Integrated Water Management for Rural/Urban India

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ABSTRACT

Contamination of surface and groundwater resources is rampant in rural/urban India with wastewater entering fresh water bodies or seeping into groundwater. An integrated approach is needed to manage the water and wastewater treatment so that water supply is kept clean and wastewater is recycled for beneficial use in agriculture and industry. This paper will present a study that was completed for the Hammond Sanitary District in Indiana where 38 million gallons per day (MGD) will be recycled after secondary treatment for beneficial use by land owners in Northwest Indiana. In addition, a case study of the Kurkhumbh wastewater recycling plant near Pune, India, will be provided to demonstrate that a Common Effluent Treatment Plant (CETP) can conserve a lot of fresh water in industrial estates. The two case studies demonstrate that wastewater can be economically recycled for reuse. The paper concludes that every drop of wastewater in rural and urban India should be recycled for reuse so that it does not contaminate our drinking water supplies and conserves scarce water resources for satisfying the thirst of the entire population.

INTRODUCTION

Water is critical for all life on the planet. Rapid industrialization and urbanization has caused India to face a water crisis since it has only 4 percent of the world's water resources. In order to resolve the crisis, India has to look for alternative water resources which may include rain water harvesting, grey water and sewage reuse and desalination. Rain water harvesting is practiced in many parts of India, with many projects working well in Tamilnadu and Karnataka. Grey water is defined as wastewater generated from the bathroom, laundry and kitchen. Nearly 70 percent of the water used in households results in grey water which can be treated using simple technology and reused. Reuse of grey water reduces the fresh water requirement and reduces the amount of sewage sent to treatment plants. This integrated approach to water and wastewater management is needed to assure water conservation, improvement in public health, and building economically viable water infrastructure. This paper will present two case studies of integrated water management. One case study involves the recycling of treated wastewater for agriculture in Northwest Indiana, USA, which is being planned by the Hammond Sanitary District of Indiana and the Center for Transformation of Waste Technology of Illinois. The other involves an industrial wastewater recycling project near Pune, India, where the wastewater was treated for use within the industrial estate. Such recycling projects are critical for conservation of water resources and to ensure that economic development is facilitated through proper water management.

Economics of Integrated Water Management

Water is not evenly distributed on the planet. There are many populated areas which suffer from water shortages. In India, the monsoons bring an abundance of water followed by periods of drought. Water use in India is roughly in the following categories: agriculture (80%), industry (15%) and domestic consumption. In order to ensure adequate water for domestic consumption, the large users in agriculture and industry have to be efficient in their use of water and practice wastewater recycling. Municipal wastewater has to be treated as a resource by reuse of nutrients in the wastewater for improving agricultural productivity, and for pisciculture, as is done in Kolkata. Municipal wastewater recycling programs manage the carbon, nutrient and hydrologic cycles in nature very effectively. This will dramatically increase the water available for domestic purposes and minimize the use of borewells for domestic water supplies. Recycling programs will fail unless the economics are favorable. For example, in 1998, in the Kurkumbh Industrial Estate near Pune, India, the government was supplying clean water to the industries at a subsidised rate of Rs. 8 per cubic meter. They built a wastewater recycling plant and wanted industries to recycle their wastewater for reuse. However, the cost of treating and recycling wastewater was Rs. 15 per cubic meter. Hence, industries were not recycling their wastewater but illegally disposing it and contaminating the surface and groundwater resources. When the government increased the price of clean water to Rs. 18 per cubic meter (the true cost of water delivery), the industries willingly sent their wastewater to the treatment plant and bought the recycled water at Rs. 15 per cubic meter. Hence, the policies of the government in pricing water are critical for implementing integrated water management.

Water used in agriculture can be reduced if there are economic incentives provided for recycling treated wastewater and wasteful water use is priced exorbitantly. In Israel, such pricing policies have resulted in innovations in water recycling and agricultural practices that minimize water usage. Such policies are badly needed in India if the cycle of drought and reduced agricultural productivity resulting from water shortages are to be avoided. The Hammond case study presents such an opportunity in agricultural areas of India, and should be carefully studied for replication.

HAMMOND SANITARY DISTRICT, HAMMOND, INDIANA, USA

A Proof of Concept Plan was completed by the Center for Transformation of Waste Technology (Center) in 2009 (Center for Transformation of Waste Technology, 2009). The rationale behind this study is the elimination of the discharge of the Hammond Sanitary District's final effluent of 38.0 million gallon per day into the West Branch of the Grand Calumet River which is tributary to Lake Michigan. The plan has the potential for generating revenue that would sustain infrastructure improvements and other capital projects within the District, which in turn would help keep user fees affordable to citizens served. When the plan is implemented, the District will be in complete compliance with the goals of the Clean Water Act, i.e., no discharge of pollutants to the Lake Michigan basin. Other benefits that would result for the District are: 1) no need to expand its treatment facilities to meet more stringent effluent nitrogen and phosphorous US Environmental Protection Agency standards, 2) ability of the District to use the treated effluent as a resource rather than managing it to comply with the National Pollution Discharge Elimination System Permit (NPDES) limits, 3) real possibility of revenue generation that can be equitably shared among various stakeholders. These stakeholders are the District, land owners, and the Center. The land owners would benefit from irrigation of their land by applying a highly treated, nutrient rich effluent under the guidance of the Center. The Center's mission is to encourage the use of wastes as resources that would generate revenue rather than incur additional treatment costs.

The Proof of Concept

The approach taken by the Center to prove the concept of recycling treated effluent of the District for beneficial use in the true spirit of Federal regulations concerning final effluents discharge from wastewater treatment plants involves technical, social, engineering, and economic considerations.

Technical Aspects

Based on the climatic factors, soil characteristics, and effluent characteristics, the land required for irrigating

with the final effluent from the District's facilities rather than discharging into the surface waters in the Lake Michigan (Little Calumet-Galien) drainage basin is estimated to be 11,350 acres. This land consists of golf courses, parks, cemeteries, flood control projects and private and publicly owned farmland (Figure 1).
Discussions held with Dr. Michael Unger, General Manager of the District, have indicated that it is possible to modify the existing treatment scheme that would eliminate some unit processes such as filtration of the effluent and curtailing air usage because the effluent would no longer be a nitrified effluent. Additional benefits would also include, 1) downsizing the aeration tank volumes and 2) reduction in within-plant pumping among treatment units. These changes would significantly reduce the operation and maintenance costs of the existing facilities.

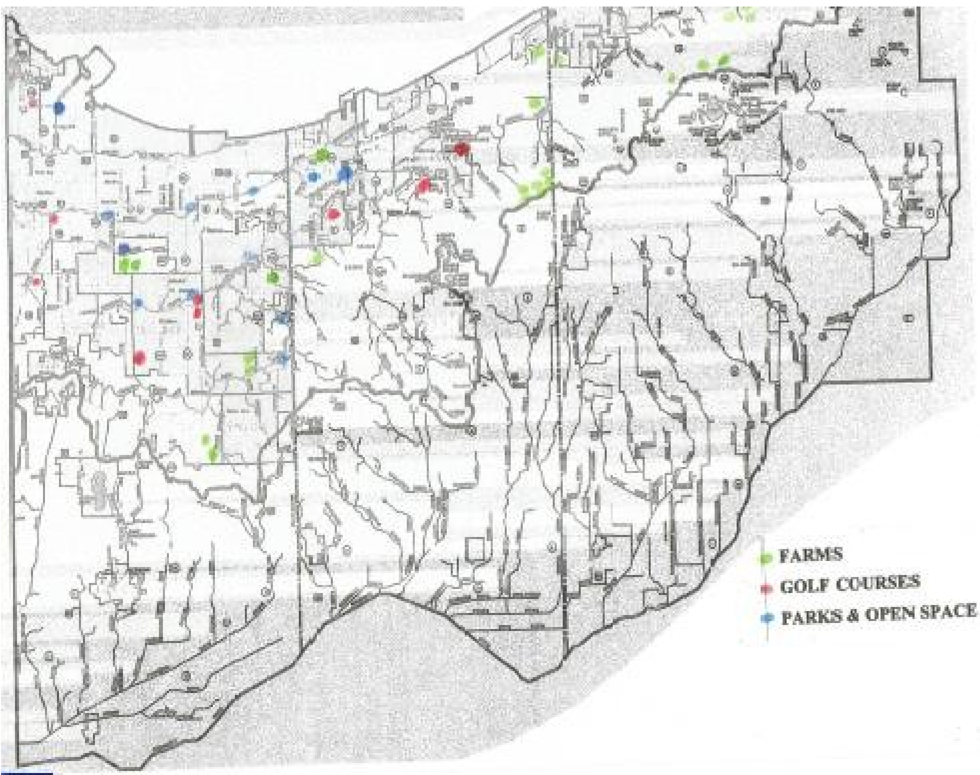

Figure 1. Aerial Distribution of Irrigation Sites

<u>Social Aspects</u>
The Center believes that unless land owners are convinced that the benefits they would receive for providing 30-year irrigation easements are significant, they would be unwilling to participate in the Hammond Water Reuse Project. Hence, an Issue Specific Reputational Method (ISRM) survey tailored to the northwest Indiana region (modified from the standard approach) was conducted by the Center to identify potential land owners who would be willing to participate in the project. The ISRM accomplished two objectives: first, it elicited information from the stakeholders and; second, it informed the stakeholders of potential benefits that can accrue from the project.

Based on the ISRM approach, the Center identified and met with approximately 40 landowners within the Basin, representing over 16,000 acres of farmland, parks and recreation areas, golf courses, airports, cemeteries, and land preserved for flood control along the Little Calumet River. Owners of over 8,000 acres in Lake, Porter, and LaPorte Counties have agreed by a Letter of Intent (LOI) or other means to participate in the program. The favorable response demonstrates that there is sufficient interest in the program to proceed to the planning, design, permitting, and financing phase of the project. Negotiations are underway to secure additional irrigation easements in Lake County to increase the cost effectiveness of the project.

Engineering Aspects

The Center has examined alternative locations of the conveyance pipeline(s), storage reservoir(s), pump stations, irrigation pipeline sizing and routes including procuring right of ways for the pipelines. Figure 2 shows the different routes, along railroad right-of-ways and bike trails, that are being considered for the pipeline. In addition, land for storing over 120 days of water in a large reservoir (which cannot be used during the winter) is being procured by the District. The Center and the District have initiated interaction with officials and staff in the three counties, as well as with regional entities and utilities to finalize the pipeline route.

Figure 2. Different routes, along railroad right-of-ways and bike trails

Economic Aspects

Based on discussions with the General Manager of the District, Dr. Michael Unger, the Center made a preliminary evaluation, and has determined that it would be cost effective for the District to eliminate all discharges of effluent into the West Branch of the Grand Calumet River. In order to comply with the proposed water quality based effluent Total Nitrogen standard of 2.2 mg/l, it is estimated that the cost of retrofitting a 1.0 mgd treatment plant would be about $8,000,000. If such costs for a 1 mgd plant are prorated to the size of the District's plant (38 mgd), a very significant capital expenditure would need to be incurred, and user fees would increase accordingly.

The preliminary cost of the Hammond Water Reuse Project is estimated to be approximately $140 million dollars. This estimate includes the pipeline, reservoir, irrigation system and its appurtenances, an ethanol plant, a confined animal feeding operation (CAFO), and an anaerobic biogas digester (Figure 3). The Center is working with the District to obtain the project financing from private and public entities . This synergistic program creates significant benefits to the economy of Northwest Indiana, which include:

1. improved corn yields from the nutrient laden water delivered to farmers
2. reduced user fees for Hammond Sanitary District's residents
3. reduction in capital and operating costs to the District.
4. reduction in fertilizer use by farmers, which qualifies for carbon credits
5. production of ethanol from the corn
6. jobs created by the ethanol plant, CAFO and the anaerobic digester, and
7. improvement of water quality in Lake Michigan, a large drinking water source.

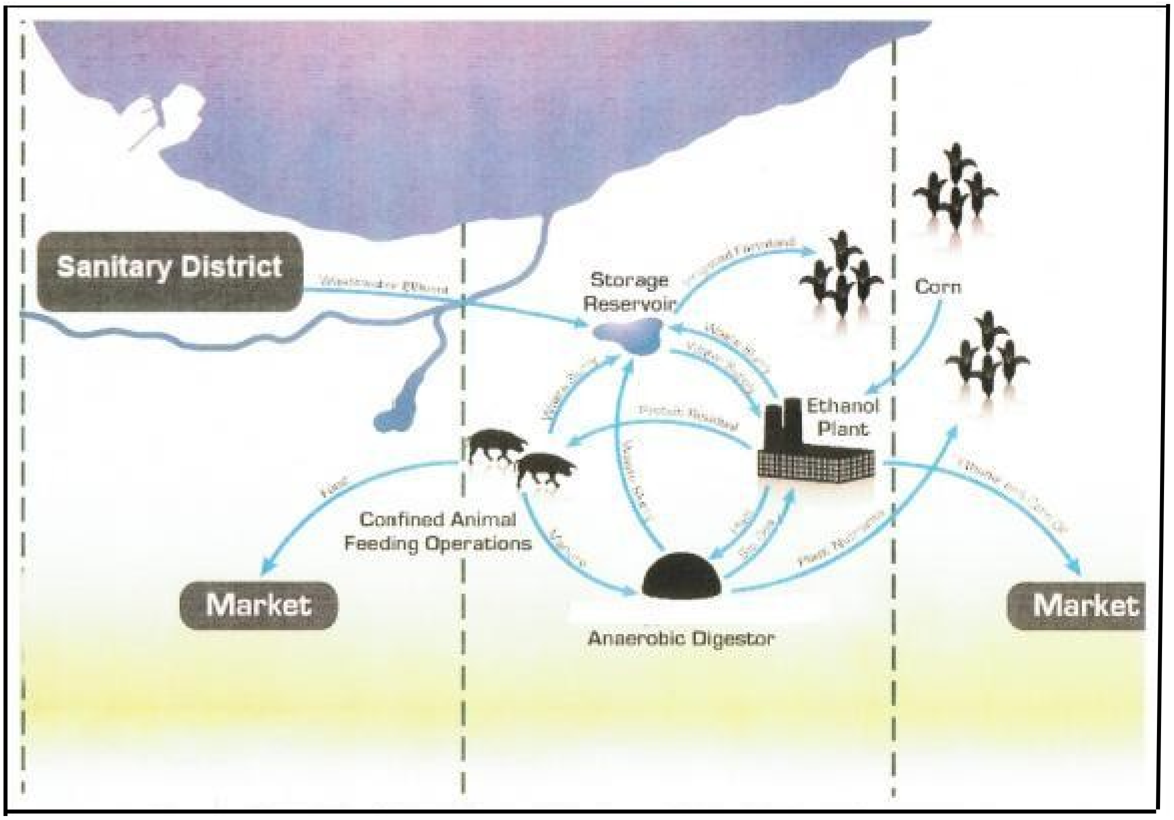

Figure 3. Sketch Plan Utilizing Waste Effluent as a Catalyst to Generate Economy

Table 1 describes the synergistic benefits of the project and Table 2 details the estimated costs of the project.

Table 1: Tabulation of Synergistic Transactions

TRANSACTIONS	Annual Amount
1. Corn – 1,493,000 bushels @ $3.20	$ 4,777,000
2. Corn oil – 1,493,000 lbs of corn oil @0.60/lb	895,276
3. Ethanol – 7,000,000 gallons @ $1.75/gallon	12,250,000
4. Protein Residual- 28,000 tons @ $100/ton	2,800,000
5. Cows – Milk/Calves	8,000,000
6. Carbon Credits – 567,550 tons @ $30.00/ton	17,026,500
7. Fertilizer – Purchase avoidance savings of Nitrogen and Phosphorous	1,427,194
8. Nitrogen - removal of 2,555,000 lbs @ $11.00/lb[a] from Lake Michigan	28,105,250
9. Phosphorus - removal of 462,981 lbs @ $5.00/lb[a] from Lake Michigan	2,314,905
Total	$60,570,499

[a] Based on the creation of a Lake Michigan mineral and nutrient exchange program.

Table 2: Start-up Cost Estimates for the 38 mgd Hammond Water Reuse Project

Item	Cost Estimate ($)
1. Detailed Planning Proof of Concept	$ 200,000
2. Design (Plans and Specifications) and permitting	3,000,000
3. Effluent distribution pipelines	40,000,000
4. Effluent and Irrigation Pump Stations	10,000,000
5. Storage Reservoir 38 mgd x 13 days (13,178 acre feet)	14,000,000
6. Irrigation of acres	11,350,000
7. Payment for Irrigation Easement	11,350,000
8. Monitoring Wells 180 x $2,000	360,000
9. Site Improvements	248,000
Sub Totals	$ 90,510,000
9. Contingencies 25 %	$ 22,627,500
Total	$ 113,137,500

Thus, integrated water management in Northwest Indiana has the potential to improve the economy of the region, create jobs, improve public health, and convert the nutrients in treated wastewater to improved corn yields to farmers. Such projects should be planned and implemented in India to take the treated water from cities to the rural areas where there is always a demand for water for agriculture, and where over 700 million people live and produce the food for India. For example, a project to recycle Mumbai's wastewater to the drought stricken parts of Maharashtra will transform millions of lives.

KURKUMBH INDUSTRIAL ESTATE, PUNE, INDIA

The Maharashtra Industrial Development Corporation (MIDC) has 70 industrial estates including the Kurkumbh Estate. The estate is located about 70 kilometers east of Pune, and contains a total area of about 483 hectares. As of 1998, there were about 51 industries in the estate, although 109 industries are eventually planned. The estate overlies a freshwater aquifer, and hence, discharging of untreated wastes on land or to a water body is prohibited. Of the industries, 18 percent are classified as large, 12 percent are medium-scale and 70 percent are small scale industries. A common effluent treatment plant (CETP) was built by the State to treat the effluent from the small- and medium-scale industries. The plant capacity is 1 – million-liter- day (L/day) and has provisions for primary treatment, biological secondary treatment, and chlorination. Since the State did not want to operate the CETP, they issued a contract to Tetra Tech India Limited (TTIL) to conduct a feasibility study to determine the optimal use of the treatment plant (Tetra Tech India Limited, 1998).

Phase 1 of the feasibility study consisted of inventorying the industries in the estate, and determining the types of effluent that they generate. Phase II consisted of collection of composite wastewater samples from various locations within the estate, estimating the flow volumes, and performing bench-scale testing to determine the scope of the pilot plant testing in Phase III. During Phase III, a pilot plant was built to treat bulk composite effluents from the industries for a 3-week period. Phases II and III of the study are briefly described below along with recommendations made to MIDC.

During Phase II, collected samples were analyzed for pH, biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), total kjeldahl nitrogen, oil and grease, chlorine, sulfates, acidity/alkalinity, and heavy metals. The pilot plant capacity was 50 L/hour and the influent water and treated water characteristics are shown in Table 3 below.

Table 3. Test Results from the Industrial Wastewater Treatment Plant.

Sampling locations	**pH**	**COD (mg/L)**	**BOD (mg/L)**	**TDS (mg/L)**
1. Influent Water.	**Acidic to Neutral.**	**4000 to 5000**	**1500 to 2500**	**2500 to 4500**
2. Treated Water.	**Neutral**	**250**	**100**	**2500 to 4500**

Based on this sampling, the following treatment scheme was established for the pilot plant:

1. Primary treatment including precipitation of inorganics and removal of oil and grease,
2. Secondary biological treatment including post-treatment chlorination and activated carbon filtration.

The BOD could be reduced to less than 100mg/L if the hydraulic retention time is about 1 to 2 days. The COD could be reduced to less than 250mg/L if the retention time is between 3 to 6 days. The chemicals used for primary treatment were lime, urea, and diammonium phosphate.

The secondary treated water will either be recycled for industrial use, or for horticulture in the estate. In addition, the CETP can be expanded to include a Reverse Osmosis unit for tertiary treatment of the water if the industries will pay for the cost involved in tertiary treatment.

The cost of the treated water with secondary treatment was estimated at about Rs.15 per cubic meter, and if with tertiary treatment, the estimated was Rs.30 per cubic meter. However, the cost of raw water at the industrial estate in 1998 was Rs.8 per cubic meter. Hence, unless the price of raw water was significantly increased, the CETP cannot be operated economically. Hence, TTIL recommended to MIDC that they increase the price of raw water supplied to the industries to a least Rs.18 per cubic meter to encourage conservation and wastewater recycling. MIDC did not increase the price of water as recommended till 2001, and so the plant remained idle till 2001. In 2002, the government raised the price of raw water to the industries to Rs.18 per cubic meter and the CETP became operational and wastewater is being recycled at the Kurkumbh industrial estate.

Conclusions

The case studies indicated that wastewater recycling can be accomplished using simple and well established technologies. With rain water harvesting, water conservation and wastewater recycling, we can have adequate water for all citizens in India. User fee policies that promote water conservation and wastewater recycling should be established at the central and state governments. Subsidies for the poor should be balanced with adequate user fees enforced for the middle and upper economic classes, and for the industry and agriculture sectors of the economy.

References

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