CHALLENGES AHEAD

2013

WATER QUALITY AND HUMAN HEALTH

Second International Symposium

PROGRAMME AND PROCEEDINGS

15th & 16th March 2013

POSTGRADUATE INSTITUTE OF SCIENCE (PGIS), UNIVERSITY OF PERADENIYA -SRI LANKA

Organized by the

BOARD OF STUDY IN ENVIRONMENTAL SCIENCE,

POSTGRADUATE INSTITUTE OF SCIENCE (PGIS), UNIVERSITY OF PERADENIYA

In joint collaboration with the

International Research Center, University of Peradeniya

Toyama Prefectural University, JAPAN

Toyama National College of Technology, JAPAN and

Basha Research Corporation, India

PROCEEDINGS

2nd International Symposium on

WATER QUALITY AND HUMAN HEALTH: CHALLENGES AHEAD

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Editorial Board

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Toyama National College of Technology, Japan and Basha Research Corporation, India

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Welcome address by

Director of the Postgraduate Institute of Science (PGIS)
Sri Lanka

It is with great pleasure I welcome you to the International Symposium on "Water Quality and Human Health: Challenges Ahead" organized by the Board of study in Environmental Science of the Postgraduate Institute of Science (PGIS), University of Peradeniya in collaboration with International Research Center, University of Peradeniya, Sri Lanka Toyama Prefectural University, Japan, Toyama National College of Technology, Japan and Basha Research Corporation, India. I congratulate the organizing committee led by the symposium coordinator Dr. Sudharma Yatigammana for organizing this important activity.

This is the second International symposium in this series and this has now become an annual event. We know that water is a key component in determining the quality of our lives. The provision of safe drinking water is fundamental to protecting our health. Emerging health risks associated with drinking water supplies requires the continuous development of innovative technologies, research and a management strategy to ensure that drinking water is of a good quality.

Water also plays a fundamental role in regulating the climate and weather conditions. Increasing water demands from a growing population, economic expansion and new industries mean that we need to emphasize the wise use, proper management and protection of this important resource. As such, there are several challenging issues, which require in-depth studies and investigations.

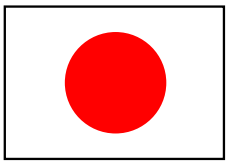
I hope that this symposium would provide an ideal platform for the researchers to identify challenges and address the connected issues with the water quality and human health. I hope that you will find the symposium both enjoyable and valuable and particularly hope that the foreign delegates will have a pleasant and a memorable stay at Peradeniya. Also I take this opportunity to thank the International Research Center, University of Peradeniya, Techno Instruments (Pvt.) Ltd and Haycarb Plc. for their generous support.

I wish the symposium every success.

Thank you.

Professor B S B Karunaratne
Director, PGIS

Address by



Chair of the Department of Environmental Engineering,
Toyama Prefectural University, Japan

It is my pleasure to write this message to the Second International Symposium on "Water Quality and Human Health: Challenges Ahead" organised by Postgraduate Institute of Science, University of Peradeniya.

The world faces a worsening series of regional and local water crises, according to "Comprehensive Assessment of the Freshwater Resources of the World", prepared for the United Nations Commission on Sustainable Development. Overuse and pollution are limiting the amount of freshwater available to safely meet the needs of human society and of the ecosystem. Water use has been growing at more than twice the rate of population increase during the 20th century. In 1995, 20 % of the world population did not have access to safe drinking water and 50 % lacked water for proper sanitation. One third of the world population and approximately one half of the people in the developing world are suffering from diseases associated with poor quality water.

Water pollution has a long history in Japan. The outbreak of Minamata disease, which occurred as a result of methylmercury poisoning, was first reported in 1956. People were affected after consuming large quantities of fish that had ingested and accumulated methylmercury, after the toxin was discharged into Minamata Bay by chemical plants.

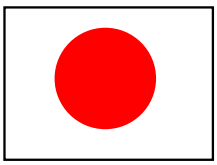
After 1960s, problems of environmental pollution associated with water increased throughout the world. For example, cadmium contamination in the Jinzu River caused a disease that makes bones brittle. Having experienced severe problems associated with pollution during 1950s and 1960s, Japan has been strengthening its environmental policy. Regulations over water quality were enforced under the "Water Pollution Control Law", resulting in a reduction of pollutants during the 1970s and 1980s. If these actions had been taken earlier, the costs incurred by the pollution could have been reduced substantially. Developing countries can avoid such high costs attributed to policy delays by taking early action to improve their environments.

In Sri Lanka, the economy is continuing a high growth. Sometimes rapid economic growth makes consideration to environment desertion. Therefore, it is very important for researchers and policy makers to hold this kind of symposium to conserve water resources.

I hope all the participants in this symposium will hold fruitful discussions on the future of this country.

Thank you very much.

Professor Tomonori Kawakami
Toyama Prefectural University, Japan



Address by

Dr. MasamotoTafu
Toyama National College of Technology
Institute of National Colleges of Technology, Japan

It is my great pleasure to write this message to the 2nd International Symposium on “Water Quality and Human Health: Challenges Ahead” organized by Postgraduate Institute of Science, University of Peradeniya.

First of all, we would like to introduce “National College of Technology (NCT)” Toyama, Japan. The NCT (KOSEN in Japanese) in Japanese education system was founded in 1962. Objective/mission of the NCT is to “foster practical and creative engineers.” We have been continuously benefitting from a good reputation within various fields owing to the great efforts of our academic/administrative staff, the success of our graduates, and support from industry, government, and academia. In the NCT, students from various countries are studying with Japanese students.

Our advantage in academic research is that we focus on "work-ready” technologies because the NCT collaborate with companies in the local area. The technology developed from research in the NCT such as water technologies is applicable to the benefit of developing countries.

Toyama National College of Technology has started research concerning fluoride treatment in ground water from 1995. We have undertaken to improve ground water in China, and now we have the challenge to improve water quality in China, Tunisia and Sri Lanka with various research institutes including Toyama Prefectural University, University of Tsukuba and various companies.

Toyama is located in the coast of Toyama Bay. One important area is the research on Tsunami which is one of the important issues for the local society.

In this conference, we will present our achievements concerning water treatment and Tsunami simulation. We hope that our research achievement supports the improvement of water quality in Sri Lanka.

Thank you very much.

Dr. MasamotoTafu
Toyama National College of Technology, Institute of National Colleges of Technology, Japan

Address by

Vice President – Operations
Basha Research Corporation

I am glad that Board of Study in Environmental Science, Postgraduate Institute of Science, University of Peradeniya, Sri Lanka is organizing an international symposium on "Water Quality and Human Health: Challenges Ahead" in joint collaboration with International Research Center, University of Peradeniya, Toyama Prefectural University, Japan and Toyama National College of Technology, Japan during 15-16 March 2013. The Energy and Environment Research Group of Basha Research Corporation (BRCORP), India is also collaborating with this symposium to strengthen the research outputs by joint research programs and joint publications. Some of the reviewed full length papers submitted to this symposium shall also be published in International Journals of BRCORP.

This symposium is expected to focus on the new and emerging areas for drinking water resources and its quality improvement techniques for safe consumption, involving aspects of Environmental Science and Engineering to bring awareness among scientists, academicians, researchers and students of the various aspects of the field related to human health. I trust that this symposium will provide a good opportunity to those who work in this area to exchange their views on the latest developments and challenges in the field. I have no doubt that the participants will have fruitful discussions and interaction of value for furthering research in this emerging area.

I wish the symposium a great success.

Ranipet Hafeez Basha
Vice President – Operations
Basha Research Corporation

Message from the Chairman
Board of Study in Environmental Science
Postgraduate Institute of Science,
Sri Lanka

It is with great pleasure that I provide this message to mark the two-day International Symposium on Water Quality and Human Health: Challenges Ahead. With the continuous race of humans to have more comfortable life, urbanization and expansion of industrial activities have become a necessity. Consequently, deterioration of the environment has been happening at an alarming rate, which has already become a global problem. Toxic pollutants present in air, water and soil have already threatened the health of all living beings. Although the environmental damage that has already occurred is not completely reparable, it is the responsibility of scientists in all disciplines to hold hands together, and provide their knowledge and expertise to mitigate environmental pollution.

The Board of Study in Environmental Science (BSES) of the Postgraduate Institute of Science (PGIS), Sri Lanka, has been actively involved in providing environmental education and promoting research in the diversified area of environmental science related to biological, chemical, geological and physical aspects in an attempt to improve the quality of the environment. In light of this, the Board of Study in Environmental Science of PGIS (Sri Lanka), in collaboration with the International Research Centre, University of Peradeniya (Sri Lanka), Toyama Prefectural University (Japan), Toyama National College of Technology, (Japan) and Basha Research Corporation (India), has organized this valuable international symposium to bring scientists of academic, research and industrial sectors in Sri Lanka and abroad, who are interested in environment and health, to a common forum to disseminate their novel findings.

This is the second symposium under the theme of “Water Quality and Human Health: Challenges Ahead”, at which about fifty research papers covering many aspects of environmental science will be presented. I have no doubt that this symposium will be a great success. I congratulate the organizing committee of the symposium for having this event at international level.

Prof. Namal Priyantha
Chairman, Board of Study in Environmental Science

Ileperuma, O.A., Priyantha, N., Chandrajith, R., Perera, A., Yatigammana, S.K. and Wijesundara, C. (editors) (2013): Symposium Proceedings, Second International Symposium on Water Quality and Human Health: Challenges Ahead, 15-16 March, PGIS, Peradeniya, Sri Lanka

Keynote Paper

UNDERSTANDING OUR HYDRAULIC HERITAGE – SOME UNBEATEN TRACKS

C.M. Madduma Bandara

Emeritus Professor, University of Peradeniya, Sri Lanka.

With a recorded history of two thousand five hundred years and a prehistory of several millennia, Sri Lanka was under foreign rule for only less than five centuries; or less than one-fourth of the total historical record. For almost two thousand years, the inhabitants of the Island, not only lived and earned their living from this land by using available resources prudently, but also built great civilizations excelling in certain arts, artifacts and technological feats. One of the main fields in which they undoubtedly excelled was in the utilization and management of water resources. These skills blossomed in the emergence of 'hydraulic societies' (Leach, 1959) and a highly developed 'hydraulic civilization' (Needham, 1971).

Civilizations whose agriculture was dependent upon waterworks for irrigation and flood control were called "hydraulic civilizations" by the German-American historian Karl A. Wittfogel in his famous book *Oriental Despotism* (1957). Wittfogel believed that such "hydraulic civilizations" were quite different from those of the West for they have functioned under highly centralized systems of governance. It went far beyond the Wittfogellian doctrine, and encompassed not only local and regional systems of governance, but also in water-based life styles, cultures and systems of beliefs, values and social norms. The village tank culture formed core of our own hydraulic heritage that flourished in the Dry Zone of Sri Lanka. Of the three types of ancient tank systems, found in ancient inscriptions, namely *danavapi* (privately owned small tanks), *gamikavapi* (or village tanks managed by the local community) and *mahavapi* (State managed larger systems due to higher investments needed). Around the village tanks grew a 'hydraulic culture' that pervaded the rest of the society. These tanks were not mono-functional or just for irrigation but were multifunctional, catering to other needs such as, cattle raring, domestic supplies, ecological, aesthetic and religious needs. While many larger scale monuments of this hydraulic civilization collapsed and dissipated, the village tank systems survived indicating their durability and long-term sustainability. They also symbolized the essential symbolic 'trinity' of our cultural heritage – *Wewa, Wela and Dagaba* (The tank, rice field and the religious monument).

In order to align towards the conference theme, i.e. 'Water Quality and Human Health : Challenges Ahead', an attempt is made here to probe into and understand how ancient people traditionally maintained the quality of water in their tanks, fields, canals and in domestic use for over such a long periods of history without the benefit of modern science. The author is inclined to advance the hypothesis that, through simple and nature friendly and culture controlled approaches of water management, ancients have attained certain standards of water quality that were not so inferior to those of the present day. A series of questions tend to buttress the above argument. Were they more vulnerable to disease and ill health due to lack of quality water or did their tanks and field suffer more due to water quality issues than what is experienced today with all the benefits of modern science? Were they an unhappier lot than the modern society which enjoys all scientific advancements and technological sophistication? If that was the case, how then could they find the virility of body and mind to build such a great civilization at that distant time in the historical past, with giant 'stupas' (like *Ruvanmeliseya, Jetavanaya and Abhaya giriya*) competing with the highest pyramids of Egypt, or constructing nine stories high buildings (*Lowamahapaya*) with nearly thousand rooms, and those thousands of tanks, anicuts (*amunu)* and canals with high levels

of technical precision?. These are certainly colossal monuments, an unhealthy population cannot imagine to build.

It may also be argued that, some common principles and moral driving forces moved the society towards the protection of precious water bodies from pollution. A cardinal culture trait behind water quality maintenance by the ancients was their 'deep respect for water' and the sanctity with which it had been treated at all times. The children were trained from young days on required values and norms. Some people in remote villages still believe that water is actually alive like other living beings (Sandell, 1985). The concept of 'respect for water' necessarily included restraining personal behaviors such as not spitting, urinating or defecating on water. Some writers preferred to call this an "Unwritten Science" (Gunawardhana, 2009). The design of the toilet systems (as compared with the present day flush toilets) where they were available, indicate their safe disposal waste to the environment in a way that it can be absorbed easily by the nature. Sometimes it is argued that, the population densities were much less at that time and therefore, ancient practices only suited their time only. On the other hand, can it be argued that the pollution as witnessed today, is more due to the lack of respect for it and the callous nature of human behavior seeking quick gains leading ultimately to the present imbroglio?

A second underlying principle that governed the maintenance of water quality in ancient times seems to be the ability to and the enjoyment of living in harmony with nature. A case in point is the 'cascading village tank systems' that reflected the principles of recycling and sustainability - concepts that have gained more currency in recent times. These inter-connected tank clusters functioned as silt-traps and natural filters making the water flow cleaner downstream. In complete contrast today, with widespread use of agro-chemicals, water gets more polluted downstream (Madduma Bandara, Yatigammana & Paranavitana, 2010) with increasing salinity and other pollutants. It has also been demonstrated recently that the ancient type of sluice (*keta or kumba horowwa*) was indeed more efficient (than the modern *yaturu horowwa)*, in filtering tank water before it was conveyed to the rice fields for irrigation. The tanks and cascade systems functioned as man-made ecological entities harbouring a variety of characteristic fish, aquatic flora and fauna. The fish in the tank is considered as a community by itself, according the leadership to native Snakehead *Channa striata* (Loolla) in whose absence only Kanaya (smaller varieties of *Channa* spp.) is assumed to take his place. The quality of water in the tanks was also maintained by some floating aquatic flora such as "haalpehi" and more tank-bed rooted plants such as water lilies, Kekatiya and Diya siyambala, Diya havariya and Diya beraliya.

The third principle that contributed to sustain the general purity of water bodies, appears to be the use of appropriate indigenous technology more as a slave than as a master. A variety of indigenous technologies ranging from simple water storage and processing for domestic needs, up to the construction of valve-pit (*bisokotuwa*) in tanks, and long canals (Giant Canals) with imperceptible gradients using the contour and certain elements of the 'regime theory' in hydraulic design, were commonly observed across the Island. For drinking purposes, water was often stored in earthen water pots (*kalagedi*) or *Kotale*. Perhaps the shape of *Kalgediya* may have been gradually evolved from the more simple *labu-kete* (dried shell of a goblet melon grown under *chena* farming) used earlier. It would have also been influenced by the shape of human breasts that stored milk for the offsprings as reflected in some folk poetry. There were of course different water vessels for different functions ranging from highest as used in royal coronation ceremonies (*rankendiya* or golden pot with a spout) and at the Temple of the Tooth Relic. Water clocks (chronometers or *Paeteti)* were used by the royal houses as well as by the indigenous physicians. The wide variety of water containers is reflected by multitude of names used such as *Taaliya, Kalaya*, *kalasa*, *kotale, kendiya*, *gurulaettuwa*, *sembuwa* (Tamil) *Koraha*, and *muttiya* .In order to quench the thirst of tired passers- by, it was customary to keep a *pintaliya* by the road side containing drinking water. The makers of earthen ware were given the honorific title of *Pandithaya* (pundit). Some of the pots carried artistic engravings and some were used in popular folk dance

forms (*kalagedi netuma* still in vogue) and folk poetry. There were also traditional methods of water purification such as the use of seeds of *Inginiya* trees.

A fourth principle that may have contributed to the maintenance of water quality and health was the simplicity of living styles with minimum needs that left hardly any significant ecological or water foot prints. The habits of bathing daily and using water for personal hygiene was considered essential. In a village tank there were several sites of water use such as *naana mankada* (bathing) *rada mankada* (for washing) and *gava mankada* for animals. The priests, men and women preferred to use different *mankada* for bathing due to cultural reasons. There had also been a wide variety of water sports such as *diyabun and diyakokila*, as recorded in some *sandesa* poetry. The women folk who did not feel demeaning to carry pots of water, pound rice or hew firewood were also in turn benefitted by their health and therapeutic effects.

A fifth principle is rooted in the communal system of local governance. At the hey-day of the hydraulic civilization, regional system of governance was based on tanks and continued to prevail until the full enforcement of the British Rule. There is evidence to suggest that in *Nuwara Kalaviya* (named after the three major tanks of Nuwarawewa, Kalawewa and Padaviya) –that formed the core area of hydraulic societies, a governance system based on *Wanni Unnehe* was in operation parallelly with British colonial administration during its first phase. The term *Wanni*or *Wanniars*is often interpreted as a people of the forest (Sanskrit term *Vanya* for forest may have influenced this interpretation). Another interpretation by linguistic scholars is to attempt deriving it from *Vahni* (flowing or draining substance) and *Vanni Unnehes* would have been those skilled in the art and science of water management. The spillway of a tank is still referred to as *waana* attributing it to flowing excess water. The *Wanni Unnehes* governed the whole region of *nuwarakalaviya* under the leadership of a Maha Vanni Unnehe based at Nuwarawewa- the primary city tank (*nagara vaapi or nakharavaapi*) in Anuradhapura even as late as the 1850s (Karunananda, 1978). At village level *gamarala* (derived from *gama radala* or the village nobility) and later *Vel Vidane*) (literally the executive of the rice fields, but wielded much power and authority over many aspects of village life). Both reflected strong traditional leadership and controlled not only water but also the communal, ethical and spiritual aspects of the rural communities.

A final question that inevitably arises is whether there are any lessons from the past that could prove useful in planning for coping with the challenges ahead? In this regard one has to be cautious in getting entrapped in over- romanticizing everything in the past. In this regard, much more than the technology itself, what one can extract is the spirit and principles behind them. As Kennedy (1933) - a reputed Director of Irrigation, in his guidance to engineers mentioned in relation to village tank rehabilitation, “Every Village Irrigation work has an individuality of its own, and … the engineer has…… to acquire the ‘sense and substance’ of that individuality”. There is also a fresh need to revisit our traditional cultural norms that protected nature and particularly the water resources over the centuries.

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Keynote Paper

WATER QUALITY AND HUMAN HEALTH

O.A. Ileperuma

Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka.

Water pollution is a global environmental problem and is the leading cause of premature death and diseases. Every day more than 14,000 people die due to water borne diseases. UN predicts an acute shortage of fresh water suitable for drinking by the year 2025. Increased population and large scale urbanization are responsible for the ecological degradation of our waterways. The main cause of freshwater pollution is the discharge of untreated sewage and other wastes into the major rivers which in turn contaminate both groundwater and municipality water supplies. In addition, our major rivers are getting contaminated owing to intensive agriculture, increased use of pesticides and industrial wastes.

It is rather difficult to attribute specific health effects to an isolated toxin and most likely some of these toxic materials work collectively in causing various diseases in humans. Increasing kidney disease and cancer amongst the general population of Sri Lanka is likely due to the chronic exposure to toxic chemicals.

Water borne diseases spread primarily through contaminated water. Bacterial pathogens such as Escherchia coli, Salmonella, Shigella, Vibri cholorae and many other types are responsible for diseases such as gastroenteritis, cholera, dysentery, typhoid and a host of other diseases. Various types of viruses also cause a large number of diseases. Human activities also contribute to the addition of a large number of chemicals which eventually contaminate drinking water supplies. Pesticides such as organosphosphates and carbamates damage the nervous system and cause cancer. These pesticides often found in the parts per billion ranges in drinking water are chronic toxins owing to bioaccumulation. Some examples of adverse health effects of individual pesticides are atrazine (cardiovascular diseases, reproductive disorders), 2,4-D (kidney, liver and adrenal problems) and methoxychlor (reproductive disorders).

Heavy metal accumulation by green leaf crops cultivated close to contaminated water streams is a serious health problem since these are staple constituents of a typical meal. The accumulation of chromium by water plants such as *Kankun* has been scientifically established and its consumption may result in cancers. The leachate from waste dumping sites is rich in heavy metals such as lead, nickel, cadmium and mercury from various types of discarded batteries. Their health effects have not been properly assessed but very likely affect the general health of people.

More than 100,000 synthetic compounds which are in use today are found in the aquatic environment. Out of these, persistent organic pollutants (POPs) represent the most harmful class of compounds affecting human health. These accumulate in fish and through their consumption enter the human body. Extensive pesticide use results in ground water contamination with POPs. Compounds such as dioxins are extremely toxic and some water schemes in the USA had to be abandoned owing to contamination from dioxins. Polychlorobiphenyls (PCBs) represent another group of chemicals arising from the runoff of landfills and discharge of waste chemicals and these compounds are responsible for immune deficiencies and skin diseases.

Arsenic occurs ubiquitously in nature and high concentrations of this element are found in drinking water in many parts of Bangladesh. The clinical symptoms of arsenic poisoning, collectively referred to as arsenicosis and include skin lesions and cancers of the bladder, kidney and skin. Arsenic concentrations of more than 3000 μg/kg is found in larger fish and its consumption results in the daily excretion of about 300 μg L^{-1} of arsenic. In chronic arsenic

poisoning such as what is found in Bangladesh, urinary excretions of arsenic are in the range of 200 – 400 μg L^{-1}.

Arsenic is one of the many possible causative factors suggested for the chronic kidney disease of unknown origin (CKDu) in certain parts of Sri Lanka. However, this does not explain why this disease is not found in some other areas where identical pesticides and fertilizers are used. The distribution pattern of CKDu patients strongly correlates with the fluoride concentration in ground water suggesting the involvement of fluoride as a possible causative factor.

The water quality alone does not give a true picture of the pathways for the intake of heavy metals and other toxins into the human body. There are other processes unique to the lifestyles of a particular community which often lead to enhancing the effect of an otherwise innocent pollutant. Water quality standards adopted in developing countries are based on those already in force in developed countries having entirely different life styles to those living in developing countries. While the fluoride standard of 1.5 ppm assumes an average intake of not more than 1 mg per day, farmers drinking several litres of water working in the hot sun results in the intake of several mg a day. Also, the use of acidic spices results in the leaching of heavy metals from sub-standard cooking utensils. In the presence of fluoride aluminum leaches out from cooking utensils in the form of alumino fluoride complexes which represents a case of *chemical amplification* of pollutants. Such socio-economic realities and lifestyles should be seriously considered in stipulating water quality standards for developing countries.

Excessive nutrient loading of the reservoirs causes algal blooms which generate highly toxic algal toxins. Three main categories of algal toxins are known: endotoxins, hepatotoxins and neurotoxins. Many of the reservoirs in Sri Lanka in Sri Lanka experience such algal blooms and recently an unusual red algal bloom was reported from two small reservoirs in Kandy. Consumption of this water resulted in diarrhea, vomiting and other minor ailments resulting in the hospitalization of a number of affected people. There is no monitoring done on such algal toxins in government sponsored water schemes.

Water is so essential for life and people take it for granted that the water we drink from a water supply scheme is safe. Yet the cumulative effect of a wide variety of pollutants ingested through water containing minute amounts of toxins and their possible interactions is a serious matter of concern for all of us.

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RECHARGE AND ISOTOPIC VARIATIONS IN THE NATURAL WATER REGIMES IN THE KALA OYA BASIN - SRI LANKA

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Most of the water sources dried out in the dry zone of Sri Lanka during the long dry period in the first two quarters of 2012. In this study, groundwater recharge in the upper Kala Oya basin was investigated using isotope techniques. Surface, shallow and deep groundwater samples were collected from 43 locations in September 2012, and stable isotope composition (18-Oxygen [^{18}O] and Deuterium [^{2}H]) was measured. Global Meteoric Water Line in $\delta^{2}H$ vs. $\delta^{18}O$ plot was used to interpret the isotopic values of collected samples. Falling of isotopic values of most of the surface and shallow water samples along the evaporation line and having a slope of less than 8 indicates that most of surface and shallow water have been subjected to intense evaporation.

The $\delta^{18}O$ and $\delta^{2}H$ in surface water varied from -4.42 to 0.07‰ and –23.94 to –0.50‰, respectively. Shallow groundwater is characterised by lighter isotopes ($\delta^{18}O$, –7.41 to –2.27‰ and $\delta^{2}H$, –48.15 to –12.72%) as compared to surface water. Deep groundwater is much more depleted than other water samples investigated ($\delta^{18}O$, –7.32 to –4.06‰ and $\delta^{2}H$, –47.28 to –25.14‰). The data demarcated clearly three main recharging regimes for deep groundwater in the study area. The deep groundwater with most depleted isotope values ($\delta^{18}O$ < -7.11‰) can be found only in the uppermost part of the basin, and the rain experiencing in the higher elevations of Kala Oya basin would recharge this part directly. Some intermediate isotope values (-6.79‰ < $\delta^{18}O$ < -6.43‰) can also be found in deep groundwater in the upper part of the basin, which would probably indicate some limited recharge from shallow groundwater and surface water. Intermediate isotope values are common in the deep groundwater found in the middle part of the study area of the basin suggesting enhanced contribution of shallow groundwater and surface water for the deep groundwater recharge. Comparatively enriched isotope values (-6.07‰ < $\delta^{18}O$ < -4.06‰) are found in deep groundwater towards the lower part of the study area in downstream of major tanks (e.g., Kalawewa and Kandalama tanks). Contribution of surface water for groundwater recharge is more significant in these areas. Enriched isotopic compositions can also be seen in Dambulu Oya, and Eraula Oya, indicating that the water of the above two streams is distinctly different from that in the Kala Oya basin. Consequently, Dambulu Oya and Eraula Oya do not contribute to groundwater recharge in the study area. It is important to note that both these waterways receive water diverted (at Polgolla) from the Mahaweli River. The present study reveals that long-term monitoring of isotope indices of water could facilitate precise assessment of the groundwater recharge mechanism in the Kala Oya basin.

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SEASONAL VARIATION OF NITRATE-N IN GROUNDWATER: A CASE STUDY FROM CHUNNAKAM AQUIFER, JAFFNA PENINSULA

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The Jaffna Peninsula has four main aquifer systems, of which the largest Chunnakam aquifer is in the Valikamam area. This is an intensively cultivated area in the Jaffna Peninsula, and consequently, excessive application of nitrogen fertilizer is found. Other sources of nitrate include organic manures, and urine and excreta of animals through human activities.

The aim of this study was to assess the N-nitrate contamination in drinking water of the Chunnakam aquifer, which was a sub-objective of a research project carried out by the International Water Management Institute (IWMI). Forty four (44) groundwater samples were collected from wells representing different uses and land use patterns. The sampling covered the period from January to December, 2011, representing all seasons. Nitrate-N in sampled water was determined colorimetrically using a spectrophotometer. The spatial variations of the water quality were mapped using ArcGIS 10. Nitrate-N values from domestic, domestic with home garden and public wells ranged from below 0.1 to 12.1 mg L^{-1}. During the rainy season, 38% of the agro-wells exceeded the limit of WHO drinking water guidelines (10 mg L^{-1}) and these were not suitable for drinking purposes. However, this percentage was 15% at the end of the dry season. A decreasing trend in nitrate-N concentration was observed from January to March. During the rainy season, the soil was wet enough up to the water table facilitating nitrate leaching. Nitrate-N found in most of the wells surrounded by areas with highland crops (onions, chillies, tobacco and brinjals) also exceeded the acceptable level (10 mg L^{-1}). Even though these wells are used for agricultural purposes, people who work in the field use agro-wells for drinking.

This water pollution is very likely related to the heavy use of N-based fertilizers for cultivation in the region. This leads to groundwater unsafe for drinking. Therefore, effective management of groundwater quality in the region is vital and further, creating awareness among population would possibly reduce the excessive use of chemical fertilizers in agriculture.

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STATUS AND SEASONAL TRENDS OF MAJOR CATIONS IN IRRIGATION WATER IN LEFT AND RIGHT BANK CANALS OF MINIPE ANICUT

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Major cations, such as Na^+, K^+, Ca^{2+} and Mg^{2+}, in soil originate from chemical weathering, and reach surface water bodies by runoff and subsurface flow. Additionally, these ions are added to the agricultural watershed by human beings. The relative proportion of Na^+ to other cations, such as Ca^{2+} and Mg^{2+}, is determined by the Sodium Adsorption Ratio (SAR). Any increment of SAR of irrigation water (IW) causes increase in exchangeable sodium in soil solution leading to loss of soil permeability required for crop growth. Therefore, estimation of SAR is essential to assess the quality of IW and the threshold value of SAR for IW is 6.

Mahaweli River (MR) has been diverted at Minipe and the water is distributed through the Left Bank Canal (LBC) and the Right Bank Canal (RBC) to irrigate paddy lands located in the downstream areas of MR. Even though several studies have been carried out to assess the quality of IW of some reservoirs of the Mahaweli basin, no report on the quality of IW of the Minipe canal system is available. In this investigation, levels of Na^+, K^+, Ca^{2+} and Mg^{2+} were determined in water samples collected from LBC, RBC and MR during both dry (August 2012) and rainy seasons (December 2012).

Increasing order of the concentrations of cations in water of LBC, RBC and MR is $K^+ < Mg^{2+} \approx Na^+ < Ca^{2+}$ in both seasons. Except K^+, the levels of other three ions in MR are slightly higher than those in the canals. Cation levels increases downstream of LBC from 50 km to 74 km from the beginning of the anicut with gradients (in mg dm^{-3} km^{-1}), 0.5 ($R^2 = 0.960$), 0.1 ($R^2 = 0.769$), 1.1 ($R^2 = 0.966$) and 0.3 ($R^2 = 0.958$), for Na^+, K^+, Ca^{2+} and Mg^{2+}, respectively in the rainy season. Low flow rate and high evaporation rate would be possible reasons for the increasing gradients of the cations along the section. However, the concentration gradients of metal ions in other waterways investigated do not follow a particular trend.

The mean values of SAR for both LBC and RBC are 0.4 and 0.3 in the dry and rainy seasons, respectively, suggesting that water of the canals is safe for irrigation. Further, the mean values of SAR of MR during both dry and rainy seasons are 0.5 and 0.3, respectively, suggesting that the impact of agricultural and anthropogenic activities along the left and right banks of MR on the water quality is minimal.

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EVALUATION OF THE WATER QUALITY IN DADUGAM OYA BY USING WATER QUALITY INDEX (WQI)

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The main focus of this study was to determine the level of contamination of the water in Dadugam Oya, Sri Lanka. Water of Dandugam Oya is heavily used as a drinking water source by the Water Supply and Drainage Board, and also for some domestic activities and agricultural purposes. Fourteen water quality (WQ) parameters were monitored from January to August 2012 on a monthly basis from six selected sampling locations to develop a Water Quality Index for Dadugam Oya. Canadian water quality index (CWQI) was selected as the model for the evaluation of water quality. The proposed Central Environmental Authority's (CEA's) inland water quality standards were used as benchmark values for this study. The CCME WQI relies on the measure of the scope (F_1), frequency (F_2) and amplitude (F_3) of excursions from objectives. The CCME WQI relates the way in which individual factors are combined to provide a final index value which can vary from 0-100, where a value of 100 is the best possible value and a value of 0 is the worst possible.

It was revealed that the quality of the water of Dadugam Oya is not satisfactory with respect to all parameters used in this study. The index shows that the ecological condition of the water is poor at all sampling locations. The WQ of upstream water (Kiridiwita and Kotugoda) does not show any evidence of industrial pollution, while domestic sources such as microbiological contaminants and non point sources contribute heavily. The highest WQI of 58 was recorded at Kiridiwita and the second highest (57) was recorded at Kotugoda.

The WQ of the mid stream site to downstream indicates evidence of industrial pollution as compared to the domestic and non point sources which is clearly indicated from Opatha to downstream. The gradual decrease of DO in water and high level of COD from Opatha to downstream were frequently recorded. The level of D.Cr and D.Pb are lower than the detection limits of the method and nutrients are significantly below the proposed standards of the CEA during the total monitoring period for all monitoring sites . The significant increases of D.Cr (from the level of 0.01 mg L^{-1} to 0.04 mg L^{-1}) were reported from Opatha to downstream from August 2012. However, it is below the level of ambient WQ standard proposed by the CEA, Furthermore, values obtained for COD for the latter stretch of the river were generally higher than the standard value. There is a significant difference between the values obtained during the low and high flow rates for all pollution indicators.

The WQI gradually decreases up to 45 towards the downstream direction of the Dadugam Oya. The microbiological contaminants become less significant in downstream from Opatha compared to the upstream. The WQI evaluated, excluding turbidity and faecal contaminants, clearly shows that the domestic sources are more prominent in the upstream site of the Dadugam Oya.

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PRELIMINARY RESULTS OF CESIUM-137 AND CESIUM-134 IN SEA WATER OF SRI LANKA AFTER THE NUCLEAR POWER PLANT ACCIDENT IN FUKUSHIMA, JAPAN

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Release of radioactive isotopes, such as cesium-137 and cesium-134, to the marine environment occurred due to the Fukushima nuclear power plant (FNPP) accidents in Japan in May 2011. The contamination of marine biota and subsequently sea-food with radioisotopes has caused considerable alarm within the scientific community and the general public as a whole after the FNPP accident.

This particular study was carried out to determine the radioactivity levels of cesium-137 and cesium-134 in collected around the coast of Sri Lanka. Samples were collected from Beruwala, Trincomalee, Mannar and Kalpitiya. About 100 L samples were brought to the laboratory and pre-concentrated using the AMP co-precipitation technique. Sampling was done from September 2011 to November 2012. The co-precipitates were measured for 72,000 seconds (20 hours) using a hyper pure germanium detector system at the laboratory of Life Sciences Division of the Atomic Energy Authority.

The radioactive isotope of cesium-137 was detected in trace levels, whereas cesium-137 isotope was not found in detectable levels in all samples analyzed. The levels of cesium-137 ranged from 1.01 ± 0.03 to 1.35 ± 0.03 mBq L^{-1}. It was also noticed that the levels are comparable to the reported values in sea water of the southern-hemisphere whereas the levels are significantly lower than the values reported for sea waters in the northern hemi-sphere. Non- detection of cesium-137 by this preliminary study reveals that the ocean around Sri Lanka has not yet been contaminated with radioactive traces released due to FNPP accident.

However, all the samples analyzed shows the presence of a trace amounts of radioactive cesium-137 suggesting the occurrence of background level of cesium-137 in sea water. This could possibly be due to the different inputs of cesium-137 into the environment that had occurred in the past such as nuclear-weapon testing and nuclear power plant accidents. As there is a possibility of increasing cesium-137 radioactivity in sea water due to various physical phenomena in the ocean, the study will continue collecting sea water samples from the coastal areas of the island. However, the finding of this study will definitely be of immense use in the future as no such recorded data are available for cesium-137 in sea water of Sri Lankan sea. Therefore the present data could be utilized as baseline values to estimate whether there is any increase of radioactive cesium-137 in seawater due to accidental release into the environment in future.

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INVESTIGATION ON SUITABILITY OF GROUNDWATER FOR DOMESTIC CONSUMPTION IN GAMPOLA TOWN, SRI LANKA

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A viral hepatitis outbreak was reported in May 2007 in Gampola, Sri Lanka due to faecal contamination of drinking water. The public prefers groundwater in spite of the availability of pipe borne water for various reasons. Groundwater is used in hotels, restaurants and residential houses because of its continuous availability and the low cost.

This study was conducted to assess the suitability of the groundwater, with reference to the microbial. Twenty wells were selected to monitor bacteriological quality, the water level, pH, electrical conductivity (EC) and total dissolved solid (TDS) for a period of 5 months covering wet and dry periods in 2010/2011. A total of 80 water samples were analyzed. A questionnaire survey was conducted among 47 well owners on the usage and the reasons for the use of groundwater.

All wells are contaminated at least once either by total coliform or *Escherichia coli* in both wet and dry seasons. Water level from the surface ranged from 0.9 - 11.5 m. Average EC and TDS values were 368 µS cm^{-1} and 165 mg L^{-1}, respectively. All the samples were slightly acidic showing pH values between 4.9 and 6.5. Out of 80 water samples tested 50 samples were not suitable for drinking as per the WHO standard.

Topography, recharge, distance from soakage pits and usage were identified as important factors affecting the microbial quality of groundwater. Wells located at lower elevations are more prone to contamination due to higher seepage from surrounding areas. The wet season is more vulnerable to contamination due to the higher water table that reaches the depth of soakage pits. It was found that 75% of wells located less than 15 m from the soakage pits show unacceptable levels of *E. coli* and total coliform counts. Low usage wells show higher contamination than the high usage wells.

Out of 47 well owners 57% were using tube well water and pipe borne water, 30 % only tube well. About 81% were not aware about the quality of their shallow well water and 51% of the well owners were not satisfied with pipe borne water and the main reasons given were muddy and higher price of pipe born water. Use water from shallow well without proper guidance and treatment could lead to a health disaster.

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ATMOSPHERIC DEPOSITION OF POLYAROMATIC HYDRO-CARBONS IN MOSS (*Hyophila involuta*) IN SOME URBAN AND REMOTE AREAS IN WESTERN PROVINCE, SRI LANKA

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Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous compounds which contain two or more benzenoid groups. They are found in the environment in natural media, such as soil, sediment, water, air and plants, as a result of both natural and anthropogenic processes. PAHs are toxic compounds emitted by incomplete combustion of wood and petroleum products, which have a great impact on human health and living organisms. Sixteen PAHs are defined as priority pollutants by the American Environment Protection Agency (EPA) based on their toxicological profile. Nine of them, namely naphthalene, phenanthrene, anthracene, fluranthene, pyrene, benzo(a)anthracene, chrysene benzo(a)pyrene and dibenzo(a,h) anthracene were identified and quantified using mosses (*Hyophila involuta*) as a biomonitor in the Western Province of Sri Lanka.

In June 2011 and August 2012, moss samples were collected from four different sampling sites (*i.e.*, Sedawatta, Dalugama, Sapugaskanda and Biyagama). The background levels were monitored using samples collected from the Kottawa rain forest. Identification and quantification of PAH in moss samples were carried out using HPLC with a C-18 PAH column as the stationary phase and acetonitrile:water as the mobile phase. Optimization of the mobile phase of HPLC was performed based on isocratic elution [acetonitrile: water (90:10)] and gradient elution by varying the polarity of the mobile phase. Nine PAHs identified by comparing with retention times and spiking with those of standards. They were quantified using the external calibration method.

Isocratic elution method was carried out for samples collected in June 2011; however it was difficult to identify the first set of peaks (mainly naphthalene) using the retention times of the chromatograms due to the contribution of other compounds in the fraction of PAHs. Therefore, a better cleaning procedure was developed to obtain improved separation by homogenizing moss with anhydrous Na_2SO_4 during the extraction and introducing a gradient elution method to expand the retention times between naphthalene and phenanthrene. This improved method was used to identify and quantify the nine PAHs.

In June 2011, the concentrations of total detectable PAHs at sampling sites were in the range 3.92–21.91 mg /kg dry weight of moss (*Hyophila involuta*) with a mean value of 11.59 mg/kg dry weight whereas their range was 4.00-24.59 mg /kg dry weight of the moss (*Hyophila involuta*) with a mean value of 15.67 mg/kg dry weight in August 2012.

The increasing order of the total detectable PAHs for selected sites was Dalugama < Sedawatta < Biyagama < Sapugaskanda when compared with the remote area, Kottawa rain forest. Vehicular and industrial emissions of the study areas may cause the formation of total detectable PAHs. Sapugaskanda known to be the largest industrialized area in Sri Lanka, shows the highest accumulation of PAHs as compared with other sites. As moss can uptake pollutants in large concentrations, it can be used to monitor pollution in a particular region and for source identification of pollution. Moss can also be effectively used as a biomonitor to monitor atmospheric deposition of PAHs.

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WATER, CULTURE AND THE TIME TO COME: A POLICY ANALYSIS FOR UNDERSTANDING DILEMMAS OF WATER COMMODITIZATION IN SRI LANKA.

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Sinhalese people have maintained ethical and moral relationships with water since the earliest history. Water and its availability decided the livelihood of civilians in the country for millennia. Customs, rituals, social norms and cultural practices related to water, which persist to this day, imply that the natives have long understood the importance and necessity of water conservation. Water is considered to be not only an essential good, but also an iconic symbol of the prosperity and wealth of the nation.

A basic policy analysis method was used to address the forthcoming policy problems related to water commoditization in Sri Lanka. Culture, traditions, ancient practices and history were used as evaluation criteria for the study. Published literature and participatory social survey records were also used in certain areas for critical analysis of the problem.

The local administrative bodies governed traditional water management systems at in rural and regional levels, managed water and environment together, and supported the livelihood. The lack of understanding of colonial rulers and later government institutions on the collective importance of self-sustained cascade systems in the Dry Zone of Sri Lanka caused a ravage of ancient irrigation system and the livelihoods related to it.

To this day, a majority of people in the county depend on free water resources. The reverence paid for water due to an understanding of the importance and scarcity of water, has been somewhat interrupted by the modern market-oriented environment. As the attitudes of those who purchase water is not positive, according to our social surveys, it is advisable to re-impose cultural and traditional values regarding water in communities.

If true management of water is required to conserve water, then the best practice is return to the traditional community-based governance of ancient irrigation systems. The top-down approach of water commoditization will essentially create problems for food security, environmental balance, household economy and livelihood of poor, and especially troubles agricultural and fishery societies. Omissions of analysis of the cultural, historical, and domestic uses of water will create burgeoning problems among poor livelihoods, while turning a profit for companies.

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GROUND WATER QUALITY OF A RESIDENTIAL AREA CLOSE TO A DUMPING SITE IN BATTICALOA

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Thirupperumthurai dumping site is the largest waste dumping site in Batticaloa district and about 45 tons of garbage is dumped daily. There are about 200 people residing in the area near the site, and many of them use groundwater for their daily requirements. The objective of the present study was to investigate the groundwater quality in the area and to identify the influence of the dumping site on water quality.

Twenty wells located near the dumping site spreading within 600 m linear area parallel to the main road were selected for sampling. Electrical conductivity (EC), pH and total dissolved solids (TDS) were measured on the site, while biochemical oxygen demand (BOD), chemical oxygen demand (COD), total hardness, coliform level, Cu concentration and Pb concentration were measured at the laboratory. It was shown that EC of certain wells exceeded the desirable levels of the Sri Lankan standards. However, the conductivity values of all samples are below the maximum permissible levels. TDS of 13 wells are higher than the WHO standard (250 mg L^{-1}). In certain wells, pH exceeded the maximum permissible values and sixteen wells had exceeded the highest desirable value of pH 7.00. Phosphate levels were within the range of 0.45 - 1.44 mg L^{-1}, which is lower than the maximum permissible value of 2 mg L^{-1}. Nitrate in all the wells were within the range of 55 – 156 mg L^{-1} exceeding the permissible level of 45 mg L^{-1}. BOD of all wells were within the range of 1.6 - 6.7 mg L^{-1} and the total coliform 100 mL^{-1} were within the range of 4-29 where the maximum permissible value is 10. More than 50% of the wells studied exceeded permissible level indicating pathogenic microbial contamination of groundwater. Analysis of heavy metals shows that Cu and Pb contamination is also a prominent effect of dumping sites on the groundwater. Cu concentrations in the wells studied were within the range of 0.05 - 0.14 mg L^{-1} and the highest desirable and maximum permissible levels were 0.05 and 1.5 mg L^{-1} respectively. Analysis of Pb concentrations in groundwater ranged from 0.05 - 0.11 mg L^{-1} in all the wells except for two wells. Considering the distance between groundwater wells and dumping site, it is obvious that EC, TDS and TH of water have a direct relationship to the distance. It can be concluded that all the wells were with high levels of phosphate and nitrates. The electrical conductivity of certain wells was high, and therefore, it can be concluded that these wells affected by both Batticaloa lagoon and the dumping site.

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WATER QUALITY ANALYSIS OF LAKE GREGORY, NUWARA ELIYA WITH RESPECT TO THE DYNAMIC INPUT AND OUTPUT

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Water is a very important factor for all living beings. Most of the research on water quality determination and management has been focused on irrigation based water reservoirs, such as "*Kala Wewa*" and "*Minneriya Wewa*" and multi-purpose water bodies such as "*Polgolla*" and "*Randenigala*". Less effort has been taken for lakes, such as Kandy Lake and Lake Gregory, which are mainly used for aesthetic and recreational purposes. Gregory Lake greatly contributes to tourist industry in Sri Lanka. It is one of unique water bodies which should be paid awareness comprehensively. In this research, Lake Gregory and its main inlet (*Nanu Oya upstream*) and outlet (*Nanu Oya downstream*) were considered. Thirteen (13) analytical parameters which are recognized as key parameters for water quality determination have been considered and compared with similar water bodies such as Beira and Kandy Lakes. These are COD, BOD, DO, pH, turbidity, EC, temperature, concentration of NO_3^-, PO_4^{3-} and Cl^- and heavy metal content (Pb, Cu, and Cr). All parameters have been collected in chronological order (monthly basis) in 2009 for each and every sampling point.

Pollutants, such as nitrate (0.74 mg L^{-1} - 1.10 mg L^{-1}) and phosphate (0.01 mg L^{-1} - 0.08 mg L^{-1}) levels increase from top to bottom of the upstream and a clear decline of DO along the inlet (7.0 mg L^{-1} - 4.0 mg L^{-1}). These results agree with the fact that the various pollutants accumulate into the inlet from various sources including toilet waste and solid-wastes. Other water quality parameters, such as EC (0.02 mS cm^{-1} – 0.08 mS cm^{-1}), Cl^- (2.0 mg L^{-1} -11.0 mg L^{-1}), pH (8.0 - 6.9) and T (15.6 ºC - 17.9 ºC) give slight variation and heavy metals content (dissolved Pb, Cr and Cu) show trace amount of level (less than 0.01 mg L^{-1}) in upstream of Nanu Oya.

A significant effect for the Lake Gregory is the accumulation of organic waste that comes from different sources in the catchment, such as sewage, urban and agricultural runoffs. A small stream in Nuwara Eliya which passes through tea plantations and agricultural lands contribute to increase in the COD (5.0 mg L^{-1} - 35.0 mg L^{-1}) and BOD (1.0 mg L^{-1} - 6.0 mg L^{-1}) levels and give rise to unpleasant odour in the Lake Gregory.

There are no significant deviations in parameters determined in the outlet stream [BOD (1.0 mg L^{-1} - 2 mg L^{-1}), COD (6 mg L^{-1} - 13 mg L^{-1}), EC (0.05 mS cm^{-1} - 0.11 mS cm^{-1}), Cl^-(8.0 mg L^{-1} - 11.0 mg L^{-1}), pH (6.7-7.8) and Temperature (16.9 ºC - 18.7 ºC)], although parameters such as PO_4^{-3} (0.01 mg L^{-1} - 0.02 mg L^{-1}) and NO_3^- (0.74 mg L^{-1} - 1.10 mg L^{-1}) show a slight decreasing trend, which may be due to self cleansing or sedimentation processes.

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SHORT RANGE TEMPORAL TRENDS OF ATMOSPHERIC DEPOSITION OF HEAVY METALS IN AN INDUSTRIALIZED AREA IN SRI LANKA USING MOSS (*Hyophila involuta*) AS A BIOINDICATOR

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Sri Lanka is a developing country and its urbanization and industrialization rate is very high. Consequently, the atmosphere is being polluted and in order to control air pollution, a systematic air pollution monitoring method is much required. As air monitoring requires sophisticated, expensive equipment, it is essential to pay attention to alternative cost-effective methods, such as biomonitoring, which is very suitable for the Sri Lankan context. In this study, the atmospheric deposition of heavy metals was performed quantitatively and trends were identified by analyzing moss (*Hyophila involuta)* as a biomonitor.

Samples of *H. involuta* were collected at four sampling sites; Biyagama, Dalugama, Sedawatte and Sapugaskanda. Kottawa rain forest was selected as the control. The moss samples were analyzed for five heavy metals (Pb, Cu, Ni, Cr, and Cd) using atomic absorption spectrophotometry (AAS). In order to investigate the correlations present among the heavy metals, the Pearson correlations were tested using SPSS version 16.0 for windows (SPSS Inc., USA). A significance level of 95% was the threshold for all tests.

The levels of metals retained by the mosses are expressed in $\mu g/g_{moss}$ of the dry weight of the moss sample. Concentrations of lead were found in the range of 74.45 – 355.55 µg/g in all four sampling sites. In general, lead concentration in mosses increased from 2006 to 2011 in all sampling sites. There has been a gradual increase except the sudden escalate of concentration in 2007 - 2008 time period. Concentrations of copper and nickel increased throughout the period from 2006 to 2011 with ranges 31.92 - 127.50 µg/g and 43.56 - 87.61 µg/g, respectively. All chromium measurements ranged from 103.68 – 232.07 µg/g. Cadmium concentrations gradually increased until 2008 followed by a drastic decline and again a gradual increase.

The time series studies on moss concentrations indicate that generally each heavy metal reveals a positive increasing trend with occasional fluctuations in all the sites in the time period, 2006 - 2011. Lead and chromium showed significant increase, while nickel and copper increased slightly. The gradual increasing trend had been disturbed by sudden escalates in some elements, such as chromium and lead. High traffic congestion, oil combustion in power plants and emissions of oil refinery and Lindel Industrial Zone were identified as major anthropogenic sources. Statistically treated data illustrate that most of the heavy metals reveal positive correlation with each other. Lead and chromium reveal a homologous trend through the period and have a strong positive correlation relationship. Nickel and copper also show a quite similar trend and have a moderate positive association. Hence, there is a high probability that those heavy metals had been emitted by the same sources. Therefore, such correlation studies will lead to the identification of the pollution source, on which regulations could be implemented to minimize heavy metal air pollution.

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WATER QUALITY IN UPPER DIVISION OF MAHAWELI RIVER IN SRI LANKA

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The Mahaweli is the longest river in Sri Lank**a** and originates from the central highland of the island. Its drainage basin is the largest in the country, and covers almost one-fifth of the total area of the island. Western tributary of the Mahaweli River originates from the Samanala mountain range in the western side of the hill country. The objective of this research is to identify the current situation of the Mahaweli River and provide baseline water quality information.

Physicochemical parameters, such as pH, conductivity, turbidity, temperature, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), phosphates (PO_4^{3-}), nitrates (NO_3^-), chlorides (Cl^-) and hardness were determined for water samples taken at eight locations along the Mahaweli River. Wastewater streams, domestic wastewater canals and leachate from municipal dumping sites connected to the river were considered in selecting sampling sites.

Water quality monitoring was started in April, 2012 and continued up to April, 2013. It was observed that physicochemical parameters varied with weather conditions. The minimum and maximum pH values of 6.2 and 7.5 were recorded in August and April, respectively. According to the proposed water quality criteria [Class (111) waters Category No. 2 (Drinking water with simple treatment) and Category No. 3 (Bathing)] for surface waters prepared by the CEA, pH values are within the tolerance limits from April to August, 2012. The minimum and maximum COD values of 2 mg L^{-1} and 28 mg L^{-1} were recorded in July and May, respectively. The maximum phosphate concentration of 0.95 mg L^{-1} was recorded in May. The minimum and maximum nitrate concentrations of 0.38 mg L^{-1} and 1.45 mg L^{-1} were recorded in July and June, respectively. The upper division of the river belongs to the wet zone of Sri Lanka with a mean temperature of 24.5 °C.

The pH value and nitrate concentration of each sample complied with the proposed standards. However, phosphate concentration varied periodically. In addition, electrical conductivity, turbidity and COD varied from place to place and from time to time. It was observed that the turbidity exceeded the standard except in the month of May. The impacts of the non-point pollution sources are more significant than point sources of pollution in the Mahaweli River. Continuation of such a water quality monitoring programme will enable to design a model for water quality in the Mahaweli River.

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WATER QUALITY OF NUWARA WEWA IN ANURADHAPURA IN SRI LANKA

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Anuradhapura is one of the ancient capitals of Sri Lanka and Nuwara Wewa is the largest irrigation tank in Anuradhapura. This tank has been constructed by the greatest king Pandukabhaya. Major uses of this tank are for drinking and irrigation purposes. The objective of this research is to identify the current situation of the water in Nuwara Wewa and construct a base line for any pollution trends.

Physicochemical parameters, such as pH, conductivity, turbidity, temperature, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), phosphates (PO_4^{3-}), nitrates (NO_3^-), chlorides (Cl^-) and hardness, were determined for water samples taken at eight locations around Nuwara Wewa. Catchment streams, waste water streams and domestic waste water canals connected to the lake were considered in designing sampling sites.

Water quality monitoring of the tank water between April 2012 and April 2013 indicates that physicochemical parameters vary with weather conditions. The tank is situated in the dry zone with a mean temperature of 30.0 °C. The minimum and maximum pH values of 6.7 and 8.0 were recorded in October and September, respectively. According to the proposed water quality criteria [Class (111) waters Category No. 2 (Drinking water with simple treatment) and Category No. 3 (Bathing)] for surface waters prepared by the CEA, pH values are within the tolerance limits from June to October. The minimum and maximum COD values of 6 mg L^{-1} and 127 mg L^{-1} were recorded in October and September, respectively. The maximum phosphate concentration of 1.45 mg L^{-1} was recorded in August when the water level was at the minimum level due to the drought that affected the location. According to the results, maximum nitrate concentration of 0.75 mg L^{-1} was recorded in June. During the inter-monsoonal period, a minimum nitrate concentration of 0.08 mg L^{-1} was recorded in October.

According to the results, it was observed that turbidity exceeded the standards at all times. The pH value, chloride and nitrate concentration always complied with the standards. Other parameters such as BOD, COD and phosphate concentration occasionally fluctuated and exceeded the standard. In the dry period, water level was balanced by filling the tank through network canals from other tanks, especially from Nachchiyaduwa Tank. This is the probable reason for the fluctuation of the parameters. During the study period, water quality in the tank was the worst in September as compared to other months. However, with the inter-monsoonal period starting in October, the water quality gradually comes to normal conditions. Continuation of such a water quality monitoring programme will enable to design a model for water quality in Nuwara Wewa.

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EFFECT OF PIPELINE SOURCES ON DRINKING WATER QUALITY IN SELECTED AREAS IN JAFFNA PENINSULA, SRI LANKA

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People in the Jaffna peninsula depend mainly on groundwater for their utilities as other water sources such as tanks and rivers are not available, and fresh water ponds and rainfall are not sufficient. However, the groundwater in Jaffna is in danger due to over exploitation and pollution caused by excessive use of agrochemicals and fertilizer.

In this study, the quality of groundwater was analysed for physical and chemical parameters, such as colour, odour, pH, cations (Ca^{2+}, Mg^{2+}, K^{+}, Fe^{3+}) and anions (total alkalinity, NO_3^{-}, Cl, PO_4^{3-}, SO_4^{2-}). Well water samples (Kondavil, Kalviyankadu, Thirunelvely and Nallur) and water samples distributed through pipelines (Maintank, Yamunari, Kurunaghar and Ariyalai) were taken into consideration.

The chloride content of water samples from Kondavil, Kalviyankadu, Yamunari and Main tank was found to be greater than 300 mg L^{-1}. The water samples from Thirunelvely and Kondavil were rich in nitrate content as compared to other places. This could be attributed to excessive usage of nitrogen fertilizers as these are agricultural areas. Further, water samples from Kondavil and Thirunelvely were found to contain high amount of calcium which causes water hardness. Iron, potassium, sulphate and phosphate contents did not show significant variation in the selected areas. The pH of the water samples was found to be almost neutral (7.0 – 7.7). Total alkalinity was high in the water samples collected from Kalviyankadu, Thirunelvely and Kondavil.

Analysis of water samples from pipelines made of asbestos, cement, cast iron and PVC revealed that the quality of water in pipelines is the same as that from their sources of origin.

It can be concluded that the high levels of alkalinity, chloride and water hardness are detected in the Jaffna peninsula.

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ANALYSIS OF HEAVY METALS AND TRACE ELEMENTS IN REGIONAL GROUNDWATER IN THE PERSPECTIVE OF MINERAL EXPLORATION: A CASE STUDY IN THE CRYSTALLINE ROCK TERRAIN, SRI LANKA.

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The geochemistry of regional groundwater has been utilized worldwide to discover subsurface mineral deposits, though it has not yet been investigated in Sri Lanka. The present study focuses to apply geochemistry of groundwater for mineral exploration in Udawalawe area of South-central Sri Lanka, where two serpentinite bodies exist within the crystalline basement. The area is also in the proximity to the litho-tectonic boundary between Highland and Vijayan complexes. Thus, the scope of the study was to uncover unidentified geological anomalies.

In order to achieve this objective, mineralogy, petrography and regional groundwater geochemistry of serpentinite deposits have been studied, since a relationship between regional groundwater geochemistry and geological anomaly is expected to be established. pH and electrical conductivity of groundwater samples were measured *in-situ*. The metals Al, Ba, Be, Cs, Cu, Fe, Li, Mn, Pb, Rb, Sr and Zn, were quantitatively determined with atomic absorption and emission spectroscopy. Replicates of each sample were analysed to improve the precision.

The present study reveals that concentrations of the above elements are significantly higher in the groundwater of the study area. Regional groundwater close to the serpentinite body showed the highest concentration of elements Cu and Zn, while elevated levels of Al, Ba, Be, Fe, Li, Pb, Rb and Sr were recorded. Relatively higher concentrations of elements, such as Be, Cu, Li, Mn, Pb, Rb and Zn, found in groundwater in the area between the two serpentinite bodies indicates possible occurrence of a subsurface mineral deposit. Thus, this study reveals an occurrence of a geological anomaly between two serpentinite bodies.

It can be concluded that the study indicates the importance and feasibility of the application of regional groundwater geochemistry as a tool for discovering mineral deposits. Detail observations on groundwater flow patterns, fascias changes and associated elemental mobility could effectively help in accurate demarcation of the lateral extents of the deposits.

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HYDROCHEMICAL AND ISOTOPE CHARACTERISTICS OF GROUNDWATER IN PANAMA, SRI LANKA

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Hydrogeochemical investigations were carried out in the dry zone coastal aquifer basin of Panama in South-east Sri Lanka to identify the major geochemical processes that regulate the groundwater geochemistry in the area. Groundwater resources in this area are used particularly for domestic and irrigation purposes. Thirty groundwater samples were collected and analyzed for their major ion concentrations and stable isotopes of oxygen and hydrogen content. Major cations and anions were measured by spectrophotometric methods, while measurements of oxygen and hydrogen isotope ratios in water samples were carried out by wavelength-scanned cavity ring-down infrared spectroscopy that was coupled with a vaporization module. The abundance of the major anions in groundwater is in the order, $Cl^- > HCO_3^- > SO_4^{2-} > NO_3^-$, while it is $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ for cations. The dominant hydrochemical facieses of groundwater is Na-Cl type, and mixed Ca-Mg-Cl type. Based on the Piper plot, it was inferred that the groundwater chemistry is controlled by mixing and cation exchange reaction between two end members. The results of PHREEQC based saturation index calculations indicate that groundwater in the area are saturated to under-saturated with respect to calcite, dolomite and gypsum. The stable isotope and geochemical data suggest that hydrogeochemistry of the region is mainly regulated by evaporation and that precipitation infiltrates without further modifications. The regression between δ^2H and $\delta^{18}O$ for groundwater in the region agrees well with the regional and global meteoric water lines. Groundwater in the aquifer is recharged by precipitation and cation exchange processes further regulate the hydrogeochemistry. The interaction between ground and sea water is however considerable and sea water mixing was observed in some wells as indicated by mass balance calculations. This might increase either by excessive exploitation or due to sea level rise associated with global climatic change. Assessment of water quality indicates that groundwater in the study area presently is chemically suitable for drinking and agricultural uses. Understanding of the chemical evolution of the groundwater provides insight into the interaction of water with the environment and contributes to better resource management in the study region.

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WATER QUALITY ANALYSIS TO IDENTIFY POSSIBLE REASONS FOR THE UNUSUAL COLOUR CHANGE OF COOKED RICE IN INDIKOLAPELLASSA, SRI LANKA

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Rice, the staple food in Sri Lanka usually does not show a noticeable colour change after cooking. A previous study on water quality variation in water bodies around Indikolapellassa area in Sewanagala has pointed out an issue of unusual colour change in cooked rice. The study reported in this paper was carried out in villages around the serpentine deposit at Indikolapellessa to find out possible chemical reasons for the unusual colour changes occurred in cooked rice. The study was carried out in three stages. A questionnaire given to villagers at the beginning of the study was analyzed to identify any correlation of the colour change either with the source of water or the rice variety. Based on the answers of the questionnaire, water samples were collected from fifteen locations that were used for both cooking rice and further testing. Measurements on pH, concentrations of CO_3^{2-} and OH^- were used to determine the alkalinity of collected water samples. Atomic Absorption Spectroscopic (AAS) measurements were carried for identifying metal ions present in water samples. Infrared spectroscopy was used to identify any functional groups responsible for the colour change in cooked rice.

The results revealed that both the hardness and the alkalinity of water samples collected around the serpentine deposit in Indikolapellessa were exceptionally high in certain dug wells and were in the range of 100-650 mg L^{-1} (as $CaCO_3$) and 50-400 mg L^{-1}, respectively. Brown rice turns dark red and white rice turns yellow if rice was cooked in water of total alkalinity of 200 ppm or above. No significant colour change was seen for rice cooked in water having a hardness of 100-650 mg L^{-1} (as $CaCO_3$) while keeping the total alkalinity at a constant value of $\leq$100 mg L^{-1}. Parallel to this observation, white rice turned yellow only when rice was cooked in dug-well water of alkalinity $\geq$ 200 mg L^{-1}.

The issue of colour change in cooked rice is prominent only in the villages around the serpentine deposit when well water is used for cooking purposes. IR spectra of the rice cooked with and without CO_3^{2-} show a dramatic change in the 1500-2000 cm^{-1} range implying a significant compositional change at alkalinity $\geq$ 200 mg L^{-1}. Structural changes occurred in the polysaccharides present in cooked rice due to the exposure to high concentration of CO_3^{2-} which may be the reason for giving a yellow colour to the cooked rice. Trace metal data did not reveal any leaching out of metal ions to water sources collected from the dug wells closer to serpentine deposits. It can be concluded that weathering of CO_3^{2-} containing minerals such as magnesite in serpentine deposit leads to high concentrations of dissolved CO_3^{2-} and HCO_3^- in groundwater making it more alkaline. The overall study reveals that the exceptionally high alkalinity present in water causes the colour change in cooked rice regardless of the rice variety.

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ADAPTABILITY OF WATER PURIFICATION PRACTICES AT HOUSEHOLD LEVEL: A STUDY FROM THE ERAVUR PATTU DIVSIONAL SECRETARIAT DIVISION, BATTICALOA

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Water quality is a major issue in Sri Lanka. Pollution and waste dumping contaminate water supplies leading to serious health impacts for water users. This leads to a steady growth in the need for water purification, which comes from all categories of users – commercial, industrial, institutional, municipal and residential. A broad range of applications for water quality has stimulated the water treatment industry to develop new water purification technologies.

Batticaloa District lies in the Eastern Province of Sri Lanka, where the groundwater is the only source for irrigation, drinking and domestic purposes. This study examines the adaptability of the households in the water purification practices for drinking purposes. The study also provides the impact of water purification practices on the prevalence of water borne diseases in the community. The study was carried out in 27 villages in the Eravur Pattu Divisional Secretariat (DS) Division in the Batticaloa District. The survey was based on the programmes carried out by the Non-Governmental Organizations and the Ministry of Health related to water and health impacts on the rural community.

The study consisted of primary and secondary data gathered from a structured questionnaire, data collection from the DS Office and the MOH Office, and base-line statistics from relevant non-governmental organizations. The questionnaire survey was carried out using the Random Sampling Method. The number of interviewers was selected according to the proportionate of the village population. The questionnaire was based on three indicators: Percentage of households having year round access to clean and safe water, percentage of care given using at least one method of water purification, and prevalence of water borne diseases in the area during the last six months.

The study shows that 57.2% of the house-holds have year-round access to safe and clean water. It also shows that the adaptability of the community in purification practices has been increased by continuous monitoring and follow-up actions by the relevant organizations. 65% of the population practices at least one method of water purification, where the value has increased from 53.9%. More than 85% of the population has adopted boiling and filtering as the common purification practices. However, there were also a few innovative methods such as solar water disinfection (SODIS) practiced in communities. At the same time, the prevalence of water borne diseases in the area has become zero in 2012 from 7% in 2010.

In conclusion, this work highlights how the community based programmes resulted in awareness about the importance of water purification which makes an impact on the health of the community. It is also showed that the community is aware on the quality of drinking water. The study also recommends introducing other simple water purification techniques which will be adapted progressively to improve the health of the community.

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DETERMINATION OF GROUNDWATER HARDNESS IN MAHAWA – SIYAMBALANGAMUWA AREA AND PRELIMINARY INVESTIGATIONS ON POTENTIAL USE OF *Terminalia arjuna* (KUMBUK) IN REDUCING WATER HARDNESS

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Increasing hardness and deteriorating quality of groundwater, the primary source of potable water, has been the general observation of inhabitants of predominantly agricultural areas in the dry zone of Sri Lanka. A preliminary investigation, therefore, was carried out to determine the ground water hardness and its variation across the study area using samples drawn from dug-wells located in Mahawa-Siyambalangamuwa area. Kumbuk (*Terminalia arjuna*) which naturally grows along streams and rivers, and traditionally known to reduce water hardness was brought under study to investigate the means through which this capacity can be harnessed to reduce hardness of drinking water.

Samples were taken in triplicate from the surface of water and from the bottom of wells selected across the elevation gradient, during a six month period (March to August, 2012), and preserved as necessary. Total hardness was measured using EDTA titration (EPA 130.2) method. Data were statistically analyzed using one-way ANOVA.

Two month old Kumbuk seedlings were grown in hydroponic systems were filled with water of known hardness. Total hardness was measured in each system within two day intervals for two weeks. Dried and powdered mature Kumbuk seeds, collected from the study area, were also tested to reduce hardness. Two glass columns were prepared with and without coconut shell and activated carbon. Ground Kumbuk seeds (20 g) were washed with hot deionized water and packed in a glass column and another portion was packed with coconut shell carbon (20 g) and activated carbon (5 g). Groundwater of known hardness was passed through the columns and total hardness in filtered water was measured.

Total hardness of the surface water samples ranged 30 – 400 mg L^{-1} and bottom samples 120 – 410 mg L^{-1} during the study period that received scanty rainfall. Except for one well, all others contained very hard water (>150 mg L^{-1}). The well of the lowest hardness (< 60 mg L^{-1}) is located at the highest elevation of the area. Water in the wells located close to the paddy fields recorded the highest (300 mg L^{-1}) total hardness and the values showed a statistically significantly difference ($p < 0.05$) from the rest. Hardness in bottom layers of water in the wells was significantly higher ($p < 0.05$) than that of the surface water samples.

Total hardness in containers with Kumbuk seedlings showed a statistically significant reduction, from 400 to 200 mg L^{-1} within 2 weeks. It was observed that seedlings that have developed fibrous roots developed are more effective in reducing hardness, indicating the phytoremediation capacity of Kumbuk in improving drinking water quality. The total hardness dropped from 350 to 200 mg L^{-1} by Kumbuk seed powder without carbon, which was further reduced to 125 mg L^{-1} in the column with Kumbuk seed powder, coconut shell and activated carbon. These findings imply the potential use of amply available Kumbuk seeds to reduce hardness in drinking water, and thus, developing a low-cost home filter unit affordable by local inhabitants.

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DETECTION OF *Aeromonas* Spp. IN DRINKING WATER SOURCES IN MIHINTALE GRAMA NILADHARI DIVISION

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The genus *Aeromonas* comprises facultatively anaerobic, oxidase positive, gram negative bacteria that cause many diseases ranging from gastroenteritis to wound infections in humans. The US EPA has included them in the contaminant candidate list as an emerging pathogen. This study assessed the occurrence and the diversity of *Aeromonas* spp. in drinking water sources (well and tap water) from March to June, 2012 from randomly selected residential localities in the Mihintale in the Mihintale Grama Niladhari Division (GND). Fifteen well water samples and ten tap water samples were collected (in duplicate) and the occurrence of *Aeromonas* spp. in each sample was detected by the Membrane Filter Technique (MFT). Total coliforms (TC) and *E. coli* (EC) were enumerated using M-Endo and M-FC media, respectively. Biochemical identification was conducted as described in the Bergey's Manual for Determinative Bacteriology.

Aeromonas spp. were identified from four tap water and from six well water sources. Among the *Aeromonas* spp. identified from tap waters, 50% were *Aeromonas sobria*, 20% were *Aeromonas veronii* and 10% were *Aeromonas hydrophila* subsp. *hydrophila*. In well water sources, 36% were *Aeromonas sobria*, 21% were *Aeromonas veronii*, 36% of were *Aeromonas hydrophila* subsp. *hydrophila*, 36% were *Aeromonas eucrenophila*, 7% were *Aeromonas salmonicida* subsp. *Salmonicida* and 7% were *Aeromonas salmonicida* subsp. *smithia*. Other than these identified *Aeromonas* spp., an unidentified *Aeromonas spp* was also detected in tap water samples. Except for *Aeromonas salmonicida*, which is a fish pathogen all other species are considered as emerging human pathogens causing health disturbances including serious illnesses. In addition to these identified *Aeromonas* spp., *Proteus* (four spp.), *Escherichia coli*, *Serratia* (three spp.) and *Enterobacter* (four spp.) were also identified and characterised.

Mean bacteriological colony counts obtained for TC and EC exceeded the WHO permissible levels, ranging from 10^2-10^4 CFU/100 mL in both well and tap water samples. This is an indication of fecal contamination occurring in the distribution systems of tap water and groundwater sources. Results indicated that the drinking water sources (tap and well water) in the Mihintale GND are highly contaminated with many pathogenic and opportunistically pathogenic bacterial species. Contamination in tap water might occur at the source, treatment facility or any other point in the distribution system, indicating the possibility of forming biofilms. Contaminations in well water might be due to the surface run off into unprotected wells, groundwater contaminations, intrusion of contaminated water through protective walls and possible contamination from closely built latrines.

Since *Aeromonas hydrophila* is listed in the contaminant candidate list of US EPA, their presence in drinking water is a serious issue. It can be concluded that the drinking water sources (tap and well water) in Mihintale GND are unsafe and require more efforts to safeguard the quality of both the surface and the groundwater sources. It is recommended that the drinking water wells must be analysed for bacteriological quality on regular basis. Further studies are required to determine the clinical significance of the *Aeromonas* spp. isolated from drinking water sources.

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SPECIES COMPOSITION AND RELATIVE DOMINANCE OF RESERVOIR PHYTOPLANKTON IN SRI LANKA: INDICATORS OF ENVIRONMENTAL QUALITY

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Temporal patterns of the occurrence of phytoplankton in Sri Lankan reservoirs subjected to different hydrological regimes were diagnosed using the outcome of a long-term study conducted on species composition and their relative dominance in relation to environmental variables. Nearly 200 taxa belonging to nine taxonomic groups were identified and compiled from 48 man-made inland water bodies located in both wet and dry zones of the country. Species list showed a wide variety in taxonomic composition. Species richness hardly exceeded 50 taxa for a particular reservoir ecosystem although the majority of them did not reach > 1% in most samples. Twenty one genera were found to be very common but, only 14 taxa showed time-specific numerical dominance.

Desmids (Family: Zygnematophyceae) represented the highest number of taxa in Sri Lankan reservoirs and some species were numerically dominant in least conductive oligo-mesotrophic waters. Species richness of green algae (Class: Chlorophyceae) and blue-green algae (Class: Cyanophyceae/Cyanobacteria) were more or less similar in species richness. Although several toxigenic genera of Cyanophytes were identified (*e.g*., *Anabaena*, *Aphanizomenon*, *Ceolosphaerium*, *Cylindrospermopsis*, *Lyngbya*, *Microcystis* and *Nodularia*) only *Microcystis aeruginosa* and *Cylindrospermopsis raciborskii*, formed into blooms in certain reservoirs including those used for drinking after conventional treatment. Of the diatoms (Class: Diatomophyceae), only the chain forming centric diatom, *Aulacoseira granulata* played an important role in the phytoplankton bio-volume and oscillated with *Pediastrum simplex* (Chlorophyceae) in meso-eutrophic waters subjected to rhythmic water level fluctuations. Other groups of planktonic algae (viz., Chrysophyceae, Cryptophyceae, Xanthophyceae, Dinophyceae and Euglenophyceae) were of minor importance for the species assemblage.

Apparently, relative abundance and species spectrum can be used to classify the water bodies into three distinct groups viz., oligo-mesotrophic (large and deep canyon-shaped, newly built hydropower reservoirs), meso-eutrophic (dry zone irrigation tanks subjected to high flushing rates) and eutrophic-hypereutrophic (terminal irrigation reservoirs experiencing long water retention and urban water bodies receiving urban waste). A majority of reservoirs showed a distinct seasonal variation in phytoplankton abundance influenced by monsoon driven rainfall pattern. Some exhibited non-rhythmic successional episodes in relation to site-specific hydrological regimes and specific chemical environments. Grazing seems to be less effective in regulation of phytoplankton biomass perhaps due to lack of zooplankton, but a large quantum of plankton biomass is lost during water release from the shallow irrigation reservoirs. *C. raciborskii*, attains the maximum growth in these water bodies during the dry season under low water level, creating a grave health risk if they are being used for human consumption after conventional treatment.

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BIOMANIPULATION: A REVIEW OF BIOLOGICAL CONTROL MEASURES IN EUTROPHIC WATERS AND POTENTIAL FOR WATER BODY MANAGEMENT IN SRI LANKAN RESERVOIRS

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To meet the high demands of the ever increasing human population, industrialization, urbanization intensive farming activities have increased worldwide during the recent history. Effluents of these accelerated development activities ultimately contribute to pollution and nutrient loading of aquatic systems. This has resulted in major changes of the ecological structure and threatened the health of ecosystem. The recent increase of algal blooms that appeared in Sri Lankan reservoirs is also known to be associated with nutrient loading, mainly from urban environments and agricultural lands. Despite several attempts taken by authorities and scientific community, nuisance algal blooms have become widespread in our systems. In addition, recent surveys reveal that exotic plantivorous fish are dominating our water bodies resulting in low abundance of large limnetic herbivorous zooplankton.

A biological restoration method, known as Biomanipulation, is a technique of using aquatic organisms of control algal blooms in freshwater systems. This method has been successfully applied in many of the developed countries in the temperate regions of the northern hemisphere. Possibility of applying biomanplation has also been investigated in temperate and subtropical regions of Australia as a remedy for emerging algal blooms. In this technique, the herbivory is enhanced through the reduction of planktivorous fish by introducing piscivorous fish. Then the grazing pressure on zooplankton is reduced and the grazing pressure on phytoplankton (algae) is increased. Through this approach, water clarity is enhanced allowing submerged macrophyte growth. This method was initially proposed in 1975 and various approaches have been developed to make the application to suit the local environments. However, applications of biomanipulation techniques to control algal blooms in tropical freshwater are rare.

As freshwater reservoirs in Sri Lanka are dominated by exotic planktivorous fish and small zooplankton, the growth of algae especially when there is allochthonous nutrient input is inevitable. Fortunately, when compared to the past, present limnological conditions of Sri Lankan reservoirs for biological restoration appear to be a practical solution. However, trial experiments should be carried out using mesocosm before applying them to natural system. This review suggests biomanipulation as a tool for controlling algal blooms that appear in Sri Lankan reservoirs using native Snakehead *Channa striata* (Loolla) and large herbivorous zooplankton.

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STUDY OF MARINE OSMOREGULATION AS AN ALTERNATIVE ZOOLOGICAL METHOD TO REVERSE OSMOSIS IN CONVERTING SEA WATER INTO DRINKING WATER

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Sea level rise due to global warming has the potential to influence freshwater supplies from conventional sources. Harnessing fresh water from the abundant saline ocean waters for human consumption and irrigation have always been an area of focus. However, compared to transporting water from groundwater/rivers, the desalination methods such as reverse osmosis are found to be expensive and lack the naturally occurring minerals that are essential for human health. However, the places that face chronic water problems still depend on supplies from desalination plants. Therefore, it is important to explore the potential of new methods for desalination. One such mechanism is carried out during the osmoregulation of sea water fish. Like other species, saltwater fish do need fresh water for metabolic processes; they get water by drinking salt water. Salt water fish species are particularly efficient in concentrating and excreting excess salt. Interestingly, it has been found that the water coming out of their gills is saltier than what goes in. Thus they consume salt with the sea water, then some of the excess salt is released from the bloodstream through their gills, and the rest is concentrated by the kidneys for excretion. This combined osmotic work of the gills and kidneys results in the retention of water and excretion of excess salt. This paper shall focus on the study of marine osmoregulation mechanism especially in the salt water fish and explore the possibilities of a zoological method as a process for converting sea water into drinking water.

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DISTRIBUTION OF *Cylindrospermopsis raciborskii* (A TOXIN PRODUCING CYANOBACTERIUM) IN FRESHWATER RESERVOIRS OF SRI LANKA

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Sri Lanka possesses over 10,000 multipurpose reservoirs that are distributed throughout the country. Many of these reservoirs are under the threat of physicochemical and biological pollution. Among these, appearance of algal blooms has become a major water quality problem during recent times. Especially, the detection of a predominance of toxigenic cyanobacteria in many fresh water reservoirs indicates a future human health hazard unless immediate mitigation measures are taken. In addition, prevalence of these organisms could affect the ecological balance of the system. When an ecosystem health is affected by the dominance of cyanobacteria, even long term water body recovery techniques, such as application of biomanipulation, may not be successful.

The current study was initiated as an initial step to understand the prevalence of toxigenic cyanobacterial species, *Cylindrospermopsis raciborskii*, in Sri Lankan reservoirs. Sixty reservoirs representing all the climatic regions with varying environmental conditions were selected for the study. The surface areas of the reservoirs ranged between 105 acres to 6300 acres and maximum depths were between 2.44 m and 33.53 m. The study was conducted from October 2010 to January 2012, and sampling for the analysis of *Cylindrospermopsis raciborskii* was done using a plankton net (pore size 10 µm) at three month intervals to cover all the seasons of the year. Identification of the species was done using an Olympus CX 31 research microscope equipped with phase contrast optics.

According to physicochemical analysis, all the reservoirs fall into eutrophic category having total phosphorus levels of more than 30 µg L^{-1}. Specific conductance of the reservoirs ranged between 38 µS cm^{-1} and 637 µS cm^{-1}, and the salinity level was below 1 ppt. The results of the biological analysis of toxigenic cyanobacteria reveal that *Cylindrospermopsis raciborskii* is dominant in shallow urban reservoirs during the dry season, terminal reservoirs and reservoirs with low flushing rates and in deep reservoirs with persistent water stratification, especially during the dry season. In addition, morphological variations of this species were also noticed especially in urban reservoirs and shallow reservoirs that maintain high water residence time. Although they commonly occur at coiled–shape, highly eutrophic reservoirs appear to support other morphotypes: straight, sigmoid or tricomatous. Further, it was noticed that the cell size of *Cylindrospermopsis raciborskii* is exceptionally large in a high altitudinal wet–zone reservoir that usually maintains a temperature range of 10 ^{o}C - 20 ^{o}C throughout the year.

As *Cylindrospermopsis raciborskii* is widely distributed in reservoirs of Sri Lanka, and as this species is known to be highly adaptable to new environments, the presence of several morphotypes signifies the potential for rapid distribution and prevalence in other reservoirs of Sri Lanka.

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RESTORING RIPARIAN VEGETATION – A PROMISING MEANS TO ENSURE CLEAN WATER

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Forest cover in Sri Lanka has declined from 44 % in 1956 to < 29 % in 1983 of which riverine forests form a substantial part. Aside from stabilizing stream banks, controlling soil erosion, providing shade and habitat for surface and aquatic biodiversity, their importance as riparian buffers to mediate the inflow of polluted surface water or in the bioremediation of ground water must not be underestimated.

The most serious loss was experienced in the upper watersheds where montane forests were cut in the 1800s to plant tea. Current land use in these areas is dominated by tea and vegetable cultivation that use massive amounts of chemical fertilisers, herbicides and pesticides. Many agrochemicals produce and disseminate xenobiotics and their metabolites, which may result in dangerous health issues both in the area of application and downstream. Parallel to their impact on surface water quality, the impact of agrochemical leaching into groundwater is equally serious. The experience in Kalpitiya where nitrogen based fertilizers have contaminated the prevailing *Gyben Herzberg* type aquifers, is well known.

The Neo Synthesis Research Centre (NSRC) has from 2001 to date been engaged in the restoration of riparian vegetation alongside banks and gullies in the upper reaches of the Mathatilla Oya, Maragala Oya, Bolgoda Ganga, Hulu Ganga, Rakwana Ganga, Lemastote Oya and Maha Oya as well as around Lake Richmond in Haputale. The vegetation used in the landscape design of the riparian buffer zone mimicked the natural forest vegetation of the area. As the buffer zone was inhabited with people who had tea, home or vegetable gardens, efforts were made to induce trees in the area adjacent to the water body and convert cultivation to adopt organic regimes. However, most of these areas suffer from lack of sanitation. Hence such as intrusion of faecal coliform bacteria into surface water bodies, compounding water quality further were originated. Further, Toilets have been constructed, though many more are required. Restoration has, in all instances, been undertaken with the participation of the community.

NSRC pioneered the bioremediation of nitrate-N in groundwater in Kalpitiya where research conducted from 2001 to 2011 involved the restoration of native forest cover around a drinking water well in Nawakkaduwa village. Within an overall hydraulic retention time of 3.5 years, nitrate concentrations in well water reduced to potable levels. This initial experiment was first undertaken for the National Water Supply and Drainage Board resulted in the technology being extended to other public and private drinking water wells in Kalpitiya and around wells in Kalmunai, which were contaminated with sewage in the aftermath of the 2004 Tsunami.

These results confirm that the restoration of riparian vegetation around and along the surface and groundwater bodies may be a promising and low-cost solution to avert the contamination of water resources in Sri Lanka.

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DIVERSITY AND ABUNDANCE OF PLANKTON AND THEIR RELATIONSHIPS TO MEASURED ENVIRONMENTAL VARIABLES IN KANDY LAKE

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Kandy Lake is an ornamental freshwater body located in the highly populated city of Kandy, Sri Lanka. During the past few decades, the lake experienced several water quality problems including appearance of algal blooms, increase of fish parasites and presence of bottom anoxia in the deeper areas. Several planktons, such as diatom, green algae and golden brown algae are known to be the best biological indicators in environmental studies to understand the water quality changes, such as eutrophication, acidification, and salinization. Kandy Lake also has shown changes of community composition of planktons annually and seasonally. These changes appear to be related to seasonal rainfall and human activities in some instances. Therefore, understanding of the plankton composition of the Kandy Lake may help to predict the trends in environmental variables before problems become serious. In addition, monitoring of the community changes of these organisms helps to understand appropriate remedial measures to bring back the system to an ecologically balanced condition. If the ecology of these organisms is known it could be useful for bio manipulation applications, which would be the only viable option for lake recovery according to the most recent findings of environmental scientists and lake managers. Therefore this study was undertaken to investigate the diversity and abundance of plankton in the Kandy Lake and their relationship to some important measured environmental variables.

Plankton samples from the lake were collected twice a month for a period of six months, December 2011 - May 2012. Plankton was identified and relative abundance of each type was calculated following standard methods. Limnological variables were measured and any relationship between limnological variables and species composition was determined using correlation coefficient (Minitab 14 version). Zooplankton composition of the Kandy Lake includes all the prominent groups of zooplankton; rotifera, cladocerans, copepods and ostracods. In addition, a protozoan family, Vorticellidae was also recorded although low abundance. Phytoplankton composition of the Kandy Lake recorded ten families belonging to four major phyla of algae. Out of 10 families recorded, five families were recorded from phylum Chlorophyta being the most diverse algal group of the Lake. In addition, two families of phylum Chrysophyta, two families of phylum Cyanophyta and a single euglenoid family of phylum Euglenophyta were recorded. Although Kandy Lake had a high abundace of plankton, the diversity can be considered as low when compared to an ecologially balanced system. However, phytoplankton were abundant than zooplankton in all the study sites.The most abundant phytoplankton was *Pediastrum simplex* and the most abundant zooplankton was nauplius larvae. The statistical analysis performed showed that the species composition of the Kandy Lake is negatively correlated to all the measured environmental variables.

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THE USE OF PLANKTON AS INDICATORS OF WATER QUALITY OF KOTHMALE RESERVOIR

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Although Kothmale reservoir has completed its ontogeny period, during the past few years it experienced several algal blooms. As the reservoir is fed mainly by three Mahaweli tributaries, which flow through a vast area of land that practices intensive conventional agriculture, appearance of algal blooms can be attributed to land use practices of the catchment. Therefore, understanding of the long-term nutrient dynamics of the reservoir will help understand the plankton dynamics to save the health of the reservoir especially from eutrophication. We explored the possibility of using planktons to detect environmental changes in the Kotmale reservoir.

Monthly samplings of plankton were conducted from June 2008 to June 2009, and sampling at three month intervals was conducted from June 2009 – June 2011 from 22 sites with different environmental characteristics. Plankton samples were collected using plankton nets with appropriate pore size, and species were identified. From each sample, at least 500 individuals were counted for calculation of the relative abundance. This procedure was repeated for each sample and the mean value was taken to determine the species dominance at each site.

A total of ~117 different plankton species were identified and most of them were phytoplankton. Among them were 16 species of Diatoms, 56 species of Green Algae including 25 spp. of desmids and 11 spp. of Blue Green Algae. Thirty two species of zooplankton belonging to the groups, Cladocera, Copepoda, Rotifera, Ciliata and Nematoda were also identified. The abundance of phytoplankton was higher than that of the zooplankton in all the sites. Orders Desmidialea and Chroococcalea were the dominant phytoplankton groups while Cladocera and Protozoa were the dominant zooplanktons. *Staurastrum cingulum* was the dominant species in sites where the catchment is covered with reservation forest with no significant inflow streams and were located along the right bank of the reservoir. *Botryococcus braunii* was dominant where Punaoya reach the reservoir. *Microcystis* spp. is abundant in many sites located in the left bank, where there are several inlets to bring water from adjacent villages. Further, both *Microcystis* spp. *Staurastrum leptacanthum* were abundant in sites located closer to the dam.. Diatom species, *Navicula* spp. and *Aulacoseira granulata* were abundant in regions where Pundaluoya reach the reservoir. While *Cladocera* species were abundant in sites where *Staurastrum cingulum* was identified, rotifers and ciliates protozoans were identified closer to the dam and the sites with high dominance of *Microcystis* spp. Although there was a significant increase in the abundance of dominant species during the dry season, no variation of species composition was noticed between wet and dry seasons. The measured limnological variables, temperature, dissolved oxygen, turbidity and nutrients varied between study sites, while pH and conductivity were similar throughout the reservoir. Thus, our study suggests that plankton species respond to various environmental conditions in Kothmale reservoir indicating potential use of them as environmental indicators.

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NUISANCE ALGAE AND CYANOBACTERIA IN SOME SELECTED WATER BODIES IN SRI LANKA

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Previous research information shows that almost all water bodies in Sri Lanka harbour toxic cyanobacteria, hazardous to human and animal health. Depending on the species and their concentration, algae and blooms affect badly on water treatment plant operations and the water quality. Microcystins are well-studied, chemically stable hepatotoxins predominantly produced by freshwater cyanobacteria, including species of *Microcystis*, *Cylindrospermopsis*, *Anabaena*, *Nostoc*, *Planktothrix*, *etc*. Conventional water treatment processes have failed to remove microcystins to recommended levels, hence posing a challenge in water supply projects. Thus, regular study is required to monitor microcystins and potentially toxic cyanobacteria in freshwater bodies.

The research study was conducted to understand algae composition and density along with cyanotoxin contamination in fifteen drinking and irrigation water bodies in Sri Lanka. Water samples were collected for each water body at five sampling locations in triplicate from February 2010 to December 2011. Some important physico-chemical and biological parameters, species composition and abundance of phytoplankton were determined. Immuno-Strips were used to screen the microcystin and HPLC done to detect the toxin (PDA). Data compilation, processing and analysis were performed using XL software and MINITAB statistical package.

Total phosphate concentration in Nuwara wewa (2.14±0.29 mg L^{-1}), Thuruwila (2.56±0.49 mg L^{-1}), Kattakaduwa (3.73±0.05 mg L^{-1}) and Ridiyagama (2.5±0.05 mg L^{-1}) exceeded the maximum permissible level for drinking water quality standards (2.0 mg L^{-1}). All the other water bodies showed low phosphate (< 2 mg L^{-1}) and low nitrate (< 0.1 mg L^{-1}). Cyanotoxin, Microcystin-LR was detected only in Kattakaduwa tank (10 µg L^{-1}) that exceeded the safe limit (1 µg L^{-1}) given by WHO for drinking water.

The study showed that the fifteen water bodies were dissimilar to each other with respect to their morphometry, drainage area, source water, hydrology and utility related operational and fishing practices resulting in variable water quality characters and species composition and density of plankton algae. Potentially toxic, nuisance cyanobacteria species, *M. aeruginosa*, *Cylindrospermopsis raciborskii* and *Anabaena* sp., were reported dominantly in almost all study water bodies, detected with high phosphorous content most of the times, without any bloom condition observed during the study period. However, due to the growing algae problem, provision of safe drinking water will be a global challenge in the near future emphasizing further studies on nuisance algae, cyanotoxins and water quality.

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DIVERSITY AND ABUNDANCE OF PLANKTONIC ALGAE AND THEIR RELATIONSHIP TO MEASURED ENVIRONMENTAL VARIABLES IN THREE SELECTED FRESHWATER RESERVOIRS IN CENTRAL PROVINCE, SRI LANKA

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Monitoring the water quality of reservoirs can be done by both physicochemical and biological analyses. During the recent past, microscopic planktons have become popular as successful biological indicators in environmental studies. Among them, diatoms have become the most promising biological indicators to predict eutrophication especially cultural eutrophication. It is essential to understand the diversity, abundance and ecological characteristics of these indicators in a particular biogeographical region before using them in any environmental application.

Sri Lanka claims remarkable history of reservoir construction and as a result 4% of the total land area is covered with human made lentic water bodies. Small reservoirs have also been constructed to supply water for animal husbandry and other farming activities within the Wet Zone and in the marginal areas of Sri Lanka. As many of these Wet Zone reservoirs have started to show signs of water quality problems such as development of algal blooms, sudden fish kills and development of bottom anoxia, it has become an urgent need to understand them and to apply suitable mediatory measures.

Three reservoirs located in the Kundasala area were selected for the current study; Lake Walala, Lake Kundasala and Lake Dambarawa to assess the potential use of planktonic algal community as indicators in environmental applications. Phytoplankton samples were collected once a month for a period of six months during, December 2011-to May 2012. Following standard procedures phytoplankton composition and abundance in each reservoir was determined. Selected limnological variables (pH, conductivity, dissolved oxygen, temperature) were also measured at each sampling and the relationship between species composition of phytoplankton and measured environmental variables were analyzed using correlation coefficient (Minitab 14 version). The results revealed that *Microcystis aeuriginosa*, *Aulacasseira granulata*, *Pediastrum* sp., an unidentified filamentous algae and *Euglena* sp. were the dominant taxa in the study reservoirs. The most abundant group recorded from Walala reservoir was *Microcystis aeuriginosa.* In Kundasala reservoir filamentous green algal variety and *Microcystis aeuriginosa* were recorded as the dominant taxa and in Dambarawa reservoir *Microcystis aeuriginosa* and *Aulacasseira granulata* were dominant. Accordingly the study reveals that *Microcystis aeuriginosa* is the dominant species in these isolated reservoirs. Statistical analyses show that in Walala reservoir, pH, conductivity and dissolved oxygen were negatively correlated with species composition of phytoplankton while temperature was positively correlated. In Kundasala and Dambarawa reservoirs, temperature and dissolved oxygen were positively correlated with the species composition while pH and conductivity were negatively correlated with species composition. Accordingly, the identified phytoplankton species in the three study reservoirs appear to be sensitive to some measured environmental variables, showing the potential of using them as water quality indicators.

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BIOSORPTION OF LEAD(II) FROM AQUEOUS SOLUTIONS BY *Hydrilla verticillata*

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Discharge of effluents from industries, such as battery, paint and plastics, causes lead pollution in water resources. Since lead is toxic to life, it is necessary to remove it from the environment. Biosorption offers an alternative, cost-effective and biological environmental remediation methodology instead of conventional physico-chemical methods which are more expensive. The purpose of this study was to determine the potential of dry biomass of *Hydrilla verticillata* as a biosorbent to remove Pb(II) from aqueous systems.

The biosorbent was prepared by drying the plant biomass at 70 °C to a constant weight and grinding with a mortar and pestle. The effect of contact time was determined by mixing 200 mg of ground sieved biosorbent with 100 cm^3 of 6.0 mg L^{-1} Pb(II) solutions at ambient temperature and at pH 5.0. The suspensions were shaken on an orbital shaker at 140 rpm at predetermined time intervals and filtered. The filtrates were analysed for residual lead concentration by atomic absorption spectrophotometry (AAS). In addition, the effects of solution pH and initial metal ion concentration on the removal process were studied by varying necessary parameters. The surface of the biosorbent, before and after the sorption process, was analysed by Fourier transform infrared (FTIR) spectrophotometry to determine the types of functional groups involved in the adsorption process.

Batch sorption studies showed that 86% of Pb(II) could be removed from aqueous solution within two hours. The extent of sorption increased with the increase in the pH of the medium and reached an optimum value at 4.0 and decreased with further increase in pH. The adsorption capacity at equilibrium was significantly increased with the increase in the initial Pb(II) concentration in the aqueous solution. The biosorption process followed the pseudo second-order kinetic model with a rate constant of 0.140 g mg^{-1} min^{-1}. The adsorption of metal ions on to the surface of the biosorbent obeyed both the Langmuir and Freundlich isotherm models, indicating that either a mono-layer or a multi-layer of Pb(II) ions could be formed during the biosorption process. FTIR spectra of the biosorbent confirmed the involvement of –OH groups of the biosorbent surface for Pb(II) removal process. This research indicates that non-living biomass of *Hydrilla verticillata* is suitable as a cost-effective biosorbent for the removal of Pb(II) from contaminated effluents.

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POTENTIAL USE OF *Azolla pinnata* AS A BIOSORBENT FOR REMOVAL OF AQUEOUS LEAD(II)

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The use of heavy metals in manufacturing processes has lead to major environmental and health concerns in the society, due to the absence of safe disposal and recovery methods. Health effects of heavy metals are caused by vary low dosages and cause chronic effects on humans, which can be biomagnified in the food chain. Among heavy metals, Pb(II) is used in the paint industry, battery manufacturing and even in plumbing domestic pipes which are used to deliver water. Pb(II) can be absorbed into the human body by inhaling, orally, or through the skin. In oral toxification, gastrointestinal tract absorbs 5-15% of Pb(II) which is mainly retained in the bones. In the human body, Pb(II) ions can bond with hemoglobin in erythrocytes, which has a short life span of hours to days. These hemoglobin bonded metal ions are then transported to soft tissues, and finally excess lead is retained in the bones. Therefore, it is essential to remove Pb(II) from contaminated environments. Removal of heavy metals from aqueous systems includes conventional physico-chemical methods, such as ion-exchange, membrane filtration and chemical precipitation, which are expensive and require intervention of the environment. This study investigated the capacity of dead *Azolla pinnata* biomass to remove Pb(II) from contaminated aqueous systems.

A. pinnata was dried at 60 $^{\circ}$C for 24 hours, ground with a mortar and pestle and sieved. Batch sorption studies were carried out by mixing 0.2 g of biomass with 100 mL of 3.0 mg L^{-1} Pb(II) solution at room temperature and at pH 5.0 on an orbital shaker at 100 rpm. Samples were filtered and analysed by atomic absorption spectrophotometry. Biosorbent surface was characterised by Fourier transform infrared (FTIR) spectrophotometry.

Batch sorption studies with the dried biomaterial removed 97% of Pb(II) from the aqueous system within 30 minutes. The removal capacity at equilibrium was 1.67 mg g^{-1}. The pH of the medium showed a significant effect on biosorption with an optimum pH range from 4.0 to 6.0. FTIR spectral analysis to identify the functional groups involved in biosorption revealed that -OH groups were involved. The Pb(II) removal data were compatible with the pseudo-second order kinetics model with a rate constant of 0.46 g mg^{-1} min^{-1}. The Freundlich isotherm was found to represent Pb(II) adsorption by dead biomass of *A. pinnata* more accurately than the Langmuir model. The analysis of adsorption data also showed that the removal of Pb(II) by *A. pinnata* is a complex process, involving both boundary layer diffusion and intra-particle diffusion. This study indicates that dead biomass of *A. pinnata* could be used as a cost-effective and environmentally friendly biosorbent to remove Pb(II) from contaminated aqueous environments.

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DEVELOPING CATHODE MATERIAL WITH HIGH ELECTRO-ACTIVE AREA FOR ELECTROCHEMICAL DENITRIFICATION IN CHLORIDE-FREE ELECTROLYTES

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The use of synthetic fertilizers is a common practice in agricultural countries, such as Sri Lanka. The increased use of nitrogen–based fertilizers has been reported to lead to elevated levels of nitrate in groundwater. Nitrate is a known cause of methamoglobinemia, and it can be carcinogenic. In accordance with the World Health organization (WHO)'s drinking water standard, the maximum limit of 50 mg L^{-1} NO_3^- (15 mg L^{-1} NO_3^- for infants) in drinking water is permitted.

Among other denitrification technologies, such as physiochemical and biological methods, electrochemical denitrification is an attractive technology since it is easy to operate and maintain. In addition, by careful development of material, electrochemical denitrification can offer high efficiencies at lower energy cost. However, most of the reported studies are based on commercially available electrode materials. As electrochemically generated chlorine is used to oxidize byproducts of nitrate reduction, available methods are confined to electrolytes with chloride ions.

In this study, the attention was paid to the development of novel electrode materials considering electrode properties pertaining to a higher degree of nitrate removal in chloride free environment. Cathode material was developed using copper as the main coating material. Optimization of cathode material was done by statistical based experimental design using Minitab 16 software. The experiment was performed by varying three independent parameters, namely, current density, plating duration and copper concentration. Anodic charge which represents the electro-active surface area of the electrodes was measured using Metrohm Autolab PGSTAT 128N. Nitrate reduction was accomplished using the cathode developed in chloride free environment with the oxide of rare earth metal (IrO_2), as the anode.

Removal of nitrate is feasible under laboratory conditions by the use of copper coated on Ti substrate as cathode material and an electrode coated with rare earth metal oxides (IrO_2) as anode material. High degree of nitrate removal (70%) was achieved by this electrochemical reduction process within a short time period as 120 minutes. In accordance with the results obtained, optimum electrode plating conditions for current, duration, and copper concentration were 50 mA, 3 hours and 0.2 mol L^{-1}, respectively.

Higher current densities, higher plating durations and lower copper concentration produce electrodes with higher surface area. The efficient removal of nitrate is generally represented by electrodes with higher anodic charge, which indicates higher electrochemically active surface area of the electrodes. All three parameters investigated play a significant role in nitrate reduction by Cu/Ti cathode. In conclusion, high current densities and long plating durations increase the surface area while high copper concentrations decrease.

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EVALUATING THE EFFICIENCY OF A WASTE TREATMENT PLANT IN A TEXTILE MANUFACTURING COMPANY IN SRI LANKA

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Textiles are manufactured to perform a wide range of functions and made up of different types of fibres mixed in varying proportions. Existing textiles industries significantly contribute to the current deterioration of the environment in the country. Some textile industries do not have any wastewater treatment facilities, and wastewater is directly discharged into water bodies or onto the ground, causing surface and ground water pollution. The wastewater discharge from textile industries consists of varying degrees of pollution strengths, such as, hot, alkaline, strong smelling and coloured dyes and chemicals. Some chemicals are toxic and can lower the dissolved oxygen content of receiving water, which can threaten aquatic life and damage general water quality downstream.

Analysis of effluent in terms of parameters BOD_5, COD, TSS, pH and conductivity was carried out using standard methods to check the efficiency of the waste treatment plant selected. The textile industry selected dealt with scouring, bleaching, dying, printing and washing while taking raw cloth as raw material. As a result, effluent of this industry contains mainly starch, glucose, enzymes, excess dyes, pigments, chlorinated aromatic organic compounds, etc. The treatments employed in the wastewater treatment in this industry are chemical (Coagulation, flocculation and sedimentation) and biological (Aerobic) treatment.

With the addition of chemicals, such as alum and ferric chloride, most of the substances clogged leaving a small amount of waste for chemical degradation with oxidising agents. When suspended solid particles are removed by coagulation, BOD is automatically reduced. Therefore, chemical treatment through coagulation, flocculation and sedimentation has been very effective in this process. In this study, the difference between COD and BOD gives a clear idea that waste contains a large amount of biodegradable matter, such as starch and glucose. The average removal efficiencies further confirmed that the chemical treatment unit of this industry is operating smoothly and efficiently with respect to BOD and COD removal of 83% and 59%, respectively. However, both sand bed and aerated lagoon showed very low removal efficiencies (20 – 35%) for both BOD and COD leaving fairly high BOD and COD at the end. The final values do not meet the tolerance limits according to the national standards for waste from textile industries being discharged into inland surface water (1/2008). Therefore, the treatment unit has to be optimised to achieve the best possible performance. It is suggested that the contribution of effective and efficient microorganisms be strengthened to achieve environmentally friendly and less toxic effluent.

The pattern of changing total suspendable solids (TSS) with different treatments indicates that a drastic drop of TSS after the sand bed treatment indicating efficient removal of solids. The pH decreases with treatment due to the addition of acidic chemicals,

although it increases during aeration as it promotes the breakdown of organic matter by biological organisms. The increase in pH confirms a reasonable decomposition and the efficiency of biological organisms in the system even though the removal efficiencies are low.

The overall results conclude that the effluent treatment plant investigated performs reasonably well for TSS with sand bed treatment and does not operate efficiently for BOD and COD with sand bed and aeration treatments while lowering the performance of the entire process. The low efficiency may be due to insufficient chemical dosage, improper settling of sludge in the sedimentation tank, operational failures, poor maintenance and poor conditions of the aeration tank of this industry. The results also suggest that having a sand bed after activated sludge could further improve the quality of final discharge due to the presence of sludge after biological treatment.

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EFFECT OF ADDITION OF ALUMINUM ION FOR COLOUR REACTION OF LANTHANUM ALİZARİN COMPLEXONE AND APPLİCATİON TO VİSUAL ANALYSİS OF FLUORİDE İON

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Fluoride contamination of drinking water has caused serious health problems, such as mottled teeth in developing countries. Therefore, development of a simple analytical technique for fluoride determination is highly desirable. Colorimetry is one of the effective methods for on-site analysis of fluoride, because it does not require an instrument to determine sample concentration. However, this method causes individual differences of the analytical result, due to difficulties in judging the concentration by colour contrast. Recently, we have found a binary colour reaction when aluminum ion is mixed with lanthanum alizarin complexone (La-ALC), which is the colour reagent for fluoride. Moreover, number of discoloring rectangles is changed with fluoride concentration using this binary color reaction (Figure 1). Based on these findings, the binary reaction of La-ALC and aluminum ion was examined, and the development of visual analysis for fluoride using the binary color reaction was attempted.

For this purpose, 0.1 mL each of an aluminum ion solution with several concentrations was added to La-ALC solution. After addition of samples to each of the rows, fluoride concentration was judged by counting the number of color changing rectangles.

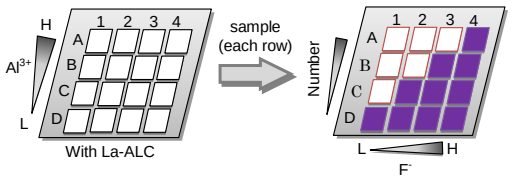

Fig.1 Principle of the proposed method

It was found that a binary colour reaction was observed when aluminum ion was mixed with La-ALC and that fluoride concentration required for discoloration changes depending on the concentration of aluminium ions. By using this binary color reaction, fluoride concentration can be determined by counting the number of discoloured rectangles.

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STUDY OF ORDER OF REMOVAL OF HEAVY METALS USING BREADFRUIT PEEL WASTE

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Environmental pollution has increased at an alarming rate as a result of population growth, industrialization and urbanization. Improper management of solid waste results in pollutants, such as metals and dyes, which would eventually end up in water ways leading to health and environmental consequences. Even though there are methods available, such as ion exchange and chemical precipitation, for the removal of heavy metals, environmental scientists attempt to provide low-cost and environmentally friendly solutions for the removal of pollutants from contaminated water. In this context, substances, such as different clay types, peat, rice husk, saw dust and plant components, have been investigated.

In this study, breadfruit peel, a waste material, has been used as an effective biosorbent to investigate the extent of removal of metal ions from aqueous solution. Percentage removal was determined using atomic absorption spectroscopic measurements of 50.0 cm^3 of each metal ion, Cd(II), Cr(III), Cu(II), Pb(II) and Zn(II), of 10 ppm concentration when treated with 0.10 g breadfruit peel for 2 h shaking time at 150 rpm followed by 4 h settling time. The order determined was Pb(II) > Cd(II) > Cu(II) > Cr(III) > Zn(II). Lead shows the greatest affinity towards breadfruit waste with a removal of 91% from solution, while only 28% of Zn(II) is removed. Removal efficiencies of Cd(II), Cu(II) and Cr(III) are 85%, 69% and 61%, respectively.

Sorption of metal ions from aqueous solution to breadfruit peel occurs through many modes of mass transfer, including ion exchange, complexation and adsorption. Surface titrations indicate that breadfruit peel has a negative charge at the ambient pH of 4.8, suggesting the possibility of Columbic attraction promoting direct adsorption which would be followed by ion-exchange. Thermal gravimetric analysis and Fourier Transform Infra-red spectroscopic studies reveal that breadfruit peel contains organic functionalities, such as carboxylic acids, amides and phenolic compounds, which could be responsible for sorption of these cations through complexation. The order of removal of cations investigated can be explained by considering the formation constants of metal ions for complexation with acidic moieties and their hydrated radii.

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EVALUATION OF ION ADSORPTION CAPACITIES OF MURUNKAN CLAY AND COIR AS COST EFFECTIVE MATERIALS FOR DESALINATION OF WATER

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With the increase of global population, potable water mass is becoming insufficient. Searching for alternative water sources suggests the possibility of desalination of sea water which covers a large mass of the earth's crust. Many attempts for cost effective methods of desalination of sea water have being reported. However, none of them have proven to be economically efficient and environmentally friendly. Considering the current global and local need for an efficient physical method for desalination, this study focuses on exploring low-cost, efficient, eco-friendly and sustainable materials suitable to be used in domestic or regional level desalination plants.

Pure Murunkan clay and three different types of coir; red coir, pith free coir and activated coir have been used as materials for the study. Coco coir was chosen as a suitable material due to its high ion holding capacity and porosity, and Murunkan clay was chosen due to its high ion exchange capacity (70 – 100 meq/100 g at pH 7).

Adsorption of the cations, Na^+, K^+, Mg^{2+} and Ca^{2+}, was evaluated using Atomic Absorption Spectrometry at the respective wavelength of each cation. Water samples from the Negombo lagoon were used to study the ion removal by Murunkan clay in both column and batch modes. In the latter mode, respective water samples were stirred in clay for 30 min and kept in contact for a further time period. Optimization of ion adsorption was accomplished using purified and unpurified clay by varying the clay mass and contact time. To evaluate ion adsorption capacity by individual coir types, 50.00 mL water samples were passed through columns packed with filter material. Optimization was done by varying the mass of filter material and contact time. Furthermore, water samples were passed through a column combination of three types of coir after stirring in clay for an optimized period to evaluate the total ion removal by the two types of material. All measurements were replicated, and the average values are reported.

It was found that all three types of coir show the maximum percentage removal of ions initially, which decreased with a longer contact time. Saturation of coir is observed after 50 min of contact time. The concentrations of Na^+, K^+, Mg^{2+} and Ca^{2+} before treatment were found to be 30 112, 634, 35 385 and 1 147 mg L^{-1}, respectively. Under optimized conditions, the extent of removal of Na^+ pith free coir and red coir by saturates between 40% - 30%, while activated coir which has a higher surface area than normal coir shows a maximum of 55% removal. The percentage removal of Na^+ by the coir mixture is quite high (75%) at the very beginning and remains constant at 55% after 80 min. The maximum Na^+ removal in 1.0 L of lagoon water was achieved with 40 g of coir. The highest percentages of removal of ions was observed in the column combination method with values of 50%, 52%, 63% and 85% for Na^+, K^+, Mg^{2+} and Ca^{2+}, respectively, under optimized conditions.

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OPTIMIZING THE REMOVAL OF SUSPENDED MATTER AT FLOCCULATION TANKS BY USING ZETA POTENTIAL MEASUREMENTS

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Safe drinking water should be clear of suspended matter, which is removed at sedimentation and filtration processes by adding aluminum or iron based chemical coagulants. Over dosage of aluminum may lead to residual aluminum in drinking water. High aluminum uptake has been linked to Alzheimer's disease. Addition of an optimum dosage of coagulants for removing suspended matter is important. Usually in water treatment plants, coagulant dosage is determined by the Jar Test which simulates the treatment process itself. However, the results of this test depend on the operator's experience and knowledge of water chemistry. Another method of determining the appropriate coagulant dosage is the Zeta Meter Method, which has not yet been introduced to water treatment plants in Sri Lanka.

This study was conducted as a pilot experiment with the primary objective of optimizing the chemical consumption of coagulants in water treatment plants by Zeta meter measurements. The secondary objective was to examine the suitability of the Zeta meter method to replace the conventional Jar test method with preset standard matrices of dosages against raw water pH and turbidity.

Two treatment plants from each of the three water supply subdivisions of the National Supply and Drainage Board (Central Province) were used for the study. Water samples collected from each treatment plant were first subjected to conventional Jar Testing method. Six Jars containing equivalent volumes of raw water were tested for turbidity, and a series of predetermined (PAC/Alum) chemical dosages were added. The six jars were mixed concurrently under 300 rpm for 25 minutes and 20 rpm for 20 minutes. After 20 minutes of settling time, turbidity of water in each jar was tested and the chemical concentration corresponding to the jar containing the least turbid water was taken as the optimum chemical dosage. The samples were subjected to the Zeta Meter Method, and the same procedure was repeated except that the six jars were mixed individually under 300 rpm for 1 minute only. Using the Zeta meter system 4.0, the Zeta potential of each water sample was measured. By plotting the Zeta potential vs. concentration, the concentration relevant to zero Zeta potential was determined as the optimum concentration. The results obtained from each method were compared to determine the best chemical dosage.

The results indicated that the Zeta Meter Method is relatively more sensitive and less time consuming than the Jar Test. The optimum chemical dosages determined by the Zeta Meter Method were either greater or less than the values obtained from the Jar Test depending on turbidity of water and stock solution concentration. Due to greater accuracy, less chemical and time consumption and lower cost compared to the conventional Jar Test, Zeta Meter Method is more suitable to be used in water treatment plants.

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POTENTIAL APPLICATION OF PEAT FROM BRUNEI DARUSSALAM IN DECOLOURIZING INDUSTRIAL EFFLUENTS: EQUILIBRIUM AND KINETIC STUDIES ON ADSORPTION OF CRYSTAL VIOLET (CV)

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The demand for coloured textiles continues to increase. As a result, the use of textile dyes and their discharge as industrial effluents have increased, causing damage not only to aquatic life, but also to the human beings on the account of the mutagenic and carcinogenic effects possessed by some of these dyes. Therefore, it is extremely essential to discover economical and effective methods to remove dyes from industrial discharges. Various treatment methods, including coagulation, adsorption, electrochemical techniques and fungal decolonization, have been used in this regard. Among these methods, adsorption has become popular due to its efficiency and low-cost for the removal from waste stream.

The study reported here was focused on the potential use of peat available in Brunei Darussalam to remove crystal violet (CV) from wastewater. Peat, contains a large amount of organic substances and was especially selected as it is low-cost, locally available, eco-friendly and highly efficient to remove dyes. The study was carried out by varying experimental conditions, such as agitation time, settling time, pH and dye concentration, at ambient temperature to optimize parameters for the most efficient sorption. The results show that the optimum agitation time for the heterogeneous system of peat-dye solution to reach the equilibrium is 2 h, which is shorter than many other adsorbent-dye solution systems. The optimum pH for adsorption of CV is 5.19. Among Langmuir, Freundlich and Tempkin adsorption isotherms, Langmuir isotherm shows the best correlation with a monolayer adsorption capacity of 67 mg/g. Sorption kinetics was found to fit well on the pseudo-second-order model with a high regression coefficient (R^2).

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REMOVAL OF FLUORIDE FROM DRINKING WATER BY CHICKEN BONE CHAR

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Groundwater is an indispensable source of drinking water of many rural communities in Sri Lanka. However, in some regions, groundwater is known to contain high levels of fluoride. As a result, many people suffer from health problems, especially dental and skeletal fluorosis. In addition, the Chronic Kidney Disease of unknown etiology (CKDu) is becoming common in high fluoride areas of Sri Lanka. Therefore, the present study was initiated to remove fluoride from drinking water as it has become an urgent need.

The current study was undertaken to remove fluoride using chicken bone char (CBC) since the material is economically viable and that could also be acceptable from the religious point of view. Previous studies have shown that fluoride concentration could be decreased to near zero by CBC in a tea bag immersed in water. The adsorption rate of CBC does not depend on the temperature of water in the range of 20 °C and 40 °C. In addition, it has been found that the adsorption rate is not affected by the particle size although the efficiency of the performance of removal of fluoride could be increased by increasing the amount of CBC.

Therefore, a defluoridation column filter with a diameter of 5.6 cm, bed height of 16 cm filled with 142 g of CBC was prepared to maximize the performance of fluoride removal. A solution containing 50 mg L^{-1} of fluoride was allowed to pass through the column at the rate of 7 mL min^{-1} which is equivalent to 10 L day^{-1}, an average drinking water consumption of a Sri Lankan family. It was found that the fluoride concentration in the solution decreased to 0.3 mg L^{-1} after 66 minutes at the beginning of the experiment. However, it increased gradually with time. We made a numerical model based on the experimental data to reproduce the variation of the fluoride concentration assuming first-order kinetics. According to kinetics analysis, a defluoridation column filter was designed with a diameter of 10.7 cm and column length of 21.0 cm and 558 g of CBC. This apparatus is expected to fulfill the requirement of drinking water of an average family of fluoride affected areas in Sri Lanka for approximately 5 months. Monitoring of the performance of the defluoridation column filter is currently in process

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ADSORPTION BEHAVIOUR OF METHYLENE BLUE (MB) AND METHYL VIOLET 2B (MV) ON THE SKIN OF NANCHEM (*Artocarpus* Spp.) GROWN IN BRUNEI DARUSSALAM

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With uncontrollable increase in water pollution due to ever increasing industrial activities, it is important to explore possibilities of using natural, environmentally friendly and low-cost materials for remediation of water contaminated with pollutants. An attractive approach is to develop methodologies for bioremediation of pollutants, based on food waste as potential biosorbents, which is otherwise wasted without any useful applications. In this context, the research reported here is on the use of the skin of Nanchem, a hybrid of *Artocarpus cempedan* (Cempedak) and *Artocarpus heteropyllus* (Jackfruit), grown in Brunei Darussalam as a potential material for bioremediation of methylene blue (MB) and methyl violet 2B (MV), both of which are used in many industrial activities such as colouring cotton, wood and silk.

The two phase dye solution-*Artocarpus* (skin) biosorbent system approaches sorption equilibrium relatively fast. The maximum removal was obtained at a shaking time of 1.5 h and 3 h for MB and MV, respectively. Analysis of the amount of each dye adsorbed on *Artocarpus* skin as a function of the equilibrium concentration of the dye indicates that the isotherms follow the Langmuir adsorption model with high regression coefficients for interaction of the dye. Based on the Langmuir model, the maximum capacities of the Nanchem skin are determined to be 190 mg/g and 226 mg/g for MB and MV respectively. The high adsorption capacity of Nanchem skin towards MB and MV, even without any chemical modification, demonstrates its great potential as a biosorbent to remove dyes. Further, the Langmuir isotherm model leads to higher regression coefficients than those led by the Freundlich isotherm, indicating that monolayer coverage of the dyes is favorable over multilayer coverage.

Rate of biosorption of each dye on the skin of this *Artocarpus* variety, determined while the concentration of the dye is in excess, indicates that the linearized pseudo second order kinetics model is valid with high regression coefficients. Having the second order kinetics fulfilled is indicative of the presence of two reactive centers of *Artocarpus* biosorbent for attraction of dye molecules. Expansion of such studies for dynamic conditions that can be further expanded in real applications will be the next logical step of this research.

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THE EFFECT OF BREEDING PLACE ON THE FILARIAL INFECTION RATE OF LARVAE

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Mosquitoes spread diseases and are therefore a health hazard. All mosquitoes breed in collected water, although the breeding places can be different. In order to control disease, the effect of breeding place on the spread of disease needs to be studied. As Filaria is one of the most commonly observed diseases, prevention and control programs are vital to keep the spread of the disease to a minimum level. Mosquito studies were carried out in Sri Jayawardenepura during 1981-1982 by the Medical Research Institute (MRI) of Sri Lanka. Sri Jayawardenepura area, at that time, was a neglected marshland until steps were taken to relocate the capital as the country at that time. Thus, this location was an ideal place for studying the breeding of mosquitoes. The main objective of the study was to identify and examine breeding habits and filarial infection rate at larval stage of filarial disease carrying mosquitoes.

Twelve towns and villages that represent urbanised, semi-urbanised and rural areas around the new capital city were selected for this study. Weekly visits were made during the period from March 1981 to February 1982 for larval collections, which were done using the Stratified Random Sampling Method. Mosquito larvae were collected from a wide range of breeding habitats, dissected and tested at the MRI laboratories for filarial infection. The data set consisted of 240 observations and 8 breeding places, namely, tyres, plant axils, pools, swamps, drains, wells, tree holes and pits.

Descriptive analysis was used to explain the distribution of all mosquito larvae among the breeding sites. Univariate analysis in terms of Chi-square tests was carried out to determine whether the distribution of filarial mosquito larvae was different at different breeding sites. The advanced analysis consisted of logistic regression on the binary variable was performed to quantify the effect of the breeding sites on larval infection.

Results revealed that the location and the month had no effect on the infection of larvae, but only the breeding place affected for the filarial infections in mosquito larvae ($p = 2.07*10^{-3}$). Investigation of the model parameters showed that the highest infection rate was observed in tyres followed by tree holes, wells, swamps and pits. Mosquito larvae in pools and drains, which are regularly cleaned or to have clear water, showed a much lower rate of filarial infection.

The odds of larval infection being present in tree holes, wells, swamp holes, pits, pools, drains and plant axils are 0.16 ($p = 0.002$), 0.15 ($p = 0.002$), 0.09 ($p < 0.001$), 0.08 ($p < 0.001$), 0.08 ($p < 0.001$), 0.04 ($p < 0.001$) and 0.03 ($p < 0.001$), respectively, as compared to tyres. This indicates that the popular breeding sites of Filaria vector mosquitoes are the places where there is stagnated water. Thus, destroying stagnant water sites can be recommended in order to eradicate Filaria.

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OCCURRENCE OF NONTUBERCULOUS MYCOBACTERIAL SPECIES IN DIFFERENT WATER SOURCES OF SRI LANKA

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Nontuberculous mycobacteria (NTM) are a major cause of opportunistic infection, especially in immune-compromised patients. Water plays a major role in the epidemiology of nontuberculous mycobacterial infections in humans, as it is one of the natural sources for transmission of this group of organisms. The present study focused on determining the occurrence of NTM species in different water sources of Sri Lanka.

A total of 302 water samples were collected from all 25 districts of Sri Lanka, from four different water sources namely; surface water (n=88), ground water (n=76), aquarium water (n=70) and chlorinated tap water (n=68). Mycobacteria were isolated from the water samples by decontamination using 4% sodium hydroxide and cultivation on Lowenstein-Jensen medium. Phenotypic tests and polymerase chain reaction – Restriction Fragment Length Polymorphism analysis (RFLP) of the RNA polymerase beta subunit genes (PRA – rpoB) were employed for species identification. Twelve surface water samples were excluded from the study owing to the overgrowth of contaminants. Of the remaining 290 samples, 45 (15%) from 19 districts were positive for NTM on culture. The frequency of isolation of mycobacteria for aquarium water, surface water, ground water and chlorinated water were 29% (20/70), 26% (20/76), 5% (4/76) and 1% (1/68), respectively. Twelve different NTM species were identified by PRA – *rpoB* namely, *M. fortuitum* type I (n=11), *M. fortuitum* type II (n=4), *M. phlei* (n=7), *M. scrofulaceum* (n=5), *M. gordonae* type I (n=2), *M. gordonae* type II (n=2), *M. marinum* (n=3), *M. malmoense* (n=2), *M. terrae* (n=2), *M. avium* (n=1), *M. szulgai* (n=1) and *M. celatum* type II (n=1). The RFLP profiles of four NTM isolates did not match any known mycobacterium species and might represent mutants or previously undescribed NTM species. *M. fortuitum* type I was the most frequently isolated organism from all four water sources (11/45, 24%) as well as the predominant NTM isolate of aquarium water (10/18, 56%). The widespread occurrence of NTM species in water sources of Sri Lanka could be a potential public health hazard especially for those with immunodeficiency disorders.

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EFFECT OF COEXISTING IONS ON THE REACTION OF FLUORIDE WITH CALCIUM PHOSPHATE (DCPD) FOR WATER TREATMENT

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Removal of fluoride from the water environment is one of the important issues for the environmental engineering such as treatment of waste water and ground water. Various fluoride removal techniques, such as precipitation and adsorption have been reported. Formation of fluorapatite (FAp) is one of the suitable methods for fluoride removal because of low solubility of FAp. However, addition of an excess amount of calcium and phosphate salts is required for the formation of FAp from waste water containing fluoride. We therefore, focused on FAp formed from another calcium phosphate compound, calcium hydrogen phosphate dihydrate (DCPD), and investigated reaction with a small amount of fluoride. DCPD used for fluoride removal can be prepared from under-utilized resources, such as corbicula shell and industrial sludge. In using this reaction to remove fluoride in polluted water (such as ground water), investigation of the effects of various coexisting ions to the reaction is very important. In this paper, effect of magnesium ion (common element in natural waters) on the reaction of DCPD with fluoride ions was investigated.

Reagent grade DCPD (Taihei Chemical, Japan), solutions of sodium fluoride and magnesium nitrate were used in this study. A 20 mg sample of DCPD was mixed with 20 mL of solution containing 20 mg L^{-1} of fluoride and various amounts of magnesium ion. The mixture was shaken by a reciprocal shaker for 24 hours. Temperature was controlled at 25 ºC by installing the shaker in an incubator. Liquid and solid phases were separated by centrifugation and filtration. Fluoride concentration in the liquid phase was measured by ion chromatography. The solid phase obtained was subjected to powder X-ray diffraction and optical microscopic observation.

Experimental results show that the fluoride removal efficiency depends on the magnesium ion concentration. Fluoride is not removed from the solution containing 5 mg L^{-1} of magnesium ion at pH 10. It was found that magnesium ion inhibited the reaction of DCPD and fluoride ion, and the threshold amount of magnesium ion concentration was changed by the pH of the aqueous solution. Fluoride is efficiently removed from the solution containing 10 mg L^{-1} of magnesium ions at pH 4. Controlling pH value was effective to improve reactivity of DCPD with fluoride ion in an aqueous solution containing magnesium ion.

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HIGH SPEED FLOODWATERS SIMULATION BY USING GPGPU

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High speed floodwaters simulation is achieved by using General Purpose Graphical Processing Unit (GPGPU) at the Toyama-bay coastal region in Japan. Floodwaters simulation is required in various cases to prevent water disasters, *i.e*., a water reservoir overflow, a river flooding and a water-level rise at the coast. Floodwaters sometimes damage the human residential areas with very complex features. Therefore, the high resolution data must be included in the simulation.

Graphical Processing Unit (GPU) has high performance parallel calculation units for the computer graphics. In recent years, this ability has been applied to the general numerical calculation (GPGPU). In the present study, the Tsunami (high wave) run-up simulation by using GPGPU was developed. The core technique of simulations is applied to the river and the water reservoir flooding simulation on the land easily because they both are similar phenomena at the point of view the water runs-up on the dry bed.

Tsunami wave is described by the following long-wave theorem, *e.g*., the continuity equation and the momentum equations.

$$\frac{\partial \eta}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial x}=0$$

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left[\frac{M^2}{D}\right]+\frac{\partial}{\partial x}\left[\frac{MN}{D}\right]+gD\frac{\partial \eta}{\partial x}+\frac{gn^2}{D^{7/3}}M\sqrt{M^2+N^2}=0$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}\left[\frac{MN}{D}\right]+\frac{\partial}{\partial x}\left[\frac{N^2}{D}\right]+gD\frac{\partial \eta}{\partial y}+\frac{gn^2}{D^{7/3}}N\sqrt{M^2+N^2}=0$$

where x and y are space coordinates, h is static depth, g is gravity acceleration constant, η is elevation, D is total depth (= h + η) and n is Manning coefficient. M and N are flux for x and y directions, respectively. These equations are discretised by using Leap-frog method for continuity and momentum equations. The first order upwind scheme is adopted for the advection terms. Iwasaki and Mano method was included as the leading edge condition of the wave on the dry bed.

According to the results of Tsunami run-up simulation at the Toyama New Port in Japan, high waves get over the breakwater and runs-up on the land. The simulation includes grid size geometry data, and as a result, 3,341,250 (2,475 × 1,350) points were used. The simulation is calculated on the GPU named TESLA C2075 (NVIDIA) in about 136 seconds and it is more than 80 times faster than the CPU calculation. The simulation realizes both the high resolution (5 m intervals) and the high performance calculation.

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REMOVAL OF HEAVY METALS USING RICE HUSK AND BRICK CLAY AS ADSORBENTS: A STUDY OF DYNAMIC CONDITIONS

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Treatment of industrial waste water has become a necessity to remediate environmental pollution problems which occur mainly due to urbanization and industrialization. Most of the treatment methods available at present are neither economical nor environmentally friendly. Therefore, low-cost and environmentally friendly effluent and waste water treatment methods based on sorption onto natural substances have become attractive alternatives.

In this research, effectiveness of thermally treated rice husk and brick clay were investigated as sorbents for heavy metal ions under dynamic conditions. A mixture of cations consisting of Cd(II), Cr(III), Cu(II), Ni(II), Pb(II) and Zn(II), each at 10 ppm concentration, was tested on these two adsorbents by passing through a column (i.d. = 2.0 cm) packed up to 30 cm with the respective sorbent. The optimum firing temperatures of 100 °C for rice husk and 200 °C for brick clay were used in this investigation for maximum metal ion removal efficiency. Subsequently, two sandwich types of packing: rice husk at the bottom (15 cm) and brick clay on the top (15 cm) [rice husk – brick clay packing], and the reverse order were also employed. After a 5 minute interaction period of the cation mixture with the sorbent, effluent fractions were collected at 5 min intervals for the determination of remaining heavy metal ion concentrations.

According to atomic absorption spectroscopic analysis of the effluent, the extent and the order of removal of metal ions by each sorbent/sorbent mixture depend on the interaction time. The relative ability of rice husk in removing heavy metals is in the order, Pb > Cu > Ni ≈ Cd > Cr > Zn and that of brick clay in the order, Pb ≈ Cr ≈ Cu ≈ Cd > Zn ≈ Ni, based on the average of ten elutions. On the other hand, sandwich columns follow the order, Pb > Cr > Cu > Cd > Zn > Ni for both brick clay- rice husk and rice husk-brick clay packings.

The solutions collected from the column packed with a combination of the sorbents, rice husk-brick clay column results in a higher removal than the brick clay-rice husk column. Further, it is the general observation that Pb(II) shows the highest removal while Ni(II) gives the lowest removal among the cations investigated. It can also be concluded that brick clay is superior to rice husk for the removal of heavy metal ions from solution. This methodology can be extended for treatment of industrial effluents containing heavy metal ions.

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REMOVAL OF AVAILABLE PHOSPHORUS FROM SIMULATED BRACKISH WATER - A LOW COST PRELIMINARY APPROACH

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Removal of nutrients from wastewater is important to manage the nutrient load which impair the sustainability of the receiving environment. Nutrients, such as phosphates (PO_4^{3-}) and nitrates (NO_3^-), prefer to remain in the aqueous phase and are freely mobilized in water. Presence of these species either in excess or at inappropriate places is considered to be nutrient pollution. Wastewater consisting of such anionic pollutants is cumbersome to treat, and consequently, research is needed for the development of simple and economical methods for the treatment of waste containing nutrients.

Current research is based on the preliminary investigation of the removal potential of available PO_4^{3-} from simulated brackish water through adsorption on granulated solid waste material prepared by crushed autoclaved aerated concrete (CAAC), that consists of SiO_2 and $CaCO_3$. Consequently, this approach functions in a dual way by value addition to solid waste and management of pollution load caused by PO_4^{3-} in the receiving environment. This is important especially in aquaculture industry that generates a vast amount of nutrient-rich brackish water during the grow-out period and discharge of pond water at harvesting. Investigation carried out at laboratory level by varying the concentration of PO_4^{3-}-P between 10 mg dm^{-3} and 5000 mg dm^{-3} exhibited outstanding removal efficiency with a maximum removal of about 98% at 100 mg dm^{-3}. Importantly, this solid waste is able to remove PO_4^{3-}-P at significant levels even from solutions of concentrations solutions beyond 2500 mg dm^{-3} under optimized contact time of 240 min at 150 rpm and settling time of 20 min. Moreover, isotherm studies carried out at different concentrations best represent the adsorption of phosphorus from the liquid phase onto the solid phase by the Langmuir isotherm model with a regression coefficient of 0.996.

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FLUORIDE ASSISTED ALUMINIUM LEACHING DURING COOKING AND ITS RELEVANCE TO CHRONIC RENAL FAILURE IN THE NORTH CENTRAL PROVINCE OF SRI LANKA

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Chronic kidney disease of unknown origin (CKDU) in the North Central Province of Sri Lanka is a serious health problem affecting people in this province. The reasons for this disease remain unknown although various risk factors have been suggested. Among these, the role of fluoride in drinking water is an attractive hypothesis since this disease is restricted to high fluoride areas. Other hypotheses such as arsenic in combination with hard water and cadmium are unlikely causative factors since these cannot explain why this disease is restricted to certain geographic areas.

In an earlier study, it was shown that, fluoride enhances aluminum leaching from cooking utensils made of inferior quality aluminium pots. This experiment was carried out in pure aqueous solutions containing fluoride and it is important to investigate aluminium leaching under the actual conditions of food preparation. Therefore, aluminium leaching was studied when rice and dhal were prepared in the presence of an aluminium piece (2.5 × 2.5 × 0.1 cm) taken from an actual aluminium cooking pot. Rice and dhal curry were cooked separately with water containing different amounts of fluoride ions in the 0.5 to 6.0 mg L^{-1} range. In order to account for any aluminum leached from rice or dhal, a control experiment was carried out in the absence of the aluminum piece during cooking. Leached aluminum was determined colorimetrically using the aluminon method. The experiment was repeated by adding several food additives commonly used in cooking in the affected areas, viz., tamarind, gambago (Garcinia) and tomato extracts and the aluminium leached under these conditions were determined.

The amount of aluminium leached was 4.0 mg L^{-1} in the absence of any fluoride during rice cooking. It increased to 14.5 mg L^{-1} level when the fluoride concentration was increased to 6.0 mg L^{-1}. When dhal was cooked under the same conditions, the dissolution of aluminium increased from 2.0 mg L^{-1} in the absence of fluoride to 7.7 mg L^{-1} level when the fluoride concentration was 6.0 mg L^{-1}.

According to the results, intake of aluminum with one meal is estimated to be approximately roughly 60 mg of aluminum in the absence of fluoride which increased to 180 mg in the presence of fluoride. This means that the intake of aluminum by a person in one meal is what is allowed as the safe aluminium intake over a period of 3.6 days according to WHO standards.

Aluminium leaching from rice and dhal with acidic spices is due to the acidic conditions created by the presence of organic acids present and also due to the chelating ability of these acids towards Al^{3+}. Since aluminium is associated with complex aluminofluorides such as AlF^{2+}, AlF_2^{+}, AlF_3 and AlF_4^{-}, the intake of fluoride into the human body through food is also enhanced.

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A POSSIBLE METHOD TO MITIGATE CKD: DEVELOPMENT OF A LOW COST WATER FILTER FOR DOMESTIC USAGE

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The quality of water available for human consumption is very important as it has a direct influence on the health of people. However, obtaining good quality drinking water is an emerging concern in many parts of the country. A commonly found lethal illness among the farmers in the North Central Province (NCP) and the Uva Province of Sri Lanka, Chronic Kidney Disease (CKD) is believed to be due to the poor quality of drinking water.

Many theories have been developed and studied by several scientists in Sri Lanka to identify the root cause of CKD. The exact cause(s) for the disease is yet to be finalised although some studies exhibit considerable correlation. High fluoride content, high hardness, cyanobacteria and arsenic levels are the major concerns. Some experts believe that it is a combined effect of a few or all of the contaminants mentioned above.

Reduction of above contaminants, especially dissolved ions is straight forward with latest technologies such as reverse osmosis. However, the initial and running costs are beyond the reach of an average income person in Sri Lanka. The major objective of the work reported here was to investigate the cost-effective methods available to remove individual contaminants present in water and to apply such techniques at once to obtain a single unit that can be used for domestic purification of water.

The water filter was made by clay due to its ease of handling and low cost. Each filter medium was stored separately in the composite filter assembly and the short-circuiting of water is minimized by the unique design. Filters consisting of ion exchange resin, activated alumina, nano-silver, activated carbon and silica are used to remove hardness, fluoride, arsenic, bacteria, organic chemicals and suspended solids, respectively. The concentration of each known contaminants before and after passing through the assembled filter systems was measured. The results of the study reveal that 80-95% removal of all the above contaminants after filtering through the low cost filter assembled.

The filter is capable of producing a minimum of 20 liters of good quality drinking water per day, which will be sufficient for a family of 5 members. Operating at the above rate, the ion exchange resin needs to be regenerated on a weekly basis by a 10% solution of table salt and the activated alumina has to be replaced once in every three months. The total running cost for the filter will be less than Rs. 200 per month in a continuous run.

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EFFECT OF RAINFALL AND THEIR LAGS ON DIFFERENT TYPES OF DENGUE INFECTION IN SRI LANKA

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Dengue is the most prevalent mosquito-borne viral infection disease, and millions of persons living in tropical and subtropical regions around the world are infected each year. Currently, there is no specific treatment to protect against dengue. Therefore, it is essential to identify the factors which contribute to the spread of the disease as vector control is the only available preventive method. Weather patterns significantly affect the distribution and incidence of dengue through their impact on the mosquito vector. Moreover, the ambient temperature, humidity, as well as human activities affect the viability, duration of survival, replication and transmissibility of the viruses. In Sri Lanka, cases of dengue typically vary throughout the year. However, there is a regular pattern, normally in association with changes in temperature, rainfall and humidity. Since the collection of stagnant water favours the breeding of mosquitoes, Sri Lanka tends to experience dengue outbreaks twice a year due to two monsoon seasons.

This study mainly focuses on identifying the impact of rainfall and their lags on different types of dengue infections, specifically, Dengue Fever (DF), Dengue Hemorrhagic Fever 1 (DHF1) and Dengue Hemorrhagic Fever 2 (DHF2). To accomplish this objective, data about dengue patients reported at from districts during the period of 2006-2008 were utilised. It could be observed that the patients belonging to the same district would tend to have similar characteristics. Thus, it is possible to consider that the individual records of the patients could be clustered within districts to which their residence belongs. This leads to use the concept of multilevel models.

The data were primarily subjected to a descriptive analysis and to a newly introduced technique known as the Generalized Cochran Mantel Haenszel Test for correlated categorical data to assess the relationship between factors and the response in the presence of a multi level data structure. This was followed by an advanced analysis, which adopted the multi level multinomial model as the responses were categorical in nature.

The descriptive analysis showed that the Western Province is a high risk zone for dengue. This may indicate that highly populated urban areas are more favourable for dengue transmission. Further, it was observed that, in each year, two peak incidences occurred within the periods of June-August and September-November for DF. However, the year 2006 has been a high incidence year for DHF1 and DHF2 with one peak around June-August specific pattern for DHF 1 and 2 during the rest of the months. The univariate analysis shows that there is a strong relationship between the type of dengue infection and the rainfall of the previous month ($p = 0.0356$) and two months before ($p = 0.0005$), while the rainfall of the current month shows no relation ($p = 0.0944$). The fitted multinomial model indicates that, when adjusted for other influential factors, the rainfall of the previous month is a risk factor for DHF1 ($p = 0.0032$; or: 1.5281) and DHF2 ($p = 0.0181$; or 0.7565).

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MODEL TO IDENTIFY THE EFFECT OF WATER QUALITY PARAMETERS ON INCIDENCE OF HEPATITIS

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Viral Hepatitis is one of the main water borne diseases and occurs primarily in third world countries. Hepatitis has been endemic in Sri Lanka for many years and, several recent outbreaks were reported during last few years. The dangerous aspect of the disease is that more than 90% of the infected were children. The organisms are transferred through contaminated food, water and faeces of infected people. There are no major research studies on viral hepatitis in Sri Lanka. As contaminated water is one of the major causes of water borne diseases, it is vital to identify the main water quality parameters which cause to Hepatitis. The purpose of the research was to identify the factors affecting the incidence of Hepatitis. Data on this issue were gathered from the Epidemiological Unit (EU) from 2005 to 2008 as per the availability of computerised information. The data consisted of information of all the patients reported to a private or government hospital and collected by the EU. Due to the inconvenience of obtaining the water quality parameters throughout the above period with respect of each district, the scope was limited to the year 2007 within which the number of patients had significantly increased. Data related on water quality was collected from the website of Industrial Technological Unit. The research was based on limited water quality parameters such as pH, conductivity, turbidity, hardness and faecal coliform. These secondary data were measured at different places throughout the year in each district. The time effect was incorporated by considering effect of the month on the response.

As the number of hepatitis cases is ordinal scale and the water quality parameters are continuous, Spearman's correlation coefficients were calculated to explore the primary association of hepatitis cases and water quality parameters. The correlation coefficients (ρ) imply that the incidence of hepatitis has a positive relation with pH (ρ=0.17 with p=0.016) and faecal coliform (ρ=0.1 with p-value=0.15), while conductivity (ρ =-0.216 with p=0.002) has a negative relationship (20% significance level). Incidence of hepatitis was modeled as a function of explanatory variables in this research. Since data are collected on the same units (districts) across the successive structure and the responses are correlated within the cluster (district) and time (month), Generalized Estimation Equations (GEE) methodology was used. The negative binomial distribution was chosen for the response which is appropriate in cases such as this when there is an excess of zeros. Significant variables for the model were selected by considering both the p-value and the Wald test statistics, while following the forward selection procedure. As per the best model, faecal coliform and conductivity are the main factors which affect the incidence of hepatitis out of variables considered with p<.0001 on both. The parameter estimates of the model produces the contribution of each variable to the log of expected number of hepatitis cases recorded in each district of the country throughout the year. According to the best fitted model, one unit increment in the faecal coliform of the water in a particular month increases the expected number of hepatitis cases of that month, where as expected number of hepatitis cases of a particular month decreases as a result of one unit increment in the conductivity of the water.

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