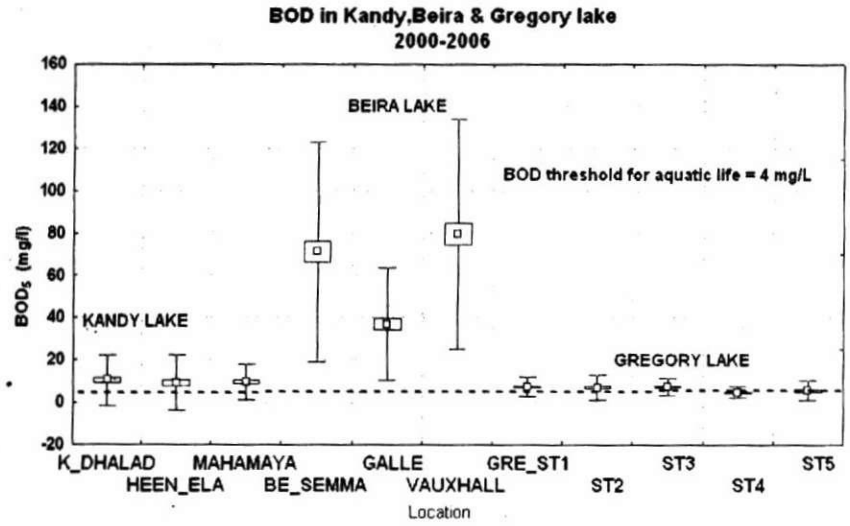
All algal toxins are highly toxic and difficult to control, and should not be used for supply above the alert levels.

Toxicity is caused by:

(a) contact with water containing blue-green algae;

(b) consumption of fish taken from contaminated waters; or

(c) drinking water with algal toxins.



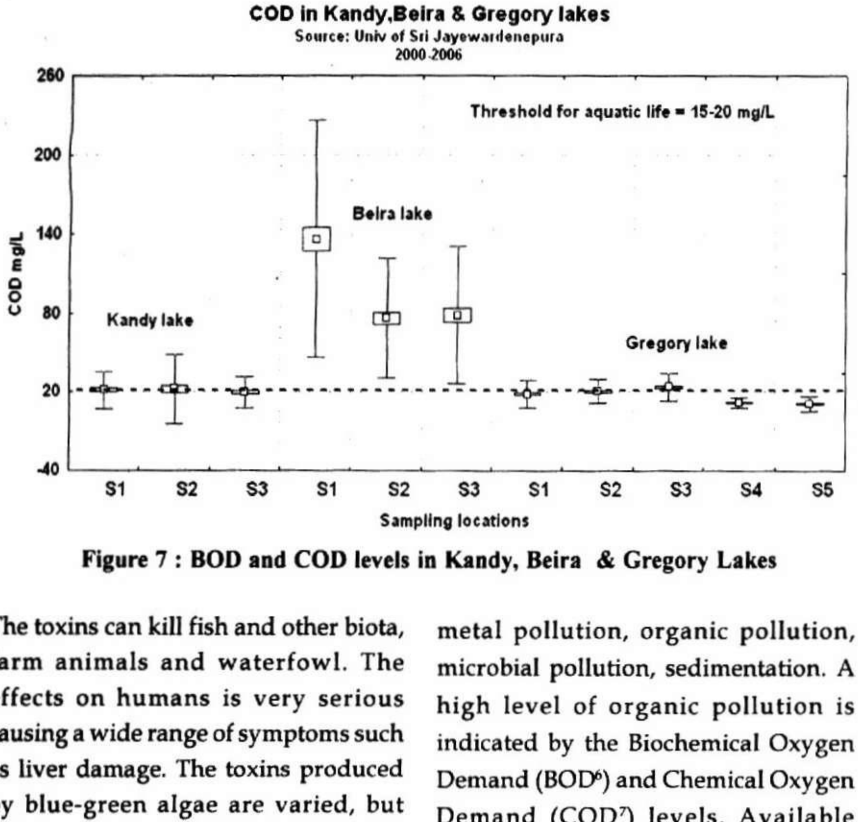


Figure 7 : BOD and COD levels in Kandy, Beira & Gregory Lakes

The toxins can kill fish and other biota, farm animals and waterfowl. The effects on humans is very serious causing a wide range of symptoms such as liver damage. The toxins produced by blue-green algae are varied, but include: (a) neurotoxins (mainly alkaloids) produced by species of the genera of *Anabaena Aphanizomenon* and *Oscillatoria*, (b) hepatotoxins (microcystin - peptides) produced by species of the genera of *Microcystis, Oscillatoria, Anabaena* and *Nodularia*, that mainly cause severe and often fatal liver damage. The World Health Organisation (WHO) has proposed a guideline value of 1 mg per liter for Microcystin-LR in drinking water.

Other Pollution Types

Other types of pollution in stagnant waters are; pesticide pollution, heavy metal pollution, organic pollution, microbial pollution, sedimentation. A high level of organic pollution is indicated by the Biochemical Oxygen Demand (BOD[6]) and Chemical Oxygen Demand (COD[7]) levels. Available water quality data in such stagnant waters indicate that they exceed the guidelines published by the Central Environmental Authority (CEA) or other international standards, indicating their unsuitability for aquatic life and for other purposes such as consumption, swimming, etc. However the data available on such parameters are scanty. Figure 7 illustrates some available data on BOD and COD levels in three stagnant waters exceeding the CEA standards of 4 mg/l for BOD and 15-20 mg/L for COD.

4.2 Rivers

Rivers get polluted due to release of heavy loads of organic substances, fertiliser, wastes, etc into the running waters via surface runoff. Some of the river catchments are densely populated such as Kelani River. The Mahaweli river catchment is utilised for multipurpose activities such as irrigation, agriculture, homesteads, tea plantation, small industrial activities, etc., and also some parts of the river in its journey through the dry zone, are heavily populated.

Apart from that, many rivers face with problems due to excessive mining of sands from their river beds and due to soil erosion in the catchments. Sand mining in the Kelani River has lowered its beds, and the water level has dropped bellow sea level (SOE 2001). As a result, intrusion of seawater occurs affecting the drinking water supplies to the Colombo city.

There are four major rivers in the western region of the country, namely, Kalu Ganga, Kelani, Attanagalu Oya and Maha Oya. Out of these, the Kelani River is the second largest river in Sri Lanka, and its river mouth region is highly populated where city of Colombo is located, and most of its organic pollution is received in its last 50 km.

Water quality testing of the Kelani River has been carried out by National Building Research Organisation (NBRO) for National Water Supply and Drainage Board (NWSDB) since 1989. CEA also have conducted some water quality assessments of the river. The results indicated that the Dissolved Oxygen (DO)[8] levels in the range of 6-8 mg/l at Ambatale region which is used for distribution to city for drinking purposes Anon, 1993). The COD ranged from 10-13 mg/l. Other parameters (Nitrate, Nitrite, Ammonia, Phosphate Sulphate, iron, etc.) tested by NBRO comply with the national standards (Anon, 1993).

However, at the downstream region close to the river mouth, the industrial pollution load discharged to the river was estimated from limited sampling industries in the Colombo area. A total of 25 industries discharged industrial process waste, with a BOD range of 80 - 405 mg/l at rates between 500 m^3 per day (Anon, 1993). The San Sebastian North and south canals were found to be the most heavily polluted, with BOD_5 of 165-180 mg/l more than twice the level found in the next most heavily polluted canals.

The river Mahaweli is the longest river of Sri Lanka which drains about 1/6[th] of the country's land area. While its journey through this large catchment area, it passes through densely populated regions, receiving large quantities of organic loads. In Kandy, at Meda Ela alone, it receives organic load of 712 1507 kg BOD/day (Anon, 2000 b). Apart from the city centers, the Mahaweli river waters receive large amounts of agro-chemicals via its catchment oriented towards agricultural activities, mainly through the paddy cultivation.

Some information exists on nutrient enrichments in the tributaries of the upper Mahaweli Catchment (Piyasiri, 1995; Piyasiri, 2001) and reservoirs via surface runoff due to excessive usage of fertiliser in the tea estates.

The 103 river catchments and the large number of tanks distributed over the country face pollution threats due to lack of proper water resources management criteria, and a coordinated mechanism is needed for water resources management.

5.0 Water Resources Management

5.1 Present status and required initiatives

Sri Lankans assume that the water is a freely available resource, but the demand is exceeding availability in some regions with the increasing population, urbanisation and industrialisation. To achieve harmonious integration of the multiple uses of aquatic resources, proper plans for water resources management are essential.

There are many policy documents, legislations and institutions dealing with water issues. Over 100 acts of parliament exist with relevance to environmental management, and over 40 refer to water sector.

As a result of administrative units based on political boundaries, the activities of water resources management are diffused, and there is no proper coordination among institutions. Many organisations have the powers in controlling pollution, but none does strong law enforcement. Therefore, it is necessary to concentrate on basin-level management which will be more efficient and more scientific.

It is important to consider following in integrated water resources management (IWRM):

1. Consider a basin level management

2. Initiate proper water quality management criteria. Develop water quality Index (WQI) mechanism as in the other developed countries to classify the waters based on their quality. CEA and National Science Foundation can initiate the interest of scientists to develop the index.

3. The catchment management mechanism shall incorporate conservation of riparian zone, hyporhic zone, 100m sensitive zones, wild life areas, etc. in IWRM.

4. Form River basin committees to integrate the water resources managementactivities.Administrators, the experts on water and catchment management, have to be incorporated into such committees toavoid problems encountered in lack of coordination among institutions.

5. Water policy document is already approved by the government, but it is important to consider the proposed water act with required revisions to omit or modify the sensitive issues such as water pricing.

5.2 Issues in water resources management

5.2.1 Water quality, data bases and national guidelines

It is important to find out the status of the waters by proper water quality (WQ) monitoring programs. CEA, National Aquatic Resources Agency (NARA), National Water Supply & Drainage Board (NWSDB), National Building Research Organisation (NBRO) and some universities have undertaken water quality monitoring of surface waters for different objectives. As most of the available WQ data are scanty and not in a central database, such information is wasted and cannot be utilised properly in the management activities. Therefore, our waters are not yet quantified and classified based on status, and such data cannot be used efficiently to develop national guidelines or threshold levels for different water quality parameters. Therefore, a water policy or legislation should incorporate a mechanism to encourage the scientists to send their data to a common database for future use. Criteria could be adopted to have a database with a possibility to acquire information through internet, even by introducing a nominal fee for information.

It is essential to develop a basin-level database with other relevant information, including forest degradation, vegetation types, biodiversity, etc. for IWRM. It is suggested to include an administrative and an information unit in each river basin for handling such data and to develop a distribution mechanism for other users.

Table 2 : Water users categorised into simple groups		
User Category	**Quality Requirements (Criteria)**	**Uses**
1	water with highest quality and free of pathogens	drinking water supply, fishery, swimming and certain industrial processes such as food processing
2	water of lesser quality, but still free from toxins and pathogens	coarse fishery, amenity and recreation such as boating, also agricultural irrigation and certain industries
3	quality is unimportant, just quantity	cooling water and navigation

Proper water quality-monitoring programs and research oriented towards major catchment issues also should be encouraged to obtain required information to develop national guidelines. A committee has to be formed, inviting water sector experts, to initiate research to develop national guidelines and Water Quality Index (WQI) for our waters to be used in water resources management.

Many developed countries have developed such national guidelines, and use them in developing WQI values for their waters, integrating important physical, chemical and biological parameters to come up with a single value which will be very useful for water managers to develop relevant criteria for management of our waters.

5.2.2 Water quality monitoring

Status of the water resources could be determined only through the water quality assessment of such waters. However, the water quality is very hard to be defined, and to a great extent, extremely subjective, and it is not simply a case of the cleaner or purer the better. For example, distilled water is extremely pure chemically, and its quality can be considered as being high as it contains no toxicants or pollutants. However, yet, it is unsuitable for potable use as it lacks the trace elements necessary for freshwater biota. Therefore, the water quality can only be defined in relation to some potential use for which the limiting concentrations of various parameters can be identified.

Classification of user groups

Classification of user groups was originally proposed by the World Health Organization (WHO). There are a variety of uses for water, each requiring their own set of specific quality requirements (criteria) as illustrated in Table 2.

In water management, decisions are based on the comparison of water quality data with criteria and standards. Sets of criteria exist for different categories of specific water use such as

(i) drinking purposes
(ii) recreational
(iii) aquatic life
(iv) agriculture and,
(v) industry.

Water quality standards and water users

The proposed legislation by CEA is based on quality standards relating to suitability for a specific use and protection of receiving waters when waste water is released into water ways. However, Sri Lanka has not formulated the necessary legal and administrative procedures for adopting quality standards for surface water other than the proposed maximum allowable concentrations for selected water quality variables for different uses; nature conservation, drinking, bathing, fisheries, conservation of aquatic life, irrigation and agriculture proposed by the CEA. The proposed water quality standards are based on the existing international standards of the WHO, European Union, Canada, Union of Soviet Socialist Republics (USSR) and the Environmental Protection Agency of the United States of America (USA).

Water quality monitoring program

It is important to introduce a proper water quality monitoring program to investigate required water quality parameters to be used in IWRM. Water monitoring and modeling studies are important to analyse and predict pollution trends in major water resources. This should contribute to a national water quality database for decision making processes.

5.2.3 The water quantity management

Surface water accounts for 98% of available water in Sri Lanka, of which, only about 25% is used. To get the maximum usage, we have to improve the efficiency of our water storage and usage mechanisms. As a result of competition among people for limited water for various purposes such as agriculture and industry, there are conflicts among competing water users. The irrigation sector alone accounts for about 96% of the national water consumption, and other users are competing with irrigation for water supply. Therefore, water managers have to develop an efficient water distribution mechanism.

5.3 Catchment issues in management practices

Most of the water quality issues stem from the relevant catchments. As discussed under indicators, due to human activities in the catchment, most of the nutrients, pesticides, industrial effluent, sediment, microorganisms are sent to water resources with the surface runoff. Therefore, the water quality of the surface waters indicates the symptoms of pollution of the relevant catchment. Therefore in the IWRM, it is necessary to look into the catchment issues responsible for water pollution, and criteria should be adopted to manage the catchment issues in order to protect the surface waters. It includes waste management from urbanised areas, control usage of excessive fertiliser in the agricultural areas, implement strategies to protect sensitive areas such as 100m sensitive area around the reservoirs, riparian zones, forest reservations, etc.

5.3.1 Controlling non-point source of pollution

The non-point sources are the major source of water pollution in many surface waters, which are responsible for most of the suspended solids, oxygen-demanding loadings, nutrients, and bacteria counts. Proper management criteria should be introduced to manage the tea, paddy and home garden cultivations in the catchments where excessive fertiliser and pesticide applications occur.

The bare land should be minimised to reduce soil erosion. Performance standards could be introduced to place limits on the rate of pollution discharge to the water ways. Deforestation activities should be stopped in the catchments without proper environmental assessments.

5.3.2 Waste management

Government should provide required infrastructure and support services for efficient removal and recycling of garbage collected within the sensitive catchments, as there is a high potential of water pollution threats due to garbage accumulation. Agro-based industries at the vicinity of the reservoirs should be encouraged to set up anaerobic digesters which are compact, low energy consuming and efficient for high organic wastewater. Instead of using imported technologies, local institutions should adapt suitable cost effective technologies for this purpose. In the highly populated areas, the pollution of water ways through sewage (microbial contamination) should be controlled through a mechanism of bypassing the water resources by introducing proper sewerage canals (Piyasiri, 2008).

5.3.3 Conservation of 100m sensitive area

If the developmental activity or any industry (minor or major) located within the 100 meter sensitive area of a reservoir or a water body, their outputs are very significant because the reservoirs receive the discharges in the concentrated form. (e.g. hotels may discharge organic waste; textile industry may release dyes, etc.). Therefore, it is recommended that the management of the 100m buffer zone in conservation of reservoirs according to the National Environmental Act.

5.3.4 Conservation of riparian zone around the reservoirs

Riparian strips should be introduced to protect riverine areas saturated with river waters and the shoreline areas of the water bodies. This filters the nutrients and toxic substances, minimising their effects on the receiving waters. Riparian buffer zones are highly effective in nutrient and sediment removal, and are increasingly used to protect all types of water resources.

5.4 Awareness programs

Farmers, general public and the schoolchildren should be educated through the awareness programs to minimise the pollution in neighboring water resources.

Media should be used as an effort to introduce awareness programs to educate the farmers about the nutrient traps (nutrient absorbing plant strips) in controlling the nutrient loading effect via catchments where high fertiliser usage exist.

To accelerate the provision of sanitary facilities, the low income groups need to be educated on the importance of sanitation and its association with diseases. The current lack of trained and qualified health education personnel needs to be remedied.

5.5 Research and education

Government agencies should cooperate with universities and other institutes to carry out research activities focused on environmental protection. It is recommended to focus research activities towards catchment management practices to avoid degradation of water resources.

5.6 Implementation and operation

In Sri Lanka, the major problem in management is lack of proper coordination between the issue identifier and the implementing organisation. The catchment management criteria which are very weak within the existing institutional frame work of Sri Lanka, and it has to be refreshed. Links should be maintained among various organisations which involve in the studies on catchment issues to obtain information for this purpose.

Conclusion

1. The surface water resources of Sri Lanka are threatened due to excessive usage of fertilizer and pesticides in their respective catchments. The statistics on nutrient usage by crops and over the years indicates increasing trends of their applications.

2. The recent water quality studies in Arugam Lagoon and Batticaloa lagoon indicates increasing rates of microbial pollution (Faecal coliforms) related to lack of proper sanitary facilities in the respective catchments. The 1% of the population in the country without access to proper toilet facilities will be a threat towards surface water pollution.

3. There is no proper coordinated water quality monitoring programmes in the country to use in water resources management. The available data are scanty and there is no national data base to be used in water resources management. The responsible authorities have to focus on this matter to formulate such a data base similar to available data bases of Census and Statistics Department.

4. The ambient water quality standards or national guidelines are lacking for some parameters in Sri Lanka. Such gaps have to be filled for the efficient water resources management.

5. In order to monitor the trends of water quality it is advisable to initiate water quality index programmes in the country. The research grants have to be focused more on this aspect as in the other developed countries of the world.

6. The water sector organizations have to form decision making bodies for conservation of surface waters with affective coordination.

7. Integrated water resources management has to be encouraged in all the policy documents and in water sector acts to be implemented.

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Footnotes :

[1]The climatic condition of Sri Lanka is based on the generation of monsoonal wind patterns in the surrounding oceans

[2]There are four basic rainfall seasons in the country namely:

- *(i) The South- west monsoonal period (May to September);*
- *(ii)The inter- monsoonal season of October November;*
- *(iii)The North-East monsoonal period December to February; and*
- *(iv)The inter-monsoonal period of March to April.*

[3]The point of origin of the stream is termed as headwaters.Initially a stream is a temporary one and later, when the channel is cut below the level of ground water table (or when fed by streams), it becomes permanent.

[4]The ephemeral rivers flow only during or immediately after periods of precipitation. They generally flow less than 30 days per year. Intermittent streams flow only during certain times of the year and their seasonal flow usually lasts longer than 30 days per year.

[5]According to Land and water conservation Department of New South Wales, Australia, and the alert levels for blooming are as follows:
Alert level 1-500-2000 cells / ml of water- Does not indicate an algal bloom. But there may be taste or odour problems and an indication that an algal bloom be developed.

Alert Level 2- 2000- 15000 cells /ml of water- Still not considered as a bloom although water treatment using activated carbon or use of alternative water supply is recommended.

Alert Level 3- More than 15000 cells/ ml of water- indicating of bloom. It is assumed at this stage that the bloom is toxic and action should be taken accordingly. Monitoring should be conducted monthly or ideally biweekly because two-week is the approximately minimum time for algal blooms. (Australia: State of Environment Report 2001).

[6] The BOD of natural waters is related to the dissolved oxygen concentration, which is measured at zero time and after 5 days of incubation at 20°C. The difference is the dissolved oxygen used by the microorganisms in the biochemical oxidation of organic matter. This indicates the rate of oxygen depletion in the water body and if its value exceeds 4 mg/L the water body is considered as polluted.

[7] COD is an indication of the proportion of organic material present in waters that is biodegradable, although some polysaccharides, such as cellulose, can only be degraded anaerobically and so will not be included in the BOD estimation. If the COD level exceed the threshold level established by the Central Environmental Authority (values of 15-20 mg/L), the water body is considered as threatened of pollution. The COD: BOD relationship varies from 15 to 20 depending on the type of organic substances present in the water.

[8] The amount of Oxygen Dissolved in water which is an indication of the health of the water resources.