

**A Case of Technological Change and Transfer in the
Treatment of Municipal Wastewater: The Constructed
Wetlands of Quilehtla, Tlaxcala, Mexico**

Dr. Firdaus Jhabvala

Director, Centro de Estudios de Investigación del Sureste A.C.

Villahermosa, Tabasco

1 Introduction

Wetlands have been constructed for wastewater treatment since the mid seventies in the developed countries. Ever since Siedel¹ (1952) and Kickuth² (1978) tried to simulate nature to treat wastewater in Germany, constructed wetlands technology has progressively grown in quality, depth and width. Sophisticated models for the design of different types of wetlands exist in many countries all over the world.

One aspect of constructed wetlands technology stands out glaringly: there are few examples and fewer studies done on successful cases of wetlands technology in the Developing World. The absence of good information on this technology is even more surprising considering that it could serve better the billions who inhabit the Tropics, where temperature, luminosity, and plant and microbial growth are much more favorable to nature-oriented technologies; the need for wastewater treatment is much greater; and the technology is clearly intermediate (or appropriate), taking into account its zero use of chemicals, virtually no use of mobile mechanical parts that need constant replacement, its low energy costs and its general versatility and ubiquity.

Faced with the enormous real advantages of this technology, this paper outlines the steps that were taken to build a wetlands plant in the municipality of Quilehltla in the State of Tlaxcala in the central highlands of Mexico; the results of that plant; the difficulties of constructing the plant; the importance of individuals in the implementation of new technology; and the contribution we would like to make towards the development of a general model of wetlands technology for developing countries.

2. The Technology of Constructed Wetlands

Constructed Wetlands mimic nature which has been cleaning up wastewater for millenia before Kathy Seidel thought of imitating it for this purpose. Nature uses ponds, already in use by man in the past century in the form of lagoons, later aerated, but used with aquatic plants in wetlands technology; vertical flow wetlands, as when precipitation seeps in; horizontal flow as when water moves through a delta; and waterfalls, as with the biological filtering of dripping water. Sometimes, biofilters may be excluded from the tool box of wetlands technology since wetland plants are not used, as also its heavy use of pumping, although the other characteristics of the technology may all be in place.

These first generation models, typically reed beds, used as all-purpose wastewater treatment plants, rapidly clogged up and the biological reactor short-circuited due to overcharging. It became painfully obvious that while nature was the best wastewater cleaner, it also had its

¹ “Constructed Wetlands for Water Quality Improvement”, Moshiri, Gerald A; Lewis Publishers, 1993.

² “Constructed Wetlands for Wastewater Treatment”, Hammer, Donald A; Lewis Publishers, 1993

hydraulic and loading conditions. Basically, wastewater carries solids ranging from 200 ppm (parts per million) or 200 mg/l, through to 1,000 mg/l for places like Quilehla.

Of course agricultural, livestock, industrial and other wastewater goes even higher. Now, all substrates cannot handle any influent strength. Moreover, the time needed to optimally use a constructed wetland had to be figured out in an equation linking influent and effluent qualities with the other variables: temperature, size, depth, porosity of the substrate, etc. This is what I call the basic scientific problem of wetland technology.

The removal of large particles was efficiently done with normal pretreatment processes (screen bars and sand pits), and the sedimentation of small particles, as also their anaerobic digestion, was taken care of through digestors, developed on the existing technology of Imhoff tanks. So, basically, wastewater had to go through an assembly line process where different processes prepared the solids for ultimate disposal. The objective here has always been to dispose off all solids, unlike conventional treatment plants which continue to battle with solids long after wastewater has been treated, an important additional cost to the economy and the health of the municipality.

The use and incorporation of pretreatment facilities and the development and use of digestors took up close to a decade so that the second-generation of constructed wetlands incorporated these before introducing wastewater into the treatment system. Nevertheless, the basic scientific problem of how much of each type of wastewater could be processed to yield an effluent of a desired quality in different circumstances was to take up a longer time, and the equations for wetland design are still being battled over, and may be considered skimpy in general, and worked out in some detail only for subsurface and surface flow wetlands which move water laterally through the cell from one end to the other, in the first case totally below the surface, and in the second to a height that varies to about 30 cm., the length of the stalk of the wetland plants used. This process of converting experience into science, not just rule-of-thumb technology, is still in its cradle despite monumental efforts made by a dedicated group of wetlanders in the developed world.

Despite these drawbacks, the appeal of natural technology to human beings is so great that wetlands for wastewater treatment have sprouted like mushrooms all over the developed world, and there are at least 2,000 of these plants in all the continents, and more are springing up all the time. The plant in Quilehla has been visited by people who have made Herculean efforts to get there. One person from Venezuela, on visit to the U.S., stopped off in Mexico City, made the road trip to Quilehla to see the plant and then continued on his trip. Teachers and students regularly trek several miles to visit the plant. An ecologist drops in from the Sierra Gorda of Querétaro because she heard that there exists a people-friendly technology that is an alternative to the “white elephants” being built all over. And so, as in the Developed World, constructed wetlands technology is being promoted by people, not necessarily the “experts”.

3. How I got hooked to wetlands

I had earned my doctorate in Economic Theory from the Wharton School of the University of Pennsylvania. My doctoral work was on optimal control with technical change. I did not know then, that just a smattering of theoretical knowledge would not be acceptable to me, and that I would have to implement some technical change on my own to feel better inside. So, after teaching and working in government and private enterprise for a few years, I left for Mexico and started working and then consulting in the State of Tabasco in Southeastern Mexico. Now, Tabasco has been designed by nature as a series of great wetlands that filter out silt and other solids as the many rivers of Mesoamerica, prevented by mountainous terrain from easily gaining the Pacific, meander into the State and then feed the Southernmost part of the Gulf of Mexico with a wealth of species, aquatic and land, but mostly wetland inhabitants and tourists, such as Northern aviary migrants. The mysterious workings of this ecosystem have fascinated me from the day I arrived in Tabasco and decided to make this hot, steamy wetland state my home.

Now, wastewater is a curious thing. When one person sends his or her wastewater to a stream or lake, nature may be able to treat it. Of course, populations grow, and in the deltas of the world, they live next to a water course contaminating it, but also testing and tempting nature in the process. So it is in Tabasco. After the increase in oil prices in 1973, the State population virtually doubled in only about fifteen years, and as incomes grew, wastewater kept being dumped into the more than 30 rivers of the State in haphazard fashion. People began to get interested in the problem. Among them was the State Minister for Public Works. So, when friends in the U.S. began to tell me about wastewater treatment with constructed wetlands, I decided to organize a trip with the state's decision makers for wastewater. In December of 1992, we visited the Experimental Center for Wastewater of the T.V.A. in Muscle Shoals, Alabama.

The visit was a real eye-opener, and I realised that I was looking at intermediate and appropriate technology that would be much more effective in Tabasco, with its hot, natural wetlands, than in the Developed World. My thoughts were shared by all the other participants. However, I was thinking in terms of arranging a relationship with the people at T.V.A. so that they could advise us, or even build the plants themselves. My knowledge of biology was close to zero, and of engineering limited to the math, stats and computer science taught to engineering students many years ago. I felt insecure and unwilling to propose a wetland plant on my own. The Government people also viewed me as a consultant on financial and economic topics, not wastewater. I now see the many errors of perception we all made. What came of the trip was the agreement to work out a feasible plan for cleaning up the Laguna de las Ilusiones (Illusions Lake) in the middle of Villahermosa, a 202-hectare lake in the process of eutrophication. This study was completed in 1994 and concluded with the proposed construction of a small constructed wetland to treat waste before it reached the lake. I was getting closer, but ever so slowly.

In 1993, while talking about this technology to a friend, Héctor González, it turned out that he too had seen the technology, and that he too wished to promote it. So, we began to talk about it to the politicians and decision-makers we knew. One of them set up a meeting for us with government officials in the Northwestern State of Sonora. We convinced them to visit some wastewater plants with us and so we took them to see the constructed wetlands of the T.V.A. at Benton and Hardin in Kentucky. We all came back charged up. But after three visits to Hermosillo, the state capital

of Sonora, we were still at the start, and we gave up tired and exhausted. Maybe, wetlands technology could not overcome the innate suspicion of Mexicans and other developing peoples towards First World Technology, even if it be Intermediate. Perhaps, I should not spend all that money to promote a dream. Maybe, I was not the right person to do this. Anyway I had done my part seeking out groups of high-level government officials from two different states. I was dejected, confused and worried all at the same time.

4. How we started building the Quilehla Plant

I now know that a good project works on the basis of goodness which has its own logic. And so, when I was about to mentally shelve the idea of introducing and consolidating constructed wetlands technology in Mexico, the then Governor of Tlaxcala, José Antonio Alvarez Lima, asked me, his adviser on economic, financial and administrative affairs, what I know of wastewater plants. I told him my experience, and he gave me for revision a copy of the executive project for a conventional treatment plant with activated solids in the municipality of Zacatelco. I was stunned when I read the project: 60% of the total cost was for preparing the terrain and sustaining the heavy structures. The project was very expensive to build and more so to maintain. I duly reported my findings to the Governor, and recommended him not to go ahead with that project.

“If you tell me this project is no good, you have the responsibility to tell me which one is good” the Governor told me. I replied that I knew of people in the U.S. who could solve the state’s wastewater problem through a great new technology which I proceeded to describe. The Governor cut me short and told me, “If they can do it, so can you. Go to the Public Works Secretary and get a piece of land where we can try out the project and show everyone it works. Then, we can go on to building other projects.” I had not thought of this intermediate or appropriate step. It was a longer road, but the Governor’s faith in the project was even greater than mine. So, I explained the situation to the Public Works Minister, and hoped to start a constructed wetland soon somewhere, I didn’t care where, and so I stepped into another labyrinth. Haste does make waste, and waste cannot be treated in haste.

The Minister of Public Works lived in a well-off area on the fringe of the city of Apizaco. The wastewater of this area ran out without drainage or treatment. On the assurance that drainage would soon be built, I started work on the project for Santa Anita Huiloac together with Héctor González, who had introduced me to Michael Ogden of Southwest Wetlands, Inc. and whose love and knowledge of constructed wetlands elevated him to the status of a worthy guru of this technology. The team was now complete.

We finished the executive project for Santa Anita Huiloac, but there was no drainage. Meanwhile, the Secretary we were dealing with left his post. Presentations of the technology and the project were necessary at all levels: local, municipal, state and federal. And although an executive project had been completed on paper, nothing had occurred on the ground. But word got around that we could solve municipal wastewater problems. So we were given two more executive projects for small towns with no treatment: the towns of Emiliano Zapata and Díaz

Ordaz, both straddling large hills. We made the recommendations for the drainage system and the plans for the wastewater treatment facilities.

Meanwhile, Zacatelco kept dumping its wastewater and that of the towns in the basin above it that all drained their effluent into the Zahuapan River. One way of dealing with the problem would be to build a plant just for Quilehtla and treat its water. And in a later stage, build another for Zacatelco. The idea caught fire among governmental officials and so we started the executive project for Quilehtla in late 1993.

5. Construction

Once the executive project had been authorized by the National Water Commission (which converts into the acronym “CNA” in Spanish), in the State of Tlaxcala, it had to be approved once more in Mexico City because of doubts expressed at the state level. The same situation occurred for the financing institution: the Secretary of Social Development (“SEDESOL”) which approved the project both in Tlaxcala and in Mexico City.

After both approvals had been secured, the Tlaxcala State Secretariat of Public Works put the project through a bidding process and acquired sufficient land (slightly over a hectare) for the project to break ground. On my part, the company of which I am director, Impulsora Nacional de Tecnología, was to supervise the project, direct construction and also serve as a consultant on construction of the treatment plant. This is very important if the project that is really built is to be of quality. Generally, in Mexico, projects are churned out by firms that are not constructors of the project. Some one else builds, and a third party supervises, because there is enormous distrust. The result is that no one is responsible as occurs for instance in the U.S. where construction is directed by a person or firm responsible for the results obtained. So in Mexico, it is relatively easy to build useless or unworking projects with no one responsible for the waste of resources.

Construction work had just begun when it was interrupted by a mob of protesters from the next municipality, Zacatelco, threatening to close down the construction if an auditorium was not built in their town, as had been agreed upon according to the crowd by some previous government. Talks started and the State Government decided to close down the plot where construction had just begun, inside the municipal boundary of Zacatelco, and move it across the road to another plot in Quilehtla.

Soon after, the Great Mexican Financial Crisis of December of 1994 broke loose, and federal financing was cut off, so that the project was again held up until the month of August 1995 when resources were available. The break in construction was almost a disaster. Earthwork for the cells is a difficult process if it is not completed, the membranes put in place, and the cells filled up with substrate. If the cells are bared to the rains and the wind, they tend to collapse, which is what happened due to the long wait for funding to begin anew.

There was another problem associated with the construction. Since there was little or no funding, the contractor often did not turn up to work and so our supervisor also began to take hours and later days off. Keeping track of the project from Villahermosa began to become impossible, and

both the contractor and the engineer supervising began to take advantage of the situation. A total shake-up was necessary if Quilehltla was to be completed.

The Secretariat of Public Works was now run by a supremely capable architect, Julio Garcí-Crespo, who is also a confirmed ecologist and humanist. I met with Julio to reorganize the work at Quilehltla around new people all round: a new contractor, a new supervisor, and a new person responsible for the Secretariat were all found. The supervisor who had worked for Impulsora came from Héctor González, who also withdrew from the project at the same time.

After the reorganization, the plant was totally constructed by September of 1996 and the plants were sown by November of the same year. Quilehltla went into production that same year, and has been a joy to see ever since.

6. Human Perceptions

In implementing technical change, the human factor is overriding. From the start, many people played an important role in promoting the technology, and some a vital one. But essentially, the project was a result of someone promoting it until final realization, and a host of authorities in their specialized spheres. So basically, there was a small team of people in the firm promoting the technology (only two people really -the supervisor of the project, Miguel Carbayo, and to some extent, myself, aided by others in the fields of calculation, computing, etc.) The authorities are presented in Scheme #1.

Although all the institutions and people shown in the Scheme were important to the project, it is now clear to me that the project had no chance of becoming reality without the avid and positive participation of the political authority, in this case personified by Governor Alvarez Lima. By no means can Quilehltla be classified as his pet project, yet he visited the site during construction and operation more than half a dozen times, always wanting to help with something, and checking up to see that I was doing my part. His philosophy was summed up by himself in three words: “Ethics, aesthetics, efficiency”, and he was unbending in his demand of all three objectives, although total flexibility could be had on all else. Another time he explained to me the practical rules between the material and spiritual spheres of life: “A dream without an executive project leads to chaos. An executive project without a dream is devoid of life”. These simple rules permitted a truthful relationship between us, and guaranteed the completion of the project as an article of faith for both of us.

After Quilehltla, I know that the process of encountering an adequate relationship with the political authority is perhaps the most difficult step in technological change and transfer in developing countries. Without an inspired and human outlook here, nothing of class can be expected from the project. The demands of human corruption rapidly swamp the project and inundate it with mediocrity at best. In this pathetic state, recourse to irreality, that is the absence of truth, is the only alternative available, and the project cannot serve as an example. It does not carry the force of the clear demonstration of a simple truth, such as the one in Quilehltla: Man can use nature around him to convert contamination into a useful good.

Gubernatorial behavior having set the tone for Quilehltla, most of the other actors responded in very positive fashion. It would be an error on my part to try and evaluate their importance, since the project depended upon all of them. One of the people I must mention was the Secretary of Public Works, Julio Garci-Crespo. Julio also knew about constructed wetlands before we began Quilehltla. His vision of Quilehltla as an important project for cleaning up wastewater was based on his faith in life (or ecology) and the small but critical role played by man. He knows the construction industry inside out and used his knowledge to help sort out the myriad of details and problems that Quilehltla faced, and I am sure all projects face everywhere. His influence and personal integrity weighed heavily. Needless to say, Quilehltla made us good friends.

Because of Julio's constant caring, the contractors were relatively orderly, and their famed abusing of public funds was limited to the utmost. On our second project in the town of El Carmen Tequexquitla in the State of Tlaxcala, I later got to know contractors with a firm ethical position derived from their view of life. If it had not been for these two factors, coupled with really excellent supervision on site by our engineer Miguel Carbayo, I am sure that costs would have skyrocketed and quality fallen. The result would have been a financial crisis on the one hand, and interminable repairs on the other, both during construction and later in the operational phase.

It is incorrect to state that capital is scarce in the Developing World, without adding that this is so, because it is constantly being wasted and being converted to "Discapital", that is a problem. Mexico, like all Developing Countries, is strewn with useless infrastructure, capital invested in creating a problem, instead of solving another. And in wastewater treatment, the situation is certainly worse than the poor average overall. To start with, only 20% of wastewater gets any kind of treatment at all. Considering that somewhere near 80% of all diseases in the Tropics are waterborne, that is, transferred through untreated wastewater, a huge population is vulnerable to a high risk environment. So, investing in efficient wastewater treatment plants should be at the top of the list. It isn't, of course.

But when it comes to actually making the investment to do what it is supposed to do, I have found a very high percentage of plants permanently shut, for one of very many reasons. Of the rest, at least half churn out effluent that looks just like the influent. Plants that actually turn out effluent of a reasonable quality are few. So, inappropriate technology, combined with poor ethics, aesthetics, and efficiency, guarantee a long struggle simply because everything will have to be done three, four or more times, instead of once. Now capital is scarce.

In El Carmen Tequexquitla, there exists a market building, a sports unit, an auditorium, and a public plaza, all in disuse or abandoned. The plant we built was constructed on top of the ruins of a previous attempt. The drainage system is incoherent, collection pipe sizes varying at random in size and in depth. Once the Governor told me, "El Carmen has had a long history of terrible public works. Please don't make the treatment plant into one more disaster." This is the common state of affairs as far as public works are concerned, not just in El Carmen but in all of the Developing World. So, doing a project correctly requires people of quality in all phases of construction. I was fortunate to have them.

In all situations of technological change or transfer there has to be a source that is experienced, with a flexible mind to understand the problems of adaptation, wise to know that what is really at stake is not the contract, and also ethical, aesthetical and efficient. I had not imagined that such a person could exist especially in the specific field of constructed wetlands. Now, almost six years after getting to know Michael Ogden, I can say that he is all that and more. Michael drew up the plans for Quilehltla, he explained them to Héctor and to me, prevented major errors, and with oriental patience put up with our faults. Each of Michael's visits to the plant was a learning experience for me and everyone else. You could see he ran a tight ship and his innumerable recommendations were invaluable for constantly improving the quality of the project. Quilehltla works so well because Michael was there from the start and put his heart into it.

At our end, we needed an engineer who could supervise the project on site in a permanent way. Wastewater plants take anywhere from 6 months onwards to build. Less than a year is generally good going. So you need a civil engineer who actually lives at the site as the plant comes up. He has to be meticulous and watchful, or you get a plant that does not do what its design specifies. In short, you have at least a muddle on your hands, very possibly a disaster due to the intimate relationships between the various processes in the plant. I was fortunate that one of my engineering students from over 20 years ago, Miguel Carbayo, worked with us on Quilehltla and El Carmen. Both plants are doing well because he dedicated so much of his time to the supervision of the contractors.

Finally, there are too many other people who helped at each stage. Operationally, we trained a peasant from Quilehltla, Hilarion Sánchez, who has successfully operated the plant together with sometimes one assistant, and at times two. So, essentially, Quilehltla works with two people, who are both residents of the area.

7. Results*

In wastewater, it is the amount of contamination you get out that counts. Three broad indicators are: BOD₅, TSS, and TCC.

BOD₅ is the Biochemical Oxygen Demand of the water after it has been rested at 20°C for 5 days. All organic and chemical substances demand oxygen for their transformation, and when BOD is zero, water is pure on this count. Typically, BOD in municipal wastewater in the central highlands of Mexico measures around 400 mg/l and the effluent norm is 60 mg/l. On occasion, in places such as Quilehltla, due to livestock and industry, the influent could get up to 2,000 mg/l, although figures of 600 to 1,000 mg/l are the most common. So, if you have less than 90% efficiency in your plant, you won't make the grade. Quilehltla has steadily chalked up a 95% rate of removal of BOD₅.

* Detailed Results are presented in Jhabvala, Firdaus: "The experience of Constructed Wetlands Technology for wastewater treatment, the Quilehltla Case".

TSS is Total Suspended Solids. Wastewater brings in large volumes of very tiny suspended solids that have to be removed. The figures for TSS are very similar to those of BOD for Quilehltla, and efficiency is also better than 95%.

Coliforms are the major objective in wastewater treatment. They comprise a wide range of microorganisms including viruses and bacteria and go in size from a thousandth or so of a millimeter onwards. They live off and adhere to the particles in wastewater, so it is necessary to get out solids in order to decrease their population. In Mexico, and other Developing Countries, technology is being developed to attack coliforms without decreasing the solids present in wastewater which have agricultural and other uses. This technology is generally still considered immature. If it should become commercially viable, it would be a good alternative wherever round-the-year farming demands for wastewater are greater than the production, or other disposal of solids is easily available.

As of today, the state of the art indicates that you get out solids, bring down BOD, and then attack the coliforms that are still left in the wastestream. This is the line that we have followed. Coliforms are counted up by colonies per 100 ml. Since the number of colonies goes up to several billions or more, the count is expressed in powers of 10. Quilehltla gets in coliforms anywhere from 10^6 to 10^{24} colonies per 100 ml. Although the coliform count in the influent is very high, the plant brings down the coliforms by a power of 10 between 3 and 21. A power of 5 or 6 is considered excellent in wastewater. However, the norm for effluent in Mexico is 10^4 . In order to help meet it on a constant basis, we have converted a tank built for ornamental reasons into a pond at the end of the treatment through subsurface wetlands. The pond has hyacinth and water lettuce whose roots trap solids that then attract microorganisms. Water quality has improved and Quilehltla steadily achieves the goal of 10^4 colonies of coliforms per 100 ml. The final configuration of the plant is as shown in Scheme #2.

8. Conclusions and Recommendations

Foremost in my mind is the thought that Quilehltla is like bringing forth a child in this world. There are great pains and worries on the way to birth, during the first year of life, and forever after, although happily on a steadily decreasing scale. Municipal operation is still in its infancy in much of overcentralized Mexico. This is slowly changing and winds of decentralization are blowing over the country. Yet, most minds are still highly centralized after centuries of waiting for somebody else in a faraway place to take the decision or deliver the goods. So, don't get into one of these projects if you are not going to be there when you are needed, and this need may go on in a minute form, but for long. Total delinking in a dynamic, unpredictable world seems to me to be impossible unless of course the plant is to be sacrificed on the altar of populist ideology.

So, if the promotor of the new technology does not stick with it, it may be discarded or abandoned. For this, the promotor has to be appropriately organized. In my case, two privately owned organizations of which I am director, one a commercial firm for creating and distributing technology and the other, a research center, were both intensely involved. In all cases, this internal institutional support is vital. It is not just a question of seed money or even resources in general, but of everything that an institution can offer. This is also necessary in order to get

feedback from the plants and occasionally visit them, perhaps once every few months or even years. At a second level, it is convenient to leave some direct and closer institutional support for the plants. This we have done through a signed agreement with all the other state and federal institutions involved in both plants. However the future holds no absolute guarantees for anyone.

A second conclusion has to do with the type of technology selected. While its design may be a specialized task at the moment, and its construction may depend to some extent on some parts from outside the region (geomembranes, basically some 10% of total cost), operation, maintenance and repairs have to be done in the region, preferably in the community. This condition limits the kinds of technology that can be implemented successfully because of the varying technological and operational heights to which the different individuals in a given community can possibly aspire in some given time frame. The longer the time frame, the greater the possibilities, but also greater is the dependence and smaller the relative degree of delinking. So, some equilibrium has to be achieved where all the actors can securely place themselves, since insecurity is the basic cause of project failure. Basically, this means that only Intermediate or Appropriate Technology has a real chance of working in the long run. Technologies that are superior are unattainable or unmaintainable; the ones that are inferior have no chance in terms of efficiency.

The technology has to be appropriate in the sense that it is within the capacity of the community or town to operate, maintain and repair. Otherwise, it runs the serious risk of being abandoned, as is the case with at least a quarter of all the treatment plants I have visited in Mexico, or at best have substantial suboptimal operation as is the situation in another quarter of the plants visited. Of course, the threshold of appropriate technology constantly changes, so it is a question of evaluating how far up the ladder of difficulty the community, town or region can really sustain itself. In our case, operation, maintenance, repair and virtually all the construction was done by people from the area, as also virtually all the purchases were made in a small radius around the town. The next stage would be managing the project and then the design of each plant according to the different conditions of each case.

A third conclusion has to do with the people. In Quilehltla, I received massive, and in most cases unstinting support from virtually all the actors involved. The community wanted its plant built. The regulators were generous in their approvals of the project on paper; the State Government of Tlaxcala, led by its Governor, pushed hard forward; technical support was excellent; a financial crisis was absorbed; physical invasion of the original plant site could be overcome; contractors were reasonable or at least kept in line or at bay; supervision was good; and operation, maintenance and repairs have not shut down the plant completely. So, if the humans working on and around the project don't have their hearts in it, then don't start the project.

At the second plant in El Carmen, all these factors were taken into account in the planning stage, and a much more complicated plant than Quilehltla was totally completed in only 10 months. Its operational base is much stronger and more secure than Quilehltla's. It also has strong local support from the time it was planned, so local involvement in operation is only a continuation of effort invested in earlier stages.

The people are a major factor in anything, and it is here that quality is most important. All technological projects are human in content, and if this internal, intangible, but highly real factor

is not based on true love for the project, then everything else is futile. I was fortunate to find many people in this elevated state of heart, and that is why the plants are working.

Another important factor is love of and trust in nature. People have to treat nature as they expect to be treated themselves. Taking care of the solids, the plants, the well-being of the microorganisms, is important if they are to work well and happily. Otherwise, go back to chemicals and machines.

People ask me how long the plant will work, or if changes in governmental policies, financing, party politics, etc., would not upset the technology. The future is not in my hands, but in God's, understanding Him as Truth, and it is His Judgement that I would gladly accept.

9. Bibliography

1. "Constructed Wetlands for Water Quality Improvement", Moshiri, Gerald A. Lewis Publishers, 1993
2. "Constructed Wetlands for Wastewater Treatment", Hammer, Donald A. Lewis Publishers, 1993.