Revista Brasiliense de Engenharia e Física Aplicada

ESSAY

Some Thoughts on the Maintenance of Water Bodies Close to Urban Settings

A GIANT TREATMENT PLANT FOR UPGRADATION OF SEWAGE AND RECYCLING WATER

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Received: _20 Oct 2020_/ Accepted: _04 Dec 2020_ / Published: _31 Oct 2021_.

Editor's letter to readers

This essay was the last writing of my aged good friend in India, Balasubrahmanyam, who has always expressed his strong desire to be addressed informally as simply "Bala". We met briefly, but it was enough to realize that he was an excellent and fine person, and, undoubtedly, a great scientist. From his obituary, with permission of his daughter, Vibhavaree Gargeya, I reproduce here the very significant final excerpt:

> "Twenty-six students received their Ph.D. degrees working under the guidance of SNB. They now occupy prominent positions in academia and industry, both in India and abroad. He lived a contented life, mostly in the Indian Institute of Science campus, with his wife, Chanchal Uberoi, an eminent mathematician and astrophysicist (who died about two years ago). They are survived by their daughter and son, and their respective families.
>
> Overall, the life and times of SNB coincided with the rise of organic chemistry as a central discipline in science with a wide range of implications on all beings in this universe. SNB played his part in promoting this cause."

It is comforting to remember that I was able to address him some words of sincere admiration. I am sure how fruitless my condolences to his family would be, so I leave this Edition as a tribute to my esteemed colleague.

Nilo Serpa

Scientific Editor

1 Synopsis

The traditional system for rainwater harvesting, a matter of wonder, designed to make water available in the dry season in the Deccan Plateau, where rainfall is seasonal, and often ill-distributed, is briefly described. It is shown how the lay of the land and naturally formed drainage were utilized to build storage structures (artificial lakes) using simple but clever engineering. The downstream flow was used to interconnect these storage structures and, most importantly, to utilize the water, thus made perennially available, remained under local control.

The dangers attendant on not stemming abuse and destruction of inexpensively created, ancient storage facilities, not doing anything about setting down practicable wastewater emission standards, and strongly enforcing them, are highlighted. Whatever 'lake development' programs that have been undertaken seem to pay scant attention, if any is attention is paid at all, to how the lakes are going to be kept filled with useful water.

An engineering proposal is put forward in this paper to rejuvenate the ancient system whereby the water from the lake at the lowest level is pumped back into the one at the highest elevation. The many benefits that can be expected to accrue from such recycling are highlighted.

The first step in the proposal is to identify a particular system of serially connected lakes in whatever state of disrepair it may be. As is very likely, sewage ("grey water") would be already polluting the feed of the highest lake. The overflow from this lake would be feeding the next lake that would be already polluted, and so on. All these are surveyed and any repairs, probably requiring only minor engineering interventions, would be carried out. The water in the lowest lake is then pumped back into the lake at highest elevation.

The second step is to set up needed structures in the interconnecting canals for rapid biological clean-up of the re-circulated water through well-researched biological processes. The degree of elevation of the quality of water at every stage is measured by the procedures recommended for standard tests.

The whole proposal, described in some significant detail, is conceived as a gigantic sewage treatment plant. It has the potential to rejuvenate an old, well-conceived system, to maintain water at the requisite purity levels in the lakes, to elevate the quality of sewage close to that of river water, to increase the ground water table level, and so on. It is expected to yield a highly favorable cost/benefit ratio.

2 Ancient history

In a letter to the editor of a prominent Bangalore newspaper, published some time ago, a well-known writer on environmental matters thanks God for endowing a bevy of beautiful lakes in and around Bangalore. God would indeed be embarrassed to take credit for what He would certainly think He did not deserve. For, He intended that there couldn’t be any natural lakes in old geological formations, “yes” in the ‘new’ mountainous regions like the

Alps, the Andes or the 'newer' Himalayas or fractures like Lake Baikal caused by tectonic movements, and "no" in the 'old' Deccan Plateau, He would rather accept thanks for positioning a civilization on the Plateau that produced ancient and modern visionaries and engineers who created those lakes over there in the last one or two thousand years.

3 The Deccan plateau

The "Deccan Plateau" consists, in the largest part, of that triangle-shaped Peninsular India that juts into the Arabian Sea on its west, the Bay of Bengal on its east and points into the Indian Ocean on its south. No, it wasn't always here. It was part of Gondwanaland ("the Land of the Garden of the Gonda Tribe" – named after a still extant human tribe living in east-central part of India). It once touched the island of Madagascar which abutted (or was in contact with) the southeastern coast of the African Continent, while the west coast of Australia has been thought to have flanked its eastern edge. Gondwanaland broke up and the "Deccan" moved generally northeastward to meet the "soft underbelly" of Eurasia. I do not know when the collision happened (more likely perhaps it was a plowing-in) and if Eurasia was where it is now or it came there when Pangaea broke up and formed Laurasia. The Himalaya mountains were raised (and are still rising) and the sea lane between the two land masses, called Tethys Sea, was mostly closed off and got filled in to form the alluvial Indo-Gangetic Plain, largely by erosion of the Himalayas. Searching for animations of the break-up of land masses, their movements, and formation of newer seas and oceans, now available on the Internet, gives an interesting experience. Actually, the animations show a roughly triangular piece that was to become the Deccan Plateau as just about the fastest moving land, moving north-northeasterly from where it was and to where it is now. Recent investigations have been interpreted as showing that the high rate of movement of the plate associated with the Deccan is not unique to it but comparable with movements of other plates such as those associated with the Mid-Atlantic Ridge. Whatever may have happened, I feel free to think that the Deccan Plateau represents the top part of a gigantic, plow-shaped, granitic block the lower part of which plowed under (subducted) the 'soft underbelly' of the southern coast of Asia, raising up the Tibetan plateau.

Be all that as they may, the Deccan Plateau ("Deccan" is the corrupted form of the Sanskrit word "dakshina", cognate with the Latin "dextro", meaning 'right', since the south is towards your right when you stand facing the rising Sun. The original corruption happened because the invaders from the northwest, and later the British, could not pronounce Sanskrit words properly). The Plateau must have passed through regions of varied climatic conditions, from near Antarctic cold, to southern temperate, to southern tropical, to Equatorial, and to just northern tropical as it moved, through the eons, on its journey. I wonder if the seafloor spreading associated with that journey, possibly recording reversals of the magnetic poles, has been fully scientifically investigated the way it has been for the Mid-Atlantic Ridge.

The Plateau, as it now exists, has a mountain range called the "Western Ghats" (the local name is Sahyaadri in the northern part and Malayadri in the southern part) runs for about 1000 kilometers, leaving a coastal strip of about 80 to 100 kilometres width, and bounded on the east and by less spectacular hills to its, leaving a broad piedmont sloping down to the Bay of Bengal. The eastern and western ranges meet at a high point formed by the Neelagiri mountains (or Nilgiri, literally, neela - Blue + giri - Mountain), averaging 2500 metres in elevation. The northern part (the base of the triangle) is bounded by the Vindhya Mountains. While much of the water that falls on the Plateau during the monsoon rainy season is wasted into the Arabian Sea through short riverine flows, there are major east flowing rivers, the Mahanadi, the Godavari, the Krishna, the Kaveri, the Vaigai, the Tamraparni (the "flow with copper-red leaves"), and others.

Between the two main mountain ranges lies a rugged region encompassing rocky hills, broad depressions, rock outcroppings, plains regions, etc. It can be classed as semi-arid, with rainfall averaging about 100 mm, ill-distributed from humankind's viewpoint, between end of June and the middle of September caused by the Southwest Monsoon. A region near southeastern part (the state of Tamil Nadu) receives some rain during November-January caused by the reverse-flowing Northeast Monsoon.

4 Recent history – the traditional system: Artificial water bodies

Water bodies, created as collection receptacles of natural run-off, have served the inhabitants of the Deccan Plateau from times immemorial. The traditional system of rainwater harvesting for making water available in the dry season, where rainfall is seasonal and often ill distributed, is a matter of wonder. More than a millennium ago, the leading forbears of the present population, the Palyagararu and the Gowda Rajaru (nomenclature in the local language, Kannada, for Local Chieftains or Vassal Kings; the most famous of whom was Kempe Gowda I of uncertain date, possibly 12th century), entrusted visionaries and 'engineers' of their times with the task of surveying the rises spanning broad depressions, that characterize the Deccan, in order to choose particularly suitable sites for building water storage systems.. Constructing such systems was considered as an act of great merit. Kempe Gowda I and his successors, who also went by the titular name "Kempe Gowda", had many kere-s ('kere' - pronounced 'kayray' - is the Kannada word for an artificial water-holding system) constructed in their times.

Those ancient visionaries and 'engineers' employed by the chieftains were fully aware of the difficulties of carrying on productive agriculture in a tropical setting, with the seasonal rains confined to only a few months of a year. They visually surveyed ("eyeballed") the undulating land and identified suitable low lands with seasonal flows, supervised the construction of long earthen bunds (called katte-s in the local Kannada language), revetted them on the storage side with cut granite, built weirs to take care of excess seasonal flow, and so on. The planning was comprehensive: the overflow from a lake at a higher elevation was made to take a natural course to flow into a lower lake successively until the excess water in the 'last' (bottommost) lake merged with a major flow, a river bound to the Deccan's base level at the ocean. Most importantly, the water requirement of agricultural settlements could be controlled locally. Sluice gates were installed for the controlled release of water for agriculture and for use by the villagers living nearby - indeed the 'kere-s' were often named after the nearby villages. The water table remained high, and clean water that percolated was taken from stone-lined open wells sunk within the village limits, was utilized for drinking and cooking and other domestic purposes. Certain hereditary officials were appointed to take care of and oversee the repair and upkeep of the embankments and weirs. Siltation, tending to reduce the holding capacity, and that used to happen over some years, was taken care of by using the silt during dry seasons for making baked bricks. Little chapels were created on the bunds and worship, including animal sacrifice, offered to the protective, guardian deities. The occasion whenever the lake overflowed was always joyful …… I could go on in this manner but I shall stop here to ask God why He thought it fit to endow all those descendents of the original constructive people, who now inhabit the Plateau, only with low mental capacity (I avoid using the more appropriate castigate term dimwits' here) that fails to understand that these water storages are, virtually, living systems.

The command area of each of the storage structures was highly agriculturally productive. The resulting steady availability of life's needs, needless to say, led to a flowering of high civilization, fine arts like music (both the art and its science), classical dance like Bharatanaatyam, folk dance-drama like Yakshagaana-/Bayalaata, artistic painting, the construction of intricately carved temples, the associated metallurgy for making carving implements and for weapons, philosophic speculation, and so on flourished. The sight of a water body is always stress-relieving.

Fig. 1 - General view of the water body showing scrub vegetated hill edging a depression characteristic of the Deccan, water collection, stone strengthened bund and pathway.

Fig. 2 - A vertical stone "scale", placed in order to gauge the depth of the water can be seen. Clouds gathering at the beginning of the monsoon season over the water body are visible.

Fig. 3 - Strengthening 'revetment', made of dressed stone, lines this part of the earthen dam. Wild growth, which may serve to allow rainwater to percolate, can be seen on one side of the kere.

A tourist from Sydney, Australia, who stayed for some weeks in Bangalore some years ago, wrote a letter to the editor of a prominent Bangalore newspaper that he had read about Karnataka's laudable concern over air pollution, particularly in Bangalore but had seen nothing about any attempts to control water pollution. He noted that a flowing stream parallels Mysore Road leading to Mysore, the city of the palace of the old royal family (the 'Maharaja-s' of the state) southwest of Bangalore, before bending away to the south through farmland. "It is a foul, black, stinking stream which, piles up drifts of dirty foam." He wrote. "No doubt it is fed by drains and sewers but, at least as serious, it is fed by industrial wastes as well. In the crowded buses of Mysore Road, you can tell your whereabouts by its stench. Whatever industrial chemicals and other effluents it carries are certainly finding their way into the water table and the sources of washing and drinking water for the communities around. What would study of the health of people over the next few years in such communities as [a locality called] Rajarajeswary Nagar show? When I asked what grand plan was under way to control water pollution, and industrial effluents in general, and to clean up this stream in particular, I am told there is no plan at all!"

Things may change to what can be only be called 'slightly' better, at least towards greater awareness of the problem, since that letter was published. That is, some ten years after that letter was written, a sewage treatment plant was erected, with foreign collaboration, at great cost, over that particular stream ('Vrishabhavati' – river near the banks of which bulls roam – or roamed once). I believe that the plant is functioning even now though the stench appears not to have abated near the entrance to the Bangalore University situated on the Bangalore-Mysore road.

Though most of the good practices of the past continued till about the beginning of the last century a large part of the created system is being actively, almost systematically, destroyed now. Artificially created water bodies designed to collect rainwater ('rainwater harvesting' is the current buzz phrase), the kere-s, commonly called 'tanks' in the type of English used in these parts, are being allowed to die in many ways, not merely by bad planning but also by rampant, deliberate encroachment on the foreshores, obstruction of the seasonal flow channels and downright pollution. Because of urban 'development' on the foreshores that diverts runoff into storm water drains the amount of water that can percolate into the ground from rainfall has becomes reduced. Denudation that accompanies urban development allows silt and debris to be eroded into the 'tanks', quickly reducing their capacity. In most cases, raw sewage is actively diverted into the storages as part of so-called 'urban planning' because it can be done cheaply for the lazy reason that the 'tanks' occupy, of necessity, low areas. Solid waste, including building materials, dumped deliberately into the lakes, not merely by irresponsible citizens and even by municipal street-cleaning staff, compounds the matter so that when they can no longer hold enough water they are declared 'dead' - within a short time the 'tank' "ceases to exist". Land sharks, in connivance with corrupt authorities, who are empowered to give "permissions", soon claim the area for building high-rise apartment blocks whose basements often get flooded during the rainy season.

The present-day water supply to the conurbation of Bangalore depends much on pumping water from the river Cauvery through large diameter pipes. The river flows about 100 kilometers south of the city and one cannot even imagine how much, mostly thermally generated, green-house gas emitting, electric power is wasted in such effort. If anything, the Cauvery is overexploited, leading to inter-state disputes (with lower riparian Tamil Nadu state) over sharing the available water. Though the water supply is augmented with yield from bore wells not all of the needs of all parts of the city can be met. All this may not continue to be sustainable both in the short run because of power shortages and in the long run because of lowering of the water table. It is necessary to be aware that all this is happening not merely in and the vicinity of metropolitan centers but also extending to the countryside. The justification is that an increasing population needs housing. But should providing housing bring down the quality of life below even the ordinarily acceptable norm? How will that “growing population” be supplied with water and be fed?

The so-called lake-rejuvenation programs of the government does not look into wherefrom the lakes will receive water and how the lakes can be kept filled up, an absolute necessity. Rainfall within the spread (water catchment area) of the lake will never be enough and the flow of sewage through what were earlier clean seasonal flows in the catchments, that could have fed the lakes, is diverted into channels for keeping impounded water “clean”, without considering where the sewage will end up.

Can we take any remedial measures at all? Are there any low-tech, low-cost answers?

5 The UNEP report

Not too long ago, there appeared a report in a document prepared by the UN Environment Programme (UNEP) on the global threat from untreated sewage discharges to coastal people and the environment. The gist of the report was that inhabitants of southern Asia face a greater threat than anywhere else in the world from the discharge of untreated sewage, apart from endangering marine wildlife and habitats, and fisheries. The document was published as a follow-up to the World Summit on Sustainable Development (WSSD, Johannesburg). Almost 40% of the world's population lives within 60 kilometers of the coast in southern Asia, putting it at high risk of sewage-related diseases and even death.

Since the report made no mention of a tentative finding that discharge of raw sewage into the Caribbean from the southern U.S. and eastern Mexican coasts (and, possibly also, into the Guanabara Bay from the flanking metropolises, São Paulo, Rio de Janeiro …) had endangered coral formations in the Middle and South Atlantic I thought, at first, that it was of the same ilk as a paper published by U. S. authors in a respectable scientific journal holding India and China responsible for the largest emission of the greenhouse gas, methane, because domestic ruminants are kept in large numbers in those yet-to-develop countries. But then I had to take it seriously because it added: "There has been impressive progress in providing sanitation in many of the worst-affected areas …… But the population grew by 222 million, wiping out the gains that had been made." It continued: "One way of tackling this is to get key parties to set realistic but ambitious wastewater emission targets (WET-s), echoing those that have been developed in many parts of the world for emissions of toxic chemicals and noxious gases from power stations and factories. In some cases, wastewater treatment systems modeled on those in Europe and the US may be needed. *But there are many low-cost techniques that could make huge improvements* (italics mine)." The report did reflect the then current thinking but to this we must now add the increasingly large amounts of plastic waste.

6 Low-tech answers

In making its recommendations, UNEP report said the low-cost techniques could give the environment a double benefit. It added, in a rather obvious manner, that such techniques could include dry sanitation and natural sewage filtering systems like ponds, reed beds and mangrove swamps, and re-using and refilling groundwater reservoirs. It warned that many such natural systems, important habitats for wildlife such as waterfowl and fish, are being cleared and drained for agriculture and other activities. "If more people are aware of their potential as 'natural' wastewater treatment systems, then more will be conserved for their economic and health benefits, as well as for their importance for nature and wildlife." There are some expert cost estimates of providing safe drinking water and proper sanitation to everyone in the world by 2025: $180 bn a year, two to three times more than the present investments in the water sector. That may sound very high but the benefits in terms of disease reduction and dramatic environmental improvements are also high."

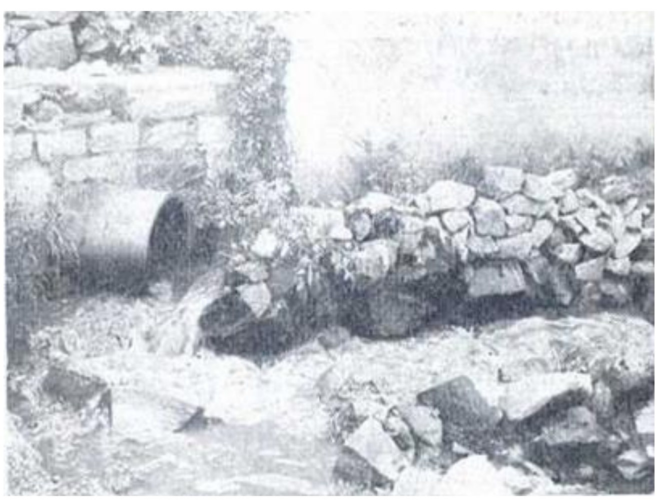
7 Courses of action

Thankfully, there is a realization on the part of responsible people, activists, organizations, etc. on the need to preserve and maintain clean water bodies in and near urban settings. But those, including even municipal bodies or government agencies who want to set things right, seem to entertain many misconceptions about how to go about such matters. Letting in untreated sewage is an unacceptable practice. But stopping sewage flow is not the remedy since that is near impossible - letting in properly treated, cleaned-up sewage is not. Indeed, that practice is necessary since, as already implied, the water bodies are virtual living systems - they need replenishment of water loss. Mere dredging and deepening, touted as "rejuvenation of lakes," for which large funding has been made available from time to time to governmental agencies, while necessary, is not a remedy that is going to pull the water bodies from the brink of death. Growth of water hyacinth [Eichhornia crassipes; Flor de aguapé in Spanish] which is common and quite extensive, is, by itself, thought of as 'pollution'. Actually, it is not only an indicator of the presence pollution but also an important cleaning-up agent. (Please see information on such use of Eichhornia available on the Internet through any search engine.) It shows there is a lot of nutrient available in the form of unclean discharges into a lake.

8 The microbiological clean-up process: A study of the natural process of cleaning sewage

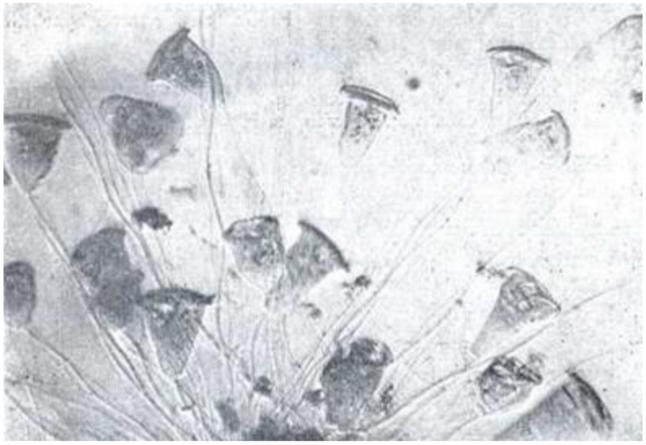
More than three quarters of a century ago, the late Dr. C. V. Natarajan (1899 – 1964), then Deputy Director in the Department of Public Health of the Karnataka state, Bangalore, India, noticed clothes being washed by washer men (‘dhobies’, ‘agasaru’, in Kannada) in the traditional manner, without any ill effects, in streams he knew carried sewage from Bangalore. A preliminary analysis at the Public Health Institute (Seshadri Road, Bangalore) showed that the water was free from pathogenic organisms some distance upstream, before the places where the washer men were active. He persuaded the late Professor S. C. Pillai of the Sanitation Biochemistry section of the Department of Biochemistry, Indian institute of Science, Bangalore, to study and pinpoint the factor or factors that seem to lead to the upgradation of flowing sewage to apparent natural river-quality water. The collaborative work of Natarajan and Pillai lead to the publication of a series of scientific papers. The one that appeared in India’s biweekly national magazine Current Science ["Natural Purification of Flowing Sewage" by S. C. Pillai, G. J. Mohanrao, A. V. S. Prabhakara Rao, C. A. Sastry, P. V. R. Subrahmanyam and C. V. Natarajan, Current Science, XXIX (12), 461 (1960)] can be regarded as a summarization of results then in hand. This paper, gathering the results of their investigation showing microbial activity that leads to the natural elevation of flowing sewage to river-quality water, disclosed that turbulence in a channel with adequate gradient facilitates the dissolution of oxygen. When once oxygen concentration reaches about 3.5 ppm fluffy masses of ciliate protozoa (Carchesiunm, Epistylis) develop and flocculate suspended matter and microbial entities, including pathogenic organisms. Since amino acids in the clarified sewage are also rapidly destroyed eventually, what underlies the development of high biological oxygen demand is removed.

The authors found that flowing sewage can be divided broadly into four zones (please see the figures below). The lengths of each of these zones appeared, understandably, depended (rather critically) on the gradient of the channel through which the sewage was directed to flow. I now quote in extenso from the Natarajan-Pillai paper:

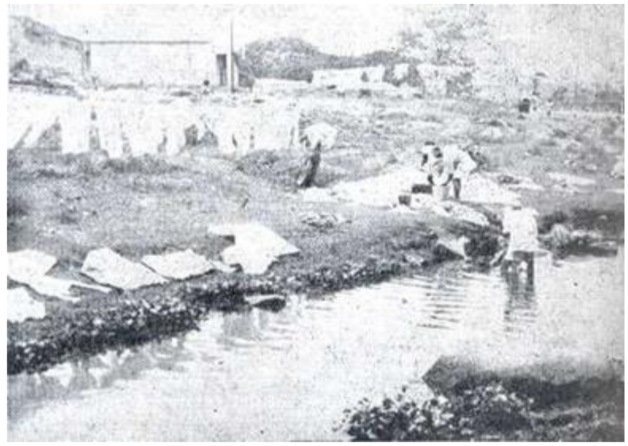


First zone: Discharge of raw sewage over rocks. Preliminary changes leading to clarification and oxygenation.

Second zone: Growth of protozoa on rock surfaces leading to further clarification and oxygenation.



Third zone: Clumped growth of Epistylis and Carchesium assist denitrification. Nitrogen-containing entities (amino acids) percolate into the soil and nitrification.



Fourth zone: The relatively cleaned-up, river-quality effluent used for clothes washing purposes with no client ill-effects.

[Illustrations reproduced from the paper in *Current Science* referenced in the text.]

"…. Bacteria, as generally found in domestic sewage, and occasionally, epidemic-causing Salmonella typhi, Vibrio cholerae, etc. were found in the first zone. Fungi of the Sphærotilus sp. were often present in samples. While algae were generally not seen, protozoa (Rhizopoda -. Amoeba and Arcella sp.; Mastigophora - Bicosoeca and Euglena sp.; Ciliophora - Colpoda, Colpidium, Coleps, Stylonychia, Paramecium, Vorticella and occasionally species of Opercularia, Epistylis and Carchesium) were beginning to be detected. Besides, insect larvae (Aulophorus sp.; Mosquito (Culex sp.); Bloodworm - Chironomus sp.) were seen often…….

"[Our] most interesting finding was that protozoa of species Epistylis and Carchesium developed in strikingly large numbers in the second zone. They formed large masses adhering to the rock or masonry surfaces of the channels. Insect larvae, now present in greater numbers, included Anopheles and Rotifera. Snails, fish Gambusia affinis that eat mosquito larvae) and frogs also made their appearance. Algae (Oscillatoria, Ulothrix, Urospora Stigeoclonium, Pinnularia) began to predominate in the third zone. Larger fish, frogs and water hyacinth began to proliferate. The water became much less odoriferous."

The authors successfully reproduced the clarification/purification process under laboratory conditions using the protozoan species taken from the sewage channels where the second stage conditions prevailed: "……. the more important factors influencing purification of the flowing sewage include: (1) adequate agitation or turbulence of the sewage and other conditions in the channel, which facilitate the dissolution of oxygen to the extent of about 3.5 p.p.m., with the (2) consequent development, in large numbers, of ciliate protozoa, notably of the species of Carchesiunm and Epistylis, which are always found in activated sludge. When these protozoan colonies were taken out, washed and introduced into the sewage (at 10-25% level, by volume) and the mixture gently shaken or into which air was bubbled for 1½ - 6 hours (depending on the number of the organisms), it was observed that the sewage was clarified and oxygenated almost to the same extent as under the natural conditions in the channels. The flocculating activity of the protozoa and the clarification of the sewage also seemed to explain the relatively high nitrogen content of the soils under the flowing sewage in the zone of clarification and to bring about nitrification and other changes, e.g., rapid; removal of amino acids from the sewage in the succeeding stages of purification in the channels. The quality of the final effluents from these channels was similar to that from the activated sludge process.

The authors concluded their paper saying: "Natural purification of flowing sewage is thus essentially an aerobic process and, under the most favorable conditions, it would proceed rapidly, as observed in the channel having l-in-50 gradient, and gives results attainable only by the activated sludge process. [Our] observations are of scientific interest as well as of practical importance as they not only relate to a sanitary principle in Nature and its bearing, particularly, on the modern methods of sewage disposal but indicate the possibility of increasing the efficiency of the activated sludge process and other methods of aerobic treatment of sewage."

These quotations clearly illustrate how the proliferation of different species in the successive stages of flowing sewage dramatically upgrades the quality of water. The work did not, evidently, look for the presence and concentration of heavy metals (e.g. chromium from tanneries, both chromium and cadmium from electroplating industries, lead from battery works, metals from manufacture of electric lamps, industrial scale washing, etc.) etc.) that might prove lethal to the organisms (protozoa) whose presence leads to the natural water quality upgradation phenomenon.

I think it is evident from these results that the natural process can lend itself to acceleration to a good degree. There already exist in the Bangalore region many channels that lead the sewage out of town. (I must add here that the channels have been engineered to make the flow straight. Expert opinion now holds that a meandering flow, being more natural, would have given a chance to the natural processes to work better.) Treatment plants have been erected but they treat only some of the discharge. The natural processes continue, of course, but they may not be able to handle, within practicable flow distances, the heavy load that should, by now, be many times more than what it was three quarters of a century ago.

9 What can be done

It appears clear that the natural process can lend itself to acceleration to a good degree. Much of the systems of the old, serially connected artificial lakes and ponds is still intact, distributed over many districts of the state of Karnataka. Of particular interest are, however, those near heavy settlements - cities and townships. There already exist in the Bangalore region many channels that lead the sewage out of town. But these channels have been engineered to make the flow fast coursing through straight, not meandering, channels. Treatment plants have been erected at great expense, and under the guidance of foreign expertise, but they treat only some, and not all, of the grey water discharge. The natural processes continue, of course, but they may not be able to handle, within practicable flow distances, the heavy load that should, by now, be many times more than what it was three quarters of a century ago.

Firstly, a survey should be conducted to map and identify a given system of serially connected lakes, a task that may not be easy now due to illegal construction. It can be assumed that at the present time all the lakes, from the one at the highest elevation to the lowest receive sewage water at various points. It is possible that some inlet points may not be identifiable or the inlet has been diverted to "protect" the lake.

The primary action to take in the second step is to restore the outflow channels and repair the weirs that carry off the excess water flowing into the lakes. Wherever possible, meanders should be introduced into the channels that connect the lakes. It will be highly advantageous to establish mechanical gatherers that operate in the meanders to remove plastic materials and floating debris. Well-designed debris gatherers (booms, nets etc.) are readily available in the market.

In order to accelerate the process of oxygenation artificial aeration has to be carried out by means of aerators of sufficient power. Aerators of standard design employing the air-entrainment principle are commercially available. An alternate method of aeration could be to erect a fountain or a series of fountains that throw water straight up to a height of about 10 meters near the centers of the lakes. No doubt, taking such actions will be energy intensive but they can be avoided by constructing waterfalls of short height and providing for flow through emplacement of large rough rocks to stir the flow of water greatly.

The third step is to create holding systems where water hyacinth is allowed to grow, where it can survive, mitigating the presence of heavy metal contamination.

10 Heavy metal contamination

Over time there may be an accumulation of sedimented heavy metal contamination in the lakes, especially within the ones at the lowest reaches. Natarajan and Pillai and their team did not specifically investigate this aspect though one may be certain they would have been fully aware that heavy metals would have deleterious effects on the proliferation of the biological organisms that are the clean-up agents, the protozoa. Presence of heavy metal contamination was, perhaps, not a serious problem at the time the investigation was carried out 60+ years ago. If anything, heavy metal content could only have increased since the 1960's due to the proliferation of diverse modern industries which may discharge their effluents directly into the channels. The investigation did show, however, that when once clean up has proceeded to an extent water hyacinth and certain water plants begin to grow.

There is widespread misconception that the presence of water hyacinth is, by itself, "pollution". Rather, its growth is a declarative symbol of pollution. It shows there is a lot of nutrient available in the form of unclean discharges in the water body. Numerous investigations have shown that water hyacinth can not only lead to the destruction of many degradable toxic materials and absorb heavy metals but can also reduce biological oxygen demand significantly. Harvesting the growth from time to time, burning it for useful heat or subjecting it to the bio-methanation process and disposing off the residues/ashes in a safe way, (treating it as if it were radioactive waste!) at designated sites wherefrom the toxic materials cannot be leached out into the groundwater are the sensible actions to do. Removing water hyacinth ('eradicating it' as it is often described) is like cutting the head off to cure one's headache!

A practical way to remove much of the metal contamination would be to create strategically located shallow (not more than one meter deep) ponds provided with controlled inlet and outlet channels. Needless to say, the inlet channel will be somewhat lower than the water level of the water impoundment with which it connects and the outlet will be made to discharge water into the lake at the next lower-elevation. Water hyacinth is cultivated in these ponds and the growth is mechanically collected from an end of the pond where it is blown by the prevailing wind. The pond can be so shaped as to facilitate such collection. Mechanical devices that collect and bring out on shore hyacinth growths have been demonstrated in Bangalore.

11 Presence of industrial and heavy greases and mineral oils

Though mineral oils and heavy greases are biodegradable in the long run there may be no clear-cut low-cost way for their removal. It is known that micro bubbles of air flock such material and bring them to the surface from where the flocculated material can be skimmed off for eventual incineration. The procedure can be expensive. It appears best to combine a chosen method of flocculating greasy materials with the aeration at the second stage, before the water enters the water hyacinth growth stage.

12 The final stage

The final stage in bringing the sewage to river quality water is to erect a pumping system of large enough capacity to convey water from the lake at the lowest elevation to the one at the highest elevation to effect the desired recycling of water. This could be the most expensive and most energy-consuming part of the proposal.

I expect that the quality of water will take time to improve but the time to become shorter gradually after the start of the process. The water needs to be tested for quality (reduction in suspended matter, in the pathological bacterial count, in biological oxygen demand, etc.) at several points of the system to enable any corrective measures to be taken. If it meets standards set for agricultural uses the water can be diverted for such use since the water in the system will be replenished constantly. Alternately, whenever the water quality permits, the excess water can be let out into nearest river system.

The way the system is designed there need not be any restriction on where additional sewage is added. It can even easily handle the extra inflows during the rainy season. Each lake, at every level, needs to get filled up after natural loss of water for different types of use during the dry season before it begins to overflow and the processes of natural improvement in the quality of water (dilution among them) will continue in an uninterrupted way.

Strict vigilance must be exercised that no non-biodegradable matter (plastics, metal structures or pieces, building debris, etc.) is thrown in. Open or clandestine discharge of non-biodegradable solid waste either into the channels or directly into the lakes should be declared a cognizable offence.

13 Concluding remarks

The lake systems of India's Deccan are a priceless heritage bequeathed to us by the forefathers of the present inhabitants. The water bodies they created are virtual living systems in that they now form part of an important ecosystem that includes traditional methods of cultivation, animal husbandry, and, indeed, the mode of daily living.

The lake systems were adequate to handle man-made pollution when the population was small and methods less exploitative. Overexploitation of ground and riverine water resources will lead to water scarcity and public unrest in the not too far future (It may be beginning to happen right now!). Lack of care, dumping of solid wastes by persons who lack civic sense and pride, absence of setting of enforced emission standards for industrial effluents, letting in raw sewage either directly into the lakes or into the connecting channels without remediation, etc. contribute to the active destruction of really valuable extant public assets in the form of ancient unnatural water bodies that replenished ground water resources.

The living lake systems need replenishment to make up for loss of water. Mere dredging and deepening under the so-called, much touted, program for the "rejuvenation of lakes", for which large funding has been made available, while necessary, is not adequate to pull the water bodies from the brink of death by eradication. Projects for building of jogging and walking paths, raising rose gardens, etc. do not look into how the lakes will get filled to the optimum level. Rainfall within the spread of the lake or even within its catchment area will never be enough and the flow of sewage through former seasonal flows, now filling some lakes, is diverted into channels for keeping impounded water "clean", without considering where the sewage will end up.

If natural methods as outlined above are adopted and the infrastructure necessary for them to work is in place, the existing sewage collection and lake network can be rejuvenated. What has been proposed will sound utopian and impracticable. But then, if achieved, it is needless to say, the benefit from clean recharging of groundwater would be incalculable. Since the sight of bodies of water and babbling streams has a stress-relieving effect, construction/rejuvenation of lakes may even help to contain human extremism and fundamentalism of various forms.

There is bound to be loss of water from the system over a period of time. The total storage in the lakes can be replenished from sources from which current supplies are drawn (in the case of Bangalore it is the Cauvery River).

If the initial operation proves successful in clarifying the sewage, in reducing its bacterial content, and biological oxygen demand, reduction of stench, no reason should stand in the way of going ahead with a fully planned project. It is thought that the proposed system, which can cater to an extended Deccan region, will be economically feasible compared with a high-technology, high-cost system that needs to be individually established for each municipality. It is unnecessary to add that the method will have beneficial effects on the water table level.

It has been said Bangalore and its environs (and, indeed all of the state of Karnataka) is fortunate in having beautiful 'lakes'. It is necessary to remember that these 'lakes' are not natural but man-made reservoirs. I hope enough wisdom will come to those who talk of something called ‘water harvesting’, as if it was something new, and then go about destroying the very facilities created for that very purpose during a more creative past.