The user adoption of horizontal subsurface flow constructed wetlands for a household scale in tropical Suriname

Applying Rogers' Diffusion of Innovation theory

B.Sc. Thesis by Tjalling Jasper Vlieg

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Bachelor thesis Irrigation and Water Engineering (IWE80806) submitted in partial fulfillment of the degree of Bachelor of Science in International Land and Water Management at Wageningen University, the Netherlands

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1. Introduction

This bachelor thesis is a follow up of my earlier study on the applicability of a Horizontal subsurface Flow Constructed Wetland (HFCW) at the orphanage Leliendaal in the district Commewijne, Suriname. The HFCW is an eco-engineered wastewater treatment system which aims on closing the quality gap between effluent from wastewater treatment plants and the required water quality for the end purpose. The National Women's Movement of Suriname currently researches the applicability of the HFCW for the treatment of domestic wastewater at rural households. The movement makes effort to understand the challenges that introduction and implementation of the technology could face. Suriname does not yet have a HFCW for the treatment of domestic wastewater and is not familiar with the reuse of treated domestic wastewater, for that reason the HFCW can truly be perceived as an innovation in the context of Suriname. An understanding of the potential adopter's decision making process with respect to this innovation can add to the pursue of adoption-oriented engineering.

The current Surinamese wastewater management practices can lead to environmental pollution and risk for human health (Strauss et al., 1997). The HFCW is a means to improve the management of natural resources by decreasing the risks for human and environment. A HFCW is a designed and constructed natural system consisting of a waterproof basin, filter material, wetland plants, and inlet and outlet structures. *'The system aims on simulating the treatment of polluted wastewater as it can be observed in natural occurring wetlands'* (Cooper et al., 1996, pp. 7). In a horizontal subsurface flow constructed wetland is the wastewater flows slowly under the surface in a horizontal direction from the inlet to the outlet structures. Treated wastewater can subsequently be applied for irrigation, fertilization, aquaculture, nature development, toilet flushing water, surface water replenishment, groundwater recharge, and even as indirect and possible direct sources of drinking water (Nkonzo, 2010). Even though the HFCW is deemed highly appropriate for developing countries (Gopal, 1999; Haberl, 1999; Kivaisi, 2001; Nanninga 2008; Rousseau et al., 2008; STOWA, 2005) its spread and implementation does not take place automatically. The diffusion process is influenced by several factors of adoption. These factors go beyond the technological features of the HFCW. As will be described more explicitly later in this report, the HFCW is not just an artifact that can be physically installed to reach its purpose. Instead the innovation is a component of a complex technology-related system which requires societal changes at multiple levels (Klerkx, 2010). These changes are induced by the adoption or rejection of potential users. The applicability of the HFCW system in the developing countries thus clearly relies on the decisions made by potential users.

The engagement between technology, technological engineers, and society is a widespread topic of research (Robbins 2007; Schot & Geels, 2008). The complexity involved to the adoption of innovations comes to expression in several relevant social-policy oriented theories, including Rogers Diffusion of Innovation Theory (DIT) (Rogers, 2003), and the Strategic Niche Management (SNM) (Schot & Geels, 2008) approach. Rogers' Diffusion of Innovations Theory offers a means to explain the factors that influence the spread and implementation of a new technology. According to Rogers the diffusion of an innovation amongst individual potential users is characterized by five different phases which a potential adopter passes through. The phases in succession are: knowledge, persuasion, decision, implementation and confirmation. Rogers typifies the potential users in early innovators, early adopters, early majority, late majority, and laggards (Rogers, 2003). The DIT aims on describing the process of diffusion of a technologically developed innovation, rather than modeling the entire technology life cycle including the interrelated technological and social context (Van Vliet, 2010). The SNM approach has proven to be of value in researching the early adoption of new technologies in a societal context. Schot and Geels (2008) state that *'the SNM approach suggests that sustainable innovation journeys can be facilitated by creating technological niches, i.e. protected spaces that allow the experimentation with the co-evolution of technology, user practices, and regulatory structures. The assumption was that if such niches were constructed appropriately, they would act as building blocks for broader societal changes towards sustainable development'* (Schot & Geels, 2008 pp 537). SNM does not suggest that the niches are inserted by the government in a top-down fashion, but SNM expects them to endogenously emerge trough collective steering (Schot & Geels, 2008). An elementary comparison between the DIT and the SNM approach results in the notice that SNM scopes on technological societal changes that initiate at the niche-level and can be '*building blocks for further societal changes'* (Schot & Geels, 2008 pp 537), whereas Rogers' DIT focuses on the lateral spread and implementation of a new developed technology at the level of the individual. Rogers seeks to answer the question why a potential adopter adopts or rejects and how diffusion takes place, whereas the SNM approach also aims on giving answer to what the favorable social-policy conditions are at multiple levels of the society. The initial developmental setting and the further spread and implementation within the technology-related system get explicit attention in the SNM approach. Together the DIT and the SNM approach have the capacity to explain the determinants of user adoption and the lateral diffusion amongst the users, and the technological and social context in which diffusion occurs at multiple societal levels. According to Van Vliet (2010) it is preferred to utilize both the DIT and the SNM approach for diffusion research. However, because of limitations in time, in this research only the DIT has been applied.

The aim of this research was to investigate the user adoption of HFCW by applying Rogers' Diffusion of Innovation Theory (DIT), so that firstly an effort can be made to understand the adoption of HFCW in the case of Suriname, and secondly to gain insight in the explaining capacity of Rogers' Diffusion. Because of its explaining capacity in several other studies on adoption of new technologies it is expected that Rogers' Model of the Innovation Decision Process will be of value if applied to the study of the HFCW-adoption. If this hypothesis is proven Rogers' Model of the Innovation Decision Process can provide future water engineers a structural tool that explains the adoption of water management technologies in contribution to adoption-oriented water engineering, also known as reflexive engineering (Robbins, 2007).

2. Objective and research questions

The National Women's Movement of Suriname currently researches the applicability of the HFCW and makes efforts to understand the challenges that the introduction and the implementation of the technology could face. Since there are no operational HFCW for domestic wastewater treatment in Suriname yet, the HFCW can truly be called an innovation. For this reason the interviewees are a selection of local possible future HFCW users, and engineers that are experienced with the spread and implementation of the HFCW in other (tropical) countries. Rogers' Diffusion of Innovation Model will be used to understand the determinants of adoption as perceived by the interviewees and can by that means contribute to future adoption-oriented engineering of the HFCW. The objective of this research is

'to understand the (possible future) user adoption or rejection of the HFCW for a household scale in tropical Suriname, by applying Rogers' (1995) Diffusion of Innovation Theory'.

This objective will be achieved by answering the following research questions:

- What are the prior conditions for the potential adopters?
- What are the characteristics of the potential adopters?
- How do the potential adopters perceive the HFCW?
- Which are the determinants of adoption of the HFCW for a household scale in the Surinamese case?

3. Methodology

The information for this research was mainly gathered by literature research and interviews of local possible future users and water engineers. The literature research has been strongly based on Rogers' book The Diffusion of Innovations (Rogers 2003) and secondly by the study of scientific journal articles on the topic of HFCW. Due to the objective to understand factors that in future can determine the adoption or rejection of the HFCW in Suriname special attention is addressed to studies in tropical regions. As Rogers provides a pathway to understand the adoption of innovations his Diffusion of Innovations Theory and his Model of the Innovation Decision Process is selected to view and understand the technological development process of the HFCW. As explained earlier Suriname has no experience with the application of HFCW for domestic wastewater treatment, but the National Women's Movement in cooperation with World Waternet has explicit interest in the system. Semi-structured interviews that were carried out during a four month internship in Suriname from November 2009 till February 2010 are used to generate information on the potential users of HFCW in Suriname. Due to a lack of actual Surinamese HFCW-users and experts an understanding of the possible factors of future user adoption further was obtained by interviewing (tropical) engineers and an adoption-expert from the Netherlands. The list of Dutch interviewees is provided in table 1. The data obtained during my internship and the qualitative data gathered during the interviews in the Netherlands was structured according to Rogers' Model of the Innovation Decision Process to firstly derive the adoption-determinants, and secondly the use of Rogers' model provides knowledge on its explaining capacity for water engineers who research the adoption and diffusion of water management technologies.

Name	Profession	Company
Marko Sas	Water engineer	BZinnovationmanamagement
Gerrit Box	Water engineer	Kilian Water
Bas van Vliet	Water engineer	Environmental development group, WUR
Frans Huibers	Water engineer	Environmental sciences group, WUR
Christine and Harold Diran	Head-couple of the orphanage Leliendaal	-
Percy Stuart	Coordinator of Environmental and Technological Services	Bureau for Public Health (BOG)

Table 1. List of Dutch and Surinamese interviewees.

4. Background information

4.1 Horizontal subsurface flow constructed wetlands (HFCW)

The in many cases mainly by Western countries perceived insufficient treatment of municipal and domestic wastewater in developing countries has led to a start in the industrialized world to search for proper wastewater treatment solutions. This search largely resulted in the acknowledgement that constructed wetlands compared to conventional treatment systems have a stronger potential for the developing countries (Gopal, 1999; Haberl, 1999; Kivaisi, 2001; Nanninga 2008; Rousseau et al., 2008; STOWA, 2005). The insufficiency of treatment, spoken of above, is an expression that is highly subjective and depending on norms and standards. Locals can perceive wastewater to be a non-issue whereas others do perceive it as a threat. In the Surinamese case the 'insufficiency' is a consequence of the Western norm that only a septic tank for domestic wastewater treatment does not result in sufficient quality for disposal into surface water. The given that the septic tanks at the location of the orphanage are not maintained and thus malfunctioning underpin this (Vlieg, 2010). As part of the search for proper wastewater treatment solutions the use of treated wastewater for a variety of purposes is gaining increased popularity as a means of preserving scarce freshwater resources. These purposes include irrigation, fertilization, aquaculture, nature, toilet flushing water, and even as indirect and possible direct sources of drinking water. Domestic wastewater (re)use is increasingly considered a method for combining water and nutrient recycling, increased household food and water security and improved nutrition for poor households.

A constructed wetland is *'a designed and man-made system which aims at simulating the treatment that has been observed to take place when polluted water is let into naturally occurring wetlands'*(Cooper et al., 1996, pp. 2). A HFCW is called horizontal because the wastewater is fed at the inlet (distributor) and flows slowly through the bed in a horizontal path until it reaches the outlet zone where it is collected before leaving via the level control arrangement at the outlet (Cooper et al., 1996). Figure 1 shows an example of a HFCW.

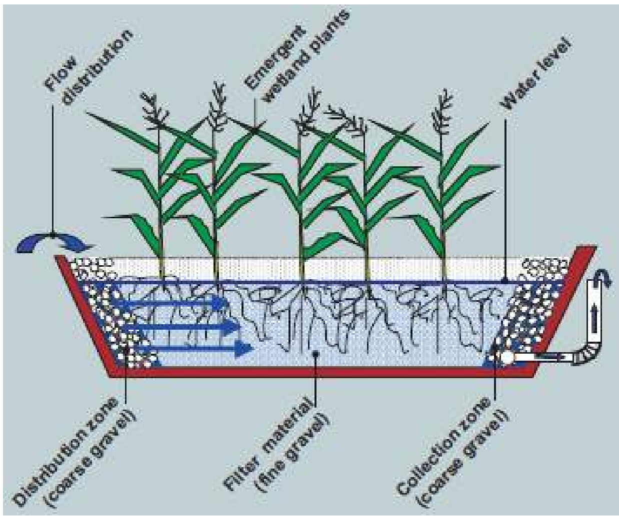

Figure 1: a longitudinal section of a HFCW (WSP-LAC, 2008)

The wide spread of the HFCW for municipal and domestic wastewater treatment in the industrialized world took place during the 1980s in the UK when the major problem of the system, namely shortly occurring clogging due to a low hydraulic conductivity, was solved by the use of coarse materials (Vymazal, 2005). The insufficient treatment of municipal and domestic wastewater in developing countries has led to a start in the industrialized world to search for proper wastewater treatment solutions for the developing world. This search largely resulted in the acknowledgement that constructed wetlands compared to conventional treatment systems have a stronger potential for the developing countries (Gopal, 1999; Haberl, 1999; Kivaisi, 2001; Nanninga 2008; Rousseau et al., 2008; STOWA, 2005). The high potential the HFCW in a developmental setting can be underpinned by the similarity between the requirements for wastewater treatment in a developing country and the principles of ecological engineering:

- a low or absent energy (electricity) requirement which is in many places not (reliably) available
- easy operation with low skilled operators
- easy to construct with locally available material
- permanent and continuous operation without too much maintenance
- more or less constant effluent quality (i.e. robust system) when the design is adequately adapted to local climate and temperature conditions
- possibility to produce biomass (e.g. algae, duckweed, flower plants, various grasses, fish) by making beneficial use of the available nutrients
- applicable at small and large scale and especially feasible in rural areas

(STOWA, 2005)

These features that are deemed to be implicit to the HFCW system have a high rate of dependence on the local circumstances, referring to the technological and social context.

4.2 The Surinamese case: the orphanage Leliendaal in Commewijne

Prior to this research a four month internship research, accompanied by the NVB and World Waternet, was conducted at the orphanage Leliendaal in Commewijne, Suriname. The orphanage, which is property of the Evangelic Church (EBGS) and relies on donations, is led by the Javanese couple Christine and Harold Diran and cares for 75 children with an age of 5 to 20 years. The cultural background of the children is diverse, as there are Javanese, Creoles, Hindustani, Maroons and indigenous children. The orphanage Leliendaal is situated in the coastal zone of Suriname, where surface and ground water is much in contact with the oceanic salt water. As a consequence the brackish water conditions obligate the residents of the coastal zone to rely on fresh groundwater resources and harvested rainwater. The fresh water resources in history have proven to be unreliable in terms of quantity, especially during the two dry seasons that Suriname experiences. The dependence on rainwater harvesting in the coastal zone thus is high, and in the case of the orphanage Leliendaal the amount of fresh water that can be stored is not sufficient to maintain water security during dry periods. Next to this quantitative problem which is mainly experienced in the coastal zone and certainly at the orphanage Leliendaal, the disposal of insufficiently treated domestic and industrial wastewater represents the qualitative problem of Suriname as a whole (Vlieg, 2010). The discharge of insufficiently treated wastewater to the environment pollutes the environment and increases human health risks (Strauss et al., 1997). The orphanage experiences a need for an increase in available and accessible fresh water. The qualitative problems have a low priority as the effects of environmental pollution due to disposal of insufficiently treated wastewater are not experienced directly (Diran, 2009-2010). The application of a HFCW can play a role in increasing the quantitative water security by reusing treated wastewater, and in decreasing the environmental pollution and human health risks. The aim of the research at the orphanage Leliendaal was *'to investigate from a technological, environmental, social and economical perspective if the Waterharmonica concept can be applied on a community level for domestic wastewater treatment to reach water security in Commewijne, Suriname'* (Vlieg, 2010). The Waterharmonica concept aims on closing the quality gap between effluent, treated by currently present treatment systems, and the required water quality for the end purpose (STOWA, 2005). The HFCW is a technological application that is part of the Waterharmonica concept. The importance of further research on the topic of HFCW-adoption is deemed high, because of the perceived quantitative and qualitative problems at the orphanage Leliendaal.

5. Rogers' Diffusion of Innovations Theory (DIT)

Rogers Diffusion of Innovations Theory has been applied for research on multiple cases of new ideas emerging from peoples mind, for example in software development and new technology development in the health care sector (Rogers, 2004). The base of diffusion studies is formed by some definitions that need to be clearly described. A new idea or the concept as such, initiating the technology development process, is referred to as an invention. Figure 2 shows the development process of an invention. The HFCW is an invention that is purely derived from nature as it is *'a designed and man-made system which aims at simulating the treatment that has been observed to take place when polluted water is let into naturally occurring wetlands'*(Cooper et al., 1996, pp. 7). An invention becomes an innovation when it is brought to the market. An innovation is '*an idea, practice, or object that is perceived to be new by an individual or other unit of adoption*' (Rogers, 2003, pp. 5). The next step in the development of the technology is the determination of the successfulness of the HFCW by the degree of spread and implementation or, in other words, the diffusion. Rogers defines diffusion as '*the process by which an innovation is communicated through certain channels over a period of time among the members of a social system*' (Rogers, 2003, pp. 5). The meaning of communication is '*a process in which participants create and share information with one another to reach a mutual understanding*' (Rogers, 2003, pp.5-6).

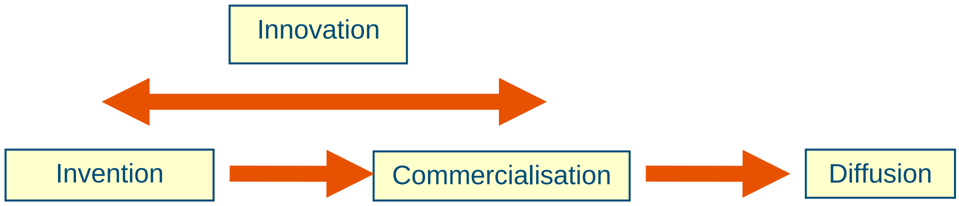

Figure 2: Technology development process (Omta, 2010)

From the definition of diffusion the four main elements of diffusion can be derived: innovation, communication channels, time, and the social system. In every diffusion research study these elements can be indentified. Figure 3 presents Rogers' Model of the Innovation Decision Process and its elements.

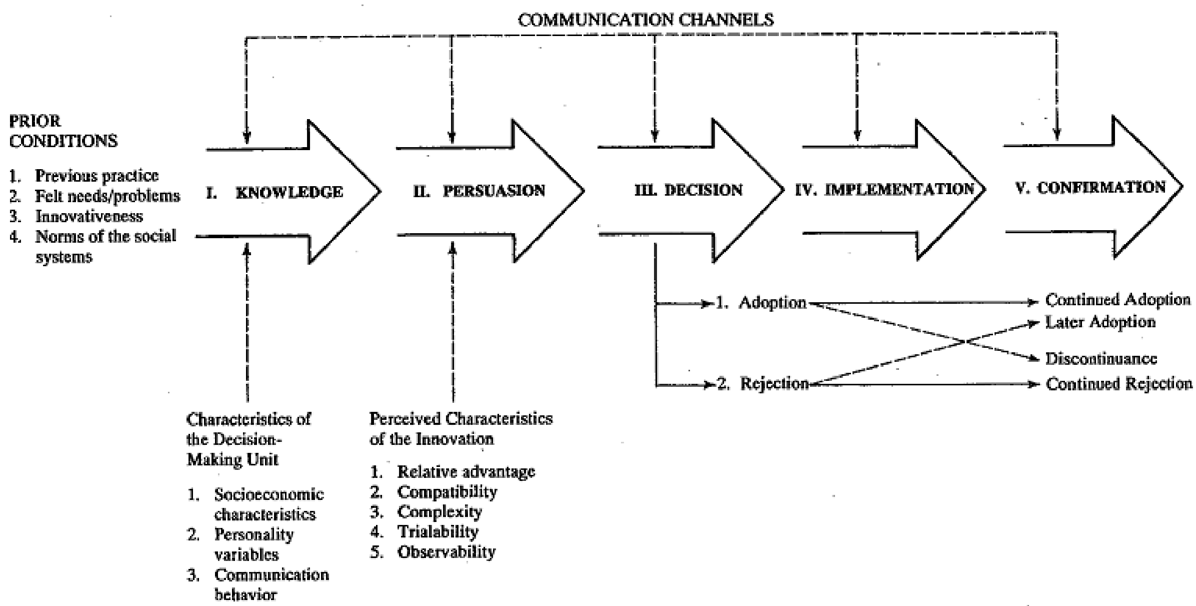

Figure 3: Rogers' Model of the Innovation Decision Process (2003)

Rogers bases his Model of the Innovation Decision Process on the given that decisions are not authoritative or collective. Each person as being a member of the social system faces his/her own innovation decision and as a consequence is regarded as a decision making unit. According to Rogers the decisions made by this person is following a process that is formed by 5 steps (Rogers, 2003):

1) Knowledge – In this stage a person becomes aware of an innovation and has some idea of how it functions, which results in a degree of certainty on the advantages and disadvantages of the innovation. The passive or active role of an individual in searching knowledge and awareness on an innovation influences their behavior toward communication messages about an innovation and the effects of such messages. Individuals are selective perceivers, referring to the individual's tendency to only expose themselves to messages that speak of an innovation that is perceived to be relevant to the individual's needs and consistent with the individual's attitudes and beliefs. Rogers states that the 'needs- or problems-driven decision making' is not a complete explanation of why individuals begin to make decisions. In many cases of consumer innovations the idea, product or technology is favored after it is communicated. As a consequence the potential adopter feels a need for it and adopts and uses it.

2) Persuasion – In this stage a person forms a favorable or unfavorable attitude toward the innovation based on his or her perception of the information about the innovation and its credibility. The potential adopter aims on decreasing the uncertainty on the advantages and disadvantages with regard to his or her own situation. Instead of looking at scientific results of innovation evaluations, most potential adopters seek social approval to know whether their thinking is right in the opinion of others, because other's opinions are more accessible and convincing. The formation of a favorable attitude towards an innovation does not necessarily lead to its actual adoption. Such a discrepancy especially occurs in cases of preventive innovations. Preventive innovations are innovations that '*an individual adopts in order to avoid the possible occurrence of some unwanted event in the future*' (Rogers, 2003 pp. 176). Rogers refers to such a discrepancy as the 'knowledge, attitudes, practice – gap' (KAP-gap). An example given by Rogers is the favorable attitude of

people in developing countries toward contraceptives, but the lack of actual use amongst most of them. Sometimes when events occur in which the advantages of the innovation clearly come forward potential adopters experience the opportunity to make more conscious choices. The KAP-gap can then be closed.

3) Decision – In this stage a person engages in activities that lead to a choice to adopt or reject the innovation. To determine the usefulness of an innovation most individuals choose to try out the new innovation on a probationary basis in their own situation. If proven to be of relative advantage most potential adopters make the decision to adopt. For some innovations it is not possible to try them on a small-scale and these innovations require the potential adopter to totally adopt or reject it. Again the potential adopters are tended to be impressionable by ‘trial by others’. These others are accessible and convincing to the potential users who project the experiences of the other(s) on his or her own situation.

4) Implementation – In this stage a person puts an innovation into use. The questions raised by adopters in this stage are practical in nature. To decrease uncertainty on the expected consequences of the innovation adopters want to know answers to questions such as ‘ Where can I obtain the operation?’, ‘How should I install it?’, ‘ How do I use the innovation?’, and ‘What are problems I might encounter?’. After the implementation proceeds the innovation reaches a point at which it has established a stable state within the technology-related system. The innovation has become a part of the adopter’s daily activities. Further Rogers states that a new idea changes and evolves during the spread amongst different adopters. This process, which is referred to as re-invention, takes mainly place in the implementation stage as the practical appliance takes place in this stage.

5) Confirmation – Some individuals tend to remain searching for information on the innovation that they have adopted to seek reinforcement. In the confirmation stage a person evaluates the results of an innovation-decision already made to avoid that he or she may get regret of his or her choices (Rogers, 2003).

The user’s innovation decision depends on the prior conditions, the characteristics of the decision making unit, and the perceived characteristics of the innovation. The sources of communication (e.g. change agents) and the means by which these factors of adoption are socially communicated (communication channels) influence the decision of the potential user (Rogers, 2003). All these variables together cause the potential users to perceive a certain risk inherent to adoption of the innovation. The costs, with regard to all facets, have to outweigh the benefits and since the information on these aspects often is uncertain or is at least perceived as uncertain, the result is that the potential user postpones his/her decision until there is (more) certainty (Rogers, 2003). The process of decision making is not uniform for all potential adopters and according to Rogers, individuals do not equally react on a new technology when it is brought to the market. The personal characteristics of the individual largely influence the decision and therefore the target group of diffusion is diverse, Rogers divides the adopters on the basis of innovativeness: 1) innovators, 2) early adopters, 3) early majority, 4) late majority, and 5) laggards (Rogers, 2003). Figure 4 presents the different types of adopters when plotted over time on a frequency basis.

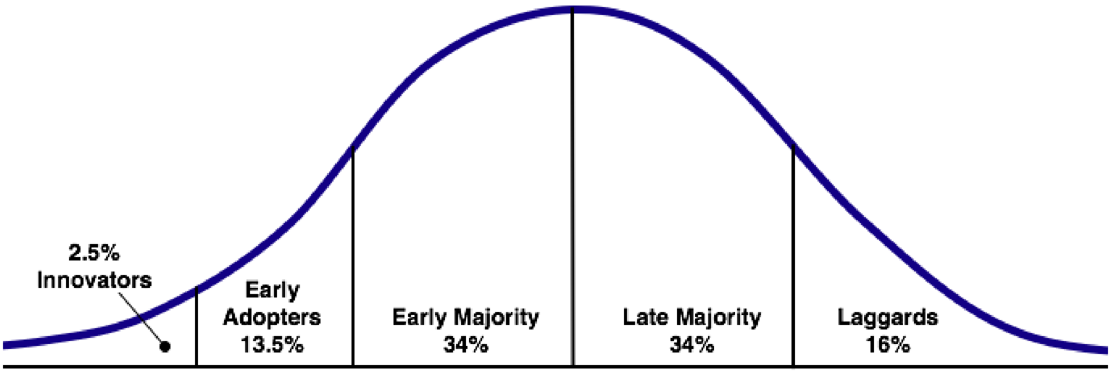

Figure 4: The bell-shaped curve of adopter groups (Rogers, 2003)

The innovators are described by Rogers as being venturesome in an almost obsessed manner. The innovator is not very embedded in the local social system, but is more in contact with other innovators who can be geographically distanced. The innovators have a very high interest in new ideas and due to their substantial financial resources, their ability to understand complex technological knowledge, and their ability to cope with uncertainty, they are able to take the risk of adoption. Even though the innovator may first not be respected, the innovator plays an significant role by placing the innovation in the technology-related system. *The early adopters* are more integrated in the local social system than the innovators and therefore have the highest degree of opinion leadership of all adopter categories. This category of adopters has local respect and this makes them highly suitable for triggering the critical mass. The early adopter is known for his or her judicious innovation-decisions which have resulted in successful applications of innovations. To retain this position he or she is aware of the importance of evaluation with his or her local peers. *The early majority* is the part of the mass that adopts a new idea short before the rest of the majority does so. This category, which makes in number of members one third of all adopter categories, follows the early adopters because of its deliberate willingness to adopt in combination with its unwillingness to lead in adoption. *The late majority* is represented by the skeptical part of the majority that adopts just after the average member of a system. This category is cautious for adoption and may be triggered by economical necessity or influences within the local social system. This category does only adopt until most of the members in their system have adopted the innovation. *The laggards* are the most conventional and traditional category. They are quite isolated in the social system and primarily interact with individuals like themselves. Other members of the local social system do not look at them as opinion leaders. The laggards are relatively the latest in adoption: because of their limited resources they need to be exactly sure of the benefits of an innovation in their own situation. According to Rogers plotting the cumulative number of adopters over time results in a S-shaped curve. The plotting based on frequency (bell-shaped) or on cumulation (S-shaped) basis are just two different ways to display the same data (Rogers, 2003).

6. The adoption of HFCW at the orphanage Leliendaal in Suriname through the eyes of Rogers

As Rogers (2003) describes in his book *Diffusion of Innovations* the adoption and diffusion of new technologies is a process that often requires much more time than technologists expect. Even if a new idea represents obvious benefits to some, it is not obvious that this will be realized by the potential adopters. As a consequence rapid spread and adoption of an advantageous innovation by the potential users is seldom the case (Rogers, 2003). Understanding of the main factors that are of influence on the adoption and spread of the HFCW is required to asses the high potential of the HFCW of which the industrialized countries speak. Why would the potential adopters of the orphanage Leliendaal chose to implement and adopt a HFCW? To answer similar questions in other cases of diffusion of innovations, Rogers (2003) developed the Diffusion of Innovations Theory (DIT). The capability of Rogers' Model of the Innovation Decision Process, that is part of his DIT, to describe and understand the spread and implementation of a new technology has already been utilized in the industrial, agricultural and public health care sector (Rogers, 2004), but has not yet been applied on the HFCW. Because of its explaining capacity in several other studies on the adoption of new technologies (Rogers, 2002; Rogers, 2004) it is expected that Rogers' Model of the Innovation Decision Process will be of value if applied to the study of the HFCW-adoption. If this hypothesis is proven Rogers' Model of the Innovation Decision Process can provide future water engineers a structural tool that explains the adoption of water management technologies in contribution to adoption-oriented water engineering.

This chapter will analyze the Surinamese technology-related system by applying the four main elements in the diffusion of innovations, as Rogers proposes them, on the orphanage Leliendaal in the coastal district Commewijne. This chapter will dominantly be based on personal communication in Suriname and semi-structured interviews with two experts in the Netherlands. The personal communication in Suriname took place with local stakeholders of the orphanage Leliendaal for which it is important to notice that the local stakeholders have not yet been in contact with a HFCW system in practice. Their degree of knowledge on this topic is limited to the theoretical information on the HFCW given in this report. These people therefore are not actual users, but possible future adopters of the HFCW system as the NVB and World Waternet are considering executing a project at the orphanage Leliendaal.

6.1 Innovation

The HFCW technology for the treatment of domestic wastewater and the possible reuse practices are new to the head couple of the orphanage, Mr. and Mrs. Diran (Diran, 2009-2010). The system has not yet been applied for the treatment of domestic wastewater in Suriname and thus can be called an innovation in this context. The perceived attributes of the HFCW system are factors that influence the degree of certainty that the potential adopters of the orphanage Leliendaal experience. According to Rogers the five attributes of the HFCW that determine its character are 1) Relative advantage, 2) Compatibility, 3) Complexity, 4) Trialability, and 5) Observability. The characteristics of the innovation form one of the inputs for the favorable or non favorable attitude of the potential adopters at the orphanage Leliendaal. Next an effort is made to describe the characteristics based on the local interviews and Rogers book Diffusion of Innovations.

The relative advantage is '*the degree to which an innovation is perceived as better than the idea it supersedes'* (Rogers, 2003 pp 15). With respect to the studied case in Suriname it is not the question if the technology is superior and able to successfully compete with comparable technologies, because the technology (HFCW) is new, the product (reusable wastewater, biomass consciously grown on wastewater) is new, and there is not yet a market for it. In that sense the HFCW does not disrupt existing comparable water management activities, because it is an addition to the existing systems, but it requires a disruptive change in what is before perceived as normal, sufficient and important. The challenge thus is to stimulate and/or create an attitude toward wastewater that says that:

- existing treatment is insufficient and due to the disposal of insufficiently treated wastewater there is a loss of water and nutritional value
- viable opportunities come along with reusing sufficiently treated wastewater
- environmental pollution and consequent human health risks must be minimized

The above given statement that the HFCW does not compete with existing comparable technologies in Suriname does not mean that competition does not occur. The relative advantage should be purely based on the perception of the local decision making units and this results in some other statements. Namely, the perception of Mr. and Mrs. Diran of what the HFCW could mean to the orphanage Leliendaal is based on a comparison with the existing technological system *and* with their current state of not performing additional treatment in favor of reuse. During personal communication they made clear that in their opinion the current treatment which takes place by septic tanks produces effluent of sufficient quality for the disposal in surface water. However it is their desire to reuse treated wastewater for toilet flushing to increase the available potable water during drought, and this desire requires additional treatment of the septic tank effluent. Mr. and Mrs. Diran see the advantage of the HFCW in relation to the existing septic tanks when it comes to reaching the required water quality for the end purpose: toilet flushing water. The disadvantage to them is that the operation and maintenance of the HFCW, and the possible reuse opportunities will require time and labor which now is addressed somewhere else. Mr. and Mrs. Diran further expressed their concerns on the possible weakening of their position in the social system when they would adopt the HFCW system, and especially the working activities in which the children could get involved (Diran, 2009-2010). The uncertainty involved to a disruptive change compared to their current respected and well established position in the social system could be a reason to reject the HFCW system. The financial investment is another great disadvantage that can only be overcome if extern parties take care of this.
The compatibility is '*the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters'* (Rogers, 2003 pp 15). As said before the conscious reuse of treated domestic wastewater is not taking place in Suriname. In fact the reuse of any kind of treated waste that has been in contact with human feces is illegal (Stuart, 2010). So the practical use (e.g. toilet flushing water, agriculture) of HFCW-treated domestic

wastewater is not consistent with the law of Suriname. A change of regulations with respect to black wastewater should precede the potential application of HFCW. As a consequence the incompatible system requires a prior adoption of a new regulatory system to become compatible. In contrary Mr. Diran has earlier been using septic tank effluent for agricultural production at Aruba (Diran, 2009-2010), and even though reuse of septic tank effluent is not advised (Strauss et al., 1997) this indicates that the practical reuse of HFCW-treated domestic wastewater is consistent with his norms. The experienced severity of the effects of the water shortage at the orphanage Leliendaal will determine the need for a HFCW system of which the effluent can be reused for toilet flushing. Since the interviewees at the orphanage expressed the desire to reduce the shortage significantly the HFCW system is compatible with their needs.
The complexity is *'the degree to which an innovation is perceived as difficult to understand and use'* (Rogers, 2003 pp 16). The complexity of the HFCW is generally perceived to be low (Gopal, 1999; Haberl, 1999; Kivaisi, 2001; Nanninga 2008; Rousseau et al., 2008; STOWA, 2005) due to the systems natural functioning and the low presence of technological components. Mrs. Diran showed that she had knowledge on the purifying effect of natural wetlands by describing her experience with water lilies in a pond where she swam in former times. According to her the water in the pond was always very clean and that was due to the wetland plants. She and her husband were not exactly informed about the processes that occur in a possible HFCW system, but they understood the purifying effect of the system on the wastewater (Diran, 2009-2010). The interviewees spoken to at the orphanage Leliendaal thus rapidly understood the innovation. However the purpose of decreasing environmental pollution and human health risks by disposing sufficiently treated domestic wastewater is not well understood and is not perceived as a necessity (Diran, 2009-2010).
The trialability is '*the degree to which an innovation may be experimented with on a limited basis'* (Rogers, 2003 pp 16). Due to its sizing and precise design requirements the HFCW system is deemed to be unsuitable for trying it on a partial base. An application of the system on a small-scale can provide insight in its functioning in the local conditions by monitoring the system. Also an insight can be gained in the required operation and maintenance. The systems sizing, financial input and precise design requirements cause the trialability of the system to be low.
The observability is '*the degree to which the results of an innovation are visible to others'* (Rogers, 2003 pp 16). The products of the technology, namely treated domestic wastewater and eventual produced biomass, are not similar in their observability. Biomass that is consciously grown in the constructed wetland system, and with the effluent, can be easily observed. The growth of for example ornamental flowers can be well visible, and give the viewer a positive impression. Such visibility can stimulate peer discussion of the innovation, because it grabs the attention of others in the local social system and it raises questions. Rogers describes that an innovation with a high observability can lead to the adoption of innovations in neighborhood clusters (Rogers, 2003). The effluent quality however is insufficiently observable as the contaminents in the water are not visible to the naked eye. Monitoring thus requires sampling and measuring equipment. If quality requirements exist for the produced biomass, e.g. because it is used for feed, testing of this product might be necessary and the observability then also is low.

The characteristics of the innovation as just described, together with the personal characteristics and the prior conditions result in a favorable or non favorable attitude toward the innovation. The uncertainty for successful applying the HFCW at the orphanage Leliendaal is a consequence of the low trialability, the low observability with respect to the water quality, and the questionable relative advantage in terms of O&M, finances, and social status. These disadvantages can largely be overcome by financial risk bearing of external parties like the NVB as being the change agency, and other funders. The risk of losing social status is important for the orphanage and this risk will only be taken if the local stakeholders perceive the current water shortages to be unacceptable and other less disruptive changes are not an option (Sas, 2010; Van Vliet, 2010).

6.2 Communication channels

The means by which the knowledge possessed by the NVB, World Waternet and other change agents is transferred to the potential adopter(s) is defined as the communication channel. The effect of this transfer is determined by the nature of the information exchange relationship between a pair of individuals. Examples of informing an audience of potential adopters are mass media and interpersonal channels. The former one is highly efficient when awareness-knowledge raising is the objective, while the latter is mostly efficient in the persuasion phase of the innovation decision process. According to Rogers this is underpinned by diffusion investigations which concluded that potential adopters are mostly basing their decisions on others that are like themselves, than looking at scientific research results. Rogers calls the vulnerability to be influenced by similar others (e.g. education, socioeconomic status) *homophilous*, and the subsequent decision making process *subjective evaluation* (Rogers, 2003). Sas (2010) gives an example of this by describing the case of farmers in Nicaragua who adopted wetland systems from their neighbor, without taking into account the specific requirements for the system if installed at their farm. In the case of the orphanage Leliendaal interpersonal heterophilous communication has taken place while the research was performed by me, being a student from the Netherlands. This communication was heterophilous, because it took place between non similar others. The awareness-knowledge sharing between the head couple Mr. and Mrs. Diran and me took place during field visits and however their hospitality was great, it was difficult to gain trust in the time given. The transfer of information in the end improved and due to that the local stakeholders have gained an elementary understanding of the HFCW system. However to stimulate the local stakeholders in making a well funded decision this transfer of information has insufficiently taken place. If decided so, a project which contains the installing of a HFCW system, requires individuals which are trusted and convincing for the transfer of awareness-knowledge. In addition of having excellent knowledge of the area's needs and sociotechnological requirements in many cases change agents choose to cooperate with a local opinion leader. This can be a person in the local social system that is homophilous to the local stakeholders and who is often asked for advice and information.

6.3 Time

The time is of importance when the conduct and duration of the innovation decision process is taken into regard. The time from first knowledge to the adoption or rejection plays a role in the further diffusion process, like the innovativeness of the potential adopter(s) does. The rate with which the innovation spreads within a system, like for example the coastal region of Suriname, is also an important time dimension dependent component. This is usually measured as the number of members of the system who adopt the innovation in a given time period (Rogers, 2003). The orphanage Leliendaal, represented by Mr. and Mrs. Diran, is in the knowledge stage of Rogers Model of the Innovation Decision process. This stage is the first of all five. As said the relative earliness/lateness with which the local stakeholders adopt the system depends among others on the personal characteristics of the decision making unit. How innovative are Mr. and Mrs. Diran and in what adopter category can they be placed? The given that Harold Diran together with a local farmer has made an effort to dig ponds from which water for toilet flushing could be abstracted indicates his venturous character (unfortunately the water was too brackish). At the same time Mrs. Diran explicitly expressed her worries with respect to a disruptive change that might include the opportunity to involve the children in working activities, because this could give them a bad name and lower their status in the social system (Diran, 2009-2010). This notice can be perceived as less innovative, because of the lower willingness to take risk. Still the head couple, Mr. and Mrs. Diran, together search for a solution for the orphanage Leliendaal to decrease the water insecurity during the dry periods and are open to a system that has the potential to do this, while minimally disrupting their daily activities. Hypothetically speaking the staff couple is expected to adopt a new innovation that can solve their water problems shortly after they have perceived its success somewhere else. Preferably the innovation ‘proves itself’ in their local social system while it is used by an opinion leader. The interviewees at the orphanage Leliendaal thus best can be placed in the front part of the adopter category named the *early majority* (chapter 5). If the first introduction and implementation of the HFCW in a rural setting in Suriname will take place at the orphanage Leliendaal do the local adopters than automatically become innovators? In my eyes the answer to this question would be that not the local adopters are the innovators, but the change agents who brought the innovation, are the innovators. Subsequently if applied at the orphanage Leliendaal, the diffusion of the HFCW can influence the rate of diffusion within the societal system.

6.4 Social system

The problem solving at the orphanage Leliendaal takes place by a set of interrelated units that are engaged in the local problems. These engaged people, called stakeholders or units, form a structure that forms the arrangement of the social system. The orphanage Leliendaal has a large social system which involves the staff, the children, the children’s parents, organizations (donors), churches (Surinamese and Dutch), companies (donors), the neighbor schools, the neighbor households, the neighbor farmer. These interrelated units give stability and regularity to the individual behavior in the system. This structure will stimulate or hinder the diffusion of an innovation in the system (Rogers, 2003). In the case of the orphanage Leliendaal the neighbor schools and the farmer, as both being important stakeholders, are found to be key players in the search for a solution. The hierarchy plays an important role in the social system. Because of conflicting interests the farmer has difficulty with managing the water on his farmer land, which surrounds the orphanage. This contributes to the problem of the fresh water shortage at the orphanage due to the brackish conditions in the area. However the local stakeholders think the farmer should change the water management in the area, they are not in the position to make him do so. As a consequence the local social system attempts to solve the problems otherwise (Vlieg, 2010). This cooperative basis is a favorable prior condition for a ‘social-system-based change’.

At the orphanage the innovation decision making process is also influenced by the norms of the social system and the importance of remaining in a good and respected position. The operation and maintenance of the HFCW and the possible reuse opportunities will require time and labor which possibly weakens the position of the orphanage in the social system. In the perception of Christine Diran this is possible when she and her husband would decide to adopt the HFCW system. The members of the social system could think badly of such a development in which wastewater is a main component. When the opportunity to let the children take part in the work activities is used people could think the children are forced to work (Diran, 2009-2010). As the orphanage depends on its social network for donations, Mr. and Mrs. Diran are cautious with taking such risks. As mentioned before it can be a key factor to include a person with a high opinion leadership. Such a person, who is able to influence the decision makers at the orphanage because of his or her similarity to them (in origin, education, socioeconomic status), could behave informally in a desired way to reach the optimal transfer of awareness-knowledge (Rogers, 2003). This person can decrease the uncertainty of the disruptive changes involved to the implementation of the HFCW system. For this reason it is advisable for the NVB and World Waternet, as being possible change agencies, to make use of the favorable characteristics of opinion leaders by using them in a social system for diffusion activities.

7. Conclusion and discussion

The potential users that this research aims on, namely the residents of the orphanage Leliendaal, can be classified amongst the *early majority* adopters. The interviewees Mr. and Mrs. Diran clearly are in the knowledge stage of the Innovation Decision Process. This stage is the first of all five stages described by Rogers in his book Diffusion of Innovations. No project is planned yet at the orphanage and so on the local stakeholders have not been confronted with making a decision. The possibility of a future project at the orphanage that aims on increasing the water security with the help of a HFCW system has led them to shape their current attitude. This attitude has been investigated in this report and due to the financial dependency of the orphanage, future development of this attitude will primarily depend on if the NVB and World Waternet are going to plan a project at the orphanage.

A possible future adoption or rejection decision is the result of the innovation decision making process which is based on the perceived attributes of the HFCW, the personal characteristics of the potential adopters of the orphanage Leliendaal, and the prior conditions. As said the interviewed head couple of the orphanage is in the knowledge stage and even though an attitude could be perceived during personal communication, this attitude is not deemed reliable because of the insufficient awareness-knowledge sharing. The knowledge that forms the basis for the current potential adopters' attitude is communicated from the NVB and World Waternet by means of interpersonal channels. Together this source and the means of communication have facilitated or impeded the adoption of the new HFCW innovation. The awareness-knowledge sharing between the head couple Mr. and Mrs. Diran and me, being a Dutch intern at the NVB, took place during field visits. Even though the local hospitality was great, it was difficult to gain trust in the time given, because of the nonsimilarity between me and the interviewees. It thus can be concluded that the source of information and the way that this was transferred to the locals has not been optimal. The transfer of information at the end of the internship improved and as a consequence the local stakeholders have gained an elementary understanding of the HFCW system. If decided so, a project which contains the installing of a HFCW system, would benefit from individuals which are trusted and convincing for the transfer of awareness-knowledge to raise the local knowledge. The NVB in cooperation with World Waternet should for that reason aim on cooperation with a local opinion leader. This can be a person in the local social system that is homophilous to the local stakeholders and who people tend to for advice and information.

In terms of complexity, compatibility and observability (e.g. ornamental flowers) the HFCW system is expected to be favored by the local stakeholders at the orphanage Leliendaal. The uncertainty for successfuly applying the HFCW at the orphanage Leliendaal is a consequence of the low trialability, the low observability with respect to the water quality, and the questionable relative advantage in terms of O&M, finances, and social status. These disadvantages can largely be overcome by financial risk bearing of external parties like the NVB as being the change agency, and other funders. The orphanage Leliendaal has a large social system which involves the staff, the children, the children's parents, organizations (donors), churches (Surinamese and Dutch), companies (donors), the neighbor schools, the neighbor households, the neighbor farmer. These interrelated units give stability and regularity to the individual behavior in the system. This structure can stimulate or hinder the adoption and diffusion of an innovation in the system (Rogers, 2003). In the case of the orphanage Leliendaal it partly hinders the adoption: the risk of losing social status is important for the orphanage and this risk will only be taken if the local stakeholders perceive the current water shortages to be unacceptable and if other less disruptive solutions are not an option (Sas, 2010; Van Vliet, 2010). The expected influence of a disruptive change on the position of the orphanage within the local social system is therefore believed to be a determinant for adoption. Assuming that financial capital is taken care of by external funders, future project development should target the locally perceived social disadvantages that are related to the implementation of a HFCW system.

Rogers DIT has proven to be a tool for the theoretically framing of water related technology research on the topic of individual adoption of new technologies. The elements of diffusion have been addressed in this research report and this created the possibility to appoint the most decisive factors for adoption of the HFCW by the interviewed local stakeholders at the orphanage Leliendaal. Based on this research it can be concluded that Rogers' Model of the Innovation Decision Process can provide future water engineers a structural tool that explains the individual adoption of water management technologies in contribution to adoption-oriented water engineering. However the critic on the DIT theory of Rogers given by the Dutch social engineer Van Vliet is that the theory has a linear lateral focus and would not be sufficient if regarded from a social-policy perspective. The disregard of multiple societal levels of the technology related system is regarded as a limitation of the DIT theory (Schot & Geels, 2008; Van Vliet, 2010), and since this more social-policy oriented facet is included in the SNM approach this approach possibly can add value to adoption and diffusion modeling in future research. Further research should be carried out to address the potential of the SNM as an addition to the DIT.

References

Cooper P.F., Job G.D. (WRc), Green M.B. (Severn Trent Water), Schutes R.B.E. (Middlesex University) (1996). Reed beds and constructed wetlands for wastewater treatment. Wiltshire, United Kingdom.

Diran C., Diran H., (2009-2010). Personal communication. Staff couple of the orphanage Leliendaal. The orphanage Leliendaal, Suriname. Novembre 2009-February 2010.

Gopal B. (1999). Natural and constructed wetlands for wastewater treatment: potentials and problems.

Haberl R. (1999). Constructed wetlands: a chance to solve wastewater problems in developing countries. Water Science and Technology 40(3): 11-17.

Huibers F.P. (2010). Personal communication. Dr.ir. at Environmental sciences group Wageningen University and Research. Lumen, Wageningen. 15-06-2010.

Klerkx L. (2010). Lecture ‘System innovations and transitions’. MST 30306, March 31, 2010.

Kivaisi A.K. (2001). The potential for constructed wetlands for wastewater treatment and reuse in developing countries: a review. Ecological Engineering 16: 545-560.

Nanninga T. (2008). Helophyte filter use for black wastewater treatment in Suriname. Unpublished Bsc-Internship report. Wageningen University. Wageningen, the Netherlands.

Omta O. (2010). MST30306 lecture 1, period 4, 2010.

Robbins P.T. (2007). The reflexive engineer: perceptions of integrated development. Journal of International Development 19: 99-110.

Rousseau D.P.L., Lesage E., Story A., Van Rolleghem P.A., De Pauw N. (2008). Constructed wetlands for water reclamation. Desalination 218: 181-189.

Rogers E.M. (2002). Diffusion of preventive innovations. Addictive behaviours 27: 989-993.

Rogers E.M. (2003). Diffusion of innovation. 5th edition. The Free Press.

Rogers E.M. (2004). A prospective and retrospective look at the diffusion model. Journal of Health Communication 9: 13-19.

Sas M. (2010). Personal Communication. Wastewater treatment specialist at BZ innovation management, Deventer. Biotechnion, Wageningen. 08-06-2010.

Schot J., Geels F.W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. Technology, Analysis and Strategic Management 20(5): 537-554.

STOWA (2005). ‘Waterharmonica’ in the developing world, report 21, Dutch Foundation for Applied Water Research (STOWA), Utrecht, the Netherlands.

Strauss M., Larmie S.A., Heinss U. (1997). Treatment of sludges from on-site sanitation – Low-cost options. Water Science and Technology 35(6): 129-136.

Stuart P. (2010). Personal communication. Coordinator of Environmental and Technological Services. Bureau for Public Health (BOG). Office BOG, Paramaribo, Suriname. February 2010.

Van Vliet B.J.M. (2010). Personal communication. Assistant professor at Environmental Policy Group, Social Sciences Group Wageningen University and Research. Leeuwenborg 2018, Wageningen. 07-06-2010.

Vlieg T.J. (2010). The applicability of the Waterharmonica concept in rural Suriname. A case study at the orphanage Leliendaal. Part I. Unpublished Bsc-Internship report. Wageningen University, Wageningen, The Netherlands.

Vymazal J. (2005). Constructed wetlands for wastewater treatment. Ecological Engineering 25: 475-477.

Vymazal J. (2009). The use constructed wetlands with horizontal subsurface flow for various types of wastewater. Ecological Engineering 35: 1-17.

WHO/UNICEF (2010). Progress on sanitation and drinking-water. 2010 Update.

WSP-LAC (2008). Constructed wetlands: a promising wastewater treatment system for small localities. Experience from Latin America. Water and Sanitation Program-Latin America and the Caribbean.