Symbiotic Recycling Systems for Harmonizing Ecological and Economical Goals

Gauranga Das, Guru Palaniappan

Abstract— With world nations looking to improve their economies a major impact has been observed on the planet's ecology. Industrialization and the consequent urbanization are straining our natural systems to the limit. A direct impact can be observed in the ever rising need for improved waste management. This paper presents how by adopting a green technique called as "Soil Biotechnology" a decentralized sewage management system can be effectively implemented without use of any chemicals or energy intensive machinery. Secondly the paper also discusses the wide-scale applicability of "Symbiotic Recycling" in rural and semi-urban areas by integration of various individual systems comprising of organic farming, cow-barn, biogas plants, composting units and green constructions. Such integration facilitates recycling or reusing of waste from one system into other, there by overturning the costs of waste management into savings. Both the techniques have been experimented and adopted in a semi-urban Indian farm community – Govardhan Ecovillage.

Keywords— Soil Biotechnology, Symbiotic recycling, Urban sewage management, Waste management.

I. Introduction

Historically it has been observed in various world economies that the manufacturing sector has had a positive influence on the nation's growth rate. Policies governing the manufacturing sector have always aimed towards improving the economy, but have laid little or no emphasis on the impact of such a growth on the ecological infrastructure of the nation. It is a tricky challenge as the systems that are aimed towards improving the economy on the short term, can potentially prove detrimental to the very infrastructure that sustains it in the long term. This dichotomy has created a schism among thinkers who have developed opposing views towards economic sustainability and ecological sustainability, deeming these two paradigms to be incompatible. However for a nation to achieve a balanced growth this dichotomy has to be reconciled. The United Nations in its Millennium development goals [1] set targets for simultaneously improving both the socio-economic conditions of people and ensuring environmental sustainability.

Gauranga Das is the Director of Govardhan Eco Village, Galtare, Hamrapur, Wada (Taluka), Thane, Maharashtra, India – 421303(phone: +91 9930141797; e-mail: gaurangadas@ecovillage.org.in)

Guru Palaniappan is with Govardhan Eco Village, Galtare, Hamrapur, Wada (Taluka), Thane, Maharashtra, India – 421303(e-mail: contactus@ecovillage.org.in)

II. Impact of Modern Developmental Systems

The popular model for socio-economic development today is the 2-pronged approach of Industrialization and Urbanization. Industries work on the principle of Demand and Supply.

It requires consumer base to prop up the demand while it also needs workforce and natural resources like iron-ore, oil, timber etc., to stroke up the supply. Urbanization solves this problem for industries by providing dedicated workforce and consumer-base clustered around the goods and service industries in the form of cities. This makes a concentrated consumption loop. However the resources needed for running the industries come from distant areas like rural areas, forests, mines, oceans etc. The wastes from these resources are dumped back in these distant areas like landfills, rivers, oceans etc. This can be called the resource loop. The industries extract from the resource loop without contributing any ecological benefit, creating a disconnect between consumption and resource loops. As the need and exploitation of these natural resources is increasing, industries are being forced to explore distant and remote areas for obtaining resources leading to a widening chasm between the 2 loops.

Developmental systems adopted today have failed to acknowledge the aspect of ecological resilience [2] or nature's capacity to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. Our modern developmental systems have been formulated on the premise that nature has abundant resources and have hence adopted a linear model of "resource-to-trash" systems. They take resources from nature, process them into a useful form and at the end of life-cycle dump it back into nature in the form of waste. Wastes are also generated at various stages in this model, whose handling costs are pretty much offloaded into nature. This model has worked for decades and has successfully improved many world economies. However such a model contradicts a basic law of economics i.e. 'a linear system with definite resources can't continue indefinitely'. Another factor that acts as leakage-hole for this model is that what has been presumed as nature's capacity to produce unlimited inputs and accept unlimited waste, was its mere persistence in the face of changes in ecosystem variables due to anthropogenic causes [3]. Every time we buy a non-biodegradable good, nature heavily subsidizes our purchases. How? Ideally a product lifecycle should span from resources-to-goods-to-wastes and finally back to recycled resources. If 'x' KJ of energy is needed to convert a set of resources into goods (which in due course of time degrade into wastes) then, according to the laws of Thermodynamics, the system being irreversible would require more than 'x' KJ to convert the wastes back to resources. Now the catch is that we participate in the product life-cycle only in the span from resources-to-goods-to-waste and leave the tedious task of converting wastes back to resources on nature. Gradually nature is losing its capacity to continuously subsidize for the increasing wastes.

With more nations of the world adopting this model there is an increasing strain on the planet's ecological resilience resulting in effects like global warming, climate change, loss of biodiversity, food shortage etc. In order to mitigate these effects, a significant amount of financial resources are being spent in the form of environmental protection measures and offering subsidies to the affected populace. Thus the modern developmental systems are straining the economy and proving to be counterproductive.

III. Urbanization Impact

A direct consequence of the modern developmental model can be the perceived in the abnormal growth in the urban population. The 2011 census report shows that for the first time in independent India the absolute increase in population is more in urban India than rural India. The trends are no different globally. For the first time in the history of humankind, urbanization has increased at such a massive pace, that more than half the world's population today lives in towns and cities. By 2030 this number is expected to swell to almost 5 billion, with urban growth concentrated in Africa and Asia [4]. This essentially means an undue overload on the urban infrastructure which has not been designed for such inflated numbers. With all modern cities being based on the resource-to-trash systems, one of the key areas that will be badly hit are waste management systems. Predictions are that waste management is going to be one of the planet's biggest concerns in decades to come [5].

With increasing costs of transportation and limitless expansion of cities, the existing models of waste handling are becoming costlier, insufficient and ineffective. For example with water becoming the most in-demand & in-shortage resource, using it indiscriminately for flush based sanitation systems is becoming questionable. In addition clogging and overflow of sewage lines during rains was observed to cause severe problems in all major Indian cities. Current waste management techniques like landfills and incineration were devised decades ago when the population density was relatively low. With rising population and steep rise in the volume of waste generated the ecological resilience is being tested to its full capacity. Conventional waste management techniques are proving to be ineffective and ecologically disastrous. In spite of the glaring ecological hazards posed by these techniques they continue to prevail especially in third world nations. Separate segregation and recycling of waste, though a highly effective solution is not being taken up on a wide scale due to various technical and financial challenges they pose.

IV. Symbiotic Recycling Systems

This dichotomy of sustainable economic and ecological development can be harmonized by a close examination of nature, its systems, processes & constituting elements. Nature also has an extensive method of development, evident by the wide variety of life forms it successfully nurtures. The well being of any model can be understood by examining the ease with which the various systems in the model function and how the individual elements constituting each system have a sustained growth.

Nature has a very unique way of waste management. Before we understand that, we need to understand what waste is. Waste can be defined as any object that neither in partial nor in totality contributes to the end goal of a system. Such an object may be produced as a "delayed waste" or as an "immediate waste" in a system. For example, in a manufacturing process, there are wastes generated at various intermediary stages in the process, constituting the "immediate wastes". And the final good produced thereby will also eventually, at the end of its life cycle, be trashed constituting the "delayed waste". The systems comprising the developmental model in nature are in such a way that the wastes from one particular system can be used as raw materials for another system, that way there is no extra energy expended in processing the wastes. In other words, what comes from nature from one system goes back to its proper place in nature in a different system where it is processed and used. Thus the various systems in nature develop a symbiotic dependence on each other and the wastes produced in various stages are recycled within the model. This concept is called Symbiotic recycling.

The modern developmental models are all comprised of disconnect individual systems that follow the resource-to-trash concept. At every stage in this model each system acts like an individual consumer, consuming resources and producing waste. Thus the overall waste produced from this model is very high. If we can formulate models comprising of symbiotically dependent natural systems then we can incorporate an inbuilt mechanism of recycling (a self-sustained feedback loop) and save all hassles of waste management. An in-built reversible system of converting wastes to resources would save the nature of having to pay for ecological Costs. Waste when converted to resources would become an asset & no longer a cost. Such a model then would not be an integration of 'consumers', but a symbiotic integration of 'contributors'.

By developmental models formulated around this concept of Symbiotic recycling we will be able to achieve the desired objective of improving the quality of life and also ensuring environmental sustainability. According to the nature and objectives of any model this concept can be implemented at varying levels of effectiveness. The details of one such successful implementation of Symbiotic recycling in a rural set up is discussed here with.

http://dx.doi.org/10.15242/IICBE.C0214014

V. Govardhan Eco Village – A Case Study

Govardhan Eco Village (GEV) is a farm community set up to highlight the importance of living a life in harmony with nature. Unlike the modern day resource-to-trash systems, GEV was modeled to provide a good quality of life by meeting the basic requirements for living like food, shelter, water, waste management etc, by integration of various symbiotically dependent systems. GEV uses specially designed green technologies to ensure comfortable living while maintaining symbiotic harmony with nature. The following table gives few of the techniques employed at GEV:

TABLE I
List of techniques at GEV

Area	**Technology**
Alternative Energies	Solar, Bio-Gas, ADPM
Green Building technologies	CSEB, Rammed Earth, Arch Panel & Mangalore Tile Roofing,
Water Resources	Landscaping, ponds, bore wells etc. based on Hydrological Survey, Rainwater harvesting, Recycling sewage water in SBT
Organic Farming	Organic Fertilizers & Pesticides, Composting, PRB Farming, Seed Preservation & Perpetuation, Traditional techniques of Rainfall prediction
Waste Management	SBT, Bio-gas Plant, Symbiotic recycling

The following sections describe the organic evolution of different symbiotic systems in GEV in its efforts for attaining sustainable living:

A. Food

At the heart of this model is organic farming and cow barn, the traditional symbols of sustainable living. The farming system produces enough grass and feed for the animals and the cow barn system produces manure and cow-urine derivatives which provide other necessary ingredients for farming. These symbiotically dependent systems have a built in mechanism of waste management and in return produce grains, vegetables, cloth, natural medicines, milk and other cow products. Thus a self sustainable cycle was established that meets our bare minimum needs.

B. Housing

Around this basic model we added buildings for human settlements. The challenge was to make buildings that were not only aesthetic and comfortable, but would also create minimal impact on the environment. So after a thorough research, we started making green buildings using an improvised mud brick technology called compressed stabilized mud blocks (CSEB). Unlike the commonly used baked bricks these unfired bricks retain mud's natural property of maintaining optimum temperature. Thus buildings made with these bricks would remain cool in hot weathers and warm in cool weathers, thus saving a lot of energy in heating and cooling systems. An entire structure made from these bricks has less than 1% the embodied energy as compared to their fired brick counterparts.

C. Water

So with food and shelter in place our focus was then to ensure a sustainable water source for the village. So we undertook a thorough survey of the ground water flow patterns, called as a hydro-geological survey, and identified ideal locations for extracting water. We also made a facility to recharge the ground water and created various rain water harvesting structures that would serve all the water requirements of our growing community.

D. Waste Management

With a growing community in place our biggest challenge was waste management. Our intention was to set up symbiotic systems that would harness nature's inbuilt concept of recycling within the existing systems for food, housing and water. But at the same time we were also conscious that not any kind of waste could be handled by this natural system, for example highly toxic industrial effluents etc. So we had to simultaneously imbibe in the eco village a culture of using compatible materials. This perhaps is the most important step in the long term sustenance of this model because as much important as it is to create right systems, it is also important to train the people using these systems. Thus the nature of wastes produced in the eco village was mainly fourfold:

1. Animal Waste and other wet wastes like food wastes etc.
2. Dry biodegradable wastes like foliage, paper etc.
3. Dry non-biodegradable wastes like plastics, construction aggregate etc.
4. Human wastes, which constitutes the sewage

To take care of the first category wastes, we added biogas plants that accept wet food wastes and cow dung from the barn system and give out digested slurry, which acts an organic fertilizer input to the farming system. The biogas thus produced is used in cooking thus generating savings on LPG bills. Thus a symbiosis between farming and cow barn systems was established. We also set up various composting pits that take in other organic wastes like paper, foliage etc., and produce compost for the farming system creating a symbiosis between community living and farming. Construction wastes like broken cement poles and bricks are utilized in making permanent raised beds (PRB) for farming. The PRBs are an innovative way of saving human labor, tractor usage, energy and time before cultivation. The land is prepared by creating these raised beds from cow manure, leaves, compost and soil. These beds are permanent and are more fertile and conducive for growing vegetables and fruits. GEV was recently listed among the top 100 agricultural innovators in India for effective usage of PRBs. The entire boundary of the PRB is made by construction wastes like cement poles and bricks, creating a symbiosis between farming and construction systems. Other construction wastes like quarry dust (an ingredient in making CSEBs) and construction aggregate was used in making cob house construction and in repairing the roads. The broken red bricks are being used in water proofing the roofs in other constructions. Waste card board cartons and cloth are used as mulch in the agriculture field. Mulch is a protective cover placed over the soil to retain moisture, reduce erosion and provide nutrients. Spreading the waste card board cartons and cloth on the land also blocks sunlight, thus preventing growth of any weeds. By using this simple technique one can avoid the labor intensive task of removing weeds or usage of any chemical weedicides. Cement Bags and other plastic bags are utilized to store mud and compost. It is also used to grow plants, esp. grasses like kusha – whose fragrant roots can be easily extracted by cutting the bag open. Wood dust, produced by sawing the wood used for construction, forms an ingredient along with cow dung, in making of chemical free incense sticks. Not only are these incense sticks fragrant, but also have the utility of being a chemical free mosquito repellent. An entire cottage industry is run in GEV which takes as raw ingredients cow dung and cow urine and manufactures various chemical free products like incense sticks, tooth powders, soaps, bathing powder etc.

VI. Need for Safe Sewage Treatment

The final category of waste, namely human waste was a serious issue to be dealt with. Initially we adopted the standard practice of septic tank based sanitation systems. However in due course of time it was found that this process was leading to foul odour, mosquito breeding and stagnation of water due to poor permeability in black cotton soil. Also it was ecologically unethical to dump the contaminated septic tank water into water bodies directly. So we required an alternative technique meeting the following requirements:

1. An ideal sanitation model to run in a self sustaining rural, sub urban and urban community.
2. Saving of ground/surface water resource via recycling of waste water for secondary usage like irrigation of farm
3. Generate photosynthetic biomass for internal use (flower, fruit and excess biomass for green manuring).

VII. Soil BioTechnology

Soil Biotechnology [6] (SBT) is an indigenous green technology for sewage processing for recycle and reuse of processed water. SBT has been developed & patented by Chemical Engineering Department, Indian Institute of Technology, Bombay. In this system combined grey water and black water streams are collected and transported via gravity driven underground sewerage network up to the raw water storage tanks. Raw sewage is then pumped and distributed over the SBT bioreactor through a network of pipes. The bioreactor is an impervious containment that incorporates soil, formulated granular filter media, select culture of macro organisms such as earthworms and plants that creates the right ecosystem for the waste processing. Organic solids and liquid wastes of human activity contain both energy and nutrients which, unless harnessed, pollute the environment. Conventional sewage treatment technologies fail to achieve this and as a result the non-utilized nutrients accumulate and disturb the natural balance of soil, water and air through overloading. Salinity, pests, diseases are symptoms of this phenomenon. SBT synergistically engages photosynthesis, respiration and mineral weathering – the three fundamental processes of nature, to process the sewage. This is achieved by soil micro-organisms and regulated by soil macro-organisms viz. geophagus earthworms etc. As a consequence the organic waste constituents of the sewage water are consumed and simultaneously water of desirable quality is produced. The entire process operates in aerobic mode, thus eliminating the possibility of foul odour. SBT removes BOD, COD, ammonia nitrogen, nitrate nitrogen, suspended solids, bacteria, color, odor - all this in a single “all green” system open to atmosphere. The processed water (after multiple passes if necessary) is collected in an intermediate collection tank. The final treated water is recycled by using in the farming and horticulture.

VIII. SBT Process Validation

The water treated using SBT has the following properties:

- Always neutral pH
- Free from any synthetic chemicals
- Odour free
- TDS does not build up in the process
- Complies with the local regulatory treated water standards

The table below gives details of how the SBT process affects individual water quality parameters in samples taken over a period of 2 months.

Table II
SBT Data

Parameters	*Units*	*Standard Specifications*	*Raw Water (Dec '12)*	*Treated Water (Dec '12)*	*Raw Water (Jan '13)*	*Treated Water (Jan'13)*
pH	---	5.5 - 9.0	6.28	7.98	6.56	7.48
COD	mg/ltr	250 max	424	42	398	38
BOD 3 days 27^{o}C	mg/ltr	30 max	178	18	168	16
Suspended Solids	mg/ltr	100 max	126	24	118	20
TDS	mg/ltr	2100 max	468	402	482	428
Oil & Grease	mg/ltr	10 max	6	<0.1	4	<0.1

IX. Advantages of SBT

A. Sustainable

Conventional sewage treatment systems are characterized by high mechanization and are highly energy intensive. Consequently the operations & maintenance is very tedious and cost intensive. As a result, in many cases the plants are not in operation, the ground water is polluted and treated water cannot be reused. SBT stands out as a very sustainable cost-effective solution to the problem of waste water management, specific to the Indian climatic, social and environmental conditions. Besides the process being natural, it depends very little on external energy sources and conserves the same.

B. Ease of installation

An SBT system can be fitted into any garden infrastructure. The civil work involves construction of equalization tank, bar screen chamber, construction of bioreactor containment tanks with suitable partitions to compartmentalize a multi-stage operation and filtrate collection tanks and treated water storage tanks. The mechanical installations include pumps for distribution of sewage water on bioreactor and then discharge the treated water into storage tank. One pump will be required for each stage of operation. One standby pump per stage can be installed for down time free operation.

C. Recovery Efficiency

The only water loss in SBT systems is due to evapo-transpiration from the plants and soil. Therefore the treated water recovery is very high. Recovery of more than 90% has been observed under all climatic conditions.

D. Power Saving

Use of SBT system results in substantial saving in electricity cost, as power usage is for pumping alone. The comparative data is as follows for the envisaged capacity of 100 KLD.

Power for SBT system – 36 units per day

Extended Aeration Process – 200 units per day

Total percent saving = (200 – 36) * 100/ 200 = 82% approximately*.

*NOTE: SBT power estimate does not include requirement for distribution of treated water just as in all other conventional systems.

E. Useful by-product

SBT also facilitates growth of biomass, flowers, biofertiliser apart from the recycled water which is marine compatible.

X. Conclusions

Villages are the backbone of any nation. And if we are looking to take any nation ahead we need to target rural specific developmental models that meet our core requirements of economical and ecological sustainability. The current approach of adapting urban waste management systems to rural and semi urban areas is overkill. Rather one can make use of nature's inbuilt systems of symbiotic recycling and thereby add value to the existing processes. The developmental systems showcased in the GEV case study can be expanded upon in a larger scale of operation in rural and semi urban areas and the impact can be studied. However in an urban set up this model will not work due to want of a larger acreage. SBT's functioning, though aligned with nature, is intensive enough to fit in a typical urban scenario that is scarce on space. An SBT system is quiet & green and forms a perfect solution for decentralized sewage management. Its deceptive look hides the intensive processes that are based on sound principles of terrestrial (soil-plant) ecology. Therefore, the quality of SBT processed products be it treated water or bio-mineral fertilizer, are by far superior to any other systems. Therefore, it qualifies for an ideal zero discharge system even in urban areas.

References

[1] http://www.un.org/millenniumgoals/

[2] Gunderson, L.H.. "Ecological Resilience — In Theory and Application," Annual Review of Ecology & Systematics 31: 425, 2000. http://dx.doi.org/10.1146/annurev.ecolsys.31.1.425

[3] Holling, C.S., "Resilience and stability of ecological systems," Annual Review of Ecology and Systematics 4: 1–23, 1973. http://dx.doi.org/10.1146/annurev.es.04.110173.000245

[4] State of World Population, UNFPA report, 2007.

[5] USEPA report, 2002.

[6] Pattanaik., B.R., "Processing of Wastewater in Soil Filters", Ph.D. Dissertation, Dept of Chemical Engg., IIT Bombay, 2000