32nd WEDC International Conference, Colombo, Sri Lanka, 2006

SUSTAINABLE DEVELOPMENT OF WATER RESOURCES, WATER SUPPLY AND ENVIRONMENTAL SANITATION

Reclamation of Treated Wastewater for Agricultural Reuse: A Case Study in Vietnam

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In the face of regional drought and with the demand from increasing populations, we must be prepared to respond to the increasing need for water supplies. Surface and underground water sources no longer offer reliable and sustainable supplies. We must focus our attention on increasing the reuse of treated wastewater as a viable alternative to conventional water supplies. Wastewater must no longer be thought of in a negative sense, but instead must be valued as a renewable resource. This paper presents the efforts of a central highlands city in Vietnam to reuse treated wastewater, thereby reducing dependence on traditional water supplies.

Introduction

Water is a precious resource, essential to life on Earth. For that reason, we must seek the means to protect our water resources and to develop alternative sources which can help us sustain our water supplies. Potable water and wastewater share an important link, which is water itself. We must recognize that our wastewater is not a waste product, but instead a valuable resource, which if reclaimed, can provide a renewable and sustainable alternative to supplement our diminishing fresh water supplies. The reuse of treated wastewater for agricultural irrigation purposes must be given high priority. This paper will present a case study from Vietnam in which a sewerage project is beneficially utilizing treated wastewater for the purpose of agricultural reuse.

Reclamation project background

The Buon Ma Thuot Sanitation Sub-Component (hereinafter referred to as 'the Project') is a DANIDA-funded intervention for improving the sanitation, health and hygiene in the central highland city of Buon Ma Thuot, Vietnam. The DKK126.2 million (USD21.7 million) infrastructure-based project primarily focuses on the collection and treatment of sanitary sewerage, initially serving the needs of 33,000 residents and with the expansion capacity to ultimately serve the needs of 104,000 residents. The Project was formulated on the basis of separate system sewerage collection, with wastewater collected directly from households and businesses and then conveyed by separate sewerage piping to the wastewater treatment plant (WWTP) for processing.

The wastewater receives treatment by means of a three-stage stabilization pond system, which was completed in December 2004. The WWTP utilizes a dual-train series of anaerobic, facultative and maturation ponds which have been designed to achieve Class B Vietnamese wastewater standards, namely 50mg/l BOD and 100 mg/l TSS. According to the original Project formulation, the treated wastewater will be discharged to an adjacent receiving stream.

Reuse of treated wastewater for the purpose of agricultural irrigation has long been a Project goal, although such reuse capability was not a part of the original Project, due to funding constraints. However, recent drought conditions in the central highlands of Vietnam have prompted the development of alternative water supplies in the face of dwindling surface and groundwater supplies. For that reason, in December 2004, DANIDA agreed with the Project's proposal to provide an additional grant of DKK8.5 million (USD1.5 million) to the Project to fund the implementation of a reclamation system for the reuse of treated wastewater, with the specific goal of providing much needed supplemental water supply support to subsistence farmers in the agricultural areas adjacent to the Project's WWTP.

Drought Year 2005, a water resource crisis

In recent years, as the result of changing global weather patterns, the historical rainfall quantities of the past have not been realized in Dak Lak Province. Less-than-normal rainfall in Year 2004 has created drought conditions for the Province's farmers in Year 2005. Normal weather patterns typically provide a sustained rainy season for the months of May through October (6 months), with the other six month period being nearly without any rain at all. For that reason, shortages experienced during the Year 2004 rainy season created significant impact on the surface and particularly sub-surface (groundwater) water supplies in the region, having great effect on the agricultural community.

Dak Lak Province, of which Buon Ma Thuot City is the capital, can be characterized as having an agricultural-based economy, with approximately 200,000 hectares of land presently committed to the cultivation of coffee. Generally, coffee is being cultivated at small-size farms. Weather conditions pose significant economic risk on the livelihood of the subsistence farmers of the Province. The loss of production in the years of poor harvest impacted by drought, create very real and immediate impacts on the living standards of this sector. The fine line of economics which separates self-sufficiency from poverty is easily crossed when drought conditions result in lack of available water during key growing periods.

Figure 1. Ethnic minority farmer, family, well & pump

Drought in the central highlands of Vietnam in Year 2005 is not the first to be experienced in our region, nor will it be the last. The impact of the drought is obvious. Those farmers who possess the means to secure available water supplies will do so by pumping groundwater from increasing depths, while incurring higher costs. Other farmers who have limited or no access to available water simply must witness diminished yields or the inevitable loss of that year's crop or, in some cases, the death of the coffee trees altogether. In any case, the effect on the economic conditions and lifestyle of the affected farmers is immediate and oftentimes devastating. Drought causes poverty and human suffering.

Reclamation of treated wastewater as a alternative water resource

Agricultural irrigation for coffee production in the Province currently utilizes both groundwater and surface water sources. In drought conditions, both of these water resources become limited. Continuing drought will effectively lower groundwater tables, which may make pumping prohibitively costly or impractical. An alternative water resource must be found to reduce dependence on surface and groundwater resources. Reclamation of treated wastewater constitutes a viable, sustainable alternative water resource.

Treated wastewater represents an ideal alternative water source, particularly appropriate for irrigation of crops which are not directly consumed, such as coffee trees. Since the stabilization pond treatment process removes only a portion of the nitrogen and phosphorous nutrients found in the wastewater, these nutrients will be available to contribute to the overall requirements of the plant growth thus reducing the need for supplemental fertilizers.

Wastewater production, as a function of daily domestic water use by the residents of Buon Ma Thuot City, will be continuous on a year-round basis, with little impact from drought conditions in the rural areas. As such, the treated wastewater provides a dependable, reliable supply for agricultural reuse purposes. In Phase 1 of the Project, the 33,000 people connected to the sewerage system will generate on the average 4,000 cubic metres per day of wastewater. In Phase 2, the Project will connect a total population of 65,000 people, generating a wastewater flow of 8,000 cubic metres per day.

Health and hygiene considerations for wastewater reclamation

As most farmers living adjacent to the Project's WWTP practice the cultivation of non-directly consumed crops such as coffee and rice, there is little concern regarding the impact of bacterial/viral content of the reused wastewater on the crop produced. However, there is a concern regarding the health and hygiene impact on the farmers who will be directly involved in the reuse of the wastewater. The risk of disease through direct contact with treated wastewater reused for irrigation will never be eliminated entirely, but can be minimized through the application of appropriate disinfection technology during the treatment process and through proper instruction to farmers in terms of safe handling of the reclaimed wastewater. Such consideration for farmer health and hygiene safety was the justification for enhancing the disinfection treatment requirements for wastewater to be reclaimed for agricultural reuse.

Disinfection of wastewater generally occurs by application of one of two methods. The first method involves the use of chemical oxidation by means of chlorine, ozone or other oxidants, and the second method involves the use of ultraviolet light, either as solar radiation (sunlight) or electrically-generated UV light. In developing countries such as Vietnam, one should focus on simple, sustainable technical solutions, those which have low operating costs. For the original sewerage project, maturation ponds were utilized, providing disinfection without the need for the use of chemicals or electricity. Through reduction in bacterial, viral and helminth egg content by means of solar radiation, sedimentation, natural die-off and predation, a sustainable level of partial disinfection can be achieved. Such level of treatment will attain the Vietnamese Class B standard of 10,000 MN fecal coliform per 100 ml, allowing for the safe discharge of the treated wastewater to a receiving watercourse.

To improve the treated wastewater quality in terms of pathogen reduction and to better protect the farm workers from contact exposure, it was decided to provide enhanced disinfection treatment through the construction of four additional maturation ponds. The two original preceding maturation ponds were converted to second stage facultative ponds, in order to enhance the BOD/TSS treatment characteristics of the treated wastewater influent to the new maturation ponds, thus improving the overall operational efficiency of the wastewater treatment system.

Basis of design - Treated wastewater reclamation system

The basis of design of the reclamation system can be divided into two parts, first, the enhanced effluent disinfection treatment and second, the use of pumping, storage and delivery system network for the reuse of the treated wastewater, as follows:

Enhanced effluent disinfection treatment

- Conversion of existing two maturation ponds for use as second stage facultative ponds. This conversion is intended to provide enhanced biologically-treated effluent to the maturation ponds. Facultative pond effluent with enhanced BOD/TSS characteristics will be more suitable for encouraging pathogen die-off in the maturation ponds.
- Addition of four new maturation ponds, two trains of two maturation ponds each in series. Each pond would have a side water depth of one metre, also encouraging reductions in numbers of bacteria and helminth eggs.

Reclaimed wastewater pumping, storage and delivery system network

- Submersible pumping station for pumping of the reclaimed treated wastewater to the elevated storage reservoirs to facilitate reuse for agriculture. Four duty submersible pumps, each pumping into dedicated pressure mains to the four storage reservoirs. The nominal design capacity of each pump is 2,000 cubic metres per day, to allow for reuse of wastewater at the Phase 2 (65,000 pe) design capacity of 8,000 cubic metres per day.
- Pressure mains constructed of DN250 uPVC piping. The two lower reservoirs would be served by pressure mains of 250m length, whereas the two upper reservoirs would be served by pressure mains of 500 m length.
- Four reservoirs constructed, each designed with a working capacity of 1000 cubic metres. Two low-lift reservoirs are sited at elevation 22 metres static lift above pumping station elevation. Two high-lift reservoirs are sited at elevation 32 metres static lift above pumping station elevation.
- Gravity delivery system using DN250 uPVC piping, installed at falling slope of 5m/1000m away from reservoirs. The delivery pipeline is fitted with valved DN50 taps at 150 meter spacing to facilitate water reuse by area farmers. Farmers are allowed access to the water pipeline during specific irrigation periods, as allowed by the operational staff of the delivery system. The delivery pipelines were hydraulically modeled using EPANET version 2.00.10 to ensure flow balancing at the taps during periods of high utilization.

Operation of the Reclamation System

Irrigation demand, notably for coffee crop irrigation, has very specific requirements. To fully optimize the production potential of coffee, the coffee trees must be irrigated at specific times during their growing season, so as to induce the correct response in the plant. If water is not available at

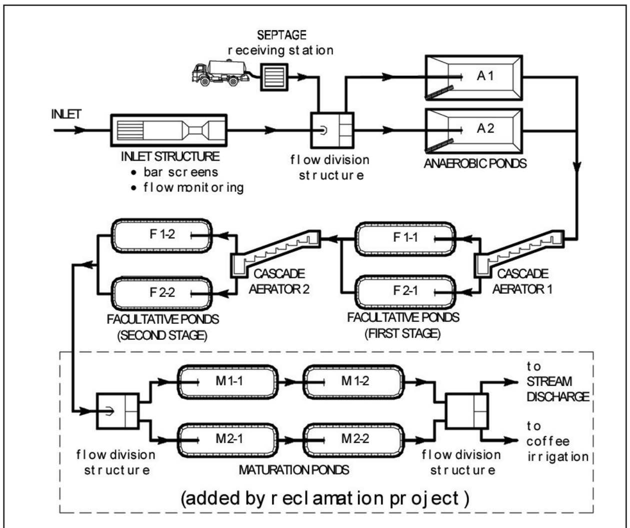

Figure 2. Reclamation System – WWTP Schematic

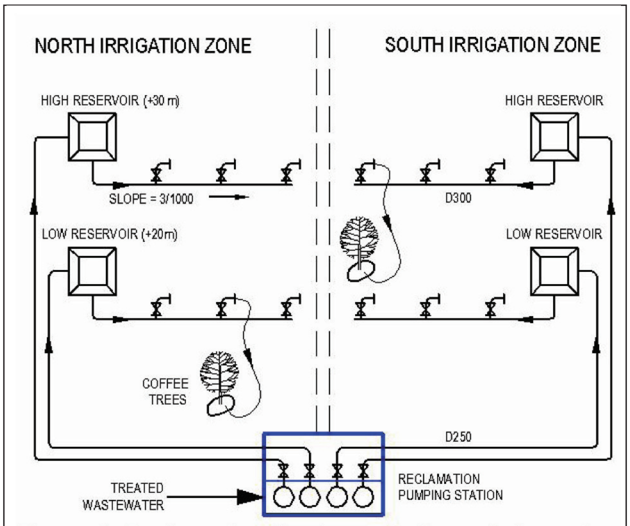

Figure 3. Reclamation System – Delivery Schematic

these critical times, the coffee trees will either produce at reduced levels, will not produce at all or in the most severe case, will result in the death of the mother plant. Irrigation demand for coffee occurs during the dry season months of December-April. During this period, coffee trees will require irrigation at four specific periods related to the propagation of the coffee flower and later seed. As the Project wants to maximize the use of reclaimed wastewater so as to provide the optimum benefit to the farmers, it was necessary to stagger the four specific irrigation periods between fields in the Project irrigation area.

At the Phase 1 production level of 4,000 cubic metres per day, approximately 100 hectares of coffee trees can be irrigated, with the irrigation times staggered between fields to allow a near continuous use of the treated wastewater during the five month irrigation period. At the Phase 2 production level of 8,000 cubic metres per day, approximately 200 hectares of coffee trees can be irrigated.

Operation of the irrigation system will require close coordination between the reuse system operator and the farmers, with strict enforcement of periods of allowed use and non-use of the system, so that the maximum number of farmers can receive benefit from the system. As the delivery system has been established with both low and high level storage reservoirs, each can easily be utilized on staggered irrigation periods to allow gravity service to those farmers tributary to that specific reservoir.

Operating costs and financial sustainability of the reclamation system

Operation of the reclamation system will incur costs, largely those costs associated with electrical power consumption for pumping. At Phase 1 design levels, 4,000 cubic metres per day of treated wastewater would be pumped for reuse, resulting in a daily electrical power consumption of approximately 800 KWH. Based upon a four month irrigation period, with pumps operating 30 days per month, the total estimated electrical power consumption would be 96,000 KWH.

At the current electrical power rate of USD 0.06/KWH, the cost of electrical power would be USD 5,800 per irrigation season. Distributing this cost over the planned irrigation area of 100 hectares, the projected average cost of treated wastewater delivery would be USD 58/hectare per season. In comparison, the typical irrigation cost using pumped surface or groundwater will range from USD60 to USD200/hectare per season, depending primarily on the pumping head required. Coffee production, given current market conditions, will generate revenues in the order of USD1,500 to USD3,000 per hectare, depending on soil type and yields. Thus, it is reasonable to conclude that the projected cost of reclaimed treated wastewater can be borne by the farmers, within their present cost reference.

Financial sustainability by definition means that revenues collected must equal or exceed the costs of operation and maintenance. In the case of the reclamation system, this would mean that all costs associated with operation and maintenance would need to be fully borne by the subsistence farmer end-users. However, recognizing the current economic challenges faced by a majority of the irrigation area farmers, of which at least 60% are indigenous ethnic (Ede) minority people, it is reasonable to say that a portion of the cost of operation and maintenance must initially be subsidized by the local government, until such time the benefits of the reliable water source can be fully appreciated by the end-users. Increased yields, sustainable harvests and reduced uncertainty over water supplies will all contribute to improved economic conditions for the farmers, who will then have a greater ability (and willingness) to pay more fully for the service provided.

Conclusions and lessons learned

Reclamation of treated wastewater offers a viable alternative to currently available surface and underground water sources. Implementation of a reclamation system for reuse of treated wastewater for agricultural irrigation provides significant benefit to the economically-challenged farmers. Supplementing the viable existing water supplies with a reliable, sustainable reclaimed water source will serve to strengthen the farmers capacity to earn a living and will reduce, if not eliminate, the economically crippling effects of drought.

Lessons learned from our experience with implementing the Reclamation Project are as follows:

- Irrigation of coffee trees with treated wastewater is a compatible and beneficial use.
- Treated wastewater contains residual nutrients which will reduce farmer's dependence upon applied fertilizers.
- Enhanced treatment of wastewater reduces potential health impacts.
- Economically, the cost of supplying reclaimed wastewater is comparable, if not lower, than the cost of current water supplies.
- Use of reclaimed water will provide a reliable, sustainable water supply which can help boost the living standards of economically – challenged subsistence farmers, thus reducing poverty and creating opportunity.

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