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Report

Naga City: Septage treatment and wastewater concept for Del Rosario

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Integrated Resource Management in Asian cities: the urban Nexus
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United Nations Building
Rajadamnern Nok Avenue
Bangkok 10200, Thailand

Edited by:
Dr.-Ing. Marius Mohr, Dipl.-Ing. Peter Renz
Fraunhofer-Institute for Interfacial Engineering and Biotechnology (IGB)
Nobelstrasse 12, 70569 Stuttgart, Germany

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List of abbreviations

BOD	Biochemical Oxygen Demand
C	Carbon
COD	Chemical Oxygen Demand
N	Nitrogen
P	Phosphorous
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids

1 Introduction and aims

Naga City, situated in the south-eastern part of the island Luzon in Bicol region in the province Camarines Sur of the Philippines (figure 1), has a population of over 175,000 inhabitants, which is growing fast. There is no sewer network operating yet, most houses have septic tanks for their wastewater. The water overflows into the rainwater drainage system and into the rivers, the septage is emptied roughly every 5 years. A septage treatment plant is currently being constructed. In this report, the concept of the septage treatment facility is analyzed and discussed and an alternative solution is presented.

Figure 1: Location of Naga City [GIZ 2012]

On the development site Del Rosario a pilot wastewater treatment system shall be installed. The wastewater from a slaughterhouse, a prison, a new housing estate and a planned high school shall be purified here. At the moment, septic tanks and a constructed wetland are used to treat the effluent of the slaughterhouse. This treatment is not functional, causes smell and pollutes the environment. The prison’s untreated wastewater runs off directly into a nearby creek. In this report a wastewater management concept for Del Rosario is presented and discussed. This wastewater concept has the aim to demonstrate on that site the technical feasibility of the production of energy from wastewater in form of biogas and the reuse of the treated wastewater in agriculture and has the potential to become an exemplary implementation of the Nexus approach.

2 Septage treatment Sitio Caromatig

2.1 Septic tanks

As mentioned above, most houses in Naga City are discharging their wastewater into a septic tank. According to the Code of Sanitation of the Philippines (from 1976, reprinted in 1998), septic tanks must be water-tight, inspected once a year, cleaned when the sludge has reduced the liquid capacity by 50%, and the sludge must be disposed of properly.

During the visit of a construction site in Camella condominium, a housing estate for the higher middle class, a septic tank under construction has been inspected. Although the design was according to the guidelines, the quality of the construction did not meet the standard (figure 2). Even if a part of the septic tanks in Naga City might be constructed according to these rules, very few will be maintained as they should be. After some years, they unavoidably get damaged, e.g. by soil movement or roots destroying the concrete walls. Most of the septic tanks are a constant source for groundwater pollution. The water overflowing into the drainage system is only partly treated and still contains most of the fecal bacteria and of the nutrients causing oxygen consumption and eutrophication in water bodies. During floods, the contents of septic tanks can be flushed into the streets and the houses, causing the transmission of diseases.

Figure 2: Septic tank under construction in Camella housing estate, Naga City

Thus, septic tanks cannot be a final solution for cities. They have to be replaced step by step by a sewer system in combination with wastewater treatment plants to protect the groundwater and surface water and to guarantee a good quality of life for the inhabitants.

2.2 Description of septage plant

As a first step to reduce the impact of wastewater discharge into the environment, the Metropolitan Naga Water District (MNWD) is constructing a facility for the treatment of septage around 15 km in the east of Naga City. Each household with water supply in Naga is obligated to have a septic tank for the pre-treatment of wastewater. While the water is supposed to overflow into the drainage system, the solids, called septage, remain in the tank. After five years a septic tank should be desludged by removing the remaining solids, called septage [MNWD 2013]. For this purpose, a vacuum truck is used, transporting the septage to the septage treatment facility. The facility is designed for 34,600 households connected to the water supply grid of MNWD and for 3,100 commercial and governmental users, or 56.1 m^3 septage per day.

The septage treatment process is planned as follows [MNWD 2013]: After pre-treatment with a rock trap and a macerator, the septage is stored in a septage holding tank. Flocculants and coagulants are added to the septage in flocculation and coagulation tanks and the solids are retained in a dewatering press. After stabilization with lime, the sludge cake is supposed to be used for composting. The liquid fraction from the dewatering press is treated in a Sequencing Batch Reactor (SBR). The sludge produced here is stabilized aerobically and then added to the septage holding tank again. After leaving the SBR, the water is running through two ponds and a horizontal gravel filter. Then it is chlorinated for disinfection and discharged into a creek.

In September 2013, the basic infrastructure for the septage treatment facility had been nearly finished (figure 3): the fence around the facility, the roads on the site, the houses for guards and staff, the garage, and the parking area. The buildings for the septage treatment processes had not been under construction yet.

Figure 3: Construction of septage treatment facility

The total project costs have been estimated to nearly 150 million PHP (3.4 million US$) and the costs for operation and maintenance to around 8.4 million PHP (200,000 US$) per year. To finance the septage treatment, a so called environmental service fee of up to 2.26 PHP (0.05 US$) per m^3 shall be added to the water fee (2013: 15.94 PHP/ m^3).

2.3 Evaluation and recommendation

It is a positive signal that the MNWD is becoming active to improve the situation of wastewater treatment in Naga. The responsible staff seems to understand that there is need for action to protect the health of the inhabitants and the environment.

With the septage treatment plant as described above, only around 0.2 % of the wastewater originating from the households connected to the water supply grid will be treated, though. The rest is either overflowing from the septic tanks into the drainage network and the rivers or seeping into the ground through damaged septic tanks. The concentration of pathogenic microorganisms is not decreased substantially in a septic tank, so the overflowing sewage can still cause diseases (see also report "Comprehensive Summary" for a more detailed discussion of the effects of wastewater and the use of septic tanks in the urban context).

By investing in a septage treatment facility instead of the collection and treatment of all sewage, MNWD is strengthening the septic tank system, making it even more difficult to come to a real solution of the wastewater problem in Naga. If the amount of septage decreases due to the introduction of a sewer system and wastewater treatment plants, the septage treatment plant as it is planned now will not be necessary any more. This could be used as an argument against the construction of a sewer system in Naga City, although a sewer system and wastewater treatment plants are necessary for the sustainable development of Naga City.

There is a lot of organic material available in the Naga area, e.g.: pig manure, molasses from sugar factories, municipal bio-waste, rice straw. If some of these substrates would be added to the septage, an anaerobic digestion process in a biogas plant could generate large amounts of biogas, which could be purified and used as fuel for the vacuum trucks collecting the septage. At the same time, a number of process steps of the planned septage treatment plant could be dropped or designed smaller (figure 4): the digested sludge would be stabilized, so addition of lime for stabilization would not be necessary anymore; aerobic stabilization of the SBR-sludge would be replaced by anaerobic digestion in the biogas plant; anaerobically stabilized sludge is easier dewaterable, so less chemicals would be consumed for flocculation and coagulation.

Altogether, the addition of a biogas plant would increase the investment of the septage treatment plant, but probably not by more than one third of the currently planned investment. The utilization of biogas would, on the other hand, generate income that is many times higher than the costs for operation and maintenance.

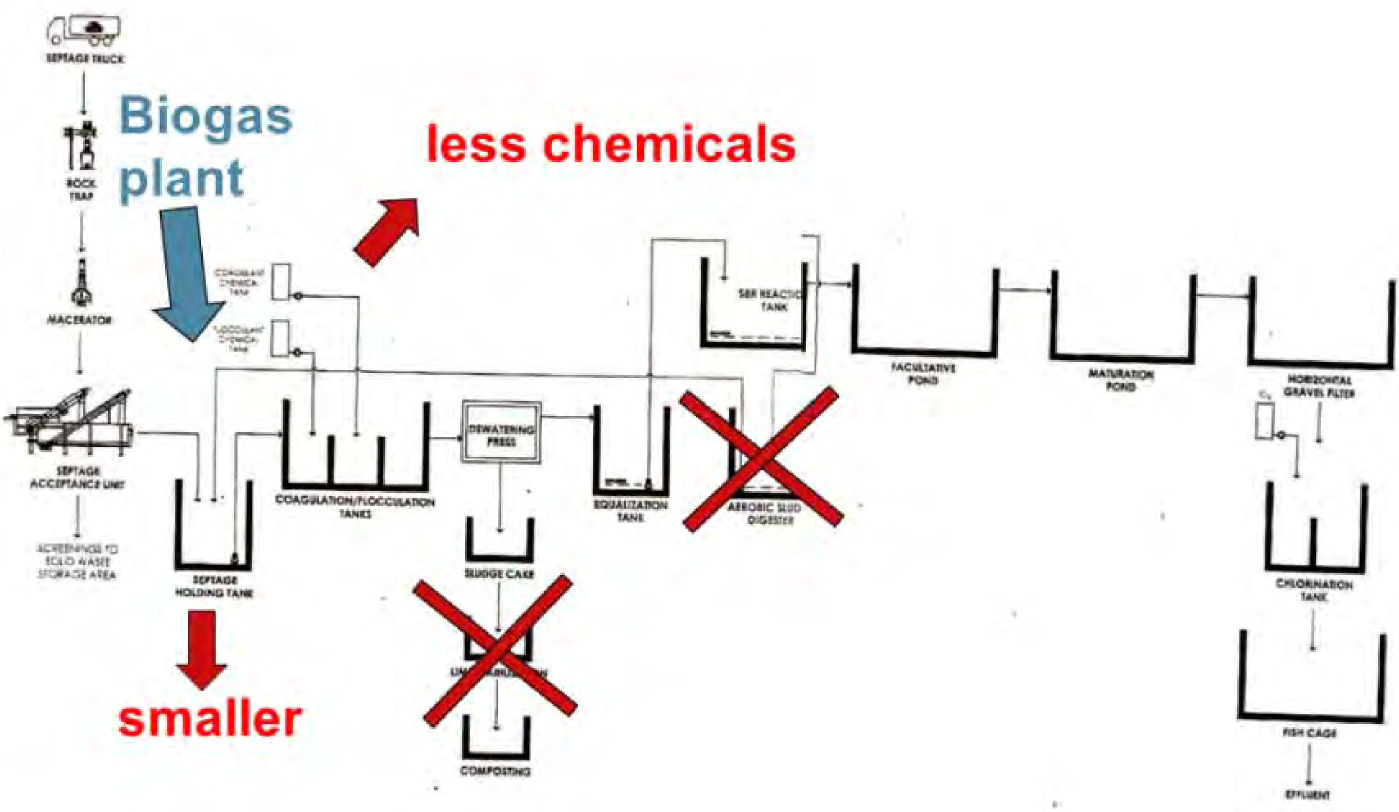

Figure 4: Process of septage treatment facility and effects of the addition of a biogas plant on it [modified from MNWD 2013]

Moreover, the available organic material would not be causing harm any more: pig manure and sugar molasses can pollute the groundwater as well as surface waters, rice straw is burned causing air pollution, municipal bio-waste is causing leachate and methane emissions at landfills.

If the wastewater system is being modified towards a system without septic tanks in the future, the biogas plant can still operate as before. It should then be evaluated if the sewage sludge from the wastewater treatment plant could even be added to that plant. This depends mainly on the distance from the new wastewater treatment plants and on the capacity of the new biogas plant.

To build a biogas plant only for the treatment of septage is not recommended, as the septage has been stored in the septic tanks for many years and does therefore not contain much degradable organic substance any more. The biogas yield of septage therefore is very low compared to other organic wastes (around 1 m^3 biogas from 1 m^3 septage compared to around 25 m^3 biogas from 1 m^3 pig manure).

3 Wastewater concept for Del Rosario

For Naga City, new solutions for the collection and treatment of wastewater are necessary if further deterioration of the environment and dangers for the public health should be prevented and the development towards a modern city with good quality of life should continue. There are a number of options, and there is not much experience with technologies for wastewater treatment in Naga. Therefore new solutions should be first tested in smaller scale to collect experiences with it in the town and to be able to adapt these technologies to the local conditions. The administration of Naga City has chosen the area of Del Rosario for such a pilot plant for wastewater treatment.

3.1 Wastewater sources

At the Del Rosario site, wastewater from the following sources has to be taken into account: a slaughterhouse, a prison, a new housing estate and a planned high school. The quantity of wastewater can be estimated on the basis of information about the water consumption for the slaughterhouse and the prison, while it has to be estimated on the basis of similar cases for the housing estate and the high school. Data regarding the quality of wastewater is not available for this site, so the quality of the wastewater is estimated based on German literature. The load of municipal wastewater is comparable worldwide, while the data of slaughterhouse wastewater vary considerably depending on the slaughtering processes. It is recommended to analyze the wastewater characteristics of the slaughterhouse in detail before designing the wastewater treatment plant. For this concept, estimations have been made that fall into the range of variation given in literature.

For the design of the wastewater treatment concept, typical chemical and physical parameters characterizing the wastewater from the different sources are considered. The presumptions for the concentrations of these parameters were derived from relevant literature [Bischofsberger 2005, Gujer 2007].The wastewater characteristics are not considering any rainwater, as a separate collection and discharge of rainwater is necessary if the wastewater should be treated anaerobically.

The wastewater from the prison, the new housing estate and from the school can be classified as municipal wastewater with a slightly increased concentration due to the absence of showers in school and the little number of showers in the prison. The total amount of municipal wastewater on a daily average is estimated to about 130 m³/d, in which 40 m³/d are derived from the prison, 60 m³/d from the housing estate and 40 m³/d for five days a week from the school. Table 1 shows the supposed values for the concentrations of the wastewater from the prison, the housing estate and the high school.

Table 1: Concentrations of wastewater from prison, housing estate and high school [based on Gujer 2007]

Parameter	Concentration [mg/l]
COD	700
BOD	350
TSS	400
TN	55
TP	17

Figure 5: Prison of Naga City

Wastewater deriving from a slaughterhouse typically has high concentrations of organic components, mainly proteins and fat, as well as nitrogen, depending on the individual production steps. For the design of the wastewater treatment plant, wastewater from washing, slaughtering and disemboweling is considered. Five working days per week and the processing of 200 pork per day were assumed. The total amount of wastewater from the slaughterhouse is about 70 m³/d. Table 2 shows the presumptions for the concentrations of the relevant parameters.

Table 2: Concentration of slaughterhouse wastewater [based on Bischofsberger 2005]

Parameter	Concentration [mg/l]
COD	5000
BOD	2500
TSS	1500
TN	325
TP	57

Figure 6: Slaughterhouse of Naga City and its wastewater ponds

For the characterization of the wastewater and the assessment of its degradability the ratio between the biologically available organic carbon (BOD_5) and the nutrients nitrogen (TN) and phosphate (TP) (C:N:P) is a decisive criterion. In general the minimum ratio for an efficient biological degradation is 100:5:1. The municipal wastewater has a mean C:N:P ratio of 100:16:5 and the slaughterhouse wastewater has a mean ratio of 100:13:2. Hence the preconditions are complied. In case of mixing the wastewater streams the nutrients ratio is 100:14:3.

Table 3 illustrates the mean load of the total mixed wastewater stream. These values have been used for design of the wastewater treatment concept.

Table 3: Mean load of the total mixed wastewater stream

Parameter	Mean concentration (mg/l)	Mean load [kg/d]
COD	2200	440
BOD	1100	220
TSS	800	156
TN	150	30
TP	30	6

3.2 Concept for wastewater treatment

If the wastewater contains organic substances that is bio-degradable in adequate concentrations (1000 mg COD/l or higher), large parts of the organic carbon can be degraded anaerobically, consuming no energy for aeration, but rather producing energy in form of biogas. As this is the case for the wastewater from Del Rosario (see table 3), an anaerobic process is designed for the treatment of the wastewater and for the treatment of the sludge. Combined treatment of wastewater and sludge is not recommended, as the residence time of the two substrates in the reactors is different and the quality of the effluent of the wastewater treatment would be negatively affected by the addition of solids.

All wastewater streams should be treated by a screen as a first step to prevent clogging in the other treatment steps. The solids removed should be dumped at a landfill with the municipal waste- their quantity is insignificant compared to the quantity of wastewater. Due to the high concentrations of fat, the wastewater from the slaughterhouse is pre-treated prior to mixing it with the other wastewater in a buffer tank (figure 7). This buffer tank should be designed to equalize the amount of wastewater running towards the anaerobic treatment: fluctuations between a) day and night and b) over the weekend, when the slaughterhouse and the high school do not generate wastewater. Depending on the actual fluctuations that should be measured before designing the plant in detail, the buffer tank will have a volume between 100 and 200 m^3.

The water from the buffer tank then flows through a pre-sedimentation unit in order to separate most solids from the water. These settled solids can be digested together with the fat from the slaughterhouse in a fully mixed digestion tank with a residence time between 15 and 20 days. The necessary volume of the digestion tank is between 20 and 30 m^3. Between 150 and 250 m^3 biogas can be produced daily from the solids. The remaining sludge (1-2 m^3/d) is largely stabilized and contains high concentrations of nutrients. It can be applied as fertilizer in agriculture, if it is managed in a way to prevent contamination of agricultural products and over-fertilization of the soil.

The water can be treated in an anaerobic process, e.g. a UASB (Upflow Anaerobic Sludge Blanket) reactor or a fixed-bed process with immobilized biomass. This way, 60 to 80 % of the organic load (COD) can be transformed into biogas. The bio-reactor should be operated with retention times between 15 and 24 hours, resulting in a necessary volume of 130 to 200 m^3. This way, 60 to 100 m^3 biogas can be produced from the water each day. The effluent has a substantially reduced organic pollution, but still contains most of its initial load of nutrients. As for this small scale, a treatment process for the removal of the nutrients is economically not feasible under the current conditions in Naga City, the effluent should be used for irrigation and fertilization in agriculture as much as possible to reduce the eutrophication of the rivers caused by these nutrients. To reduce risks for staff and consumers, the treated effluent should be disinfected prior to utilization, e.g. by sand filtration and UV-radiation. Chlorination as a frequently used disinfection method should not be applied due to the generation of toxic degradation products. An area of 0.6 to 1.2 ha can be irrigated and fertilized with the treated water.

The biogas generated in the two processes amounts to 200 to 350 m^3 per day. With an energy-content between 1200 and 2100 kWh per day, the amount is too low for the economical operation of a combined heat and power plant. It should be used to heat up water for the slaughterhouse or for the prison. Between 23 and 40 m^3 of water can be heated from 20°C to 60°C per day with the produced biogas. If additional sources for organic carbon like kitchen waste from the prison or the school are fed into the digester, the biogas production will increase considerably. Therefore a thorough analysis of available organic wastes should be carried through before designing the anaerobic digestion process.

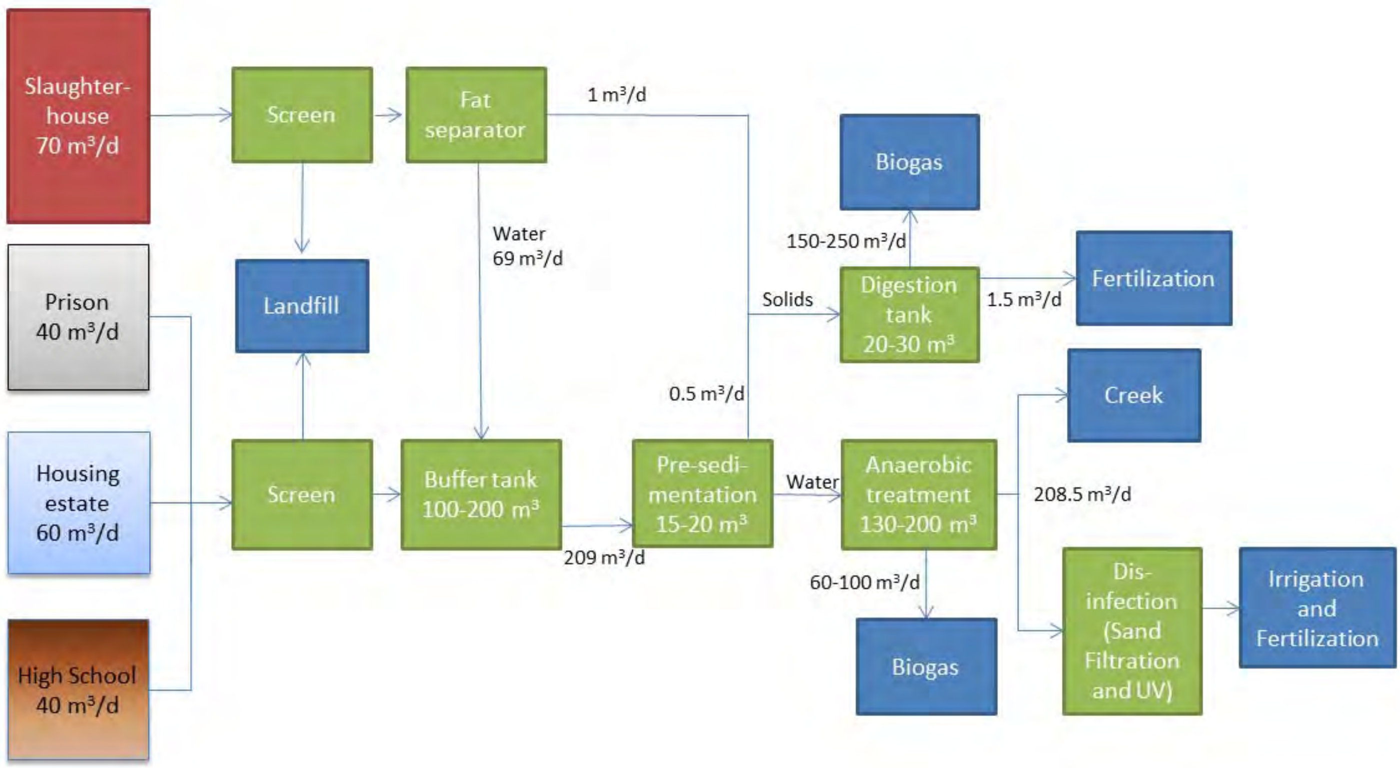

Figure 7: Scheme of the proposed wastewater treatment concept

The space requirements for the treatment processes are about 300 m^2 if the tanks are 3 m deep. The treatment facilities should be located below the wastewater sources, so the wastewater can flow there by gravity. On the other hand, the treatment facilities should be flood-proof, because flooding would cause huge damages to the facilities and the plant would have to be started up from the beginning.

Alternative processes for the wastewater treatment at Del Rosario are:

- **Aerobic processes like Activated Sludge process or Sequencing Batch Reactor:** Due to the aerobic conditions, nitrogen could be removed by nitrification/ denitrification processes. In a large scale wastewater treatment plant, this would be recommended due to the eutrophication potential of ammonium. On the other hand, organic matter would be necessary for the denitrification process, which would not be available for the anaerobic treatment any more. Due to the more complicated process, the costs for investment and operation would be considerably higher than in the proposed anaerobic process chain. Due to the small scale of the treatment facility, the discharge of nitrogen is of no consequence compared to the pollution by untreated wastewater from the septic tanks. The same accounts to phosphorous, which could be precipitated in addition to any treatment process if necessary, e.g. by addition of iron.
- **Constructed wetlands, pond systems:** The operation of these systems is easier and needs less staff. But these processes need a large specific area, so they are not sensitive in a densely populated urban area. As they are not covered, these processes might emit odor, so they should be positioned far away from human settlements. Also, the production of biogas is not possible, preventing the generation of renewable energy.

As a next step towards the implementation of the proposed concept, a feasibility study should be carried through, including a thorough analysis of the quantity and quality of the wastewater to be treated. In the case of the slaughterhouse, the production process should be included into this analysis, as it might be possible to save water or prevent mixing of solid waste with water, which would make the whole process more economically. Further focus of the feasibility study should be on the site for the treatment plant (flood proof, accessible by truck), on the utilization of the biogas, and on the irrigation and fertilization of agricultural area with the treated wastewater and the management of its application (prevention of over-fertilization, disinfection of the water plus sensibility of the farmers to prevent diseases).

As the quantity of the wastewater to be treated at Del Rosario is low, the total investment costs can be expected to be relatively low, too. On the other hand, the quantity is big enough to apply the proposed technologies, and the operation process is very similar to a large scale process. This allows the staff of the city to collect experience with these processes and to decide whether to apply them in larger scale for other parts of the city. It is important to train the staff for the operation of the treatment plant thoroughly, because often wastewater treatment plants are not operated correctly and thus do not work well.

To adapt the processes and the concept to the local conditions, scientific expertise (local, national, international) should be involved. As this would be the first implementation of such a concept (utilization of wastewater for energy and food production) in the region, research funds should be available to finance accompanying research.

At the same time, the site Del Rosario should be used for the education of the population (kindergarten, schools, grown-ups) regarding the utilization of water (e.g. water saving education), the dangers of wastewater (hygiene education), and the need for wastewater treatment. This way, the acceptance to pay for wastewater treatment would be raised gradually. As there is quite some private industry around Naga, courses for their staff can be offered at the site Del Rosario.

As at Del Rosario there is not enough space to extend the wastewater treatment plant, further implementations should be carried through at another location. This first real scale implementation should then be designed modular to extend it while the sewer system is growing.

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