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Health and environmental risk and impact assessments of waste reuse business models proposed for Bangalore

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Executive summary health assessments

Introduction and methodology

For the 4 targeted feasibility cities of the RRR project, the health components around the selected business models (BM) employed two methodologies with two different foci: Health Risk Assessment (HRA) and Health Impact Assessment (HIA). The HRA aimed at identifying health risks associated with the input resources (e.g. faecal sludge, waste water) of proposed BMs and defining what control measures are needed for safeguarding occupational health and producing outputs (e.g. treated waste water, soil conditioner) that are compliant with national and international quality requirements. The HIA aimed at identifying potential health impacts (positive or negative) at community level under the scenario that the proposed BMs are implemented at scale in Bangalore area. The magnitude of potential impacts was determined by means of a semi-quantitative impact assessment. The feasibility studies in Bangalore were oriented towards ten BMs that were selected due to their potential in the given context. These BMs are:

- Model 1a: Dry fuel manufacturing: agro-industrial waste to briquettes
- Model 4: Onsite energy generation by sanitation service providers
- Model 6: Manure to power
- Model 8: Beyond cost recovery: the aquaculture example
- Model 9: On cost savings and recover
- Model 10: Informal to formal trajectory in wastewater irrigation: incentivizing safe reuse of untreated wastewater
- Model 11: Intersectoral water exchange
- Model 15: Large-scale composting for revenue generation
- Model 16: Subsidy-free community based composting
- Model 17: High value fertilizer production for profit

Evidence-base of the HRIA

A broad evidence-based was assembled for the health risk and impact assessment (HRIA). At a large scale (i.e. city level) this entailed the collection of secondary data on the epidemiological profile, environmental exposures and the health system of Bangalore. This included statistics of health facilities from urban, peri-urban and rural areas in and around Bangalore, as well as data from the peer-reviewed and grey literature. The literature review had a focus on (i) soil-, water- and waste-related diseases; (ii) respiratory tract diseases; and (iii) vector-borne diseases, since these disease groups are closely associated with unsafe disposal of waste and waste recovery. At a small scale, primary data was collected at the level of existing RRR activities by means of participatory data collection methods and direct observations. A total of seven existing RRR cases were investigated in Bangalore area:

- Case 1: Jakkur Lake
- Case 2: Jakkur Sewage Treatment Plant
- Case 3: Waste Water Management Devanahalli Town

- Case 4: Solid Waste Management – Devanahalli Town
- Case 5: Faecal Sludge Management – Devanahalli Town
- Case 6: Karnataka Composting Development Corporation – Bangalore
- Case 7: Decentralised Waste and Composting Center (DWCC) operated by SAAHAS

The cases were studied considering the given context and by following a similar methodology in all 4 feasibility study cities. An additional important component of the case studies was an assessment of the use and acceptability of personal protective equipment (PPE) among the workforce.

In addition to the data collection activities at the level of existing RRR cases, an in-depth study was carried out in the frame of the pre-testing of the Sanitation Safety Planning (SSP) manual in Bangalore. The in-depth study aimed at filling important data gaps in the knowledge on the acceptability and practicability of health protection measures in wastewater reuse systems in Bangalore. The context of Devanahalli served as study site. A questionnaire survey and structured observations were undertaken to generate a preliminary understanding of situations or activities in which sanitary workers, farmers and consumers are exposed to various biological, physical, ergonomic and chemical hazards related to wastewater and sanitation in Devanahalli. Based on the information gathered, a semi-quantitative health risk assessment (HRA) was conducted with the aim to identify Critical Control Points (CCPs), i.e. situations/activities that bear high risks for the exposure groups. Subsequently, control measures for the hazards prevention and health protection were outlined which aimed at reducing health risks at CCPs. Finally, in focus group discussions (FGDs) the exposure groups' perceptions towards the health protection measures were assessed.

Summary of findings of the literature review and in-depth studies

According to health statistics from rural, peri-urban and urban areas of Karnataka, dog bites, tuberculosis, gastroenteritis, malaria and typhoid are the most important causes for consultations at health facilities. These are followed by Dengue fever, snake bites and viral hepatitis. Taken together, the vector-related diseases malaria, dengue, filariasis and Chikungunya are a leading cause of morbidity in Karnataka with similar case numbers as Gastroenteritis.

With regard to access to sanitation facilities, the 2005-06 National Family Health Survey (NFHS) found that 57.1% of urban households in Karnataka use some type of improved, not shared sanitation facility and 42.3% use non-improved sanitation facilities. In contrast, 82.5% of households in rural areas had a non-improved sanitation facility. Half of the households in urban Karnataka were connected to the sewer system in 2005-06, whereas this only applied to one in eight households in rural areas. In both rural and rural areas of Karnataka, more than 80% of households had access to an improved source of drinking water in 2005-06.

Soil-transmitted helminthic (STH) infections, as well as intestinal protozoa infections, are closely associated with sanitation practices. The STH surveys that have been carried out in Karnataka State found prevalence rates of >20-50%. No information could be identified on the incidence or prevalence of intestinal protozoa infections in India. Also, little information is available on the burden of acute respiratory diseases. The burden of chronic respiratory diseases and cardiovascular diseases is high, accounting for 13% and 26% of total mortality (all ages, both sexes) in India.

Various vector-borne diseases are endemic and of major public health relevance (e.g. malaria, Dengue fever, lymphatic filariasis, Chikungunya fever and Japanese encephalitis). Clearly, malaria is the most important vector-borne disease. It is a leading cause of morbidity, accounting for more than 12'000 cases in Karnataka in 2013. For the same year, 6,408 cases of Dengue fever were reported for Karnataka, including 12 fatalities.

Exposure to noise, air pollution, contaminated drinking water, contaminated surfaces and contaminated food products are important environmental determinants of health. In Karnataka State a number of studies have been carried out investigating chemical pollution (e.g. heavy metal concentration) of surface waters. For example, pronounced levels of pollution of the heavy metals copper (Cu), nickel (Ni), led (Pb) and cadmium (Cd) were found in sediments of urban lakes in Bangalore by different studies. Further environmental health concerns that have been identified for Bangalore area are elevated levels of chromium in groundwater and increased levels of particulate matter (PM) in ambient air.

Selected findings of the in-depth studies in Devanahalli are as follows:

- **Results from questionnaire survey with farmers (n=19) sanitary workers (n=7) and households (n=10)**
  - 53% farmers in Devanahalli area use open drain water to irrigate their field
  - All farmers practice furrow irrigation during which skin always gets exposed to the irrigation water
  - Farmers use hands, feet and picks to form earth heaps to stop the water flow in the furrows or to dig a furrow to start water flow
  - During work in the drainages, the wastewater is commonly touching the skin of sanitary workers
  - Neither the farmers nor the sanitary workers use PPE to protect irrigation water touching their skin
  - The majority of households (86%) in the study area has access to an own pit latrine. Pit latrine sharing is not common
  - While working the majority of workers (77%) do not have access to a toilet facility
  - Good hand-washing behaviour was reported: hand washing occurs after eating (92%), before eating (100%), after eating (94.4%) and after going to toilet (72%)
  - A majority (71.4%) uses soap when washing hands at home. At work, soap is used by 32% only
  - Washing of vegetables before cooking or before raw consumption is very common
  - Drinking water from bore wells or tap is common while water treatment is not common
  - The most frequently reported health problems were muscle pain, back pain or joint pain. Diarrhoea was not reported by the participants
- **Results from focus group discussions with farmers, community members, consumers and sanitary workers**
  - The use of gloves and boots is not practiced due to two different reasons. Farmers are not using, as it is not a custom to use rubber boots and gloves when working in their fields: "since ages we are working without boots and gloves. The land is like god for us. We are not comfortable with using boots"

- While for all farmers (N=6) gloves and boots are not acceptable, sanitary workers told that these measures are not affordable for them. The SSP team, on the contrary, experienced that when gloves and boots are provided, their workforce does not feel comfortable due to sweating and itching while wearing
- Farmers are conscious that using toilets instead of open defecation while working, would keep the surrounding near their fields clean. But they clearly told that they couldn't afford to spend money on something they feel is not necessary
- Produce restriction was very much doubted by farmers and the SSP team. The choice of products depends on the economic revenues of the produce
- Drip irrigation is practiced less frequently than furrow irrigation in Devanahalli. Farmers told that drip irrigation only works with bore well water because the "water force of the wastewater is not enough" for drip irrigation (not acceptable as not practicable)
- Farmers and the SSP team told likewise that cessation of irrigation is only acceptable for some crops. The farmers stated their main interest is growing crops and not health issues: "we put water based on the requirement and we do not bother about health reasons to stop water"
- Most farmers stated that if available they would like to use treated water for farming practices

Overall, the in-depth studies indicates that the WHO 2006 guidelines' for health protection measures regarding occupational and consumption related risk mitigation would not be easily adopted among farmers and workers. This is primarily explained by a low level of risk awareness and the unsuitability of rubber gloves and boots under hot conditions. Also affordability of PPE is a key factor. The adoption of pre-harvest intervention measures (i.e. safer irrigation, cessation of irrigation, crop restriction) lacks a financial incentive for farmers to change their current behaviour. As consequence, a close collaboration with farmers will be important to jointly discuss and find mutually acceptable solutions of risk intervention strategies at farm level and to raise awareness concerning wastewater related health risks. On the contrary, post-harvest intervention measures like safe food preparation practices and hand washing with soap were generally well received.

Key findings of the HRA

All of the identified occupational health risk – such as exposure to pathogens, skin cuts or inhalation of toxic gases – can be managed by providing appropriate PPE and appropriate design of the operation and technical elements. Since the application of PPE is not easily accepted in Bangalore area as illustrated by the in-depth study in Devanahalli Town, any PPE-based intervention needs to be complemented with an ongoing health education programme.

Biological hazards mostly derive from human and/or animal wastes that serve as inputs per se for the proposed BM (e.g. animal manure or human faeces) or are a component thereof (e.g. human waste in wastewater). For meeting pathogen reduction rates as proposed by the World Health Organization's 'Guidelines for the Safe Use of Wastewater, Excreta and Greywater' and other standards, a series of treatment options are at disposal. The HRA provides guidance on which treatment options are required for what reuse option. When it comes to the implementation of the BM, the challenge will be to respect indicated retention times and temperatures for achieving the required pathogen reduction rates. Since the proposed retention times may also have financial implications, it is important that these are taken up by the financial analysis. Also vector-related diseases are an important concern in Bangalore area and therefore vector-control measures are indicated for many processes of the BMs.

Chemical hazards primarily concern wastewater fed BMs. Pollution of surface and ground water with heavy metal and other toxic chemicals are an important environmental health concern in Bangalore area, though high local variation might apply. This needs to be taken into account for the planning of any wastewater fed BM, i.e. environmental sampling is indicated for identifying suitable locations. Where threshold values of toxic chemicals exceed national and WHO guideline values, physiochemical treatment for removing chemicals are required. Also co-composting with wastewater sludge is only an option if the sludge is compliant with heavy metal thresholds. In addition, for both irrigation with treated wastewater and the use of sludge-based soil conditioner, chemical parameters of receiving soils need to be taken into account.

In terms of physical hazards, sharp objects deriving from contaminated inputs (e.g. faecal sludge or MSW) ending-up in soil conditioner are a risk that has been identified for a number of BM. This will require careful pre-processing of inputs and sieving of End-products. Moreover, users need to be sensitised about the potential presence of sharp objects in the soil conditioner and advised to wear boots and gloves when applying the product. Also emissions such as noise and volatile compounds are of concern at workplace and community level. While PPE allows for controlling these hazards at workplace level, a buffer zone between operation and community infrastructure needs to be respected so that ambient air quality and noise exposure standards are not exceeded. Of note, the actual distance of the buffer zone is depending on the level of emissions. Finally, for businesses involving burning processes and power plants, fire/explosion and electric shock are risks of high priority that need to be managed appropriately.

Overall, the health risks associated with most of the proposed BM can be mitigated with a reasonable set of control measures. Model 10 – untreated wastewater for irrigation and groundwater recharge – is not recommended in Bangalore area. Model 15, 16 and 17, all of which use municipal solid waste (MSW) as an input, are only an option if no medical waste from health facilities is mixed with common MSW.

Key findings of the HIA

The objective of the HIA was to assess potential health impacts at community level of proposed BMs for Bangalore under the assumption that the control measures proposed by the HRA are deployed. This included consideration of both potential health benefits (e.g. business is resulting in reduced exposure to pathogens as it entails treatment of wastewater) and adverse health impacts (e.g. exposure to toxic gases by using briquettes as cooking fuels). Since the HIA aimed at making a prediction of potential health impacts of a given BM under the assumption that it was implemented at scale, a scenario was defined for each BM as an initial step. The scenario was then translated into the impact level, the number of people affected and the likelihood/frequency of the impact to occur. By means of a semi-quantitative impact assessment, the magnitude of the potential impacts was calculated.

A summary of the nature and magnitude of anticipated health impacts for each of the proposed BM is presented in Table 1. Most of the proposed BMs have the potential for resulting in a minor to moderate positive health impact.

Under the given scenarios, Model 8 (the aquaculture example) and Model 9 (treated wastewater for irrigation/fertilizer/energy: cost recovery) have the greatest potential for having a positive impact since they will result in a reduction in exposure to pathogens at community level. Model 1a – Dry fuel manufacturing: agro-waste to briquettes – bears the risk to result in a moderate negative impact by replacing more clean cooking fuels such as gas and electricity with briquettes. Also Model 11 – Intersectoral water exchange –, which aims at replacing drinking water for irrigation with treated wastewater for irrigation, has the potential for negatively impacting on the health of farmers, consumers and community members by increasing exposure to pathogens and toxic chemicals. As already highlighted under the HRA, from a health perspective it is not recommended to promote the reuse of untreated wastewater for irrigation purposes in Bangalore (Model 10).

Table 1 – Summary table of anticipated health impacts and their respective magnitude

Business model	Scale of the BM: applied scenario	Anticipated health impact	Magnitude (score)
Model 1a – Dry fuel manufacturing: agro-waste to briquettes	One percent of the population in Bangalore will use briquettes from the BM as cooking fuel	Impact 1: increase in chronic respiratory disease and cancer	**Moderate negative impact (-490)**
Model 4 – Onsite energy generation in enterprises providing sanitation services	30 villages in rural and peri-urban areas of Bangalore will implement the BM	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (432)**
		Impact 2: changes in health status due to access to electricity	**Insignificant (0)**
Model 6 – Manure to power	10 villages in rural and peri-urban areas of Bangalore will implement the BM	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (27)**
		Impact 2: changes in health status due to access to electricity	**Insignificant (0)**
Model 8 – Beyond cost recovery: the aquaculture example	3 operations serving 500 farmers. Products irrigated with safe irrigation water and safe fish from the aquaculture will be consumed by 150'000 consumers	Impact 1: reduction in respiratory, diarrhoeal, intestinal and skin diseases	**Major positive impact (4,535)**
Model 9 – On cost savings and recovery	Wastewater treatment plant with 500 farmers, 10'000 community members and 70'000 farmers benefitting from the treated wastewater	Impact 1: reduction in respiratory, diarrhoeal, intestinal and skin diseases	**Moderate positive impact (2,185)**
		Impact 2: reduction in exposure to toxic chemicals and heavy metals	**Moderate positive impact (402.5)**
		Impact 3: changes in health status due to access to electricity	**Insignificant (0)**

Model 10 – Informal to formal trajectory in wastewater irrigation: incentivizing safe reuse of untreated wastewater	Not defined	Impact 1: increase in exposure to pathogens and chemicals such as heavy metals	**Not recommended**
Model 11 – Intersectoral water exchange	5 small-scale waste water treatment plants. One plant will serve 100 farmers who supply products to10,000 consumers each. 1,000 households would gain access to fresh water	Impact 1: increase in respiratory, diarrhoeal, intestinal and skin diseases at farmer level	**Moderate negative impact (-265)**
		Impact 2: decrease in diarrhoeal, respiratory and intestinal diseases linked to access to safe drinking water	**Moderate positive impact (875)**
		Impact 3: reduction in respiratory, diarrhoeal, intestinal and skin diseases due to the promotion of waste water treatment	**Moderate positive impact (525)**
Model 15 – Large-scale composting for revenue generation	Two centralised co-composting plants are installed in Bangalore, serving 2'000 households each	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (90)**
		Impact 2: indirect health benefits due to reduced MSW loads on landfills	**Minor positive impact (12.5)**
Model 16 – Subsidy-free community based composting	The waste volume of 10,000 households will be collected by the business	Impact 2: indirect health benefits due to reduced MSW loads on landfills	**Minor positive impact (12.5)**
Model 17 – High value fertilizer production for profit	Two centralised co-composting plants are installed in Bangalore, serving 2'000 households each	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (90)**
		Impact 2: indirect health benefits due to reduced MSW loads on landfills	**Minor positive impact (12.5)**

Executive summary environmental assessments

For the Environmental Impact Assessment (EIA), business model flow diagrams are used as a tool to visualize both impact assessments. The EIA takes into consideration the "Technology Assessment", which comprises an extensive literature review on technologies for resource recovery also identifying potential environmental hazards and measures of mitigation.

Within the scope of this assessment, the environmental impact of the business models are not assessed in detail, as information on facility scale and specific location in the city was not available. Rather, with the level of technical detail currently available, the EIA shows potential environmental hazards, which should be recognized and mitigated during implementation.

More detailed analysis of specific environmental impacts can follow at a later stage if treatment infrastructure has been clearly defined based of an analysis of market demand for End-products and the respective determination of treatment goals. Such an evaluation would have to include detailed laboratory analyses of the waste streams to be utilized, so that treatment technologies can be selected and designed in detail.

Currently, and based on the EIA as a stand-alone component, the feasibility of business models cannot be ranked, which is the reason for all business models resulting in "medium feasibility". Ultimately, the implementing business has to mitigate the identified potential environmental hazards, which will results in little, or no environmental impact.

Table 2 provides a summary for all business models, the respective waste streams, End-products technologies, processes and potential environmental hazards, including proposed mitigation measures.

Table 2 – Summary table of anticipated environmental impacts and proposed mitigation

BM	Waste stream	End-product	Technologies	Process	Pot. Env. Hazard	Mitigation measures
1a	• MSW • AIW	• Briquettes	• Carbonized - low pressure • Raw - mechanized high pressure • Carbonized - mechanized	• Briquetting	• Hazardous air emissions • Accumulated inorganic waste • Process water	• Air emission control technologies (e.g. activated carbon, scrubbers) • Proximate and ultimate analyses • Post-treatment of process water
4	• Feces • Urine • FS	• Biogas -> Cooking fuel	• Single stage • Multi-stage • Batch	• Anaerobic digestion	• Air emissions • Solid residue (digestate) • Liquid effluent	• Maintenance of anaerobic digester • Solid/liquid residue post-treatment
6	• AM	• Biogas -> Electricity	• Single stage • Multi-stage • Batch • Biogas conversion technologies	• Anaerobic digestion • Biogas to electricity conversion	• Hazardous air emissions • Solid residue (digestate) • Liquid effluent	• Maintenance of anaerobic digester • Air emission control technologies • Solid/liquid residue post-treatment

8	• WW	• Fish • Treated WW	• Duckweed • Aquaculture	• Pond treatment	• Heavy metals in effluent and/or sludge from WW treatment • Solid residue (sludge from WW treatment)	• Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • Solid residue (sludge from WW treatment) post-treatment
9	• WW • WW sludge	• Electricity • Soil conditioner • Water (for reclamation)	• Conventional wastewater treatment technologies • Biogas conversion technologies	• Conven-tional WW treatment • Biogas to electricity conversion	• Heavy metals in effluent and/or WW sludge • Solid residue (sludge from WW treatment) • Air emissions	• Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • Solid residue (sludge from WW treatment) post-treament • Maintenance of anaerobic digester
10	• WW	• Water (for reclamation) • Water for groundwater recharge	• Slow rate infiltration • Rapid infiltration • Overland flow • Wetland application	• Land treatment	• Groundwater contamination (heavy metals/pathogen s) • Contamination of irrigated crops with heavy metals and/or pathogens	• Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • Crop selection • 2006 WHO guidelines
11	• Treated WW	• Water (for reclamation)	• Slow rate infiltration • Rapid infiltration • Overland flow • Wetland application	• Land application through irrigation	• Groundwater contamination (heavy metals/patho-gens) • Contamination of irrigated crops	• Crop selection • Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • 2006 WHO guidelines
15	• MSW • FS	• Soil Conditioner	• Solid/liquid separation • Drying beds • Co-composting	• Co-com-posting (MSW + FS)	• Accumulated inorganic waste • Leachate from composting • Insufficient pathogen inactivation • Liquid effluent (from FS treatment)	• Storage/transport/disposal (sanitary landfill) • Moisture control • Leachate treatment • Temperature control (compost heap) • Post-treatment of liquid effluent
16	• MSW	• Soil Conditioner	• Windrow (static/turned) • In-Vessel • Inclined step grades • Vermi-composting	• Compo-sting	• Accumulated inorganic waste • Leachate from composting	• Storage/transport/ disposal (sanitary landfill) • Moisture control • Leachate treatment

17	• MSW • FS	• Fertilizer (NPK added)	• Solid/liquid separation • Drying beds • Co-composting	• Co-com-posting (MSW + FS)	• Accumulated inorganic waste • Leachate from composting • Insufficient pathogen inactivation • Liquid effluent (from FS treatment)	• Storage/transport/disposal (sanitary landfill) • Moisture control • Leachate treatment • Temperature control (compost heap) • Post-treatment of liquid effluent

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Abbreviations

AIDS	Acquired Immune Deficiency Syndrome
ARI	Acute Respiratory Infections
BBMP	Bruhath Bangalore Municipal Corporation
BM	Business Model
CCP	Critical Control Point
Cd	Cadmium
CO	Carbon Monoxide
COPD	Chronic Obstructive Pulmonary Disease
Cr	Chromium
Cu	Copper
dB	Decibel
EIA	Environmental Impact Assessment
Fe	Iron
FGD	Focus Group Discussion
GAHI	Global Atlas of Helminthic Infections
HIA	Health Impact Assessment
HRA	Health Risk Assessment
HRIA	Health Risk and Impact Assessment
IL	Impact Level
NFHS	Indian National Family Health Survey
KII	Key Informant Interviews
LF	Lymphatic Filariasis
LoF	Likelihood or Frequency
MSW	Municipal Solid Waste
NCD	Non-communicable Disease
NFCP	National Filaria Control Programme
NFHS	National Family Health Survey
NO_x	Nitrogen Oxides
NPK	Nitrogen, Phosphorus and Potassium
NVBDCP	National Vector Borne Disease Control Programme
PA	People Affected
Pb	Lead
PLI	Pollution Load Index
PM	Particulate Matter
PPE	Personal Protective Equipment
RRR	Resource, Recovery and Reuse
RS	Risk Score
SO_x	Sulphur Oxides
SSP	Sanitation Safety Planning
STH	Soil-transmitted helminthic infections
STI	Sexually Transmitted Infection
TB	Tuberculosis
TTC	Thermo Tolerant Coliform
USEPA	United States Environmental Protection Agency
UTI	Urogenital Tract Infection
WHO	World Health Organization
WWTP	Wastewater Treatment Plant
YYL	Years of Life Lost
Zn	Zinc

Annexes

Annex I – HRIA Methodology and tools for feasibility studies in Bangalore

Annex II – HRIA Bangalore case studies

Annex III – PPE Guide

Annex IV – MSc Lena Bereitenmoser

Annex V – Indian and international health-related quality standards

1 Introduction

Outcome 7 of the Resource, Recovery and Reuse (RRR) project entails the assessments of health and environmental risks for proposed waste reuse business models (BMs). For the strategic health planning components of Outcome 7, different forms of health assessments are available with different foci, i.e. from workplace health to community health, as illustrated in Figure 1. Since both workplace health and community health are of concern for the feasibility studies of proposed BMs, a health risk assessment (HRA) and health impact assessment (HIA) methodology were employed[1]. Health needs of communities in Bangalore were also considered in the frame of baseline data collection activities such as the characterisation of the epidemiological profile and the assessment of environmental exposures. BM flow diagrams were developed to identify outputs posing health and environmental risks. The environmental impact assessment (EIA) and HRA take into consideration the "Technology Assessment" report [2], which comprises an extensive literature review on technologies for resource recovery also identifying potential environmental hazards and measures of mitigation.

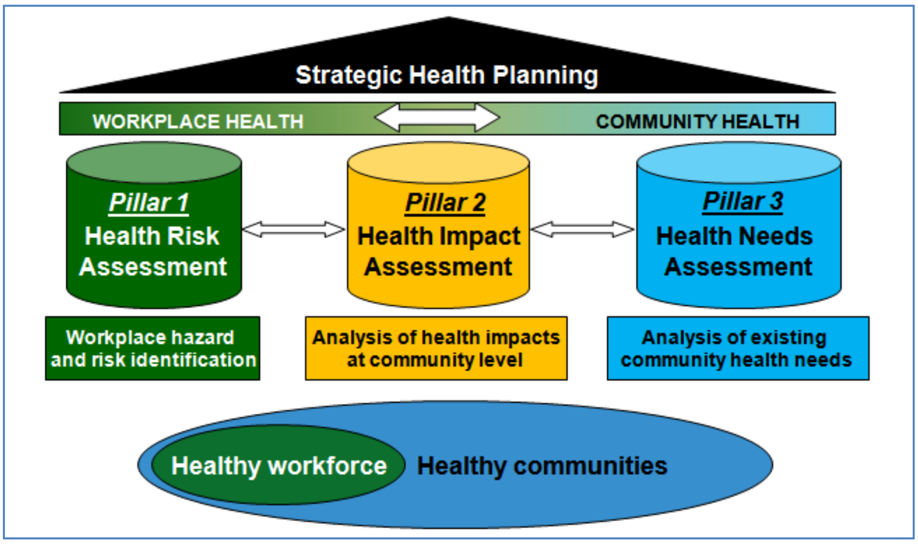

Figure 1 – Different types of health assessments and their inter-linkages

The specific objectives of the health assessments were:

- To characterise the general disease profile and exposures to environmental health hazards linked to waste streams in Bangalore
- To identify common occupational and community health risks associated with existing RRR activities in Bangalore
- To evaluate the acceptability of control measures to mitigate health risk in Bangalore
- To define control measures required for safeguarding occupational health and ensuring safe products for each of the BMs proposed for Bangalore
- To assess residual health risks with the proposed control measures in place

- To assess potential health impacts at community level (positive or negative) of proposed BMs for Bangalore under the assumption that the proposed control measures (see previous objective) are deployed.

The specific objectives of the EIA were:

- To create BM flow diagrams, identify BM outputs (e.g. emissions into air) that could form a potential environmental hazard
- To identify the specific potential environmental hazards of identified outputs (e.g. polycyclic aromatic hydrocarbons)
- To identify technical solutions for mitigation of potential environmental hazards to prevent a negative environmental impact (e.g. activated carbon, scrubbers)
- To provide guidance on technical solutions that have to be recognizes when implementing waste-based BMs

Within the scope of the EIA, the environmental impact of the business models are not assessed in detail, as information on facility scale and specific location in the city was not available. Rather, with the level of technical detail currently available, the EIA shows potential environmental hazards, which should be recognized and mitigated during implementation. More detailed analysis of specific environmental impacts can follow at a later stage if treatment infrastructure has been clearly defined based of an analysis of market demand for End-products and the respective determination of treatment goals. Such an evaluation would have to include detailed laboratory analyses of the waste streams to be utilized, so that treatment technologies can be selected and designed in detail.

Chapter 2 provides an overview of the tools and methods that were deployed for assembling the baseline data to inform the specific objectives above. It also introduces the HRA, HIA and EIA methodologies. In Chapter 3, the evidence-base for the HRA and HIA is summarized in five sub-chapters (i.e. epidemiological profile; environmental parameters; self-reported health issues by workers of reuse cases; and acceptability and use of personal protective equipment). At the core of the present report are the HRA, HIA and EIA in Chapter 4.

2 Methodology

In order to assemble the information needed for the HRA and HIA components, a methodological triangulation was carried out (see Figure 2). At a large scale (i.e. city level) this entailed the collection of secondary data on the epidemiological profile, environmental exposures and the health system of Bangalore. At a small scale, primary data was collected at the level of existing RRR activities by means of participatory data collection methods and direct observations. In addition, in-depth studies that aimed at assessing acceptability and practicability of health protection measures in wastewater reuse systems was carried out in the frame of the pre-testing of the Sanitation Safety Planning (SSP) manual in Bangalore.

Section 2.1 provides an overview of the survey tools and methods that were employed for the different baseline data collection activities. The full description of survey tools and methods is available in Annex I ('Methodology and tools for feasibility studies: baseline data collection for the health risk and impact assessments'). A summary of the key findings of the different data collection activities is provided in Chapter 3. These data serve as evidence-base for the HRA and HIA in Chapters 4 and 5.

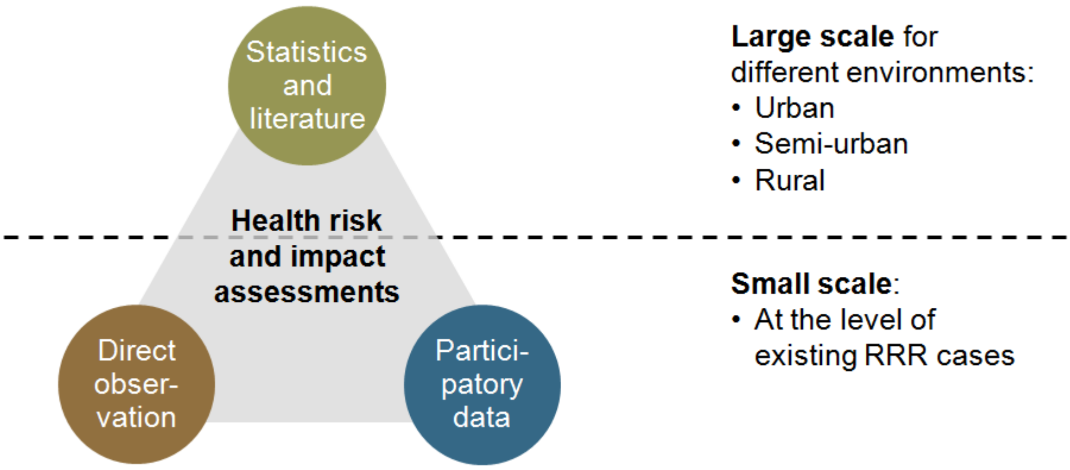

Figure 2 – Methodological triangulation for the health risk and impact assessments

2.1 Baseline data collection activities

The description of the epidemiological profile, environmental parameters and other contextual information of Bangalore is a crucial element of the health assessments. The baseline data collection activities involved the assembling of secondary data, as well as primary data collection exercises. The data from various sources is presented in Chapter 3, entitled 'evidence-base of the HRA and HIA'. In order to remain focused on health issues that have a direct link to sanitation systems and resource reuse activities, the epidemiological profile is structured along three disease groups: (i) soil-, water- and waste-related diseases; (ii) respiratory tract diseases; and (iii) vector-borne diseases.

2.1.1 Data collection at the level of existing RRR cases

With the goal to determine the range and magnitude of potential occupational and community health risks associated with the proposed BMs for Bangalore, a number of existing RRR cases were assessed. In addition, it was considered important to evaluate the cultural and financial acceptability of health risk mitigation measures in the given context. The selection of existing RRR cases aimed at covering cases that have as many as possible commonalities with the BMs proposed for the feasibility studies in Bangalore. In total, 7 existing RRR cases were analysed:

- Case 1: Jakkur Lake
- Case 2: Jakkur Sewage Treatment Plant
- Case 3: Waste Water Management Devanahalli Town
- Case 4: Solid Waste Management – Devanahalli Town
- Case 5: Faecal Sludge Management – Devanahalli Town
- Case 6: Karnataka Composting Development Corporation – Bangalore
- Case 7: Decentralised Waste and Composting Center (DWCC) operated by SAAHAS

For the data collection at the level of existing RRR cases, a specific set of tools and methods was developed. A detailed description of the different working steps and associated survey tools is provided in Annex I. The main steps can be summarized as follows:

1. <u>Case description</u>: this includes a *system flow diagram and a process description*, as well as the identification and characterization of different exposure groups (i.e. farmers, workers, local community and consumers)
2. <u>Identification of health hazards, exposure routes and validation of existing control measures</u>: this step was carried out using data collection tools for hazard identification, control validation and risk assessment
3. <u>Risk assessment</u>: the ranking of the risk associated with each health hazard aimed at identifying which of the health hazards are already well controlled or insignificant, while highlighting those that represent a major health risk. For this purpose a semi-quantitative risk assessment was performed
4. <u>Key informant interviews (KII) and focus group discussions (FGD)</u>: the KII were carried out (i) with the RRR case business owner/operator and (ii) health care providers in proximity to the RRR case. FGDs were conducted in the community living in proximity to the RRR business case. Both KII and FGD were guided by semi-structured questionnaires
5. <u>Worker questionnaire:</u> a questionnaire-based interview was conducted with the workers of existing RRR cases, covering the following topics: (i) worker health; (ii) worker risk perception; (iii) worker safety (e.g. use and acceptance of personal protective equipment (PPE)); (iv) reasons for potentially missing PPE; and (v) willingness to pay for potential controls/mitigation

The data that were collected in the different case studies are summarised in Annex II.

2.1.2 In-depth studies

In addition to the data collection activities at the level of existing RRR cases, an in-depth study was carried out in the frame of the pre-testing of the Sanitation Safety Planning (SSP) manual in Bangalore.

The in-depth study was led by Lena Breitenmoser; an MSc student of the Swiss Federal Institute of Technology. Lena's master thesis project aimed at filling important data gaps in the knowledge on the acceptability and practicability of health protection measures in wastewater reuse systems in Bangalore. The context of Devanahalli served as study site. A questionnaire survey and structured observations were undertaken to generate a preliminary understanding of situations or activities in which sanitary workers, farmers and consumers are exposed to various biological, physical, ergonomic and chemical hazards related to wastewater and sanitation in Devanahalli. Based on the information gathered, a semi-quantitative health risk assessment (HRA) was conducted with the aim to identify Critical Control Points (CCPs) i.e. situations/activities that bear high risks for the exposure groups. Subsequently, control measures for the hazards prevention and health protection were outlined which aimed at reducing health risks at CCPs. Finally, in focus group discussions (FGDs) the exposure groups' perceptions towards the health protection measures were assessed.

The detailed methodology and findings of the study is available in Annex II – MSc thesis Lena Breitenmoser. Key findings of the study are presented under chapter 3.3 – Health protection measures in wastewater reuse systems: acceptability and practicability of adoption.

2.2 Health risk assessment

The objectives of the HRA were:(i) to identify potential biological, chemical and physical hazards and hazardous events associated with the proposed BMs in the given context; (ii) to define a set of mitigation measures that need to be incorporated in the final BM description for eliminating or controlling the identified risks; and (iii) to assess the residual health risk with the proposed control measures in place, taking into account the technical efficiency and cultural acceptability. For this purpose, the HRA combined the findings of various data collection activities with the technology of the proposed BMs. The ultimate goal of the HRA was to assess whether potential health risks of proposed BMs can be managed appropriately. The approach described in the subsequent sub-chapters has been applied to each BM proposed for Bangalore.

2.2.1 Input characterization and quality requirements for outputs

As an entry point for the HRA, input-resources of the BM (e.g. solid and liquid waste products) were characterized in terms of composition and associated potential health hazards. Source documents for this initial step were the 'technology assessment' and the 'waste supply and availability' reports for Bangalore[3]. For the outputs of the BM, quality requirements at national level are listed as per the institutional analysis for Bangalore[4]. Of note, as described by the institutional analysis, in India Health care concerns are predominantly covered by Ministry of Health and Family Welfare at both Centre and State levels. Health care concerns in India are also covered in various National Policies and to name a few, National Health Policy, National Population Policy, National Policy for Older Persons and Environmental Policy. Health is covered by urban local bodies only in few select places in India. In Bangalore City, health care services are provided by The Bruhath Bangalore Municipal Corporation (BBMP) City Corporation.

The Ministry of Health oversees health in general across the country but the focus is on health programs and services. Occupational health as a standalone issue is addressed. However there are legislations like Factories Act, Workmens Compensation Act and few others which seek to address the occupational health issues.

Institutionally there is a gap in managing occupational and public health risks. NGOs and some public bodies are aware of this and efforts are being made to sensitise government officials and to introduce practices to protect public health but efforts are not widespread or institutionalized [4]. Hence, due to the limited number of Indian health-related quality standards, international standards are referenced for the HRIA such as those set by the WHO guidelines on the safe use of wastewater, excreta and grey water or the United States Environmental Protection Agency (USEPA) [5].

2.2.2 Identification of potential health hazards linked to specific processes

In consideration of the epidemiological and environmental baseline data for Bangalore, potential biological, chemical and physical health hazards were identified for each of the processes described for the BM:

- Biological hazards: disease causing agents (pathogens) with the potential for causing impacts on occupational and public health such as viruses bacteria, pathogenic protozoa, helminthic eggs and disease vectors
- Chemical hazards: chemicals with the potential for causing acute or chronic health effects, i.e. organic and inorganic substances and those with accumulative effects such as heavy metals and pharmaceuticals
- Physical hazards: hazards that could result in injury to the workers (e.g. open water bodies, working at height, noise pollution and radiation)

In a next step, hazardous events linked to each of the identified hazards (e.g. discharge of untreated waste or release of toxic gases) were described. The potential exposure groups were also listed in this process. Finally, general issues (e.g. operational matter), which cannot be assigned to a specific process of the BM but would rather affect the entire operation, were also added to the list of hazardous events in order to be considered in the subsequent steps of the risk assessment.

2.2.3 Identification and appraisal of control measures

For each of the health hazards and hazardous events identified in the previous step, the control measures are listed. The full range of control measures were considered such as physical barriers (e.g. screening or filtration), physical processes (e.g. sedimentation, decomposition), chemical treatment options (e.g. chlorination), disease prophylaxis (e.g. preventive chemotherapy), behavioural measures (e.g. health education), protective measures (e.g. PPE) and modifications/additions to the design of the technical components of the BM (e.g. covering open water bodies, access restriction, retention basins, protection shields and backup generators). Since in many cases multiple control options for a given hazard exist, a prioritization was made by rating the technical efficiency and acceptability (which includes cost considerations) of the proposed measure. This rating of the 'mitigation potential' of the control measure was based on the multiplication of a technical efficiency score (low: 1; medium: 2; and high: 3) with the acceptability score (low: 1; medium: 2; and high: 3). Resulting values were classified into three levels of mitigation potential:

- Low mitigation potential of the control measure: range 1-3;
- Medium mitigation potential of the control measure: range 4-6; and
- High mitigation potential of the control measure: range 7-9.

For the appraisal and mitigation of biological health hazards, the pathway of pathogens through the technical process of the BM was determined and log reduction rates were indicated as per the 2006 WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater (here after referred to as 'WHO 2006 Guidelines')[5] and other source documents. In consideration of the reuse scenario of the different products of the BM, it was evaluated whether the technical processes of the BM (e.g. retention time; processing temperature) allow for compliance with the pathogen thresholds defined by WHO, as well as national standards. Recommendations for improving pathogen reduction were made throughout the process wherever indicated. In case the targeted reduction rate could not be achieved along the technical process of the BM, a multi-barrier approach, as proposed by the WHO Guidelines, was considered, with additional control measures at the level of inputs, reuse activities or consumers. The acceptability and feasibility of such 'outside the system' control measures was taken into account in the subsequent risk assessment.

The appraisal and mitigation of chemical health hazards followed the same process as for biological hazards, though, no log reduction rates apply and considerable data gaps exist. For chemical hazards with unknown transformation and elimination processes, the worst case scenarios (i.e. no reduction by simple physical processes) were applied.

In general, control of physical hazards through engineering methods is most effective. For example, in the context of motorised or machines involving moving parts, such as the ones used in wastewater treatment plants, control measures at the engineering level are most appropriate. In many instances, physical health hazards can also be mitigated by means of PPE, which has a high technical efficiency if applied appropriately. Since workers will often operate multiple processes, the choice of PPE needed has to be made on an individual basis. Therefore, the summary term PPE was used for the control measure indication. Guidance on which type of PPE is required to prevent specific physical hazards is provided in Annex II.

2.2.4 Semi-quantitative risk assessment

By means of a semi-quantitative risk assessment, the theoretical residual risks of the proposed BM were assessed, i.e. under the assumption that the identified control measures are in place. For this purpose the **impact level** (**IL**) (ranging from insignificant to catastrophic) and the **likelihood or frequency** (**LoF**) of the hazardous event to occur were determined for each of the identified health hazards, according to the definitions provided in Table 3. For determining the likelihood or frequency of occurrence, the mitigation potential (i.e. the combination of technical effectiveness and acceptability of the proposed control measure) was taken into account. The combination of the likelihood or frequency with the level of impact resulted in a **risk score** (**RS**) (**RS** = **IL** x **LoF**; low risk: <6; moderate risk: 7–12; high risk: 13–32; and very high risk: ≥32) as illustrated by the risk matrix in Figure 3. The entire rating was based on a modified Delphi approach (Rowe and Wright, 1999); a technique intended for use in judgement and forecasting situations in which pure model-based statistical methods are not practicable. In practice this means that the risk assessment was performed by multiple assessors who found an agreement on the final rating.

Table 3 – Definition of impact level, and likelihood for the HRA(adapted from [6])

IMPACT LEVEL (I)		
Category	**Score**	**Description**
Insignificant	**1**	No health consequences anticipated and no impact on normal operations
Minor impact	**2**	Impact not resulting in any perceivable or measurable health effect; easily manageable disruptions to operation; no rise in complaints anticipated
Moderate impact	**4**	Impact resulting in minor disability (e.g. fever, headache, diarrhoea, small injuries) or unease (e.g. noise, malodours); may lead to complaints or minor community annoyance; operations may be disrupted for short duration
Major impact	**8**	Impact resulting in moderate disability (e.g. acute intoxication, malaria, injury) or minor disability of long duration; may lead to legal complaints and major community concerns; operations could be significantly affected by the impact
Catastrophic impact	**16**	Impact resulting in severe disability, chronic disease or even loss of life; major investigation by regulator with prosecution are likely; can lead to complete failure of system
LIKELIHOOD or FREQUENCY (LoF)		
Category	**Score**	**Description**
Very unlikely	**1**	In consideration of the technical effectiveness and local acceptability of proposed control measures, it is very unlikely that exposure to the health hazard will occur (odds: <5%). Frequency: once every 5 years
Unlikely	**2**	In consideration of the technical effectiveness and local acceptability of proposed control measures, it is unlikely that exposure to the health hazard will occur (odds: 5–40%). Frequency: once a year
Possible	**3**	In consideration of the technical effectiveness and local acceptability of proposed control measures, it is possible that exposure to the health hazard will occur (odds: 41-60%). Frequency: once a month
Likely	**4**	In consideration of the technical effectiveness and local acceptability of proposed control measures, it is likely that exposure to the health hazard will occur (odds: 61-95%). Frequency: once a week
Almost certain	**5**	In consideration of the technical effectiveness and local acceptability of proposed control measures, it is almost certain that exposure to the health hazard will occur (odds: >95%). Frequency: once a day

Risk score: (RS) = (IL) x (LoF) Very high risk >32 High risk 13–32 Moderate risk 7–12 Low risk <6		IMPACT LEVEL (IL)				
		Insignificant (1)	Minor impact (2)	Moderate impact (4)	Major impact (8)	Catastrophic impact (16)
LIKELIHOOD or FREQUNCY (LoF)	Very unlikely (1)	1	2	4	8	**16**
	Unlikely (2)	2	4	8	**16**	**32**
	Possible (3)	3	6	12	**24**	**48**
	Likely (4)	4	8	**16**	**32**	**64**
	Almost certain (5)	5	10	**20**	**40**	**80**

Figure 3 – Semi-quantitative assessment matrix (adapted from [6])

2.3 Health impact assessment

The objective of the HIA was to assess potential health impacts at community level of proposed BMs for Bangalore under the assumption that the control measures proposed by the HRA are deployed. This included consideration of both potential health benefits (e.g. operation resulting in reduced exposure to pathogens since it entails treatment of wastewater) and adverse health impacts (e.g. toxic emissions of an operation, which cannot be avoided). The findings of the various data collection activities served as evidence-base for the HIA. The approach described in the subsequent sub-chapters has been applied to each BM proposed for Bangalore.

2.3.1 Definition of impact pathways

The impact definition is a description of the pathway(s) the BM may impact on the health status of affected communities (e.g. decrease in the incidence of diarrhoeal diseases due to reduced pathogen loads in irrigation water). Once the potential impact pathways of a BM were identified, literature that provides evidence for the direction and magnitude of the potential health impacts was reviewed and references were added.

2.3.2 Semi-quantitative impact assessment

By means of a semi-quantitative risk assessment, the potential health impacts of the proposed BM were characterized in terms of nature (positive or negative) and magnitude (minor to major) of impact. For this purpose the **IL** (ranging from major negative impact to major positive impact), the **LoF** of the impact to occur and the estimated number of **people affected** (PA) were determined for each of the identified potential health impact (see definitions provided in Table 3).

The combination of the IL with the LoF and the estimated number of people affected resulted in the magnitude of the health impact (Magnitude = IL x LoF x PA; low positive impact: 0–4; moderate positive impact: 10–4,499; high positive impact: ≥4,500; low negative impact: 0– -4; moderate negative impact: -10– -4,499; and high negative impact: ≤-4,500; see risk matrix in Figure 4). As for the HRA, the rating for the HIA was based on a modified Delphi approach[7].

Table 4 – Definition of impact level and likelihood for the HIA (adapted from [8])

IMPACT LEVEL (IL)		
Category	**Score**	**Description**
Major positive impact	**1**	Impact reduces incidence of diseases or injury, resulting in severe disability, chronic disease or even loss of life
Moderate positive impact	**0.5**	Impact reduces incidence of diseases or injury, resulting in moderate disability that may require hospitalisation (e.g. acute intoxication, malaria, injury) or minor disability of long duration
Minor positive impact	**0.1**	Impact reduces incidence of disease or injury, resulting in minor disability of short duration (e.g. acute diarrhoea, acute respiratory infection) that does not require hospitalization
Insignificant	**0**	Impact not resulting in any perceivable or measurable health effect
Minor negative impact	**-0.1**	Impact increases incidence of diseases or injury, resulting in minor disability of short duration (e.g. acute diarrhoea, acute respiratory infection) that does not require hospitalization
Moderate negative impact	**-0.5**	Impact increases incidence of diseases or injury, resulting in moderate disability that may require hospitalisation (e.g. acute intoxication, malaria, injury) or minor disability of long duration
Major negative impact	**-1**	Impact increases incidence of diseases or injury, resulting in severe disability, chronic disease or even loss of life
PEOPLE AFFECTED (PA)		
Category	**Score**	**Description**
Individual cases	**1**	A few individuals are concerned by the impact (e.g. road traffic accidents)
Specific population	**100**	A relatively small specific population group is concerned by the impact (e.g. people living in proximity to an operation)
Medium population group	**1,000**	A medium size population group is concerned by the impact (e.g. people living downstream a river that may be contaminated by an operation)
Large population group	**10,000**	A large population group is concerned by the impact (e.g. consumers of a widely used product of an operation)
Major population group	**100,000**	A major population group is concerned by the impact (e.g. a small city that will gain access to safe drinking water)
LIKELIHOOD or FREQUENCY (LoF)		
Category	**Score**	**Description**
Very unlikely	**0.05**	It is very unlikely that the impact will occur (odds: <5%). Frequency: once every 5 years
Unlikely	**0.3**	It is unlikely that the impact will occur (odds: 5–40%). Frequency: once a year
Possible	**0.5**	It is possible that the impact will occur (odds: 41-60%). Frequency: once a month
Likely	**0.7**	It is likely that the impact will occur (odds: 61-95%). Frequency: once a week
Almost certain	**0.95**	It is almost certain that the impact will occur (odds: >95%). Frequency: once a day

IMPACT LEVEL (IL)		PEOPLE AFFECTED (PA)				
		Individual cases	Specific population	Medium popu-lation group	Large popu-lation group	Major population
		1	**100**	**1,000**	**10,000**	**100,000**
Major positive impact	**1**	0.05	30	500	7,000	95,000
Moderate positive impact	**0.5**	0.03	15	250	3,500	47,500
Minor positive impact	**0.1**	0.01	3	50	700	9,500
Insignificant	**0**	0.00	0.00	0.00	0.00	0.00
Minor negative impact	**-0.1**	-0.01	-3	-50	-700	-9,500
Moderate negative impact	**-0.5**	-0.03	-15	-250	-3,500	-47,500
Major negative impact	**-1**	-0.05	-30	-500	-7,000	-95,000
		0.05	**0.3**	**0.5**	**0.7**	**0.95**
		Very unlikely	Unlikely	Possible	Likely	Almost certain
		LIKELIHOOD or FREQUENCY (LoF)				

Figure 4 – Impact assessment matrix (adapted from [8])

2.4 Environmental Impact Assessment

The EIA is based on the same input characterization and quality requirements for outputs as the HRA. Each business model consists of a process for the conversion of waste into a resource. Along the process of conversion, several potential environmental hazards were identified and mitigation measures considered. These hazards and mitigation measures are presented in this report in the last section of each business model chapter. The technology assessment report describes technologies for mitigation in more detail [2]. A more thorough impact assessment, based on environmental pollution, can be performed once business models are selected, that must include specific information such as scale, location and market demand for End-products.

3 Evidence-base for the HRA and HIA

3.1 Epidemiological profile

In India, preterm birth complications, lower respiratory infections and diarrhoeal diseases are the leading causes of years of life lost (YLLs). Although the burden of those disorders has changed considerably over the past 10 years, they remained the leading cause of YLLs in 2010. At the same time, there has been a strong increase (>50%) of YLLs due non-communicable diseases (NCDs) such as ischemic heart diseases and stoke. Consequently, dietary risks are the leading health risk factor in India. This change is illustrated in Figure 5, which compares the top 25 causes of years of life lost (YLLs) in 1990 and 2010 in India [9]. Hence, India has been facing an epidemiological transition resulting in a double burden of communicable and non-communicable diseases, with increasing importance of non-communicable diseases and injuries (e.g. self-harm and road traffic accidents) [10, 11].Of note, there is considerable variation in the burden of diseases between the different regions of India and in general, infectious diseases are more important in rural areas than urban areas such as Bangalore.

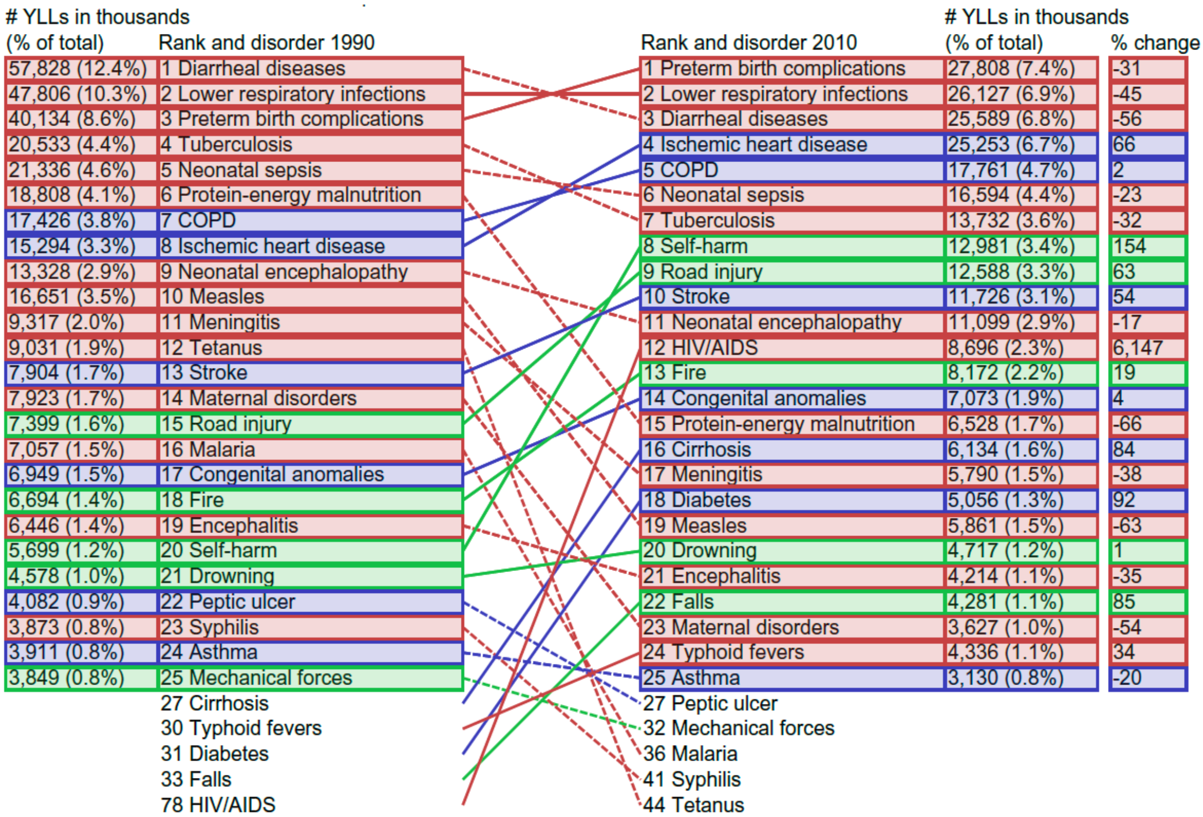

Figure 5 –Ranks for top 25 causes of YLLs 1990-2010, India[9]

In order to get estimates of morbidity patters in urban, peri-urban and rural areas of Bangalore, statistics from Karnataka and health facilities located in the districts where the data collection activities at the level of existing RRR cases took place (i.e. Bangalore North Taluka (Yelahanka), Bangalore Urban District, Devanahalli Taluka and Bangalore Rural District) were collected. In Table 6 and Table 5, health outcomes of reported cases in the years 2010, 2011 and 2012 are presented for Karnataka and selected districts.

Table 5 – Incidence of infectious diseases and injuries in Karnataka, 2010-2013

Rank	Disease Name	Particulars	Karnataka		
			2010-11	2011-12	2012-13
1	**Dog bites**	**Number of attacks**	**204,163**	**213,066**	**58,231**
		Number of deaths	15	12	02
2	**Tuberculosis**	Number of sputum smear examined			491,102
		Number of TB cases detected			65,099
		New sputum positive cases detected			**32,612**
		Sputum conversion			85%
		Cure rate			82%
3	**Gastroenteritis**	**Number of attacks**	**70,167**	**67,514**	**21,987**
		Number of deaths	43	40	5
4	**Malaria**	**Malaria cases**	**44,319**	**24,237**	**16,446**
		Plasmodium Falciparum cases	7,936	2,648	1,278
		Deaths due to Malaria	11	0	0
5	**Typhoid**	**Number of attacks**	**44,708**	**47,897**	**10,311**
		Number of deaths	5	1	0
6	**Dengue**	**Number of cases of Dengue fever attacks**	**2,285**	**405**	**3,924**
		Number of cases of Dengue fever deaths	7	5	21
7	**Snake bites**	**Number of attacks**	**11,678**	**9,737**	**1,464**
		Number of deaths	239	136	17
8	**Viral Hepatitis**	**Number of attacks**	**7,853**	**11,120**	**783**
		Number of deaths	17	8	1
9	**Filarial**	**Total number of Microfilaria cases Detected**	**425**	**399**	**281**
		Total number of disease cases	3,417	3,290	3,396
		Microfilaria rate	0.26%	0.25%	0.20%
10	**Chikungunya**	Number of cases of suspected cases of Chikungunya fever	8,740	1,941	2,382
		Number of cases of confirmed cases of Chikungunya fever	**1,430**	**225**	**205**
11	**Leptospirosis**	**Number of attacks**	**524**	**462**	**65**
		Number of deaths	12	8	2
12	**H1N1**	**Number of attacks**	**108**	**878**	**51**
		Number of deaths	16	48	04
13	**Cholera**	**Number of attacks**	**144**	**222**	**45**
		Number of deaths	0	2	0
14	**Japanese Encephalitis**	Number of cases of Suspected cases /Acute Encephalitis Syndrome	143	397	370
		Number of deaths of Suspected cases /Acute Encephalitis Syndrome	1	0	2
		Number of confirmed cases of JE	**4**	**23**	**20**
		Number of confirmed deaths of JE	0	0	0

Overall, Dog bites, Tuberculosis, Gastroenteritis, Malaria and Typhoid are the most important causes for consultations at health facilities in Karnataka. These are followed by Dengue fever, Snake bites and viral hepatitis. Taken together, the vector-related diseases Malaria, Dengue, Filariasis and Chikungunya are a leading cause of morbidity in Karnataka with similar case numbers as Gastroenteritis.

When comparing case reports from different environments, gastroenteritis and typhoid seem to be more prevalent in rural areas than urban areas. In contrast, the incidence of tuberculosis is higher in urban areas than rural areas. Vector-related diseases are reported in both environments, though dengue is more prevalent in urban areas and malaria is more prevalent in rural areas, which reflects the preferred habitat of the respective disease vectors.

Statistics from the routine health information system provide a comprehensive overview of potential disease patterns in Bangalore area. However there may some limitations with respect to accessing of government health services and diagnostic techniques used.

Table 6 – Diseases reported in various areas from April to November 2013

Diseases		**Bangalore North Taluka (Yelahanka)**	**Bangalore Urban District**	**Devanahalli Taluka**	**Bangalore Rural District**
		Number of cases	**Number of cases**	**Number of cases**	**Number of cases**
Gastro Enteritis		5	2,451	313	8,135
Dog Bite		700	16,463	1,310	5,941
Typhoid		26	668	729	1,870
Tuberculosis	CAT 1	78	1,779	28	773
	CAT 2	19	561	148	206
Jaundice		0	40	10	208
Chikungunya		0	33	7	75
Snake Bite		3	34	95	134
Dengue		0	297	8	32
Malaria	*P. vivax*	4	13	0	6
	P. falciparum	0	0	0	28
Cholera		0	0	0	0
Leptospirosis		0	0	0	0
Japanese Encephalitis		0	0	0	0

The following sub-chapters focus on soil- water- and waste-related diseases, respiratory diseases and vector-related diseases that are frequently reported in the wider Bangalore area. An important data source on general population statistics is the Indian National Family Health Survey 2005-06 (NFHS) [12].

3.1.1 Soil-, water- and waste-related diseases

The prevalence of soil-, water- and waste-related diseases depends highly on sanitation facilities and access to safe drinking water, the factors which often show high local variations. With regard to access to sanitation facilities, the 2005-06 NFHS found that 57.1% of urban households in Karnataka use some type of improved, not shared sanitation facility and 42.3% use non-improved sanitation facilities (see Table 7) [12]. The situation presents the other way round in rural areas with 82.5% of households having a non-improved sanitation facility. Half of the households (49.6%) in urban Karnataka were connected to the sewer system in 2005-06, whereas this only applied to one in eight (14.4%) households in rural areas. With regard to access to drinking water, in both rural and rural areas of Karnataka, more than 80% of households had access to an improved source of drinking water in 2005-06.

Table 7 – Drinking water sources and sanitation facilities used, Karnataka, 2005-06 [12]

Household and housing characteristic	Urban	Rural	Total	De jure population
Sanitation facility				
Improved, not shared	57.1	17.4	33.5	33.2
Flush/pour flush to piped sewer system, septic tank, or pit latrine	49.6	14.4	28.6	28.4
Pit latrine with slab	6.3	2.5	4.0	3.9
Other	1.2	0.6	0.8	0.9
Not improved	42.3	82.5	66.2	66.5
Any facility shared with other households	19.9	3.2	10.0	8.5
Flush/pour flush not to sewer system, septic tank, or pit latrine	3.2	0.4	1.6	1.4
Pit latrine without slab/open pit	2.0	0.8	1.3	1.2
Other unimproved facility	0.1	0.0	0.1	0.1
No facility/open space/field	17.0	78.0	53.3	55.3
Source of drinking water				
Improved source	88.1	84.9	86.2	85.5
Piped water into dwelling/yard/plot	39.9	15.8	25.5	24.7
Public tap/standpipe	31.4	32.4	32.0	31.1
Tube well or borehole	14.3	33.6	25.8	26.6
Other improved	2.6	3.1	2.9	3.1
Non-improved source	11.8	15.0	13.7	14.4
Other source	0.0	0.1	0.1	0.1

3.1.1.1 Diarrhoeal diseases

Diarrhoeal disease is the second leading cause of death in children under 5 years old, though it is both preventable and treatable. It is estimated that diarrhoea kills around 760'000 children under five each year and it is a leading cause of malnutrition in the same age group. A significant proportion of diarrhoeal disease can be prevented through safe drinking-water and adequate sanitation and hygiene. Globally, there are nearly 1.7 billion cases of diarrhoeal disease every year [13]. According to the health statistics available for Karnataka, gastroenteritis is an important cause of morbidity. Although gastroenteritis was not further specified in the available statistics, it can be assumed that many cases present with acute or chronic diarrhoea. In the 2005-06 National Family Health Survey (NFHS), 8.6% of mothers reported that their child aged below 5 years had diarrhoea in the two weeks preceding the survey. The youngest age groups aged 6-23 months were most affected, with prevalence rates of 16.1% and 15.9%, respectively. Interestingly, prevalence rates were similar in rural (8.4%) and urban (9.0%) areas [12].

3.1.1.2 Helminthic infections and intestinal protozoa

Soil-transmitted helminthic (STH) infections are the most common helminthic infections worldwide. Also intestinal protozoa show a worldwide distribution with infection being highest in infants and children. According to the Global Atlas of Helminthic Infections (GAHI), a total of 127 surveys on STH infections have been carried out from 1999 to 2007 in India [14]. The STH surveys that have been carried out in Karnataka State found prevalence rates of >20-50% (see Figure 6). The studied age groups are unknown. However, these data show that STH are clearly an issue in Karnataka and most likely also in Bangalore area.

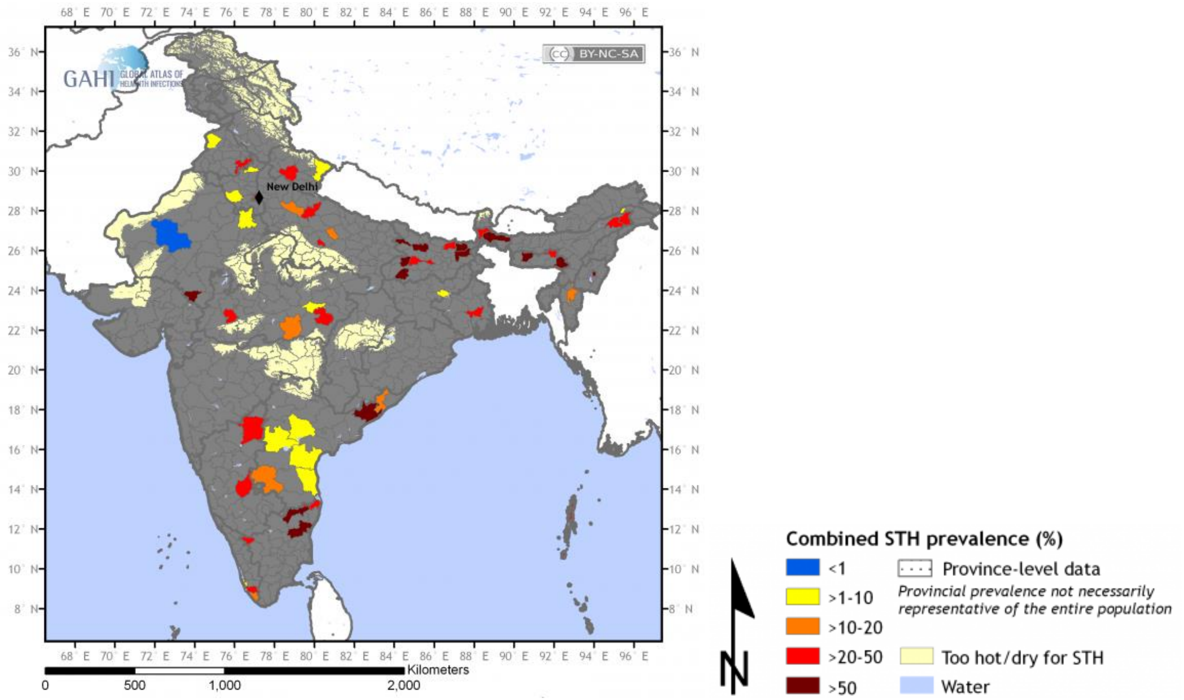

Figure 6 – Distribution of soil transmitted helminthic survey data in India[14]

No information could be identified on the incidence or prevalence of intestinal protozoa infections in India. In view of the environmental conditions and the high frequency of STH infections, it can be assumed that intestinal protozoa infections are an important health issue in Bangalore area, though many infections may be asymptomatic or result in minor disability.

3.1.2 Respiratory tract diseases

Respiratory tract diseases are diseases that affect the air passages, including the nasal passages, the bronchi and the lungs. They range from acute infections, such as pneumonia and bronchitis, to chronic conditions such as asthma and chronic obstructive pulmonary disease.

3.1.2.1 Acute respiratory tract infections

Acute respiratory infections (ARI) (e.g. pneumonia) have a variety of causes including bacteria, viruses, fungi or parasites. ARI are the most common cause of death in children and kills about 3 million children every year in the developing world. Children under the age of 5 years, and especially those under 2 years, constitute the greatest risk group. ARI can be spread in a number of ways. The most important transmission pathway is air-borne droplets from a cough or sneeze of an infected individual. The other modes of transmission include transmission via wastewater and food products that are contaminated with human waste, and thus indirectly associated with sanitation and drinking water systems, as well as resource recovery and reuse activities.

The health statistics obtained from different districts in Bangalore (see section 3.1) do not mention any ARI, which is rather surprising. The most recent data that could be identified on ARI in Karnataka is provided by the 2005-06 NFHS: the percentage of children who presented with symptoms of ARI (i.e. cough accompanied by short, rapid breathing which was chest-related) in the two weeks preceding the survey was at 1.7% [12]. This figure is very low when compared with prevalence rates of ARI that are commonly found in Africa. For example, the 2011 Uganda Demographic and Health Survey (DHS) found a prevalence of ARI in children aged under 5 years of 14.8% [15].

3.1.2.2 Chronic respiratory diseases

The most common non-infectious respiratory diseases are asthma, chronic obstructive pulmonary disease (COPD), respiratory allergies and pulmonary hypertension. In 2005, COPD caused more than 3 million deaths, with 90% of those occurring in low- and middle-income countries [16]. COPD is predicted to be the third most common cause of death in 2030. Risk factors include tobacco smoking, indoor air pollution (e.g. indoor cooking with wood or coal), outdoor air pollution (e.g. burning domestic waste or traffic related dust), allergens and occupational exposure (e.g. asbestos, silica, certain gasses). In addition to causing chronic respiratory diseases, indoor and outdoor air pollution is also directly associated with cardiovascular disease such as hypertension, stroke and cardiac infarction. According to the NFHS-3, 26.6% of urban households and 87.8% of rural households used wood as cooking fuel in 2005-06 [12]. This number may have decreased in recent years.

In India, chronic respiratory diseases and cardiovascular diseases account for 13% and 26% of total mortality (all ages, both sexes), according to estimates of the WHO (see Figure 7) [17]. Taken together, those two health conditions account for more than one in three deaths in India, which makes exposure to indoor and outdoor air pollution an important public health concern.

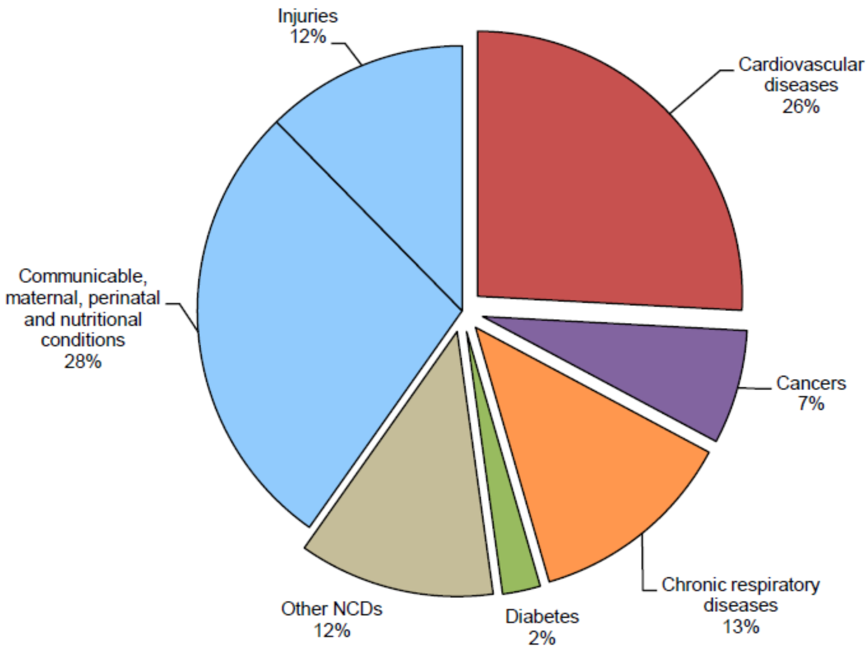

Figure 7 – NCD-related mortality (%), all ages, both sexes, India (2012) [17]

3.1.2.3 Tuberculosis

Tuberculosis (TB) is an infectious bacterial disease caused by *Mycobacterium tuberculosis*, which most commonly affects the lungs. Individuals with active pulmonary TB spread infections through airborne droplet nuclei containing infectious *M. tuberculosis* in the course of speaking, sneezing, laughing and particularly coughing. Overcrowding, poor ventilation, poor lighting and duration of exposure increase the risk of transmission. TB is one of the leading causes of mortality in India, killing 2 persons every three minute; nearly 1,000 every day[18]. In fact, in 2009 India was the highest TB burden country globally, accounting for more than one-fifth of the global incidence (i.e. global annual incidence: 9.4 million TB cases; India annual incidence 1.96 million TB cases)[19]. In recent years, TB incidence rates show a decreasing trend in India, which is thanks to a diverse set of control strategies put in place by India's National TB Control Programme. In Karnataka state, more than 30,000 TB cases were detected in 2012, making it a respiratory disease of major public health concern. However, since TB is primarily transmitted via airborne droplets and not through contaminated food or water, the disease is not of high relevance for the HRIA of RRR BMs.

3.1.3 Vector-borne diseases

In the terminology of epidemiology, vectors are organisms that transmit infections from one host to another. The most commonly known biological vectors are arthropods but many domestic animals are also important vectors or asymptomatic carriers of parasites and pathogens that can affect or infect humans or other animals. In the present chapter we will focus on diseases associated with mosquito and fly vectors.

Depending on the season, a broad range of mosquito vectors such as *Anopheles spp*., *Aedes spp*. and *Culex spp*. are present in India. Therefore, various vector-borne diseases are endemic in the country. According to the Indian National Vector Borne Disease Control Programme (NVBDCP), the most important vector-borne diseases in Karnataka are malaria and dengue[20]. But also lymphatic filariasis, Chikungunya and Japanese encephalitis are important public health concerns in Bangalore area.

3.1.3.1 Malaria

Malaria, a protozoan infection transmitted by bite of infected female anopheline mosquitoes, is the most important parasitic disease in humans. Malaria is one of the most serious public-health issues in most tropical regions of the world. Malaria is also endemic in India where about 95% of the population resides in malaria endemic areas and 80% of reported malaria cases are confined to populations residing in tribal, hilly, difficult and inaccessible areas[20]. The predominant *Plasmodium* species in India are *Plasmodium vivax and P. falciparum* (see Figure 8). The latter is the most dangerous *Plasmodium* species.

In 2013, a total of 12,302 malaria cases have been reported for Karnataka, 967 of which were identified as *P. falciparum* malaria [20]. This is a decrease compared to previous years: 2012: 16,466 cases; and 2011: 24,237 cases. Clearly, malaria is a major public health concern in Karnataka.

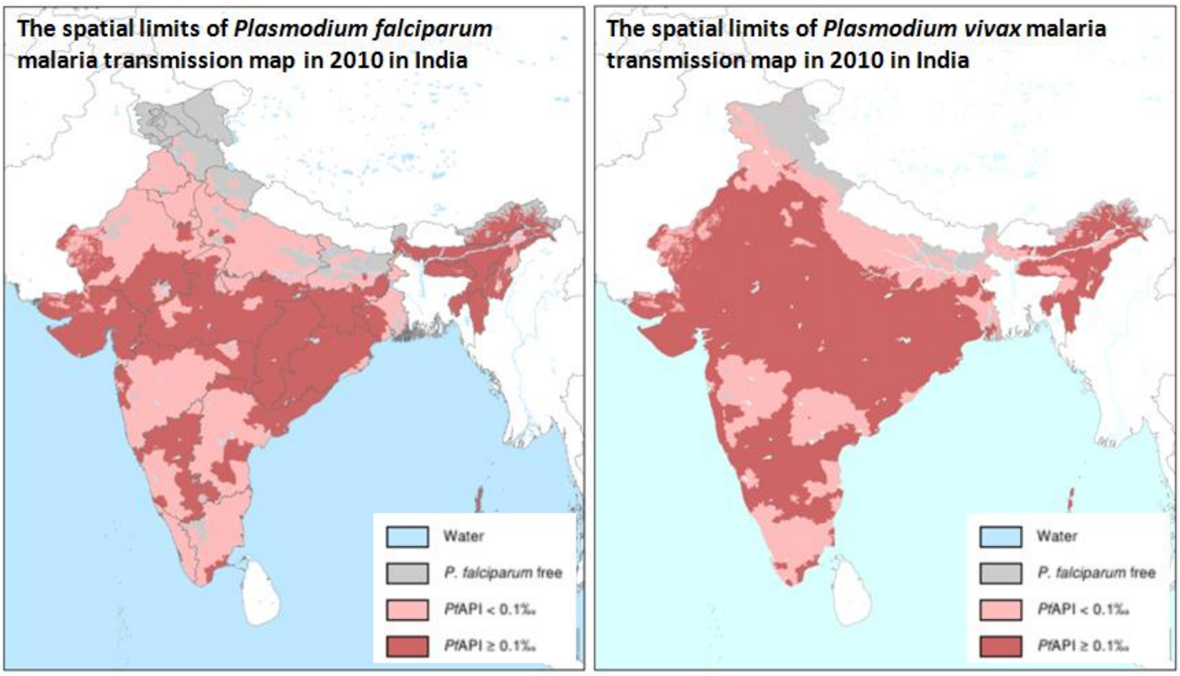

Figure 8 – *P. falciparum and P. vivax*malaria transmission, India, 2010 [21]

3.1.3.2 Dengue and other arboviral diseases

Dengue fever is an arboviral disease caused by a virus transmitted by bite of an infected female *Aedes* mosquitoes. It is one of the most common causes of illness in the world's tropical and subtropical regions. Symptoms are typically flu-like and in rare cases the disease develops into severe dengue (dengue hemorrhagic fever), with potentially life-threatening complications. Dengue fever is endemic in Karnataka (see Figure 9). In 2013, the NVBDCP reported a total of 6,408 dengue cases with 12 fatalities for Karnataka [20]. In comparison with previous years, an increase in dengue cases can be observed for Karnataka (e.g. 2012: 3,924 cases; and 2011: 2,285 cases). As shown by the data in Table 6, urban areas are more prone to dengue than rural areas. This is explained by the fact that *Aedes spp*. mosquitoes preferably lay their eggs in man-made containers such as bottles, tires, fountains, barrels, and pots.

Chikungunya fever and Japanese encephalitis are two other arboviral diseases (transmitted by mosquitoes) that are endemic in Bangalore area. The number of suspected cases of Chikungunya fever and Japanese encephalitis range between 2,000 and 5,000 per year in Karnataka. Since the diagnostic of those diseases is equipment and cost intensive, only few cases are confirmed. Many cases might also be reported as common flu or go undetected.

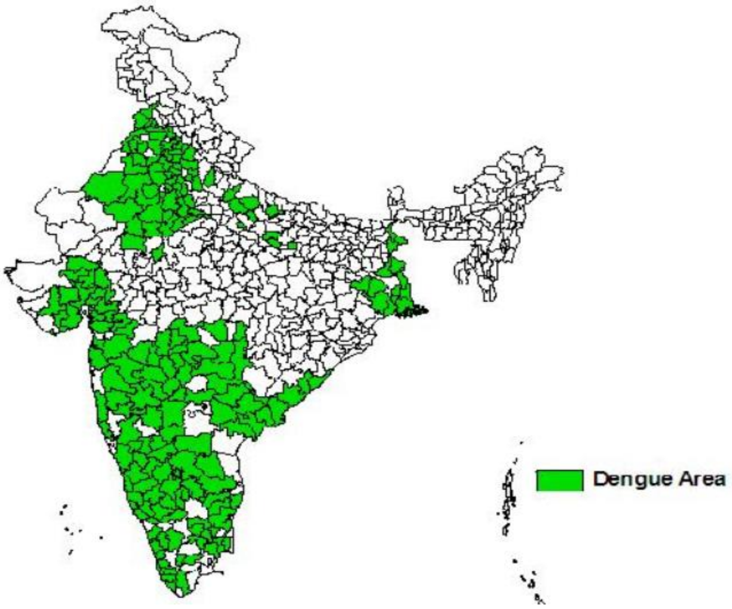

Figure 9 – Distribution of dengue in India[20]

3.1.3.3 Lymphatic filariasis

Lymphatic filariasis (LF), commonly known as elephantiasis, is a disfiguring and disabling disease. The long term physical consequences are painful swollen limbs. Infected individuals sustain the transmission of the disease. Hydrocele in males is also common in endemic areas. LFis caused by protozoan parasites that are transmitted to humans by the bites of infected female *Phlebotomine* sand flies.

In the context of sanitation, as it is know the vector *Culex* mosquito (transmits Filaria worm W.Bancrofti) prefers breeding in stagnant sewage and dirt water bodies. Therefore Lf burden also indicates the need for improving sanitation and thereof wastewater management.

LF is endemic in coastal area and few districts in north Karnataka. In 2012, a total of 281 cases of LF were reported for Karnataka (see Table 5). Despite the relatively small number of cases, the average microfilaria rate in Karnataka state was estimated at 0.6% in 2013 [20]. This represents a decline from 1.87% in 2004 and 0.93% in 2009, which is linked to the sustained efforts of the National Filaria Control Programme (NFCP).

3.2 Environmental parameters

Exposure to noise, air pollution, contaminated drinking water, contaminated surfaces and contaminated food products are important environmental determinants of health. For the HRIA of the RRR Project, a sound understanding of potential contaminants of surface waters and waste waters, as well as potential agricultural soils is needed. For example, river water can be polluted with heavy metals due to up-stream industrial activities, which has implications for the use of the river water for irrigation of agricultural surfaces but it will also influence water quality of surface waters in Bangalore.

3.2.1 Chemical pollution of surface waters

In Karnataka State a number of studies have been carried out investigating chemical pollution (e.g. heavy metal concentration) of surface waters [22-25]. For example, a study investigated how chemical fertilizers, which are extensively used in modern agriculture in India in order to improve crop yield, impact on surface water quality in Mysore District [25]. They found that application of chemical fertilizers has severe impact on water quality. Nitrate and phosphate concentrations were found to be higher than the permissible limits of WHO standards and pH of the ground water was found to be alkaline in some of the water samples.

Only few studies on environmental pollution can be found in the peer-reviewed literature for Bangalore area. A study describing the concentrations of heavy metals in the bed sediments of 17 urban lakes in Bangalore was conducted in 2009 [26]. Pooled findings are presented in Table 8. The study found pronounced levels of pollution of the heavy metals copper (Cu) and nickel (Ni), followed by led (Pb) and cadmium (Cd). Chromium (Cr) failed a single sediment quality guideline while Zinc (Zn), magnesium (Mn) and cobalt (Co) remained within the safety levels of all sediment quality guidelines prescribed for the study.

Table 8 – Concentrations of heavy metals in sediments of Bangalore urban lakes [26]

			Screening level guidelines of Ontario ministry of environment[22]		NOAA sediment quality guidelines[22]		FDEP sediment quality guidelines[22]		The (CCME) interim sediment quality		Sediment quality objectives in guidelines Netherlands [17,22,29]		
Metal	Mean (ppm)	Range (ppm)	Low	Severe	ERL	ERM	TEL	PEL	IGM	PEL	TV	MPC	Critical soil concentration ranges[23] (ppm)
Cd	8.38	4.68-14.25	0.6	10	1.2	9.6	0.68	4.21	0.6	3.5	0.8	12	3-8
Co	47.70	19.61-82.30	-	-	-	-	-	-	-	-	-	-	25-50
Cr	96.70	10.68-320.0	26.0	110	81.0	370.0	52.30	160.00	37.3	90.0	-	-	75-100
Cu	203.50	74.90-882.2	16.0	110	34.0	270.0	18.70	108.00	35.7	197.0	36.0	73	60-125
Mn	176.00	60.00-534.5	460.0	1110	-	-	-	-	-	-	-	-	1500-3000
Ni	97.64	28.31-495.6	16.0	75	20.9	51.6	15.90	42.80	-	-	-	-	100
Pb	206.00	36.58-2266.3	31.0	250	46.7	218.0	30.20	112.00	35.0	91.3	85.0	530	100-400
Zn	220.90	19.60-1118.25	120.0	820	150.0	410.0	124.00	271.00	123.0	315.0	140.0	620	70-400

The Pollution Load Index (PLI) between heavy metals in the lakes produced the following outputs: Ni >Pb> Cd > Cu > Cr > Co > Zn >Mn. Overall, the study indicates increasing levels of various heavy metals species in the sediment deposits of the lake beds of the urban wetlands in Bangalore. Hence, the urban aquatic ecosystems are strongly influenced by long term discharge of untreated domestic and industrial wastewaters, storm water runoff, accidental spills and direct solid waste dumping. All these released pollutants have a great ecological impact on the water quality of the urban wetlands and, if this trend is allowed to continue unabated, it is likely that the food-web complexes in these fragile wetlands might be at high risk of induced heavy metals contamination.

Another study aimed at capturing the environmental impacts of industrial effluent irrigation from a tanning industrial cluster[27]. The concentration of chromium was selected as key indicator for assessing the quality of groundwater in the study area, since there is considerable evidence that chromium is carcinogenic. The analysis reveals that more than half of the 30 drinking water samples tested were non-potable due to the presence of excess chromium. The study shows that there is a definite correlation between the ill health faced by the residents of the area and ground water contamination.

Also leachate from solid waste management sites (i.e. bio-composting and vermi-composting of municipal solid waste) was identified as a source of pollution of surface water and groundwater reserves in Bangalore [28]. Analysis of groundwater samples showed alarming physicochemical values closer to the waste disposal site and relatively reduced values away from the source of the waste management site.

Overall, the few studies available show that pollution with toxic chemicals of surface water and ground water is an important environmental and health concern in Bangalore area. However, more studies are needed for understanding the full extent of chemical pollution in Bangalore.

3.2.2 Air pollution

Urban areas in Bangalore need to deal with the problem of deteriorating air quality due to the presence of various contributing sources. In a recent study, the contribution of various sources towards prevailing ambient particulate matter (PM) concentrations at different land-use categories in an urban setting were investigated [29]. PM_{10} and $PM_{2.5}$ were monitored at seven locations representing different area categories in Bangalore. Results of the study show the variation in source contributions across different land-use categories. While transport had the highest contribution at the kerbside locations, diesel generator sets used as alternative power supply emerged as an important source in the residential areas. In the coarser fraction (PM_{10}), the contribution of re-suspended dust was found to be high. At city level, on an average, transport sector contributed significantly (19%) in PM_{10} and dominantly (50%) in $PM_{2.5}$. The study clearly highlights the variety of sources to be controlled in different areas of a city.

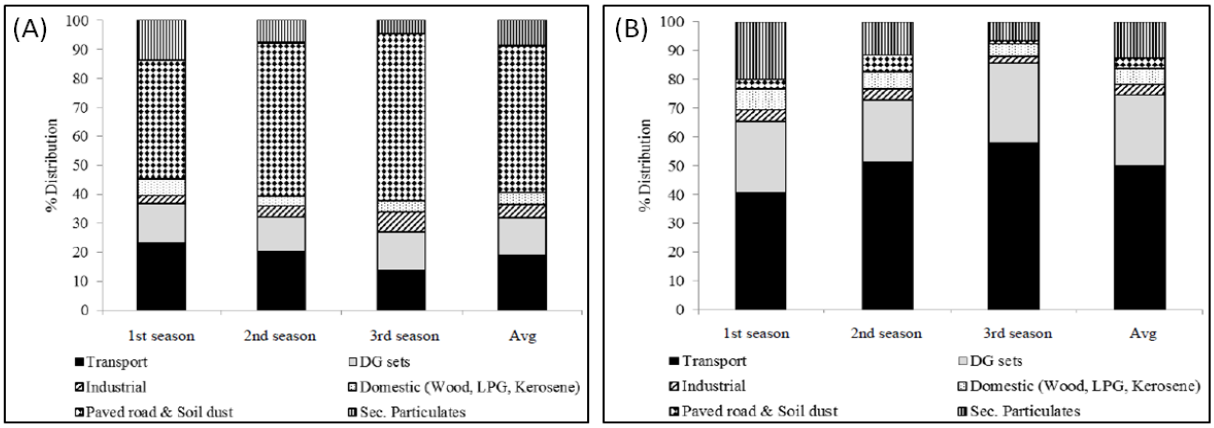

Figure 10 – Relative sectoral contributions to PM_{10} (A) and $PM_{2.5}$ (B) in Bangalore city [29]

3.3 Health protection measures in wastewater reuse systems: acceptability and practicability of adoption

The in-depth study that was carried out in the context of Devanahalli made an important contribution to the knowledge on the acceptability and practicability of health protection measures in wastewater reuse systems in Bangalore. In this chapter, findings are summarized that are relevant for the risk assessment and mitigation of the selected BM. The full study is available in Annex II.

As part of the study, 36 inhabitants of Devanahalli were interviewed, i.e. 19 farmers, 10 households and 7 sanitary workers. The farmer sample represented 23.8 % of the estimated 80 farmers in Devanahalli. Figure 11 shows the health problems reported by interviewees in Devanahalli. Among the 7 workers who were aware of health risks related to their work, 50% reported muscle pain, 38.9% reported about back pain and 27.8% stated joint pain as health risks. Injuries and tiredness (27.6%) were likewise seen as health risks among workers.

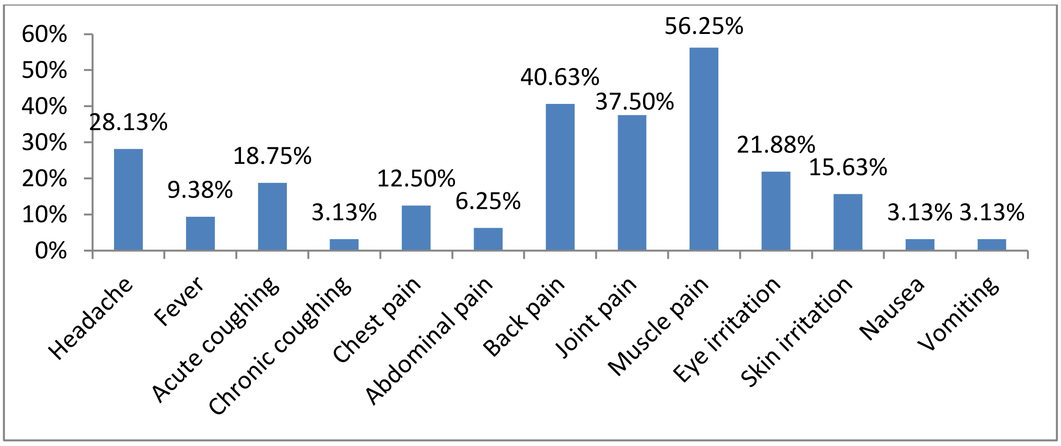

Figure 11 – Health problems reported by interviewees (N=32) in Devanahalli [30]

Key findings of the questionnaire survey and structured observations are presented in Table 9 for the following categories: (i) occupational exposures; (ii) PPE; (iii) sanitation situation; (iv) hygiene behaviour; (v) consumption behaviour; (vi) health status; and (vii) health seeking behaviour.

Table 9 – Key findings of the questionnaire survey compared to structured observations

Sections	Results from Questionnaires	Results from Observations
(B) Occupational exposure	• 10 of 19 **(53%) farmers use open drain water** to irrigate their field. • All farmers interviewed practice **furrow irrigation** during which skin always gets exposed to the irrigation water. • During work in the drainages, the wastewater is commonly touching the skin of sanitary workers.	• **Farmers engaged in furrow irrigation (2 observations) were constantly standing in wet soil and in irrigation wate**r with their bare feet. • Farmers use hands, feet and picks to form earth heaps to stop the water flow in the furrows or to dig a furrow to start water flow • **Sanitary workers had direct skin contact** (hands and feet) with the open drain water during drainage

	⇒ *Almost nil contact to open drain wastewater reported except through occupational exposure. Flooding was not reported among the participants.*	activities (2 observations) **and indirect skin contact** (hands) **to wastewater** when collecting the wet solid waste that was removed from the drains (2 observations of solid waste workers/loaders).
(C) Personal protective equipment	• **Neither the farmers nor the sanitary workers douse PPE** to protect irrigation water touching their skin.	• **No PPE was detected among farmers**. While irrigating (2 observations) and land preparation (1 observation) the farmers used only a pick to open and close the furrows with earth heaps or to loosen the soil respectively. • **None of the sanitary workers used gloves, boots or masks.** All the sanitary workers observed were wearing sandals and made use of tools. In the drainage activities shovels with short and longs shafts as well as sickles were utilised to clean the drains from the solid waste and de-weed the borders. In the solid waste collection shovels, planks and buckets are used to collect the waste.
(D) Sanitation situation	• **The majority (86%) has access to an own pit latrine**. Pit latrine sharing is not common. • While working the majority of workers (77%) do not have access to a toilet facility.	• All 4 households visited had a pit latrine inside or a little outside the living area. In 2 households washing clothes and taking a bath is happening in the same room where the toilet is located.
(E) Hygiene behaviour	• Good hand-washing behaviour is reported: Hand washing occurs after eating (92%), before eating (100%), after eating (94.4%) and after going to toilet (72%). • A big part (71.4%) uses soap when washing hands at home. At work, soap is used by 32% only.	• Hand washing was not observed during the worker observations due to on-going working activities after the observations was terminated. • During household observations, **hand washing behaviour varied among the observed households.** However, **in all households soap was available**. In 3 of 4 households the soap was wet.
(F) Consumption behaviour	• Washing of vegetables before cooking or before raw consumption is very common. • Most participants (92%) drink water from bore wells or tap. **Water treatment is not common** among the participants (83% do not treat).	• In all households, vegetables were prepared for cooking already when observations began. **In all 4 observations vegetables were cooked/fried**. 2 households used tap water for cooking; 2 households used bore well water that was filled in containers. One household uses a drinking water filter.
(E) Health status	• Health problems reported frequently among the inhabitants are muscle pain, back pain or joint pain. Diarrhoea was not reported.	-
(F) Health seeking behaviour	• People tend to prefer private doctors (96.4%). Fever (60.5%) was the most common reason for health facility visits. ⇒ *Health care providers interviewed mentioned fever, common cold, diarrhea, typhoid, skin rashes and other as common diseases among people attending their clinics in Devanahalli.*	-

Based on the findings of the questionnaire survey and direct observations, the study defined a set of control measures, as per the WHO 2006 Guidelines, that could be applied at the CCPs for controlling the identified risks. The proposed control measures where then discussed in FGD with farmers, community members, consumers and sanitary workers.

All the FGD groups seemed aware of the fact that different types of wastewater are flowing in the open drains. Used water from bathrooms and used water from clothes and vessels/kitchenware washing were mentioned by all the groups. Rainwater and toilet water was only cited in FGD2 (sanitary workers) and FGD3 (community members/consumers).

Interestingly, the farmer group was convinced that "except the latrine water and chemical water, all other waste water of the town will come into the drains".(Male, FGD2)

All the participants (N=20) from FGD2, FGD3 and FGD4 told to have bad experiences with the open drain system. The bad smell and the presence of mosquitoes are the most disturbing factors that were raised in these groups. All farmers (N=6) told to have good experiences with the open drain water as they have never faced any problems during the years they are growing crops with it.

When asked for problems that could arise when re-using this open drain water for crop production, farmers stated that they eat their own crops regularly and that there is no health-related problem at all. Slightly different perceptions where revealed in the other 3 focus groups. Despite they see and tend to understand the reasons why farmers use it (water scarcity and savings on fertilizer) they feel not comfortable when eating these crops: "the drain water helps crops to grow and farming is good but the taste of the crops is less because in the drains all waste products are there." (Female, FGD4)

Interestingly, all consumers (N=13; FGD3 and FGD4) most commonly buy their products on the local markets in Devanahalli and told that on the market they cannot differentiate between vegetables grown in bore well and in open drain water. Participants of FGD2 and FGD4 told several times that they think that also health problems could arise when consuming these crops. No further speciation on the types of health risks feared resulted.

Table 10 displays a summary of the perceptions on the acceptability of the health protection measures among participants in the FGDs and the SSP core team. The classification into available/ not available was done based on the rating system with smileys. The classification was done on the majority basis. The not acceptable and not affordable categories were done based on the issues raised during the discussion.

Some health protection measures as proposed by the WHO are already applied or used by all the participants in the FGDs (i.e. safe food preparation & vector control), while others are only partly (i.e. regular hand washing with soap, visiting doctors, covering open drains) and some are not at all (i.e. treatment of drinking water, safe sanitation at workplace, produce restriction, safe irrigation, cessation of irrigation & low cost water treatment).

All participants (N=26) expressed that they always wash vegetables before consumption. In three of the FGDs the reason for washing vegetables is to "clean the dirt or sand" from the vegetables.

Vector control is used by all the participants (N=13) in the consumer FGDs. A female in FGD4 told: "everyone will use some measures to avoid mosquitos and biting from mosquitoes. We use mesh (mosquito nets), bleaching powder, mosquito coils, mosquito mats and mosquito bats."

The hand-washing behaviour among the participants differs. Farmers and consumers (N=19) report to wash hands regularly with soap at home. The TMC told that people tend to wash hands with soap when it is available, however, their workforce sometimes does not wash out of ignorance and in some cases may be due to indifferent attitude.

All the participants told not to visit hospitals often. If they do, it is for severe reasons like having fever. For minor ailments medical shops are preferred. Nevertheless, most participants (N=19) can afford to go to doctors and do it when they do not feel well. The participants in the sanitation worker group (N=6) group stated that they cannot consult doctors owing to affordability (monetary) issues.

Table 10 –Results of the FGDs and KIIs on health protection measures

Health protection measures	**Whom asked?**	**Available/ Used**		**Reason for not using:**	
		Yes	**No**	**Not acceptable**	**Not affordable**
Regular hand washing with soap	FGD1 farmer	Yes			
	FGD2 sanitation worker		No	x	
	FGD3 consumer 1	Yes			
	FGD4 consumer 2	Yes			
	SSP Team	*Yes*			
Visiting doctors/hospitals	FGD1 farmer	Yes			
	FGD2 sanitation worker		No		x
	FGD3 consumer 1	Yes			
	FGD4 consumer2	Yes			
	SSP Team	*Yes*			
Treatment (filtering, boiling) of water prior to consumption	FGD1 farmer		No	x	
	FGD2 sanitation worker		No	x	
	FGD3 consumer 1		No	x	
	FGD4 consumer2		No	x	
	SSP Team	*Yes*			
Safe food preparation	FGD1 farmer	Yes			
	FGD2 sanitation worker	Yes			
	FGD3 consumer 1	Yes			
	FGD4 consumer2	Yes			
	SSP Team	*Yes*			
Vector control	FGD3 consumer 1	Yes			
	FGD4 consumer2	Yes			
	SSP Team	*Yes*			
Fencing/covering open drains	FGD3 consumer 1	Yes			
	FGD4 consumer2		No		x
	SSP Team		*No*	*x*	
Use of PPE (gloves, boots, mask	FGD1 farmer		No	x	
	FGD2 sanitation worker		No		x
	SSP Team		*No*	*x*	
Safe sanitation at workplace	FGD1 farmer		No	x	x
	SSP Team		*No*	*x*	
Produce restriction	FGD1 farmer		No	x	x
	SSP Team		*No*	*x*	*x*
Safe irrigation	FGD1 farmer		No	x	
	SSP Team		*No*		*x*
Cessation of irrigation	FGD1 farmer		No	x	
	SSP Team		*No*	*x*	*x*
Low cost water treatment	FGD1 farmer		No	x	
	SSP Team		*No*		*x*

The SSP team stated that filtering of drinking water is common practice in Devanahalli. Most participants (N=22) in the FGDs reported that they do not boil water for drinking purposes regularly as a practice. The main reasons for not boiling water were: "not used to drink warm water", and "no time to boil water". In two focus groups (FGD2 and FGD3) participants told only to drink boiled water when not feeling well.

The use of gloves and boots is not practiced due to two different reasons. Farmers are not using, as it is not a custom to use rubber boots and gloves when working in their fields: "since ages we are working without boots and gloves. The land is like god for us. We are not comfortable with using boots." (Male, FGD1). While for all farmers (N=6) gloves and boots are not acceptable, sanitary workers told that these measures are not affordable for them. The SSP team, on the contrary, experienced that when gloves and boots are provided, their workforce does not feel comfortable due to sweating and itching while wearing. According to the sanitary workers in FGD2 and also told by the pre-testing group (consisting of sanitary workers) masks are most desired, as participants feel that masks could provide dust from entering to nose and lungs, a problem that all street sweepers face and suffer from: "if we use mask, it can avoid dust. Due to this dust, most street sweepers fall ill and they die early. It [mask] will avoid health problems like cough and other dust allergies." (Female, FGD2).

Farmers are conscious that using toilets instead of open defecation while working, would keep the surrounding near their fields clean. But they clearly told that they couldn't afford to spend money on something they feel is not necessary The TMC stated, that even if they build toilets, most people will not use it, because they feel better to defecate in the open while working since they have done it every since (not acceptable).

Produce restriction was very much doubted by farmers and the SSP team. They reported similar concerns. The choice of products depends on the economic revenues of the produce. One SSP team member phrased it as follows: "in India people are money-minded. Farmers think about financial issues not about health issues. Carrots would be grown in all seasons if that fetched them more money or benefits" (Female, SSP team)

Drip irrigation is practiced less frequently than furrow irrigation in Devanahalli. Farmers told that drip irrigation only works with bore well water because the "water force of the wastewater is not enough" for drip irrigation (not acceptable as not practicable). The SSP was conscious about the water saving properties of drip irrigation but they noted that drip irrigation is costly. The farmers using open drain water are poor farmers, who most often cannot afford bore wells.

Farmers and the SSP team told likewise that cessation of irrigation is only acceptable for some crops. Green leafy vegetables, for example, do not withstand a cessation period of irrigation. The farmers again stated their main interest is growing crops and not health issues: "we put water based on the requirement and we do not bother about health reasons to stop water." (Male, FGD1).

Low cost water treatment is not applied so far in Devanahalli town. Main reasons for not doing so among farmers is firstly denial of health risks related to wastewater and secondly due to financial issues. However, most farmers opined that if available they would like to use treated water for farming practices. In practical terms this may impose financial barriers on municipal authorities.

Overall, the study indicates that the WHO 2006 guidelines' for health protection measures regarding occupational and consumption related risk mitigation would not be easily adopted among farmers and workers. Their low level of risk awareness and the unsuitability of rubber gloves and boots under hot conditions and for farming purposes constrain the adoption of PPE as occupational health protection measure. Similarly, the adoption of pre-harvest intervention measures (i.e. safer irrigation, cessation of irrigation, crop restriction) lacks a financial incentive for farmers to change their current behaviour. As consequence, a close collaboration with farmers will be important to jointly discuss and find mutually acceptable solutions of risk intervention strategies at farm level and to raise awareness concerning wastewater related health risks. On the contrary, post-harvest intervention measures like safe food preparation practices and hand washing with soap were generally well received. However, these behaviours were self-reported. Therefore it is not known whether and how carefully they are practiced. Further structured observations need to be carried out to evaluate hand washing and safe food preparation practices and qualitative methods (e.g. FGDs) should be applied to examine the underlying factors that promote or hinder the adoption of hygiene behaviours. Reflecting the current knowledge in hygiene education research, risk awareness programs on germs and diseases should be combined with simple messages that trigger disgust among the addresses. In addition, environmental analyses are needed to measure contamination levels (e.g. concentration of *E.coli* and helminthic eggs) of wastewater, agricultural soil and crops in order to give substantiated statements on health risks for farmers, sanitary workers and consumers.

3.4 Self-reported health issues by workers of reuse cases

In the frame of the questionnaire survey that was carried out at the level of four existing RRR cases in Bangalore, 36 workers (77.1% women; 54% never went to school) were asked around working conditions and what kind of health complaints they have experiences within the past two weeks. Results are presented in Figure 12 and can be summarized as follows: 82% of the workers work 6 days per week and in average 7.7 hours per day. Their mean age was 40 year and 54% received specific training for the job.

More than 2 in 3 workers (>60%) reported to have experienced some form of musculoskeletal pain (back, joint, and/or muscle pain) in the two weeks preceding the survey. Musculoskeletal conditions were followed by headache (66%), acute coughing (39%) and eye irritation (25%). Also injury, skin irritations, fever and abdominal pain were reported by more than 15% of all workers. Diarrhoea, which is often declared as one of the major health outcomes when handling waste, was not reported by any of the respondents.

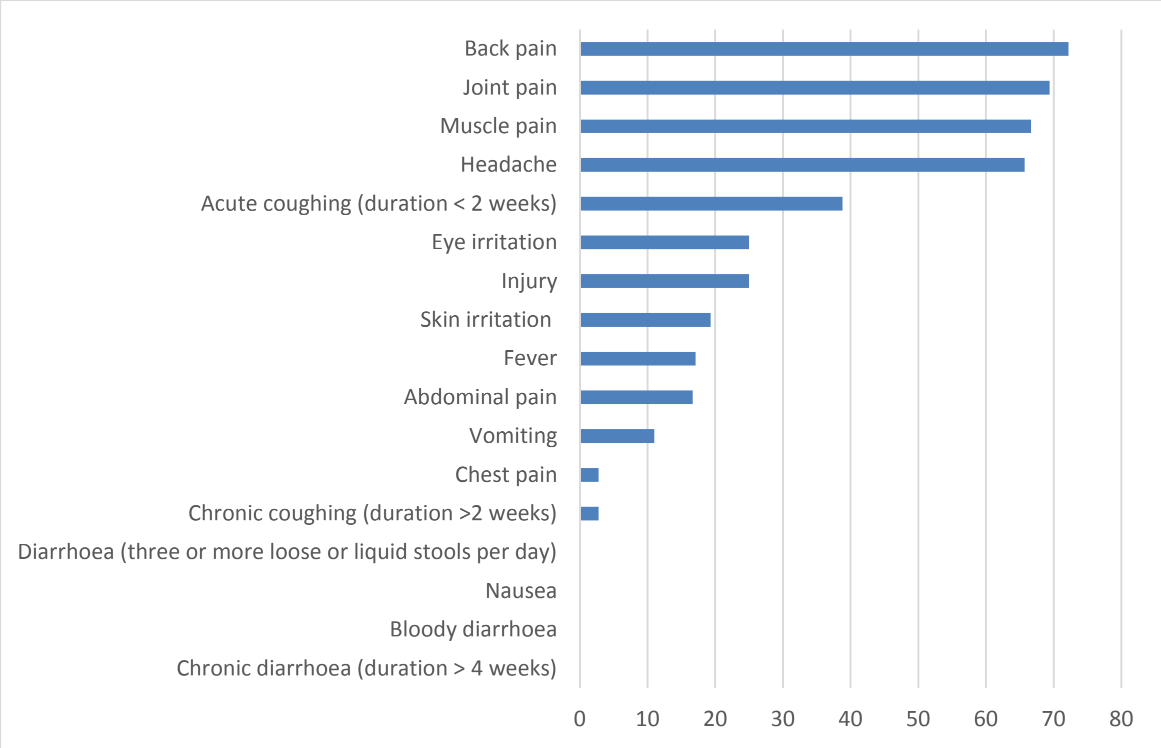

Figure 12 – Health issues reported (%) by workers (N=36) of RRR cases in Bangalore

3.5 Acceptability and use of personal protective equipment

The acceptability and use of a total of 10 different types of PPE to protect head, eyes, ears, airways, whole body, hand, legs and feet were assessed at the level of existing RRR businesses in Kampala area. A total of 36 workers participated in the study.

First, the health risk assessors pre-selected different type of PPE consider as necessary for preventing occupational health hazards at the level of each RRR case according to their expert opinion after a site visit and the key informant interview with the business operators. Overall, face masks, rubber gloves and rubber boots were considered as appropriate for all the workers (100%). This was followed by safety glasses (69.4%), ear plugs (55.6%) and uniforms (50.0%). Noise reduction head set, rain jacket, soft hat and safety boots were only seen as appropriate for 38.9%, 36.1%, 30.6% and 13.9% of all workers, respectively.

Second, whenever a PPE option was considered relevant for the given tasks of a worker, he was asked whether the worker actually uses the PPE. Details of the study on the use, acceptability and willingness to pay of PPE at the level of RRR cases in Kampala area are available in.

Third, workers were asked whether, besides PPE, they see additional measures/controls that could improve their safety during work. While the majority of workers did have any suggestion, the following proposals were made: regular medical check-ups & provide free medical service (n=2); more appropriate working hours, better quality PPE and less physical work load (n=1 each).

Table 11 – Use, acceptability for PPE at RRR cases in Bangalore

Personal protective equipment (PPE) Total worker (n:36)	Head protection	Eyes protection	Ear protection		Airway protection	Whole body protection		Hand protection	Leg and foot protection	
	Soft hat	Safety glasses	Ear plugs	Noise reduction head set	Simple face mask (quarter mask)	Uniform/ overall	Rain jacket	Rubber gloves	Rubber boots	Safety boots
Relevant for RRR case (n)	11	25	20	14	36	18	13	36	36	5
%	*30.6*	*69.4*	*55.6*	*38.9*	*100.0*	*50.0*	*36.1*	*100.0*	*100.0*	*13.9*
Worker wear PPE (n)	**2**	**3**	**0**	**0**	**25**	**17**	**0**	**16**	**11**	**5**
%	**18.2**	**12.0**	**0**	**0**	**69.4**	**94.4**	**0.0**	**44.4**	**30.6**	**100**

4 Health risk and impact assessment

In this chapter, potential health risks and impacts are outlined after a brief introduction of the BM and respective inputs and outputs. For each of the outputs, quality/safety requirements are listed, which can then also be used as operational and verification monitoring indicators during operation. Indian quality standards as defined by the national legislation are listed and reference to the source document is provided. Where no national thresholds exist, quality standards, pathogen reduction rates and threshold values as defined by the WHO 2006 Guidelines on the safe use of wastewater, excreta and graywater are recommended[5]. The full set of national and international quality standards is provided in Annex V.

The HIA provides an analysis on how the proposed BM might impact on community health if implemented at scale. The anticipated scale of the business is indicated for each BM. Based on the assumption that the control measures recommended under the risk assessment are implemented, potential impact pathways are described. Finally, the magnitude of each impact is determined by means of a semi-quantitative risk assessment.

For Bangalore, a total of 10 BMs were selected to be assessed in the frame of the feasibility studies:

- Model 1a: Dry fuel manufacturing: agro-industrial waste to briquettes
- Model 4: Onsite energy generation by sanitation service providers
- Model 6: Manure to power
- Model 8: Beyond cost recovery: the aquaculture example
- Model 9: On cost savings and recover
- Model 10: Informal to formal trajectory in wastewater irrigation: incentivizing safe reuse of untreated wastewater
- Model 11: Intersectoral water exchange
- Model 15: Large-scale composting for revenue generation
- Model 16: Subsidy-free community based composting
- Model 17: High value fertilizer production for profit

4.1 Model 1a – Dry fuel manufacturing: agro-industrial waste to briquettes

Model 1a aims at processing crop residues like wheat stalk, rice husk, maize stalk, groundnut shells, coffee husks, saw dust etc. for converting them into briquettes as fuel. The process of briquetting involves reducing moisture content in the crop residues and compress the biomass at high temperature or/and using a binding agent. To produce charcoal from crop residues by burning them in low-oxygen atmosphere is also an option. The resulting charred material is compressed into briquettes

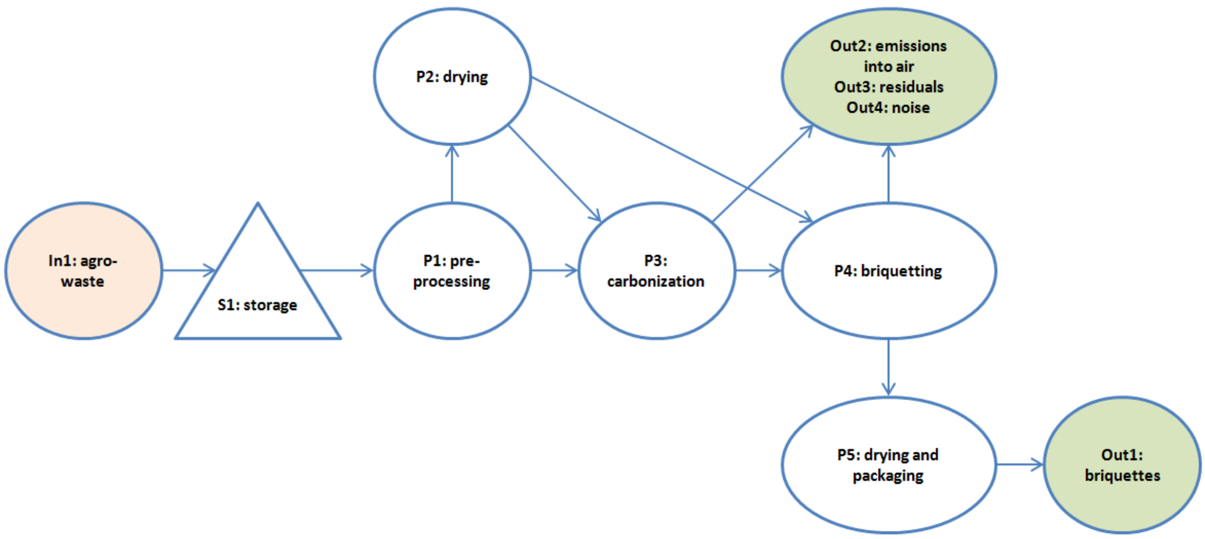

Figure 13 – Model 1: system flow diagram

4.1.1 Health risk assessment

From an occupational health perspective, heat and toxic gas emissions related to the carbonization process are of primary concern. In addition, there is a set of quality requirements linked to the briquettes for warranting safe use at household level. First, it is crucial that the briquettes are free of inorganic components in order to avoid toxic fumes when burning the briquettes. Second, the agro-waste used for briquetting needs to be free of sharp objects for preventing cuts when handling the waste and briquettes. Third, as people are likely to handle the briquettes with their bare hands, hand-to-mouth transmission of pathogens needs to be avoided by reducing pathogen load of the briquettes to a minimum. Finally, it is recommended that moisture content of the briquettes is at low levels to reduce smoke nuisances at household level.

Table 12 – Model 1a: Inputs and associated potential health hazards

Inputs of health relevance	Potential hazards
In1: agro-waste	Faecal contamination (pathogens)
	Contamination with MSW (inorganic; sharp objects)

Table 13 – Model 1a: Quality/safety requirements for outputs

Outputs of health relevance	Quality/safety requirements
Out1: briquettes	Free of inorganic components; free of sharp objects; free of pathogens; moisture content: <10%
Out2: emissions into air	Ambient air quality standards[a]: • $PM_{2.5}$: 10 µ/m^3 24-hour mean; 25 µ/m^3 annual mean • PM_{10}: 20 µ/m^3 24-hour mean; 50 µ/m^3 annual mean • Ozone: 100 µ/m^3 8-hour mean • NO_2: 200 µ/m^3 1-hour mean; 40 µ/m^3 annual mean • SO_2: 500 µ/m^3 10-minutes mean; 20 µ/m^3 24-hour mean Indoor air quality standards[b]:

	• Carbon monoxide (CO): • 15 minutes – 100 mg/m3 • 1 hour – 35 mg/m3 • 8 hours – 10 mg/m3 • 24 hours – 7 mg/m3 • Nitrogen dioxide • 200 µg/m3 – 1 hour average • 40 µg/m3 – annual average
Out3: residuals	None since considered as waste
Out4: noise	Occupational noise exposure limits[c]: • Equivalent level (8h):85 decibel (dB)(A) • Maximum level (short duration): 140 dB(A) Community noise exposure limits[d]: • Day time equivalent level: 55 dB(A) • Night time equivalent level: 45 dB(A)

[a] WHO (2005). Air quality guidelines - global update 2005. Geneva: World Health Organization
[b] WHO (2010). Guidelines for indoor air quality: selected pollutants. Geneva: World Health Organization
[c] WHO (1995). Occupational exposure to noise: evaluation, prevention and control. Geneva: World Health Organization
[d] WHO (1999). Guideline values for community noise in specific environments. Geneva: World Health Organization

4.1.1.1 Indicated control measures

The full risk assessment matrix is available in Appendix I. Indicated control measures are as follows:

- Protective equipment
  - Workers handling any raw material (e.g. agro-waste) need to wear appropriate PPE and use tools (e.g. shovels)
  - Workers that are directly exposed to fumes from the carbonization need to be equipped with gas mask respirators
  - Workers that are exposed to heat need to wear appropriate PPE
  - Workers that are exposed to high levels of noise (e.g. briquetting process; 85 decibel (dB) permanent or 140 dB short duration) need to wear hearing protection
- Processes
  - Any faecally contaminated agro-waste, as well as any inorganic contaminants such as sharp object, needs to be removed from the organic fraction that enters the briquetting process
- Infrastructure
  - Respect a buffer zone between operation and community infrastructure so that ambient air quality and noise exposure standards are not exceeded (see Table 13). The actual distance is depending on the level of emissions
  - In case the carbonization is done in a closed environment, carbon monoxide (CO) monitors need to be installed
- Behavioural aspects and prevention
  - Insect vector- and rodent-control (e.g. screening or use of larvicides, insecticides) at storage sites
  - Educate workers on ergonomic hazards and how to avoid musculoskeletal damage or injury due to inappropriate working practices

- Protect workers from long term exposure to sunlight
- Restrict access to the operations

4.1.1.2 Residual risks

By implementing all the proposed control measures, all the identified health risks of Model 2a can be reduced to **low and moderate levels**. The residual moderate risks are linked to the following processes:

- P3: carbonization: inhalation of toxic gases emitted by the carbonization process at workplace and community level was identified as a moderate risk. To enforce the use of gas mask respirators when being exposed to smoke of the process will be important. When selecting the location of the operation, a buffer zone to communities needs to be considered, taking into account pre-dominant wind directions.

Finally, it is recommended to implement a worker well-being programme that includes regular sessions (e.g. weekly) where general health concerns are reported and health protection measures are promoted (e.g. regular hand washing, purpose of PPE and sun protection, ergonomic hazards, etc.).

4.1.2 Health impact assessment

Under the assumption that the above mitigation measures are implemented, the briquettes should be free of inorganic contaminants, sharp objects and pathogens. Hence, it is a safe product. However, an important health concern that remains is the fugitive emissions from burning the briquettes at household level. Prolonged exposure to CO, sulphur oxides (SO_x), Nitrogen oxides (NO_x), hydrocarbons and particulate matter may cause human health complications [31, 32].

- **Scale of the BM:** the impact assessment of Model 1a is based on the assumption that 1% of the population in Bangalore will use briquettes from the BM as cooking fuel

4.1.2.1 Impact 1: increase in chronic respiratory disease and cancer

For assessing the potential health impact of increased use of briquettes, one has to take into consideration which cooking fuel types are currently used at household level in Bangalore. According to the 2005-06 NFHS, more than 70% of households in urban areas use LPG/natural gas or electricity as cooking fuels in Karnataka state (see Table 14) [12]. Wood is used by 26.6% of urban households and 85.3% of rural areas at 85.3%.

Table 14 – Cooking fuels used in rural and urban areas in Karnataka[12]

Household and housing characteristic	Urban	Rural	Total	De jure population
Cooking fuel				
Electricity	0.4	0.2	0.3	0.3
LPG/natural gas	57.7	7.9	28.1	26.0
Biogas	0.9	1.0	1.0	0.9
Kerosene	13.0	1.5	6.2	5.4
Coal/lignite	0.0	0.1	0.1	0.1
Charcoal	0.1	0.2	0.2	0.3
Wood	26.6	87.8	63.0	66.1
Straw/shrubs/grass	0.0	0.3	0.2	0.2
Agricultural crop waste	0.0	0.7	0.4	0.4
Dung cakes	0.0	0.0	0.0	0.0
Other	1.1	0.1	0.5	0.2
Missing	0.2	0.1	0.1	0.1

Literature on emission factors of different cooking fuel types is diverse [32-35]. Charcoal, wood, crop residuals and dung are similar in terms of emissions; they all emit a lot of toxic gases and particulate matter, and thus are important causes of chronic respiratory disease and lung cancer in low- and middle-income countries where non improved biomass stoves are used [31]. In terms of potential adverse effects on health, natural gas, kerosene or electricity are clearly better than biomass fuels.

In conclusion, biomass fuels pose many health hazards unless they are used with an improved biomass stove. The replacement of charcoal or wood with briquettes is, however, unlikely to result in a considerable increased or reduction in exposure to toxic gases and particulate matter. If the briquettes are replacing other cooking fuels such as natural gas, kerosene or electricity, an increase in hazardous emissions would result. Hence, in urban areas, where more than 70% of the population is using other cooking fuel types than biomass, the marketing of briquettes could result in a negative health impact.

Of note, to promote or even market improved biomass stoves together with the briquettes might be an interesting addition to the BM that should be further explored.

Since the replacement of wood or charcoal does not make a considerable difference in terms of emissions, the health impact assessment for Model 1a only considers the potential negative impact of people replacing more safe cooking fuels (i.e. kerosene, gas or electricity) with briquettes.

Model 1a, impact 1, assumptions:

- **Impact level:** long term exposure to indoor air pollution may increase the incidence of ARI and result chronic diseases such as COPD and lung cancer
- **People affected:** the briquetting business would be of interest to 1% of the ~7 million population in urban Bangalore; 70% of the urban population is using kerosene, gas or electricity; and only 10% of those would actually switch to briquettes (7.0 million living in urban environment in Bangalore x 0.01 x 0.7 x 0.1 = 4,900 people)
- **Likelihood:** 1 in 10 people being exposed to biomass fuel fumes would develop some form of chronic respiratory diseases or cancer

Table 15 – Model 1a, impact 1: increase in chronic respiratory disease and cancer

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Major negative impact	Medium population group	Unlikely	**Moderate negative impact**
Score	-1	4,900	0.1	**-490**

Proposed mitigation measures for reducing the potential negative impact are:

- to market briquettes only in rural areas that are predominantly using wood as cooking fuel;
- to educate consumers of biomass briquettes about the health risks associated with indoor smoke (e.g. hazard labels on briquette packaging);
- to promote the use of chimney and improvised stove construction at the household levels to prevent indoor air pollution as is being done in parts of India (smokeless 'chulha'); and
- to actively promote improved biomass stoves among buyers of biomass briquettes.

4.1.3 Environmental Impact Assessment

Potential negative environmental impacts include: (1) hazardous air emissions, such as volatile organic compounds, carbon monoxide, polycyclic aromatic hydrocarbons, methane and nitrous oxide, which are created during the carbonization process and/or during use of briquettes, (2) accumulated waste resulting from separation of inorganic fractions from MSW prior to briquetting are disposed of or used improperly, and (3) process water, which accumulates during the carbonization process and during the compaction of uncarbonised input material, and when leaching into the environment can have a negative impact. Mitigation measures to avoid negative impacts include: (1.a) air emission control technologies, such as activated carbon and scrubbers, (1.b) proximate and ultimate analyses, prior to business model implementation for the characterization of the feedstock and the final briquettes, (2) storage, transport and disposal at a designated recycling facility or solid waste discharge site (sanitary landfill), and (3) post treatment of process water, which should be monitored for its physical and chemical properties to comply with local regulations prior to discharge into the environment. Further details on technology options are outlined in the "Technology Assessment Report" [2].

Table 16 – Model 1a: potential environmental hazards and proposed mitigation measures

Waste stream	**End-product**	**Technologies**	**Process**	**Pot. Env. Hazard**	**Mitigation measures**
• MSW • AIW	• Briquettes	• Carbonized - low pressure • Raw - mechanized high pressure • Carbonized - mechanized	• Briquetting	• Hazardous air emissions • Accumulated inorganic waste • Process water	• Air emission control technologies (e.g. activated carbon, scrubbers) • Proximate and ultimate analyses • Post-treatment of process water

4.2 Model 4 – Onsite energy generation by sanitation service providers

The primary goal of BM 4 is to provide sanitation service to underserved communities who lack access to toilets. In addition, the business transforms black and brown water into electricity and soil conditioner to be sold to communities. The quality of the soil conditioner, and resulting end-use options, depend on the setup of the post-treatment of the sludge (digestate) and liquid effluent of the anaerobic digestion process. Since the post-treatment is not clearly defined as per the business model, the risk assessment is limited to the description of the efficiency of different post-treatment options but does not define which combination has to be selected. For the impact assessment it is assumed that the sludge and effluent of the anaerobic digestion are disposed of safely, i.e. appropriate disposal in case of no onsite post-treatment or treated effluent and soil conditioner that are compliant with quality/safety requirements as per the given scenario.

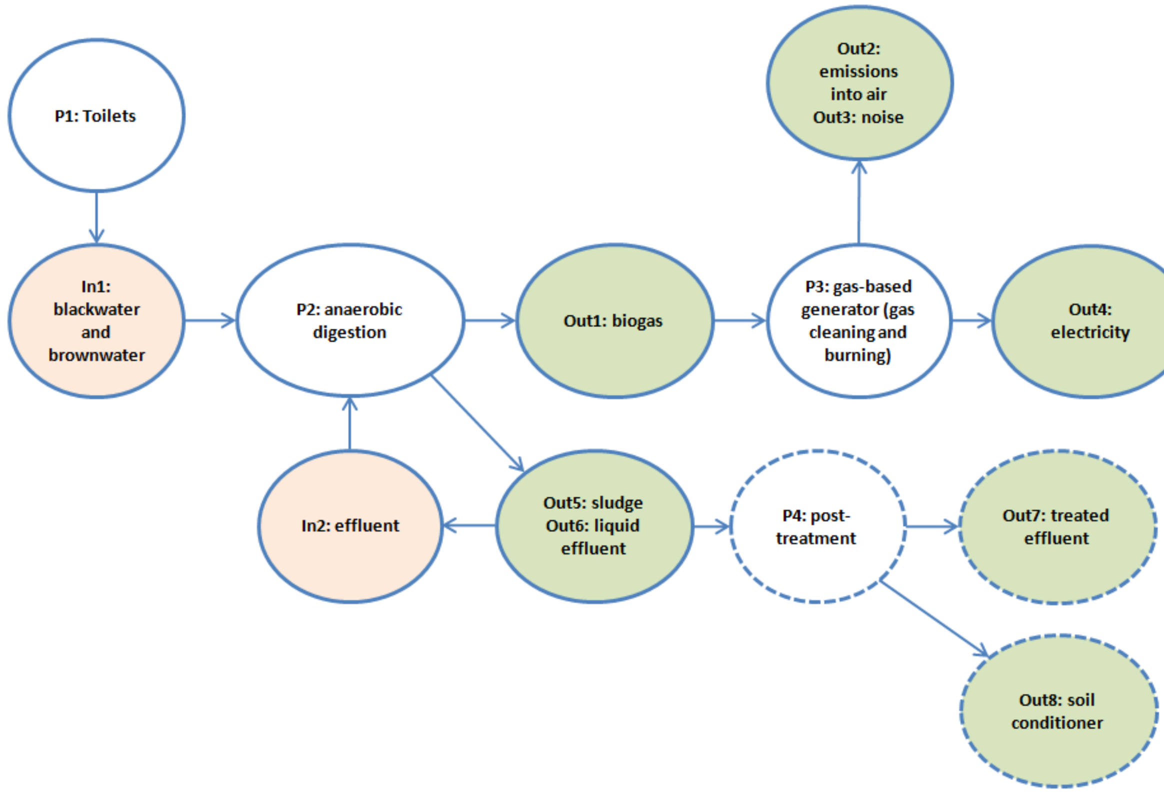

Figure 14 – Model 4: system flow diagram

Table 17 – Model 4: Inputs and associated potential health hazards

Inputs of health relevance	Potential hazards
In1: black water and brown water	Pathogens
	Contamination with sharp objects and inorganic waste
In2: effluent	Pathogens

Table 18 – Model 4: Quality/safety requirements for outputs

Outputs of health relevance	Quality/safety requirements
Out1: biogas	N.a. (within the system)
Out2: emissions into air	Ambient air quality standards[a]: • $PM_{2.5}$: 10 μ/m^3 24-hour mean; 25 μ/m^3 annual mean • PM_{10}: 20 μ/m^3 24-hour mean; 50 μ/m^3 annual mean • Ozone: 100 μ/m^3 8-hour mean • NO_2: 200 μ/m^3 1-hour mean; 40 μ/m^3 annual mean • SO_2: 500 μ/m^3 10-minutes mean; 20 μ/m^3 24-hour mean
Out3: noise	Occupational noise exposure limits[b]: • Equivalent level (8h):85 dB(A) • Maximum level (short duration): 140 dB(A) Community noise exposure limits[c]: • Day time equivalent level: 55 dB(A) • Night time equivalent level: 45 dB(A)
Out4: electricity	Intrinsically safe electrical installations and proper grounding
Out5: sludge	Considered as waste or within the system (in the case of post-treatment)
Out6: effluent	Considered as waste or within the system (in the case of post-treatment)
Out7: treated effluent (optional)	**Unrestricted irrigation** Root crops: • <10^3 *E. coli* per litre and <1 helminthic egg per litre Leave crops: • <10^4 *E. coli* per litre and <1 helminthic egg per litre Drip irrigation of high-growing crops: • <10^5 *E. coli* per litre and <1 helminthic egg per litre Drip irrigation of low-growing crops: • <10^3 *E. coli* per litre and <1 helminthic egg per litre **Restricted irrigation** Labour intensive agriculture: • <10^4 *E. coli* per litre and <1 helminthic egg per litre Highly mechanized agriculture: • <10^5 *E. coli* per litre and <1 helminthic egg per litre ➔ Chemical indicators in treated wastewater and receiving soils must not exceed thresholds as per WHO Guidelines (see Annex V)
Out8: soil conditioner (optional)	For agricultural use: • <1 helminthic egg per 1 gram total solids; and <10^3 *E. coli* per gram total solids ➔ Indian quality standards for organic fertilizer are available in Annex V

[a] WHO (2005). Air quality guidelines - global update 2005. Geneva: World Health Organization
[b] WHO (1995). Occupational exposure to noise: evaluation, prevention and control. Geneva: World Health Organization
[c] WHO (1999). Guideline values for community noise in specific environments. Geneva: World Health Organization

4.2.1 *Health risk assessment*

Black and brown water pose two main health hazards: pathogens and sharp objects such as razor blades. The faecal pathogens will not be fully eliminated during anaerobic digestion (mesophilic digestion at >35°C for >9 days only results in 1 log reduction in *E. coli* and 0 log reduction in helminthic eggs). Therefore, appropriate discharge or post-treatment of the sludge (digestate) and effluent from anaerobic digestion is required. Sharp objects that will be placed in the brown water may end up in the soil conditioner and are thus a health hazard that needs to be controlled. The operation of a gas-based generator is associated with heat, emissions into the air, noise and toxic burning-residuals. These need to be managed at the level of the plant and an appropriate buffer zone to community houses needs to be established. In order to avoid electric shock of workers or users, intrinsically safe electrical installations, non-sparking tools and proper grounding need to be assured. There is risk for injury to the body when operating the gas-based generator. Hence, safety infrastructure, PPE and education of workers are crucial. Finally, a fire fire/explosion response plan needs to be developed and implemented

4.2.1.1 Indicated control measures

The full risk assessment matrix is available in Appendix I. Indicated control measures are as follows:

- Protective equipment
    - Workers handling any raw material (e.g. agro-waste or animal manure) need to wear PPE and use tools (e.g. shovels)
    - Workers that are directly exposed to exhausts of the gas-based generator need to be equipped with gas mask respirators
    - Workers that are exposed to heat need to wear appropriate PPE
    - Workers that are exposed to high levels of noise (e.g. operating the generator; 85 dB permanent or 140 dB short duration) need to wear hearing protection
- Processes
    - Mesophilic anaerobic digestion is recommended at >35°C for >9 days (1 log reduction *E. coli* and 0 log reduction in helminthic eggs)
- Infrastructure
    - Place clearly visible signs on toilets that prohibit disposal of any sharp object and inorganic waste into the toilet
    - Provide trash bins for disposal of sharp objects and inorganic waste components in each toilet
    - Install facilities where the dried anaerobic sludge or soil conditioner can be sieved carefully for removing any sharp objects
    - Install heat shields on hot parts that may be touched by individuals
    - In case the gas-based generator is located in a closed environment: install CO monitors and ensure that exhausts are released to the outside
    - Respect a buffer zone between operation and community infrastructure so that ambient air quality and noise exposure standards are not exceeded. The actual distance is depending on the level of emissions
    - At the electricity outlet of the gas-based generator, use intrinsically safe electrical installations, non-sparking tools and proper grounding
    - Prevent gas-leakage at the anaerobic digestion plant and install CO monitors in case the anaerobic digestion takes place in a closed environment
    - Depending on the further use of the outputs of the post-treatment, the following post-treatment options are proposed:

      <u>Off-site (i.e. discharge):</u>

      - Drain/transfer effluent to the influent of existing and existing wastewater treatment plant if within load capacity, co-manage sludge/solids handling with existing wastewater of faecal sludge treatment plant

<u>On-site (in case of agricultural reuse of the outputs, a combination of the following options will be required for achieving the required quality standard (see table with quality/safety requirements for outputs)):</u>

- Septic tank (≥1 log reduction of *E. coli* and ≥2 log reduction in helminthic eggs)
- Anaerobic baffled reactor (≥1 log reduction of *E. coli* and ≥2 log reduction in helminthic eggs)
- Anaerobic filter(≥1 log reduction of *E. coli* and ≥2 log reduction in helminthic eggs)
- Constructed/vertical flow wetland (≥0.5-3 log reduction of *E. coli* and ≥1-3 log reduction in helminthic eggs)
- Planted gravel Filter
- Unplanted gravel Filter
- Planted/unplanted drying beds (1-3 log reduction in helminthic eggs)

- Behavioural aspects and prevention
  - Develop and implement a fire/explosion response plan (e.g. installation of fire detection/suppression equipment; anti-back firing systems; separate fuel storage; escape routes; and purging system with nitrogen)
  - Place clearly visible danger signs on the packaging, indicating the risk of sharp objects and that users need to wear gloves and boots when applying the product
  - Insect vector- and rodent-control (e.g. screening or use of larvicides, insecticides) at storage sites
  - Educate workers on ergonomic hazards and how to avoid musculoskeletal damage or injury due to inappropriate working practices
  - Restrict access to the anaerobic digestion plant and the generator
  - Implement a worker well-being programme that includes regular sessions (e.g. weekly) where general health concerns are reported and health protection measures are promoted (e.g. regular hand washing, purpose of PPE, ergonomic hazards, etc.)

4.2.1.2 Residual risks

By implementing all the proposed control measures, all the identified health risks of Model 4 can be reduced to **<u>low, moderate and high levels</u>**. The residual moderate risks are linked to the following processes:

- P1: toilet and P4: post-treatment: sharps ending up in the soil conditioner pose a moderate risk to users. Therefore it is crucial to sensitize users of the toilets to the issue and rigorously implement different control measures for preventing (e.g. trash bins) or removing (i.e. sieving) any sharp objects in the solid fraction of the anaerobic sludge
- P3: gas-based generator: exposure to toxic gas and noise emissions are of concern for both workers and the community. However, these risks can be controlled with

appropriate equipment, a good design of the operation and by respecting a buffer zone between the plant and community infrastructure. Also fire and explosion are major risks related to the generator. This issue must primarily be taken into account by the engineering of the plant. At the operational level a fire/explosion response plan needs to be developed and implemented

- Electric shock and fire/explosion are high risks that need to be managed accordingly

4.2.2 Health impact assessment

The provision of sanitation services to underserved communities is likely to reduce incidence of diarrhoeal diseases, ARI and helminthic infections. In addition, the provision of electricity can impact socio-economic status and wellbeing, both of which have a strong link to community health.

- **Scale of the BM:** the impact assessment of Model 4 is based on the assumption that 30 villages in rural and peri-urban areas of Bangalore will implement the BM

4.2.2.1 Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases

The 2005-06NFHS reported that in rural areas of Karnataka 4 in 5 households (82.5%) use non-improved sanitation facilities, with the large majority (78%) practicing open space/field defecation (see Table 7) [12]. In urban areas the situation is different: according to the waste supply analysis, 72.2% of the households are connected to the sewerage system and only 21% use on-site sanitation systems [3].

Unsafe sanitation practices are closely associated with diarrhoeal diseases and helminthic infections, as well as acute respiratory infections. In a recent meta-analysis by Ziegelbauer and colleagues (2012), it was found that the availability of sanitation facilities was associated with a 50% protection against infection with STH [36]. Also the link between safe sanitation systems and reduction in diarrhoeal diseases is well established [37]. Hence, the business has considerable potential to reduce the burden of diarrhoeal diseases and infection with STH in communities with poor access to safe sanitation services, i.e. in rural communities of Bangalore. In order to maximize potential health benefits, it is recommended to keep the fee for the usage of the toilets at a minimum and/or not charging a fee to children.

Impact 1, assumptions:

- **Impact level:** pathogens in human faeces generally cause disease of short duration and/or minor disability
- **People affected:** the business would be rolled out to 30 villages (average size ~300 people) where 4 in 5 households do not have access to safe sanitation (30x300x0.80=7,200 people)
- **Likelihood:** it is likely (odds: 61-95%) that the business positively impacts on diarrhoeal diseases and helminthic infections

Table 19 – Model 4, impact 1: reduction in respiratory, diarrhoeal and intestinal diseases

	Impact level (IL)	People affected (PA)	Likelihood or frequency (LoF)	Magnitude (ILxPAxL)
Category	Minor positive impact	Medium population group	Likely	**Moderate positive impact**
Score	0.1	7,200	0.9	**432**

For maximizing the health benefits of the business, it is recommended:

- to keep the fee for the usage of the toilets at a minimum;
- to provide free access to the toilet facilities to children;
- to target communities with particularly low access to sanitation for the implementation of the business; and
- to promote hand washing practice at the exit of the facility.

4.2.2.2 Impact 2: access to electricity

The impact of electricity on the health status of receiving populations is marginal and the direction of health impact (i.e. positive or negative) is not obvious. For example, an improved socio-economic status often impacts positively on access to health care but is also negatively associated with life style related diseases such as obesity and diabetes. Where access to electricity can make a real difference, is at the level of rural health facilities, particularly during the night. However, this would require the provision of batteries that can store the electricity for the night when it is needed. Since this is not part of the BM, the potential health impact of supplying electricity to local health facilities is not taken into account. In addition, many of the rural health facilities in India do have power supply.

Impact 2, assumptions:

- **Impact level:** minor positive and negative health impacts anticipated. Therefore, the impact level is insignificant
- **People affected:**30 villages with an average of 300 individuals profit from the BM
- **Likelihood:** It is possible that access to electricity impacts on the health of people

Table 20 – Model 4, impact 2: changes in health status due to access to electricity

	Impact level (IL)	People affected (PA)	Likelihood or frequency (LoF)	Magnitude (ILxPAxL)
Category	Insignificant	Large population	Definite	**Insignificant**
Score	0.0	9,000	1	**0**

4.2.3 Environmental Impact Assessment

Potential negative environmental impacts include: (1) air emissions from the anaerobic digester if not controlled properly or in case of failure, (2) solid residue from the anaerobic digestion process (digestate), which when disposed of or used improperly can have a negative impact due to high nutrient and organic matter concentrations and (3) liquid effluent from the anaerobic digestion process which when disposed of or used improperly can have a negative impact due to high nutrient and organic matter concentrations. Mitigation measures to avoid negative impacts include: (1) regular maintenance of the anaerobic digester to prevent leakages, and (2) and (3) solid and liquid residue post-treatment of the solid residue (digestate) and liquid effluent from the anaerobic digestion process. The goal of RRR based businesses should be full resource recovery of all End-products, which implies end-use of dewatered and appropriately treated sludge (digestate) and liquid effluent from post-treatment. If for some reason this is not feasible, only then should disposal of solids at sanitary landfills be considered. Further details on technology options are outlined in the "Technology Assessment Report" [2].

Table 21 – Model 4: potential environmental hazards and proposed mitigation measures

Waste stream	End-product	Technologies	Process	Pot. Env. Hazard	Mitigation measures
• Feces • Urine • FS	• Biogas -> Cooking fuel	• Single stage • Multi-stage • Batch	• Anaerobic digestion	• Air emissions • Solid residue (digestate) • Liquid effluent	• Maintenance of anaerobic digester • Solid/liquid residue post-treatment

4.3 Model 6 – Manure to power

The business model aims at transforming manure to power for carbon credit and sustainable value chain or rural electrification. The model can be initiated either by (i) livestock processing factories such as meat or diary processing factories; (ii) small, medium and commercial-sized livestock farms to utilize livestock waste to produce off-grid power for rural electrification; or (iii) individual livestock farms to achieve a self-sustaining system. The quality of the soil conditioner, and resulting reuse options, depend on the setup of the post-treatment of the sludge and effluent of the anaerobic digestion. Since the post-treatment is not clearly defined as per the business model, the risk assessment is limited to the description of the efficiency of different post-treatment options but does not define which combination has to be selected. For the impact assessment it is assumed that the sludge and effluent of the anaerobic digestion are disposed of safely, i.e. appropriate disposal in case of no onsite post-treatment or treated effluent and soil conditioner that are compliant with quality/safety requirements as per the given scenario and context.

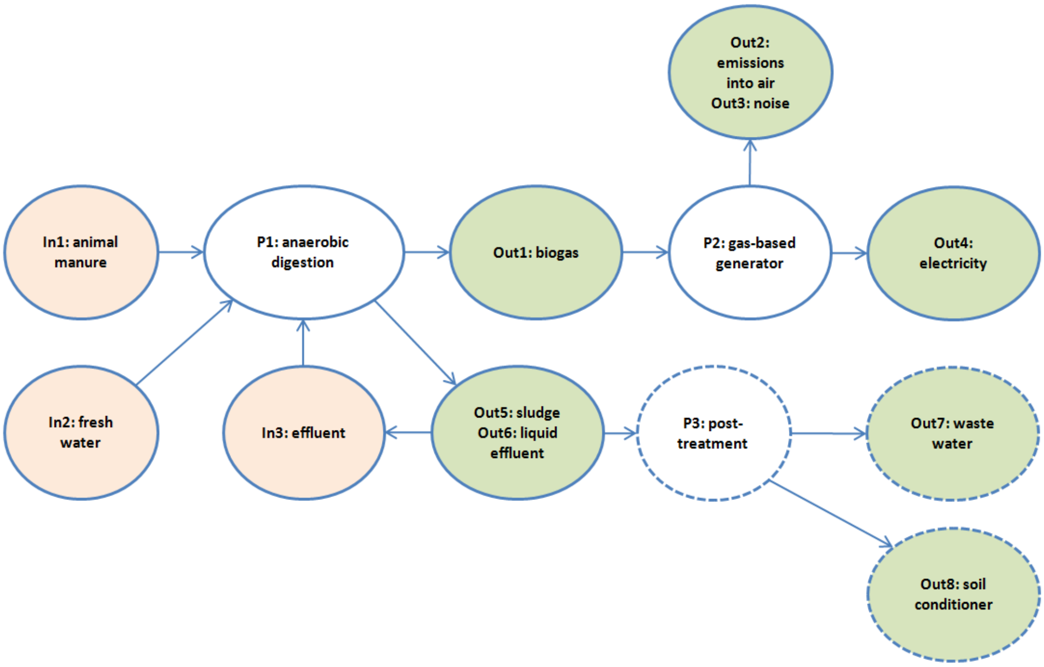

Figure 15 – Model 6: system flow diagram

Table 22 – Model 6: Inputs and associated potential health hazards

Inputs of health relevance	Potential hazards
In1: animal manure	Pathogens
	Contamination with MSW (inorganic; sharp objects)
In2: fresh water	None
In3: effluent	Pathogens

Table 23 – Model 6: Quality/safety requirements for outputs

Outputs of health relevance	Quality/safety requirements
Out1: biogas	N.a. (within the system)
Out2: emissions into air	Ambient air quality standards[a]: • $PM_{2.5}$: 10 µ/m^3 24-hour mean; 25 µ/m^3 annual mean • PM_{10}: 20 µ/m^3 24-hour mean; 50 µ/m^3 annual mean • Ozone: 100 µ/m^3 8-hour mean • NO_2: 200 µ/m^3 1-hour mean; 40 µ/m^3 annual mean • SO_2: 500 µ/m^3 10-minutes mean; 20 µ/m^3 24-hour mean
Out3: noise	Occupational noise exposure limits[b]: • Equivalent level (8h):85 dB(A) • Maximum level (short duration): 140 dB(A) Community noise exposure limits[c]: • Day time equivalent level: 55 dB(A) • Night time equivalent level: 45 dB(A)
Out4: electricity	Intrinsically safe electrical installations and proper grounding
Out5: liquid effluent	N.a. (within the system)
Out6: sludge	N.a. (within the system)
Out7: soil conditioner	For agricultural use: • <1 helminthic egg per 1 gram total solids; and <10^3 E. coli per gram total solids

	➔ Indian quality standards for organic fertilizer are available in Annex V
Out8: treated effluent	**Unrestricted irrigation** <u>Root crops:</u> • <10^3 E. coli per litre and <1 helminthic egg per litre <u>Leave crops:</u> • <10^4 E. coli per litre and <1 helminthic egg per litre <u>Drip irrigation of high-growing crops:</u> • <10^5 E. coli per litre and <1 helminthic egg per litre <u>Drip irrigation of low-growing crops:</u> • <10^3 E. coli per litre and <1 helminthic egg per litre **Restricted irrigation** <u>Labour intensive agriculture:</u> • <10^4 E. coli per litre and <1 helminthic egg per litre <u>Highly mechanized agriculture:</u> • <10^5 E. coli per litre and <1 helminthic egg per litre ➔ Chemical indicators in treated wastewater and receiving soils must not exceed thresholds as per WHO Guidelines (see Annex V)

[a] WHO (2005). Air quality guidelines - global update 2005. Geneva: World Health Organization

[b] WHO (1995). Occupational exposure to noise: evaluation, prevention and control. Geneva: World Health Organization

[c] WHO (1999). Guideline values for community noise in specific environments. Geneva: World Health Organization

Pathogens contained in the animal manure are the primary health hazard associated with BM 6. The faecal pathogens will not be fully eliminated during anaerobic digestion (mesophilic digestion at >35°C for >9 days only results in 1 log reduction in *E. coli* and 0 log reduction in helminthic eggs). Therefore, appropriate discharge or post-treatment of the sludge (digestate) and effluent from anaerobic digestion is required.

The operation of a gas-based generator is associated with heat, emissions into the air, noise and toxic burning-residuals. These need to be managed at the level of the plant and an appropriate buffer zone to community houses needs to be established. In order to avoid electric shock of workers or users, intrinsically safe electrical installations, non-sparking tools and proper grounding need to be assured. There is risk for injury to the body when operating the gas-based generator. Hence, safety infrastructure, PPE and education of workers are crucial. Finally, a fire fire/explosion response plan needs to be developed and implemented.

4.3.1.1 Indicated control measures

The full risk assessment matrix is available in Appendix I. Indicated control measures are as follows:

- Protective equipment
  - Workers handling any raw material (i.e. animal manure) need to wear PPE and use tools (e.g. shovels)
  - Workers that are directly exposed to exhausts of the gas-based generator need to be equipped with gas mask respirators
  - Workers that are exposed to heat need to wear appropriate PPE

- Workers that are exposed to high levels of noise (e.g. operating the generator; 85 dB permanent or 140 dB short duration) need to wear hearing protection
- Processes
  - Mesophilic anaerobic digestion is recommended at >35°C for >9 days (1 log reduction *E. coli* and 0 log reduction in helminthic eggs)
- Infrastructure
  - Install heat shields on hot parts that may be touched by individuals
  - In case the gas-based generator is located in a closed environment: install CO monitors and ensure that exhausts are released to the outside
  - Respect a buffer zone between operation and community infrastructure so that ambient air quality and noise exposure standards are not exceeded. The actual distance is depending on the level of emissions
  - At the electricity outlet of the gas-based generator, use intrinsically safe electrical installations, non-sparking tools and proper grounding
  - Prevent gas-leakage at the anaerobic digestion plant and install CO monitors in case the anaerobic digestion takes place in a closed environment
  - Depending on the further use of the outputs of the post-treatment, off-site and on-site post-treatment options are available (see section 4.2.1.1)
- Behavioural aspects and prevention
  - Develop and implement a fire/explosion response plan (e.g. installation of fire detection/suppression equipment; anti-back firing systems; separate fuel storage; escape routes; and purging system with nitrogen)
  - Place clearly visible danger signs on the packaging of the soil conditioner, indicating that users need to wear gloves and boots when applying the product
  - Insect vector- and rodent-control (e.g. screening or use of larvicides, insecticides) at storage sites
  - Educate workers on ergonomic hazards and how to avoid musculoskeletal damage or injury due to inappropriate working practices
  - Restrict access to the anaerobic digestion plant and the generator
  - Implement a worker well-being programme that includes regular sessions (e.g. weekly) where general health concerns are reported and health protection measures are promoted (e.g. regular hand washing, purpose of PPE, ergonomic hazards, etc.)

4.3.1.2 Residual risks

By implementing all the proposed control measures, all the identified health risks of Model 6 can be reduced to **low, moderate and high levels**. The residual moderate risks are linked to the following processes:

- P2: gas-based generator: exposure to toxic gas and noise emissions are of concern for both workers and the community. However, these risks can be controlled with appropriate equipment, a good design of the operation and by respecting a buffer zone between the plant and community infrastructure. Also fire and explosion are major risks related to the generator. This issue must primarily be taken into account by the engineering of the plant. At the operational level a fire/explosion response plan needs to be developed and implemented

- Electric shock and fire/explosion are high risks that need to be managed accordingly

4.3.2 Health impact assessment

The production of power by using animal manure has an impact on community health in two ways. First, it has the potential to reduce exposure of community members to pathogens deriving from animal manure, and thus lower the incidence of respiratory, diarrhoeal and intestinal diseases. Second, the provision of electricity can impact socio-economic status and wellbeing, both of which have a strong link to community health.

- **Scale of the BM:** the impact assessment of Model 6 is based on the assumption that 10 villages in rural and peri-urban areas of Bangalore will implement the BM

4.3.2.1 Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases

In rural and peri-urban communities of Bangalore, where the BM would most likely be operating due to the availability of industrial livestock farms, it is likely that animal manure is usually discharged into the environment. Consequently, there is a risk that pathogens from animal manure end-up in surface waters, particularly at the start of the rainy season. As a result, unsafe disposal of animal manure into the environment is likely to contribute to the incidence of respiratory and diarrhoeal diseases, as well as helminthic infections. Hence, the recycling of animal manure has the potential to reduce the incidence of those diseases.

Impact 1, assumptions:

- **Impact level:** pathogens in human faeces generally cause disease of short duration and/or minor disability
- **People affected:** the business would be rolled out to 10 villages (average size ~300 people) where 1 in 10 people is exposed to pathogens deriving from animal manure in surface waters (10x300x0.1=300 people)
- **Likelihood:** it is likely (odds: 61-95%) that the business reduces the incidence of diarrhoeal diseases and helminthic infections

Table 24 – Model 6, impact 1: reduction in respiratory, diarrhoeal and intestinal diseases

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Minor positive impact	Small population group	Likely	**Moderate positive impact**
Score	0.1	300	0.9	**27**

4.3.2.2 Impact 2: access to electricity

➔ For the impact definition, see Model 4, impact 2 (section4.2.2.2).

Impact 2, assumptions:

- **Impact level:** minor positive and negative health impacts anticipated. Therefore, the impact level is insignificant
- **People affected:**10 villages with an average of 300 individuals profits from the BM
- **Likelihood:** It is possible that access to electricity impacts on the health of people

Table 25 – Model 6, impact 2: changes in health status due to access to electricity

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Insignificant	Large population	Definite	**Insignificant**
Score	0.0	3,000	1	**0**

4.3.3 Environmental Impact Assessment

Potential negative environmental impacts include: (1) air emissions from the anaerobic digester if not controlled properly or in case of failure, (2) hazardous air emissions, such as volatile organic compounds, carbon monoxide, polycyclic aromatic hydrocarbons, methane and nitrous oxide, which the conversion of biogas into electricity, (3) solid residue from the anaerobic digestion process (digestate) which when disposed of or used improperly can have a negative impact due to high nutrient and organic matter concentrations, and (4) liquid effluent from the anaerobic digestion process, which when disposed of or used improperly can have a negative impact due to high nutrient and organic matter concentrations. Proposed mitigation measures include: (1) regular maintenance of the anaerobic digester to prevent leakages, (2) air emission control technologies, such as activated carbon and scrubbers during the process of converting biogas into electricity, and (3) solid and liquid residue post-treatment of the solid residue (digestate) and liquid effluent from the anaerobic digestion process. The goal of RRR based businesses should be full resource recovery of all End-products, which implies end-use of dewatered sludge (digestate) and liquid effluent from post-treatment. If for some reason this is not feasible, only then should disposal of solids at sanitary landfills be considered. Further details on technology options are outlined in the "Technology Assessment Report" [2].

Table 26 – Model 6: potential environmental hazards and proposed mitigation measures

Waste stream	**End-product**	**Technologies**	**Process**	**Pot. Env. Hazard**	**Mitigation measures**
• AM	• Biogas -> Electricity	• Single stage • Multi-stage • Batch • Biogas conversion technologies	• Anaerobic digestion • Biogas to electricity conversion	• Hazardous air emissions • Solid residue (digestate) • Liquid effluent	• Maintenance of anaerobic digester • Air emission control technologies • Solid/liquid residue post-treatment

4.4 Model 8 – Beyond cost recovery: the aquaculture example

Model 8 employs a wastewater-duckweed-fish rearing system on a small to medium scale. The products are: (i) treated wastewater; (ii) fish; and (iii) co-crops for consumption. The business has the potential to reduce environmental contamination and improve irrigation water quality.

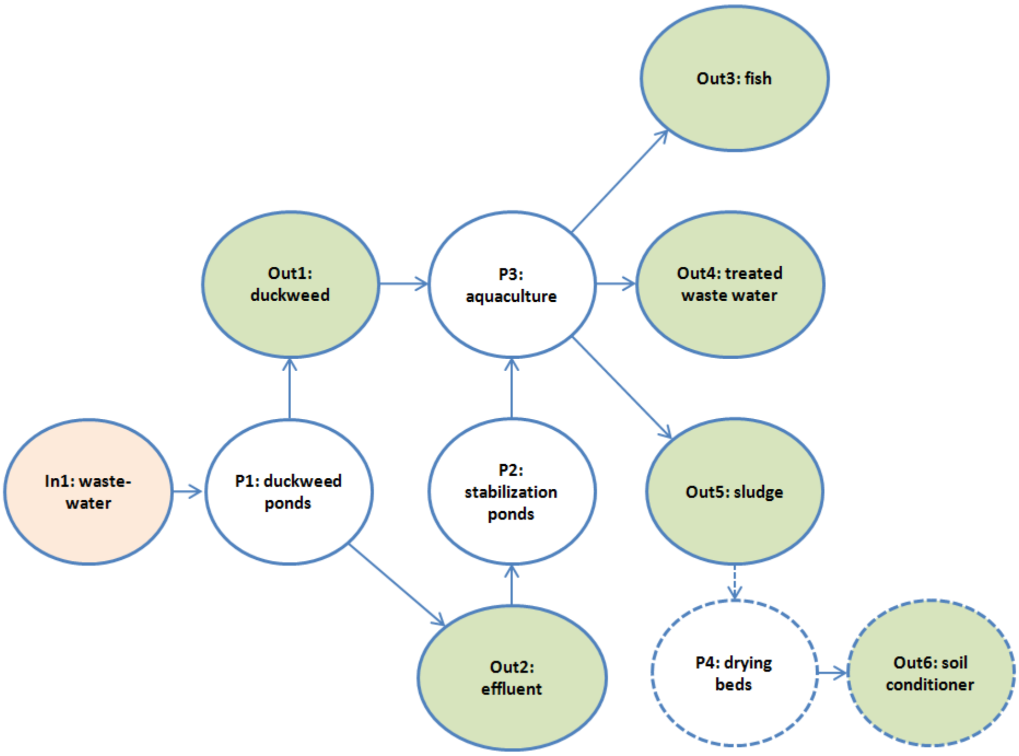

Figure 16 – Model 8: system flow diagram

Table 27 – Model 8: Inputs and associated potential health hazards

Inputs of health relevance	Potential hazards
In1: wastewater	Viruses, bacteria
	Protozoa
	Soil-transmitted helminthics
	Trematodes
	Skin irritants
	Disease vectors
	Chemicals others than heavy metals
	Heavy metals

Table 28 – Model 8: Quality/safety requirements for outputs

<table>
<tr><th>Outputs of health relevance</th><th>Quality/safety requirements</th></tr>
<tr><td>Out1: duck week</td><td>N.a. (within system)</td></tr>
<tr><td>Out2: effluent</td><td>N.a. (within system)</td></tr>
<tr><td>Out3: fish</td><td><table><tr><th>Parameter</th><th>Unit</th><th>Limit</th></tr><tr><td>E. coli</td><td>Number per</td><td>Codex alimentarius</td></tr></table></td></tr>
</table>

	gram	commission specifications
Helminthic eggs	Eggs per gram	0
Viable trematode eggs	Eggs per gram	0
Arsenic	mg/kg	Not specified
Cadmium	mg/kg	0.05-1.0
Lead	mg/kg	0.2
Methyl mercury	mg/kg	0.5-1.0
Dioxins	mg/kg	0.000 004
DDT, TDE	mg/kg	5.0
PCBs	mg/kg	2.0

Out4: treated wastewater	**Unrestricted irrigation** Root crops: • <10^3 *E. coli* per litre and ≤1 helminthic egg per litre Leave crops: • <10^4 *E. coli* per litre and ≤1 helminthic egg per litre Drip irrigation of high-growing crops: • <10^5 *E. coli* per litre and ≤1 helminthic egg per litre Drip irrigation of low-growing crops: • <10^3 *E. coli* per litre and ≤1 helminthic egg per litre **Restricted irrigation** Labour intensive agriculture: • <10^4 *E. coli* per litre and ≤1 helminthic egg per litre Highly mechanized agriculture: • <10^5 *E. coli* per litre and ≤1 helminthic egg per litre ➔ The full list of biological and chemical threshold valuesof irrigation water and receiving soils is available in Annex V
Out5: wastewater sludge	N.a. (within system)
Out6: soil conditioner	For agricultural use: • <1 helminthic egg per 1 gram total solids; and <10^3 E. coli per gram total solids ➔ Indian quality standards for organic fertilizer are available in Annex V

4.4.1 Health risk assessment

Risks associated with the business derive from the various potential hazards contained in wastewater such as pathogens and toxic chemicals (i.e. elements such as heavy metals as well as various hazardous organic compounds (see WHO 2006 guidelines; Volume II, Chapter 4.6). Phyto-remediative wastewater treatment has the potential to remove pathogens but its treatment efficiency regarding toxic chemicals is limited.

The data presented in section 3.2.1 (chemical pollution of surface waters) show that pollution with toxic chemicals deriving from industrial and other sources are an important concern of many surface waters of Bangalore. **These findings suggest that, from a health perspective, wastewater fed agriculture in Bangalore needs to be promoted with care , also since the concentration of heavy metals is likely to further increase over time due to accumulation in the soils.**

No recent data was identified on chemical parameter other than heavy metals. For identifying settings suitable for aquaculture in Bangalore, environmental sampling is required. With regard to irrigation with wastewater, the WHO 2006 Guidelines only define maximum tolerable soil concentrations of various toxic chemicals but not concentrations in the wastewater *per se*. Hence, national threshold values for toxic chemicals in wastewater apply.

Where phyto-remediative wastewater treatment and aquaculture seem feasible in terms of the concentration of toxic chemicals in wastewater and receiving soils, a series of stabilization ponds will be needed in order to assure the required pathogen reduction rates: 1. anaerobic stabilisation pond (retention time: 1–3 days); 2. facultative pond (retention time: 4-10 days); and 3. aquaculture (i.e. fish pond, P3). This setup is also important for producing fish that meets quality standards. By having two stabilisation ponds prior to the fish pond, the concentration of pathogen will be reduced.

4.4.1.1 Indicated control measures

The full risk assessment matrix is available in Appendix I. Indicated control measures are as follows:

- Protective equipment
  - Workers handling any raw material (e.g. wastewater, sewage sludge or inorganic contaminants) need to wear appropriate PPE and use tools (e.g. shovels)
- Processes
  - Mechanical screening of the wastewater before entering the duck-week pond
  - In locations where the concentration of toxic chemicals such as metals in wastewater and/or receiving agricultural soils exceed national and international standards (see Annex V), source reduction and/or physico-chemical removal processes (e.g. absorption) need to be applied.
  - Three stabilization ponds are needed: 1. anaerobic stabilisation pond (retention time: 1–3 days); 2. facultative pond (retention time: 4-10 days); and 3. fish pond (retention time: 4-10 days) (i.e. aquaculture, P3). The final retention times depend on ambient temperature and pathogen loads of the wastewater. For calculating the days needed, check WHO 2006 Guidelines, Volume III, Annex 1).
  - Store duckweed for at least 30 days under dry conditions prior to addition to the fish pond
  - Depuration of fish before harvesting by moving fish to a clean pond for at least 2-3 weeks
  - Harvest fish at young age in order to avoid accumulation of toxic chemicals
  - For pathogen removal, the sludge needs to be dewatered and put on drying beds for: (i) 1.5-2 years at 2-20°C; (ii) >1 years at 20-35°C; or (iii) >6 months by means of alkaline treatment at pH>9, >35°C and moisture <25%
  - Sieving of the soil conditioner prior to packaging for discharging any remaining inorganic contamination or sharp objects
- Infrastructure
  - Install handrails and fence dangerous areas for preventing injuries and drowning

- Behavioural aspects and prevention
  - Educate workers on ergonomic hazards and how to avoid musculoskeletal damage or injury due to inappropriate working practices
  - Protect workers from long term exposure to sunlight
  - Farmers using the soil conditioner should be advised to wear boots and gloves when applying the compost
  - Restrict access to the operations
  - Implement a worker well-being programme that includes regular sessions (e.g. weekly) where general health concerns are reported and health protection measures are promoted (e.g. regular hand washing, purpose of PPE and sun protection, ergonomic hazards, etc.)

4.4.1.2 Residual risks

By implementing all the proposed control measures, all the identified health risks of Model 8 can be reduced to **low and moderate levels**. The residual moderate risks are linked to the following processes:

- P1: duckweed ponds: in settings where the concentration of toxic chemicals in wastewater and/or receiving soils exceed national and WHO Guidelines threshold values (see Annex V), the treated wastewater is not suitable for irrigation. Consequently, source reduction and/or physico-chemical removal processes have to be applied. If not, there is a very high risk for adverse health impacts (e.g. chronic disease or even cancer linked to consumption of products that are contaminated with heavy metals and potentially other toxic chemicals) linked to wastewater-fed agriculture in Bangalore.
- P2: stabilisation ponds: the pathogen load of the wastewater needs to be monitored on a regular basis for adapting the retention times in the stabilisation ponds. If monitoring of pathogen loads is not an option, 3 days in the anaerobic pond and 10 days in the facultative pond should be applied
- P3: aquaculture: for reducing contamination of fish with pathogens to a minimum, duck-weed needs to be stored under dry conditions for 30 days prior to addition to the fish pond and the fish needs to be purified in a clean water pond for 2-3 weeks prior to harvesting
- P4: composting: in order to avoid exposure of consumers to pathogens in the soil conditioner, it will be crucial to respect the temperature and duration indicated for the drying of the sludge

4.4.2 Health impact assessment

In settings where the concentration of toxic chemicals of wastewater and agricultural soils are compliant with national and international threshold values, or source reduction and treatment processes are applied as per risk assessment, Model 8 has the potential to positively impact on health linked to the treatment of wastewater. Hence, farmers and consumers may benefit from the business.

- **Scale of the BM:** the impact assessment of Model 8 is assuming that 3 operations serving 500 farmers with safe irrigation water will be implemented. The products irrigated with safe irrigation water and safe fish from the aquaculture will be consumed by 150,000 consumers (i.e. 3x50,000 consumers). In view of the size of the operation, the general downstream population is not considered for the impact assessment since no effect is anticipated

4.4.2.1 Impact 1: reduction in respiratory, diarrhoeal, intestinal and skin diseases

Untreated wastewater negatively impacts on the health of populations, be it through direct contact, ingestion or the consumption of contaminated products. Clearly, diarrhoeal diseases and respiratory infections are important public health issues in Bangalore. Farmers are particularly exposed to risks related to untreated wastewater and besides intestinal and respiratory diseases they also suffer often from skin diseases. Hence, by replacing untreated wastewater with treated wastewater for irrigation is likely to reduce incidence of disease in farmers. One well known source of bacterial, viral and protozoa infection, besides poor hygiene practices, is through the consumption of contaminated food. Thus, the replacement of untreated wastewater with treated wastewater for irrigation can have a considerable impact on diseases incidence of consumers. The same applies for safe fish from the aquaculture. As those consumers might also consume products from other areas and may, in addition, carefully wash the products before consumption, the likelihood of the impact on consumers is set at unlikely.

Impact 1, assumptions:

- **Impact level:** pathogens in untreated wastewater generally cause disease of short duration and/or minor disability
- **People affected:**1,500 farmers (3x500) and 150,000 consumers (3x50,000) would benefit from the business
- **Likelihood:** farmers: likely; and consumers: unlikely

Table 29 – Model 8, impact 1: reduction in respiratory, diarrhoeal, intestinal and skin diseases

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Minor positive impact	Specific/large population groups	Likely Unlikely	**Major positive impact**
Score: farmers	0.1	500	0.7	35
Score: consumers	0.1	150,000	0.3	4,500
			TOTAL	**4,535**

4.4.3 Environmental Impact Assessment

Potential negative environmental impacts include: (1) heavy metals in effluent and/or sludge from wastewater treatment, which when disposed of or treated inadequately can have a negative impact, and (2) solid residue (accumulated sludge from WW treatment) which when disposed of or treated inadequately can have a negative impact. Mitigation measures to avoid negative impacts include: (1.a) upstream monitoring to ensure influent meets guidelines for heavy metal concentrations, (1.b) monitoring of effluent and solids to ensure concentrations of heavy metals do not exceed regulations, and (2) post-treatment of the solid residue (accumulated sludge from WW treatment), to ensure that it is appropriately treated for the intended end-use. The goal of RRR based businesses should be full resource recovery of all End-products, which implies end-use of appropriately treated sludge (accumulated sludge from WW treatment). If for some reason this is not feasible, only then should disposal of solids at sanitary landfills be considered. Further details on technology options are outlined in the "Technology Assessment Report" [2].

Table 30 – Model 8: potential environmental hazards and proposed mitigation measures

Waste stream	End-product	Technologies	Process	Pot. Env. Hazard	Mitigation measures
• WW	• Fish • Treated WW	• Duckweed • Aquaculture	• Pond treatment	• Heavy metals in effluent and/or sludge from WW treatment • Solid residue (sludge from WW treatment)	• Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • Solid residue (sludge from WW treatment) post-treatment

4.5 Model 9 – On cost savings and recovery

This business model aims at cost recovery of wastewater treatment through the following value propositions: two revenue streams (treated wastewater sales and soil conditioner sales), and a cost-saving mechanism using the treatment processes to capture biogas and converting it to electricity that is subsequently used to (partially) power the plant. Since the wastewater treatment is not clearly defined as per the business model, the risk assessment does not go into the details of the wastewater treatment plant or the production of electricity. However, it is anticipated that for the construction of a 1.5-230 million US$ wastewater treatment plant (as per business model description) a detailed occupational health management plant would be developed. Therefore, the HRIA of Model 9 is primarily focusing on down-stream issues.

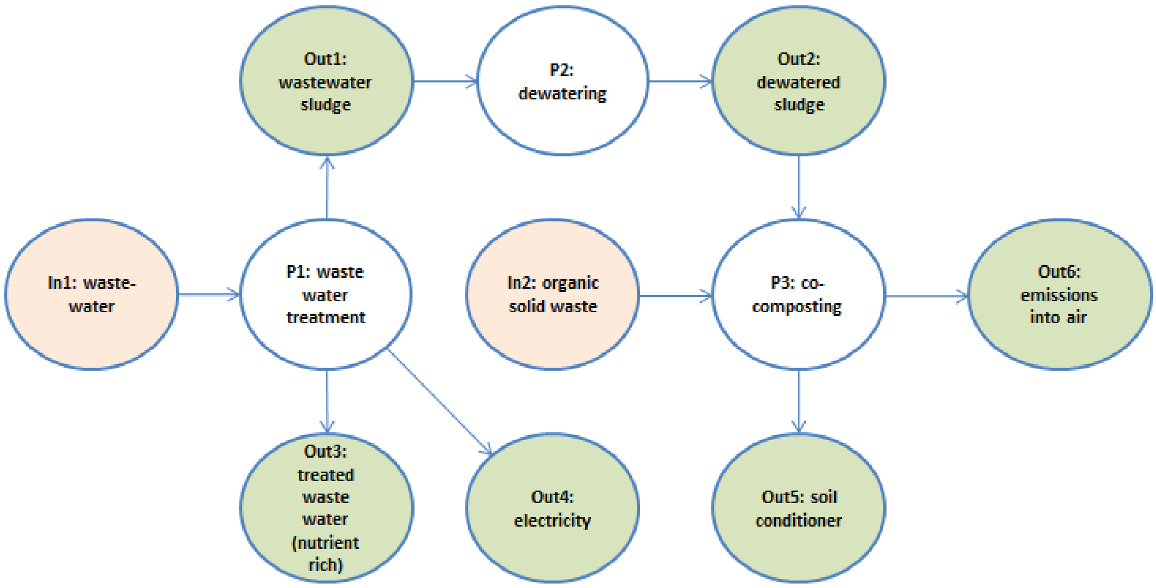

Figure 17 – Model 9: system flow diagram

Table 31 – Model 9: Inputs and associated potential health hazards

Inputs of health relevance	Potential hazards
In1: wastewater	Viruses, bacteria
	Protozoa
	Soil-transmitted helminthics
	Trematodes
	Skin irritants
	Disease vectors
	Chemicals others than heavy metals
	Heavy metals
In2: organic solid waste	Pathogens
	Sharps
	Inorganic waste components

Table 32 – Model 9: Quality/safety requirements for outputs

Outputs of health relevance	Quality/safety requirements
Out1: wastewater sludge	Maximum heavy metals concentration of wastewater sludge for composting (unit: mg/kg dried matter): Cd: 3.0; Cr_{tot}: 300; Cu 500; Hg: 5.0; Ni: 100; Pb: 200; and Zn: 2,000[a]
Out2: dewatered sludge	N.a. (inside system)
Out3: treated wastewater	**Unrestricted irrigation** Root crops: • $<10^3$ *E. coli* per litre and ≤1 helminthic egg per litre Leave crops: • $<10^4$ *E. coli* per litre and ≤1 helminthic egg per litre Drip irrigation of high-growing crops: • $<10^5$ *E. coli* per litre and ≤1 helminthic egg per litre Drip irrigation of low-growing crops:

	• <10^3 *E. coli* per litre and ≤1 helminthic egg per litre **Restricted irrigation** Labour intensive agriculture: • <10^4 *E. coli* per litre and ≤1 helminthic egg per litre Highly mechanized agriculture: • <10^5 *E. coli* per litre and ≤1 helminthic egg per litre ➔ The full list of biological and chemical threshold values of irrigation water and receiving soils is available in Annex V
Out4: electricity	Intrinsically safe electrical installations and proper grounding
Out5: soil conditioner	For agricultural use: • <1 helminthic egg per 1 gram total solids; and <10^3 E. coli per gram total solids ➔ Indian quality standards for organic fertilizer are available in Annex V
Out6: emissions into air	Ambient air quality standards[a]: • $PM_{2.5}$: 10 µ/m^3 24-hour mean; 25 µ/m^3 annual mean • PM_{10}: 20 µ/m^3 24-hour mean; 50 µ/m^3 annual mean • Ozone: 100 µ/m^3 8-hour mean • NO_2: 200 µ/m^3 1-hour mean; 40 µ/m^3 annual mean • SO_2: 500 µ/m^3 10-minutes mean; 20 µ/m^3 24-hour mean

[a] WHO (2005). Air quality guidelines - global update 2005. Geneva: World Health Organization

4.5.1 Health risk assessment

Risks associated with the business derive from the various potential hazards contained in wastewater as outlined in 3.2.1. It is well known, that accordingly designed and operated wastewater treatment plants allow for removing pathogens to acceptable levels. The removal of heavy metals, however, is more complex and cost intensive, which makes them a great concern from an economic, health and environmental perspective. Ideally, heavy metals are kept out of wastewater streams by reducing and controlling potential sources.

Table 33 – Maximum heavy metals concentration for compost and sewage sludge [37]

	Cd	Cr_{tot}	Cu	Hg	Ni	Pb	Zn
COMPOST							
class A+ → *org. farming*	0.7	70	70	0.4	25	45	200
class.A → *agriculture*	1	70	150	0.7	60	120	500
class.B → *land reclamation.*	3	250	400/ 500*	3	100	200	1,200/ 1,800*
SEWAGE SLUDGE							
for '*quality sludge compost*	2.0	70	300	2.0	60	100	1,200
for '*compost*'	3.0	300	500	5.0	100	200	2,000

* Guide / limit value for Cu and Zn; if the guide value in the compost is exceeded the concentration has to be indicated in the labelling

No threshold values for soil conditioner are defined by the Indian government. Also the WHO 2006 Guidelines lack quality requirements for soil conditioner regarding potential toxic chemicals. Maximum heavy metals concentration for compost and sewage sludge as input material for agricultural use as defined by the European Union are shown in Table 33 (unit: mg/kg dried matter) [38]. It is recommended to use those thresholds for determining whether the sewage sludge form the treatment plant is suitable for further processing in the co-composting process.

Overall, for determining whether, and if so which kind of physico-chemical treatment processes are needed in order to assure sufficient quality of the effluents of the proposed business, further environmental sampling will be required at the site where the business will be implemented.

4.5.1.1 Indicated control measures

The full risk assessment matrix is available in Appendix I. Indicated control measures are as follows:

- Protective equipment
    - Workers handling any raw material (e.g. wastewater, sewage sludge or inorganic contaminants) need to wear appropriate PPE and use tools (e.g. shovels)
- Processes
    - Primary, secondary and tertiary treatment has to be applied for reducing pathogens. Different options can be combined for reaching a minimum of 7 log reduction in bacterial indicators (e.g. *E. coli*) and 3 log reductions in helminthic eggs
    - In locations where the concentration of toxic chemicals such as metals in wastewater and/or receiving agricultural soils exceed national and international standards (see Annex V), source reduction and/or physico-chemical removal processes (e.g. absorption) need to be applied.
    - For pathogen removal, the sludge needs to be dewatered and put on drying beds for: (i) 1.5-2 years at 2-20°C; (ii) >1 years at 20-35°C; or (iii) >6 months by means of alkaline treatment at pH>9, >35°C and moisture <25%
    - The sludge of the treatment plant should be compliant with the heavy metal thresholds defined by the European Union (see Table 33). Otherwise the sludge must not be further processed for producing fertilizer
    - A temperature of ≥45°C for ≥5 days (2 log reductions in bacteria and <1 viable helminthic eggs per g dried matter) should be maintained for the co-composting
    - Moisture of co-composting material should be above 40% for reducing bio-aerosol emission
    - Sieving of the soil conditioner prior to packaging for discharging any remaining inorganic contamination or sharp objects
- Infrastructure
    - Assure good ventilation of working areas with a high load of malodours or dust (e.g. co-composting facility)

  - Install handrails and fence dangerous areas for preventing injuries
  - Respect a buffer zone between operation and community infrastructure so that ambient air quality and noise exposure standards are not exceeded. The actual distance is depending on the level of emissions
- Behavioural aspects and prevention
  - Educate workers on ergonomic hazards and how to avoid musculoskeletal damage or injury due to inappropriate working practices
  - Rodent and vector-control (e.g. screening or use of larvicides, insecticides) at waste-storage sites and treatment ponds
  - Protect workers from long term exposure to sunlight
  - Farmers using the soil conditioner should be advised to wear boots and gloves when applying the compost
  - Restrict access to the operations
  - Implement a worker well-being programme that includes regular sessions (e.g. weekly) where general health concerns are reported and health protection measures are promoted (e.g. regular hand washing, purpose of PPE and sun protection, ergonomic hazards, etc.)

4.5.1.2 Residual risks

By implementing all the proposed control measures, all the identified health risks of Model 4 can be reduced to **low, moderate and high levels**. The residual moderate and high risks are linked to the following processes:

- P1: wastewater treatment plant: in settings where the concentration of toxic chemicals in wastewater and/or receiving soils exceed national and WHO Guidelines threshold values (see annex V), the treated wastewater is not suitable for irrigation. Consequently, source reduction and/or physico-chemical removal processes have to be applied. If not, there is a very high risk for adverse health impacts (e.g. chronic disease or even cancer linked to consumption of products that are contaminated with heavy metals and potentially other toxic chemicals) linked to wastewater fed agriculture in Bangalore.
- P1: wastewater treatment plant and P2: dewatering: there is moderate risk for disease vector breeding in ponds of the treatment plant and the drying beds. Therefore, special attention is needed for implementing vector control.
- P2: dewatering and P3: co-composting: in order to avoid exposure of consumers to pathogens in the soil conditioner, it will be crucial to respect the temperature and duration indicated for the drying of the sludge and the co-composting
- P3: co-composting: sharps ending up in the soil conditioner pose a moderate risk to users. Therefore it is important carefully sieve the soil conditioner before packaging and also users need to be sensitised on the potential contamination with sharp objects. In addition, users need to be advised to wear boots and gloves when applying the soil conditioner.
- P3: co-composting: to ensure that workers are protected with respirators is important when handling the waste materials for the co-composting process. Otherwise pathogens, fungi and dust affect their respiratory system

4.5.2 Health impact assessment

The health benefits of a modern wastewater treatment plant in an environment like Bangalore primarily relate to down-stream issues like reduced exposure to pathogens and potentially also toxic chemicals. Model 9 specifically aims at producing safe irrigation water. Therefore, farmers might be the primary beneficiaries from the business.

- **Scale of the BM:** the impact assessment of Model 9 is assuming a wastewater treatment plant serving 500 farmers, whose products are consumed by 70,000 consumers. In addition, 10,000 community members being exposed to the treated wastewater

4.5.2.1 Impact 1: reduction in respiratory, diarrhoeal, intestinal and skin diseases

Prevalence rates of STH in the general population are estimated at 20-50% (see section 3.1.1.2), farmers reusing inappropriately treated wastewater in Bangalore are likely to show high infection rates with helminthic infections. In addition, there is a high burden of gastrointestinal disease in the population of Karnataka and also skin and respiratory diseases might be an important public health concern, particularly in people exposed to untreated wastewater.

The case study from Kampala, where prevalence rates of farmers and community members were assessed in a wastewater for irrigation reuse system, showed that farmers are clearly the most important exposure group of untreated wastewater. But unsafe irrigation practices do also negatively impact on the health of community members, be it through direct contact, ingestion or the consumption of contaminated products. Hence, the business has considerable potential to reduce the burden of diarrhoeal diseases, ARI and helminthic infections in exposed population groups since it aims at transforming untreated wastewater into treated wastewater, soil conditioner and electricity.

Impact 1, assumptions:

- **Impact level:** pathogens in human faeces generally cause disease of short duration and/or minor disability
- **People affected:** the business would affect 500 farmers, 10,000 community members and 70,000 consumers
- **Likelihood:** farmers: likely; general population: very unlikely; and consumers: unlikely

Table 34 – Model 9, impact 1: reduction in respiratory, diarrhoeal, intestinal and skin diseases

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Minor positive impact	Large population group	Likely Possible	**Moderate positive impact**
Farmers	0.1	500	0.7	35
Community	0.1	10,000	0.05	50
Consumers	0.1	70,000	0.3	2,100
			TOTAL	**2,185**

4.5.2.2 Impact 2: reduction in exposure to toxic chemicals

Long-term exposure to toxic chemicals (e.g. heavy metals) can cause a range of health effects, ranging from neurological damage to poisoning. In general, these effects are difficult to quantify and many knowledge gaps exist. Therefore, the impact assessment applies a simplified approach: under the assumption that the business model will operate in settings with acceptable concentrations of toxic chemicals, or will eliminate these to acceptable levels, a minor positive health effect is anticipated at individual level.

Impact 2, assumptions:

- **Impact level:** health impacts linked to long-term exposure to toxic chemicals is not perceived by most individuals but can result moderate disability. A minor positive effect (0.1) is applied as an average value
- **People affected:** the business would affect 500 farmers, 10,000 community members and 70'000 consumers
- **Likelihood:** it is unlikely that farmers will have an improvement of their health status due to reduce exposure to toxic chemicals and very unlikely that community members will experience any difference

Table 35 – Model 9, impact 2: reduction in exposure to toxic chemicals

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Minor positive impact	Large population group	Likely Possible	**Moderate positive impact**
Farmers	0.1	500	0.05	2.5
Community	0.1	10'000	0.05	50
Consumers	0.1	70'000	0.05	350
			TOTAL	**402.5**

4.5.2.3 Impact 3: changes in health status due to access to electricity

➔ For the impact definition, see Model 4, impact 2 (section 4.2.2.2).

Impact 1, assumptions:

- **Impact level:** minor positive and negative health impacts anticipated. Therefore, the impact level is insignificant
- **People affected:** the electricity generated by the plant would serve 3'000 people
- **Likelihood:** It is very unlikely that access to electricity impacts on the health of people

Table 36 – Model 4, impact 2: changes in health status due to access to electricity

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Insignificant	Medium population	Very unlikely	**Insignificant**
Score	0.0	3'000	0.05	**0**

4.5.3 Environmental Impact Assessment

Potential negative environmental impacts include: (1) heavy metals in effluent and/or sludge from wastewater treatment, which when disposed of or treated inadequately can have a negative impact, (2) solid residue (accumulated sludge from WW treatment) which when disposed of or treated inadequately can have a negative impact, and (3) air emissions from the anaerobic digester if not controlled properly or in case of failure. Mitigation measures to avoid negative impacts include: (1.a) upstream monitoring to ensure influent meets guidelines for heavy metal concentrations, (1.b) monitoring of effluent and solids to ensure concentration of heavy metals do not exceed regulations, and, (2) solid residue post-treatment of the solid residue (accumulated sludge from WW treatment), which is converted into a soil conditioner for endues in agriculture, and (3) regular maintenance of the anaerobic digester to prevent leakages. The goal of RRR based businesses should be full resource recovery of all End-products, which implies end-use of appropriately treated sludge (accumulated sludge from WW treatment) and in the case of this business model means as a soil conditioner for end-use in agriculture. If for some reason this is not feasible, only then should disposal of solids at sanitary landfills be considered. Further details on technology options are outlined in the "Technology Assessment Report" [2].

Table 37 – Model 9: potential environmental hazards and proposed mitigation measures

Waste stream	**End-product**	**Technologies**	**Process**	**Pot. Env. Hazard**	**Mitigation measures**
• WW • WW sludge	• Electricity • Soil conditioner • Water (for reclamation)	• Conventional wastewater treatment technologies • Biogas conversion technologies	• Conven-tional WW treatment • Biogas to electricity conversion	• Heavy metals in effluent and/or WW sludge • Solid residue (sludge from WW treatment) • Air emissions	• Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • Solid residue (sludge from WW treatment) post-treament • Maintenance of anaerobic digester

4.6 Model 10 – Informal to formal trajectory in wastewater irrigation: incentivizing safe reuse of untreated wastewater

Business model 10 aims at promoting the use of untreated wastewater for irrigation and ground water recharge. From a health perspective, the business can only be promoted if the untreated wastewater is compliant with national and international standards, which are depending to the form of reclamation (see Table 39). This includes chemical parameters of the wastewater and receiving soils must be taken into account.

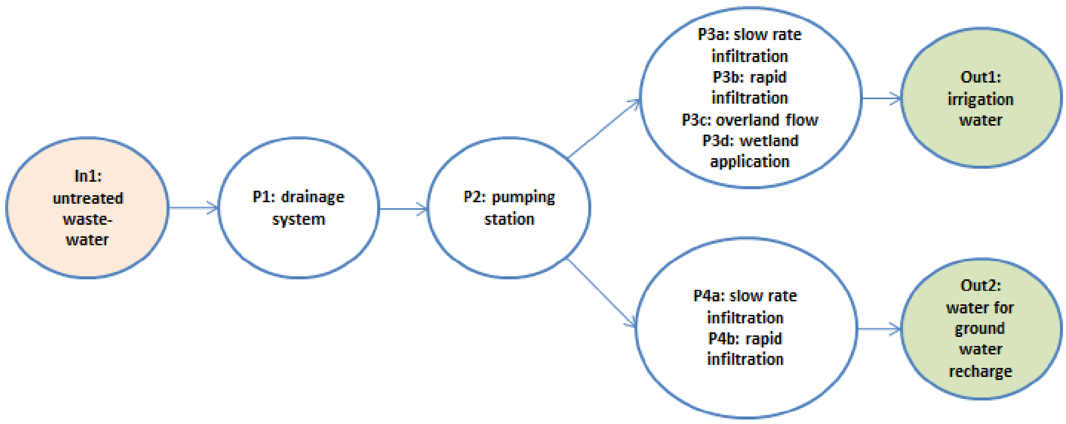

Figure 18 – Model 10: system flow diagram

Table 38 – Model 10: Inputs and associated potential health hazards

Inputs of health relevance	Potential hazards
In1: untreated wastewater	Viruses, bacteria
	Protozoa
	Soil-transmitted helminthic infections
	Trematodes
	Skin irritants
	Disease vectors
	Chemicals others than heavy metals
	Heavy metals

Table 39 – Model 10: Quality/safety requirements for outputs

Outputs of health relevance	Quality/safety requirements
Out1: irrigation water	**Unrestricted irrigation** Root crops: • <10^3 *E. coli* per litre and <1 helminthic egg per litre Leave crops: • <10^4 *E. coli* per litre and <1 helminthic egg per litre Drip irrigation of high-growing crops: • <10^5 *E. coli* per litre and <1 helminthic egg per litre Drip irrigation of low-growing crops: • <10^3 *E. coli* per litre and <1 helminthic egg per litre **Restricted irrigation** Labour intensive agriculture: • <10^4 *E. coli* per litre and <1 helminthic egg per litre

<table>
<tr>
<td></td>
<td><u>Highly mechanized agriculture:</u>
• $<10^5$ E. coli per litre and <1 helminthic egg per litre
Sub-surface irrigation
• $<10^6$ E. coli per litre and <1 helminthic egg per litre
➔ Chemical indicators in treated wastewater and receiving soils must not exceed thresholds as per WHO Guidelines (see Annex V)</td>
</tr>
<tr>
<td>Out2: water for ground water recharge</td>
<td>Drinking water
<table>
<tr><th>Drinking water quality category</th><th>Number of TTC</th></tr>
<tr><td>Compliant</td><td></td></tr>
<tr><td>Tolerable</td><td></td></tr>
<tr><td>Treatment required</td><td></td></tr>
<tr><td>Unsuitable for consumption without treatment</td><td></td></tr>
</table>
Categorization of drinking water quality based on the number of TTC in a water sample of 100 ml (REF: Wisner and Adams, 2002).</td>
</tr>
</table>

4.6.1 Health risk assessment

Health risks of this business are clearly related to the various biological, chemical and physical health hazards that are usually present in untreated wastewater. From a health perspective, Model 10 can only be supported in environments where wastewater is compliant with the safety requirements of the WHO 2006 Guidelines.

4.6.1.1 Indicated control measures

For determining the feasibility of the business in a given context, the wastewater quality has to be analysed. The biological and chemical parameters will reveal the possible irrigation options:

- If the wastewater exceeds 10^6*E. coli* per litre and <1 helminthic egg per litre, the wastewater is not suitable for any form of irrigation and the business must not be implemented. In addition, the receiving soils need to be compliant with WHO 2006 thresholds
- **P3a: slow rate infiltration and P3b: rapid infiltration** (i.e. sub-surface irrigation):$<10^6$ *E. coli* per litre and <1 helminthic egg per litre. In addition, the receiving soils need to be compliant with WHO 2006 thresholds
- **P3c: overland flow**: <u>root crops</u> ($<10^3$ *E. coli* per litre and <1 helminthic egg per litre) or <u>leave crops</u> ($<10^4$ *E. coli* per litre and <1 helminthic egg per litre). In addition, the receiving soils need to be compliant with WHO 2006 thresholds
- **P3d: wetland application**: <u>root crops</u> ($<10^4$ *E. coli* per litre and <10 helminthic egg per litre) or <u>leave crops</u> ($<10^5$ *E. coli* per litre and <10 helminthic egg per litre). In addition, the receiving soils need to be compliant with WHO 2006 thresholds

In case the business is determined to be feasible, the following control measures should be implemented (the full risk assessment matrix is available in Appendix I):

- Any slow and rapid infiltration system requires a hydrology study in order to exclude any contamination of drinking water sources
- The drainage system needs to be complemented with a pre-treatment facility (e.g. screening and grease traps) for preventing backups and overflows. In addition, regular cleaning of the drainage system is necessary for preventing clogging and overflow.
- Advice farmers who apply the wastewater to wear boots and gloves when working in the irrigated fields.
- Advice farmers who apply the wastewater to respect 2 days between last irrigation and harvesting.
- Advice farmers who apply the wastewater to wash harvested crops with fresh water

4.6.1.2 Residual risks

Even in the case where the quality requirements for the wastewater are met, a moderate to high risk remains linked to the reuse of the wastewater. This is primarily explained by the fact the even with a sophisticated quality monitoring system in place, it is very likely that the wastewater will show strong fluctuations in quality (e.g. in case of heavy rainfalls), which is difficult to control down-stream. Also with a multi-barrier approach in place, i.e. farmers applying additional control measures, there is considerable risk of exposure to pathogens and chemicals at user and consumer level.

4.6.2 Health impact assessment

In the context of Bangalore, where wastewater shows high loads of pathogen and toxic chemicals, the promotion of the use of un- or partially treated wastewater would result in an increase of adverse health impacts at farmer and community level. The extent of negative health impacts of the business depends very much on the quality of the wastewater and the applied irrigation scheme. In view of the many options given for Model 10 (in terms of scale and application), no semi-quantitative impact assessment can be done. Also, additional pilot testing of multi-barrier methods for reducing biological and chemical hazards is needed.

4.6.3 Environmental Impact Assessment

Potential negative environmental impacts include: (1) groundwater contamination with heavy metals and/or pathogens, due to inadequately treated wastewater, and (2) contamination of irrigated crops with heavy metals and/or pathogens, due to heavy metal being present in incoming wastewater.. Mitigation measures to avoid negative impacts include: (1.a) upstream monitoring to ensure influent meets guidelines for heavy metal concentrations, (1.b) monitoring of effluent and solids to ensure concentration of heavy metals do not exceed regulations, and (2) adhering to appropriate levels of multiple barrier protection, such as the WHO “Guidelines for the safe use of Wastewater, Excreta and Greywater, 2006”, which extensively describe the limitations, and environmental and health concerns for this type of application. Further details on technology options are outlined in the “Technology Assessment Report” [2].

Table 40 – Model 10: potential environmental hazards and proposed mitigation measures

Waste stream	End-product	Technologies	Process	Pot. Env. Hazard	Mitigation measures
• WW	• Water (for reclamation) • Water for groundwater recharge	• Slow rate infiltration • Rapid infiltration • Overland flow • Wetland application	• Land treatment	• Groundwater contamination (heavy metals/pathogens) • Contamination of irrigated crops with heavy metals and/or pathogens	• Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • Crop selection • 2006 WHO guidelines

4.7 Model 11 – Intersectoral water exchange

Model 11 is built on partnerships, as the business relies on a partnership between a water and sanitation entity (public or private) and farmers. Besides supplying farmers with treated wastewater for irrigation, the business model also aims at increasing fresh water supply. This is based on the assumption that farmers would replace the fresh water that they currently use for irrigation with treated waste water.

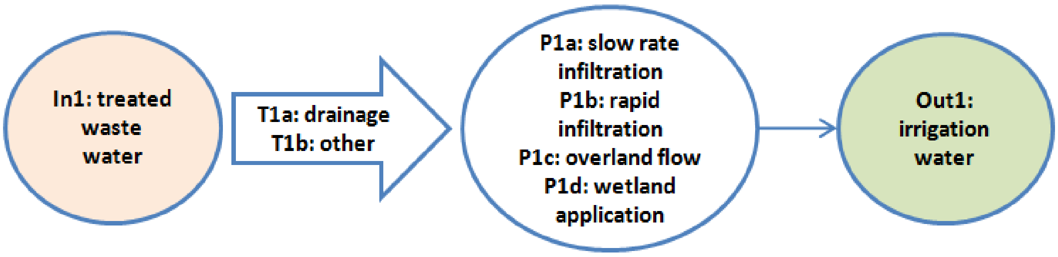

Figure 19 – Model 11: system flow diagram

Table 41 – Model 11: Inputs and associated potential health hazards

Inputs of health relevance	Potential hazards
In1: treated wastewater	Viruses, bacteria
	Protozoa
	Soil-transmitted helminthics
	Trematodes
	Skin irritants
	Disease vectors
	Chemicals others than heavy metals
	Heavy metals

Table 42 – Model 11: Quality/safety requirements for outputs

Outputs of health relevance	Quality/safety requirements
Out1: irrigation water	**Unrestricted irrigation** Root crops: • $<10^3$ E. coli per litre and <1 helminthic egg per litre Leave crops: • $<10^4$ E. coli per litre and <1 helminthic egg per litre Drip irrigation of high-growing crops: • $<10^5$ E. coli per litre and <1 helminthic egg per litre Drip irrigation of low-growing crops: • $<10^3$ E. coli per litre and <1 helminthic egg per litre **Restricted irrigation** Labour intensive agriculture: • $<10^4$ E. coli per litre and <1 helminthic egg per litre Highly mechanized agriculture: • $<10^5$ E. coli per litre and <1 helminthic egg per litre ➔ Chemical indicators in treated wastewater and receiving soils must not exceed thresholds as per WHO Guidelines (see Annex V)

4.7.1 Health risk assessment

Health risks of this business are related to the quality of the treated waste water that is promoted for irrigation purposes. As the treatment plant is not managed by the BM itself, **it is anticipated that the partnership agreement would have the requirement in place that the wastewater is compliant with national and WHO 2006 Guideline standards**. Hence, the HRIA of BM 11 is assuming an acceptable quality of the wastewater as primary input of the model.

4.7.1.1 Indicated control measures

The irrigation options of the BM are determined by the quality of the treated wastewater:

- **P1a: slow rate infiltration and P3b: rapid infiltration** (i.e. sub-surface irrigation):$<10^6$ *E. coli* per litre and <1 helminthic egg per litre. In addition, the receiving soils need to be compliant with WHO 2006 thresholds
- **P1c: overland flow**:root crops ($<10^3$ *E. coli* per litre and <1 helminthic egg per litre) or leave crops ($<10^4$ *E. coli* per litre and <1 helminthic egg per litre). In addition, the receiving soils need to be compliant with WHO 2006 thresholds
- **P1d: wetland application**: root crops ($<10^4$ *E. coli* per litre and <10 helminthic egg per litre) or leave crops ($<10^5$ *E. coli* per litre and <10 helminthic egg per litre). In addition, the receiving soils need to be compliant with WHO 2006 thresholds

Independent of the irrigation system, the following control measures are indicated (the full risk assessment matrix is available in Appendix I):

- Any slow and rapid infiltration system requires a hydrology study in order to exclude any contamination of drinking water sources

- Regular cleaning of the drainage system is necessary for preventing clogging and overflow.
- Advice farmers who apply the wastewater to wear boots and gloves when working in the irrigated fields.
- Advice farmers who apply the wastewater to respect 2 days between last irrigation and harvesting.
- Advice farmers who apply the wastewater to wash harvested crops with fresh water

4.7.1.2 Residual risks

Under the assumption of acceptable wastewater quality as input for the model, a low to moderate risk remains linked to the reuse of treated wastewater. The primary concern is the quality of the treated wastewater, which may fluctuate over time (e.g. in case of heavy rainfalls). Therefore, chemical and biological indicators need to be monitored on an ongoing basis. In case national or WHO 2006 Guidelines threshold values are exceeded (according to the given irrigation system), the water must not be used for irrigation purposes until the quality is compliant again.

4.7.2 Health impact assessment

By replacing fresh water for irrigation with treated wastewater, Model 11 may increase the incidence of respiratory, diarrhoeal, intestinal and skin diseases at farmer level. Irrigation with wastewater also results in a higher risk for contaminated products when compared to fresh water irrigation. On the other hand, the business aims at increasing access to fresh water at household and industry level, which in turn may positively impact on community health. Finally, the model may have a positive health impact by decreasing exposure to untreated wastewater.

- **Scale of the BM:** the impact assessment of Model 11 is assuming 5 small-scale wastewater treatment plants. One plant will serve 100 farmers who supply products to 10,000 consumers each. It is assumed that 1,000 households would gain access to fresh water with the operation of one plant.

4.7.2.1 Impact 1: increase in respiratory, diarrhoeal, intestinal and skin diseases

Farmers replacing fresh water for irrigation with treated wastewater are at higher risk for developing respiratory, diarrhoeal, intestinal and skin diseases. This also applies to consumers who consume products that are irrigated with treated wastewater instead of fresh water. However, since it is assumed that the treated wastewater will be of good quality, it is unlikely that impact 1 will occur at farmer level and very unlikely at consumer level.

Impact 1, assumptions:

- **Impact level:** pathogens in treated wastewater generally cause disease of short duration and/or minor disability

- **People affected:** the business would affect 5 x 100 farmers and 10,000 community members each
- **Likelihood:** farmers are unlikely and consumers very unlikely to experience an increase in treated wastewater-related disease

Table 43 – Model 11, impact 1: increase in respiratory, diarrhoeal, intestinal and skin diseases

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Minor negative impact	Large population group	Unlikely Very unlikely	**Moderate negative impact**
Score: farmers	-0.1	500	0.3	-15
Score: community	-0.1	50,000	0.05	-250
			TOTAL	**-265**

4.7.2.2 Impact 2: decrease in diarrhoeal, respiratory and intestinal diseases

Access to safe drinking water has considerable potential to reduce incidence in diarrhoeal and respiratory diseases episodes. This is not only linked to improved water quality but also to reduced water-collection distances and reduces exposure to pathogens at collection points.

Impact 2, assumptions:

- **Impact level:** pathogens in drinking water of poor quality generally cause disease of short duration and/or minor disability
- **People affected:** by replicating BM 11 five times, 5,000 households with 5 household members each would gain access to safe drinking water. Since it is primarily the younger age groups that will experience health effects due to poor drinking water quality, only every second household member will actually be impacted (5,000 x 5 x 0.5 = 12,500)
- **Likelihood:** it is likely that the impact will occur

Table 44 – Model 11, impact 2: decrease in diarrhoeal, respiratory intestinal diseases

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Minor positive impact	Large population group	Likely	**Moderate positive impact**
Score	0.1	12,500	0.7	**875**

4.7.2.3 Impact 3: reduction in respiratory, diarrhoeal, intestinal and skin diseases

As model 11 promotes treatment of wastewater, it has considerable potential to reduce the burden of diarrhoeal diseases, ARI and helminthic infections in people exposed to untreated wastewater.

➔ For the impact definition, see Model 9, impact 1 (section4.5.2.1).

Impact 3, assumptions:

- **Impact level:** pathogens in untreated wastewater generally cause disease of short duration and/or minor disability
- **People affected:** the business would reduce exposure to untreated wastewater in 5x100 farmers and 10,000 community members each
- **Likelihood:**it is possible that farmers and community members will be impacted

Table 45 – Model 11, impact 3: reduction in respiratory, diarrhoeal, intestinal and skin diseases

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Minor positive impact	Large population group	Likely Unlikely	**Moderate positive impact**
Score: farmers	0.1	500	0.5	25
Score: community	0.1	10,000	0.5	500
			TOTAL	**525**

4.7.3 Environmental Impact Assessment

Potential negative environmental impacts include: (1) groundwater contamination with heavy metals and/or pathogens, due to inadequately treated WW and (2) contamination of irrigated crops with heavy metals and/or pathogens, due to heavy metal being present in incoming wastewater. Mitigation measures to avoid negative impacts include: (1.a) upstream monitoring to ensure influent meets guidelines for heavy metal concentrations, (1.b) monitoring of effluent and solids to ensure concentration of heavy metals do not exceed regulations, and (2) adhering to appropriate levels of multiple barrier protection, such as the WHO "Guidelines for the safe use of Wastewater, Excreta and Greywater, 2006", which extensively describe the limitations, and environmental and health concerns for this type of application. Further details on technology options are outlined in the "Technology Assessment Report" [2].

Table 46 – Model 11: potential environmental hazards and proposed mitigation measures

Waste stream	End-product	Technologies	Process	Pot. Env. Hazard	Mitigation measures
• Treated WW	• Water (for reclamation)	• Slow rate infiltration • Rapid infiltration • Overland flow • Wetland application	• Land application through irrigation	• Groundwater contamination (heavy metals/patho-gens) • Contamination of irrigated crops	• Crop selection • Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • 2006 WHO guidelines

4.8 Model 15 – Large-scale composting for revenue generation

business model is a small to medium scale production that aims at (i) reducing greenhouse gas emission through processing of municipal solid waste; and (ii) collecting and treating MSW and night soil from the city for producing organic fertilizer. The business would be implemented in urban Bangalore environment linked to the increased availability of MSW.

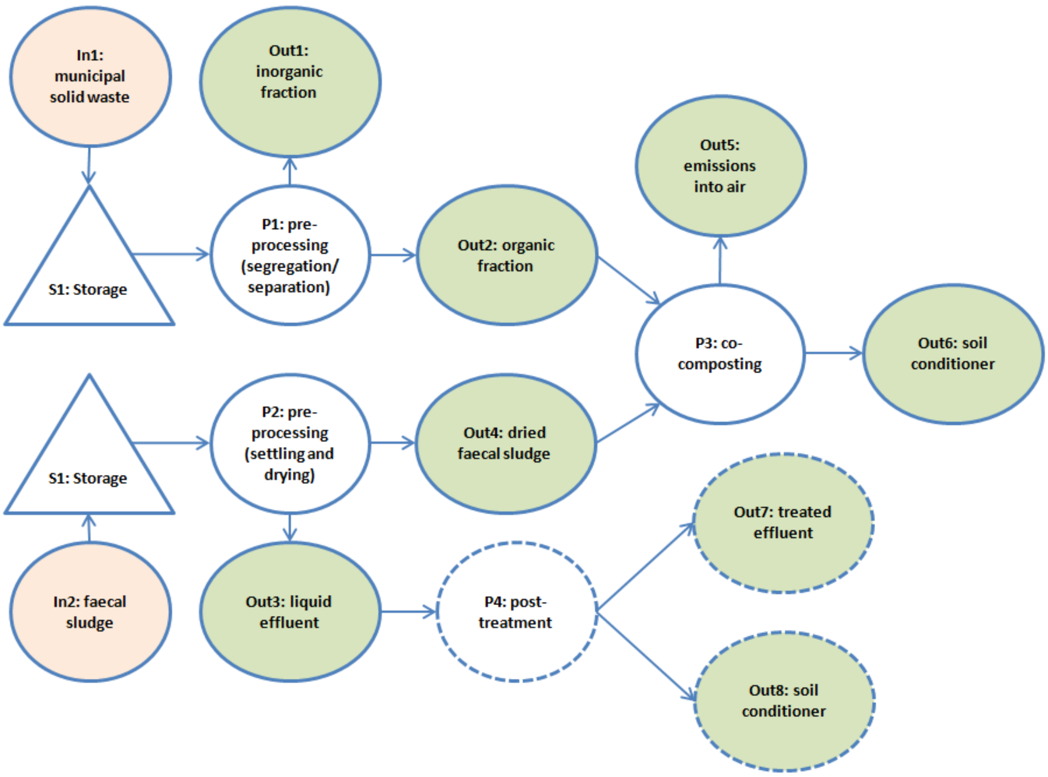

Figure 20 – Model 15: system flow diagram

Table 47 – Model 15: Inputs and associated potential health hazards

Inputs of health relevance	Potential hazards
In1: municipal solid waste	Contamination with pathogens deriving from human and animal waste (viruses and bacteria are of primary concern)
	Contamination with sharp objects
	Contamination with medical waste
	Contamination with chemical waste
In2: faecal sludge	Pathogens
	Contamination with sharp objects and inorganic waste

Table 48 – Model 15: Quality/safety requirements for outputs

Outputs of health relevance	Quality/safety requirements
Out1: inorganic fraction	None since considered as waste → appropriate disposal/recycling
Out2: organic fraction	N.a. (within the system)
Out3: liquid effluent	N.a. (within the system)

Out4: dried sludge	N.a. (within the system)
Out5: emissions into air	Ambient air quality standards[a]: • $PM_{2.5}$: 10 µ/m^3 24-hour mean; 25 µ/m^3 annual mean • PM_{10}: 20 µ/m^3 24-hour mean; 50 µ/m^3 annual mean • Ozone: 100 µ/m^3 8-hour mean • NO_2: 200 µ/m^3 1-hour mean; 40 µ/m^3 annual mean • SO_2: 500 µ/m^3 10-minutes mean; 20 µ/m^3 24-hour mean
Out7: treated effluent	**Unrestricted irrigation** Root crops: • <10^3 *E. coli* per litre and <1 helminthic egg per litre Leave crops: • <10^4 *E. coli* per litre and <1 helminthic egg per litre Drip irrigation of high-growing crops: • <10^5 *E. coli* per litre and <1 helminthic egg per litre Drip irrigation of low-growing crops: • <10^3 *E. coli* per litre and <1 helminthic egg per litre **Restricted irrigation** Labour intensive agriculture: • <10^4 *E. coli* per litre and <1 helminthic egg per litre Highly mechanized agriculture: • <10^5 *E. coli* per litre and <1 helminthic egg per litre ➔ Chemical indicators in treated wastewater and receiving soils must not exceed thresholds as per WHO Guidelines (see Annex V)
Out8: soil conditioner	For agricultural use: • <1 helminthic egg per 1 gram total solids; and <10^3*E. coli* per gram total solids • Indian quality standards for organic fertilizer are available in Annex V

[a] WHO (2005). Air quality guidelines - global update 2005. Geneva: World Health Organization

4.8.1 Health risk assessment

Health risks of this business are associated with the two types of inputs. MSW is usually contaminated with pathogens deriving from human (e.g. diapers) and potentially animal waste. Viruses and bacteria are of primary concern. In addition, sharp objects (e.g. razor blades), chemical waste (e.g. batteries) or even medical waste may be included in MSW. Pathogens are the primary hazard of the second input, faecal sludge, as well as potential contamination thereof with sharp object (e.g. razor blades). Besides the health hazards associated with the inputs, the operation of a co-composting plant involves emissions into the air such as malodours, thermophilic fungi and dust. Also the liquid effluents need to be treated appropriately. However, since the post-treatment is not clearly defined as per the business model, the risk assessment is limited to the description of the efficiency of different post-treatment options but does not define which combination has to be selected. For the impact assessment it is assumed that the sludge and effluent of the anaerobic digestion are disposed of safely, i.e. appropriate disposal in case of no onsite post-treatment or treated effluent and soil conditioner that are compliant with quality/safety requirements as per the given scenario.

4.8.1.1 Indicated control measures

- Protective equipment
    - Workers handling any raw material (e.g. MSW and faecal matter) need to wear appropriate PPE and use tools (e.g. shovels)
- Processes
    - Separation of any components that are contaminated with biological (e.g. human waste such as diapers or sanitary products), chemical (e.g. batteries) or inorganic (e.g. sharp objects such as razor blades) wastes. To be discharged into the inorganic fraction and disposed of appropriately
    - For pathogen removal, the faecal sludge needs to be put on drying beds for: (i) 1.5-2 years at 2-20°C; (ii) >1 years at 20-35°C; or (iii) >6 months by means of alkaline treatment at pH>9, >35°C and moisture <25%
    - Depending on the further use of the effluent of the faecal sludge, off-site and on-site post-treatment options are available (see section4.2.1.1)
    - A temperature of ≥45°C for ≥5 days (2 log reductions in bacteria and <1 viable helminthic eggs per g dried matter) should be maintained for the co-composting
    - Moisture of co-composting material should be above 40% for reducing bio-aerosol emission
    - Sieving of the soil conditioner prior to packaging for discharging any remaining inorganic contamination or sharp objects
- Infrastructure
    - Assure good ventilation of working areas with a high load of malodours or dust (e.g. co-composting facility)
    - Install handrails and fence dangerous areas for preventing injuries
    - Respect a buffer zone between operation and community infrastructure so that ambient air quality and noise exposure standards are not exceeded. The actual distance is depending on the level of emissions
- Behavioural aspects and prevention
    - Assure that MSW is not contaminated with any medical waste!
    - Educate workers on ergonomic hazards and how to avoid musculoskeletal damage or injury due to inappropriate working practices
    - Insect vector- and rodent-control (e.g. screening or use of larvicides, insecticides) at storage sites
    - Protect workers from long term exposure to sunlight
    - Farmers using the soil conditioner should be advised to wear boots and gloves when applying the compost
    - Restrict access to the operations
    - Implement a worker well-being programme that includes regular sessions (e.g. weekly) where general health concerns are reported and health protection measures are promoted (e.g. regular hand washing, purpose of PPE and sun protection, ergonomic hazards, etc.)

4.8.1.2 *Residual risks*

By implementing all the proposed control measures, the identified health risks of Model 15 can be reduced to **low and moderate levels**. The residual risks are linked to the following processes:

- P1: pre-processing of MSW: rigorous discharging of any human, animal or chemical waste, as well as sharp objects is essential for assuring quality and safety of the organic fraction
- P2: settling and drying, and P3: co-composting: in order to avoid exposure of consumers to pathogens in the soil conditioner, it will be crucial to respect the temperature and duration indicated for the drying of the sludge and the co-composting
- P3: co-composting: to ensure that workers are protected with respirators is important when handling the waste materials for the co-composting process. Otherwise pathogens, fungi and dust affect their respiratory system
- P3: co-composting and P4: post-treatment: sharps ending up in the soil conditioner pose a moderate risk to users. Soil conditioner must be sieved before packaging and users need to be sensitised about the potential presence of sharp objects and pathogens in the soil conditioner. In addition, users need to be advised to wear boots and gloves when applying the soil conditioner.
- **Medical waste must be collected separately for keeping it out of the BM**

4.8.2 Health impact assessment

By collecting and processing faecal sludge, the business is a purification process. Hence, exposure to faecal pathogens may be reduced at community level. Moreover, the business could indirectly impact people who are currently exposed to landfills (waste pickers or surrounding communities), since it will reduce the load of MSW ending up on landfills.

- **Scale of the BM:** the impact assessment of Model 15 is assuming that two centralised co-composting plants are installed in Bangalore, each collecting faeces from 2’000 households

4.8.2.1 *Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases*

The business entails safe collection and disposal of faecal sludge. Consequently, there is the potential that the business’ activity will result in a reduction of unsafe disposal of faecal matter into the environment. But Model 15 is more suitable for an urban environment with high density in MSW. The faecal sludge input for the business would be collected from onsite sanitation systems. In Bangalore, the emptying of onsite sanitation systems is largely taken care of by the ‘honey suckers’. Hence, the business would not result in a considerable change in faecal sludge management at community level but rather change the final destination of the faecal sludge of onsite sanitation systems: currently most faecal sludge ends up on drying beds of farmers who will apply the sludge as soil conditioner. With the business in place, the volume of faecal sludge for farmers would be slightly decreased, resulting in a safer processing of the faecal sludge at the operations of the business. This will result in a reduction in the incidence of diarrhoeal diseases, ARI and helminth infections due to reduced exposure to faecally contaminated soil. In consideration of the scale of the business and the total amount of MSW in Bangalore, the likelihood of a positive health impacts linked to the business is small.

Impact 1, assumptions:

- **Impact level:** pathogens in human faeces generally cause disease of short duration and/or minor disability
- **People affected:** the business would serve 2 x 2,000 people, which is the volume that serves approximately 50 farmers annually, who produce food crops for 15,000 consumers.
- **Likelihood:** it is very unlikely that the business will make a difference in disease incidence

Table 49 – Model 15, impact 1: reduction in respiratory, diarrhoeal and intestinal diseases

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Minor positive impact	Specific population group	Very unlikely	**Moderate positive impact**
Score: farmers	0.1	500	0.3	**15**
Score: consumers	0.1	15,000	0.05	**75**
			TOTAL	**90**

4.8.2.2 Impact 2: health benefits due to reduced MSW loads on landfills

In Bangalore, landfills are associated with a range of negative health impacts ranging from the poor working conditions of the waste pickers to downstream issues such as contamination of surface waters. Hence, a reduction of the load of waste that arrives on landfills has the potential to have an indirect positive impact on health.

Waste removal capacity of two centralized co-composting plants as proposed by Model 15 is anticipated to be 10-100 tonnes per day, which is less than 1% of the daily volume of MSW collected in Bangalore per day [3]. Consequently, the business is very unlikely to make a considerable difference at the level of existing landfills.

Impact 2, assumptions:

- **Impact level:** various pathologies are associated with landfills
- **People affected:** an estimated 500 waste pickers work on the landfills that would be affected by the business
- **Likelihood:** it is very unlikely that the business will make a difference in disease incidence

Table 50 – Model 15, impact 2: health benefits due to reduced MSW loads on landfills

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Minor positive impact	Specific population group	Very unlikely	**Minor positive impact**
Score: farmers	0.5	500	0.05	**12.5**

4.8.3 Environmental Impact Assessment

Potential negative environmental impacts include: (1) accumulated waste resulting from separation of inorganic fractions from MSW prior to composting and disposed of or used improperly (2) leachate from the composting process, which if moisture is not well controlled can leach into the environment, (3) insufficient pathogen inactivation, which may occur when temperatures are not well control over a sufficient period of time, and (4) liquid effluent from FS treatment, which when leaching into the environment can have a negative impact due to high nutrient and organic matter concentrations. Mitigation measures to avoid negative impacts include: (1) storage, transport and disposal at a designated recycling facility or solid waste discharge site (sanitary landfill), (2) appropriate moisture control of the compost heap and/or collection of leachate and post treatment, (3) temperature control of the compost heap to ensure sufficient pathogen inactivation, and (4) post-treatment of the liquid effluent from FS dewatering processes. The goal of RRR based businesses should be full resource recovery of all End-products, which implies end-use of appropriately treated liquid effluent from post-treatment of liquid effluent from FS dewatering processes. If for some reason this is not feasible, only then should treated liquid effluent from FS dewatering processes get discharged into the environment presuming that it complies with local standards for discharge into the environment. Further details on technology options are outlined in the "Technology Assessment Report" [2].

Table 51 – Model 15: potential environmental hazards and proposed mitigation measures

Waste stream	**End-product**	**Technologies**	**Process**	**Pot. Env. Hazard**	**Mitigation measures**
• MSW • FS	• Soil Conditioner	• Solid/liquid separation • Drying beds • Co-composting	• Co-com-posting (MSW + FS)	• Accumulated inorganic waste • Leachate from composting • Insufficient pathogen inactivation • Liquid effluent (from FS treatment)	• Storage/transport/disposal (sanitary landfill) • Moisture control • Leachate treatment • Temperature control (compost heap) • Post-treatment of liquid effluent

4.9 Model 16 – Subsidy-free community based composting

In this business model, a cooperative uses household and market waste as well as animal waste to produce soil conditioner for direct sale to small-scale farmers through trust and personal links. The business is a decentralized operation and compost may be fortified.

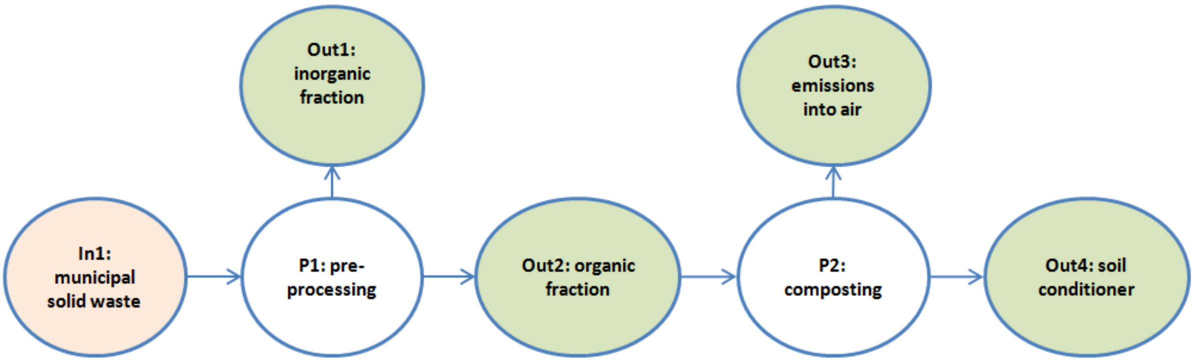

Figure 21 – Model 16: system flow diagram

Table 52 – Model 16: Inputs and associated potential health hazards

Inputs of health relevance	Potential hazards
In1: municipal solid waste	Contamination with pathogens deriving from human and animal waste (viruses and bacteria are of primary concern)
	Contamination with sharp objects
	Contamination with medical waste
	Contamination with chemical waste

Table 53 – Model 16: Quality/safety requirements for outputs

Outputs of health relevance	Quality/safety requirements
Out1: inorganic fraction	None since considered as waste → appropriate disposal/recycling
Out2: organic fraction	N.a. (within the system)
Out3: emissions into air	Ambient air quality standards[a]: • $PM_{2.5}$: 10 µ/m^3 24-hour mean; 25 µ/m^3 annual mean • PM_{10}: 20 µ/m^3 24-hour mean; 50 µ/m^3 annual mean • Ozone: 100 µ/m^3 8-hour mean • NO_2: 200 µ/m^3 1-hour mean; 40 µ/m^3 annual mean • SO_2: 500 µ/m^3 10-minutes mean; 20 µ/m^3 24-hour mean
Out4 soil conditioner	For agricultural use: • <1 helminthic egg per 1 gram total solids; and <10^3 *E. coli* per gram total solids • Indian quality standards for organic fertilizer are available in Annex V

[a] WHO (2005). Air quality guidelines - global update 2005. Geneva: World Health Organization

4.9.1 Health risk assessment

Health risks of this business are associated with the potential input of MSW, which is commonly contaminated with pathogens deriving from human (e.g. diapers) and potentially animal waste. Viruses and bacteria are of primary concern. In addition, sharp objects (e.g. razor blades), chemical waste (e.g. batteries) or even medical waste may be included in MSW. Moreover, the operation of a composting plant involves emissions into the air such as malodours, thermophilic fungi and dust.

4.9.1.1 Indicated control measures

- Protective equipment
  - Workers handling any raw material (e.g. MSW, market waste, organic waste) need to wear appropriate PPE and use tools (e.g. shovels)
- Processes
  - Separation of any components that are contaminated with biological (e.g. human waste such as diapers or sanitary products), chemical (e.g. batteries) or inorganic (e.g. sharp objects such as razor blades) wastes. To be discharged into the inorganic fraction and disposed of appropriately
  - A temperature of ≥45°C for ≥5 days (2 log reductions in bacteria and <1 viable helminthic eggs per g dried matter) should be maintained for the composting
  - Moisture of composting material should be above 40% for reducing bio-aerosol emission
  - Sieving of the soil conditioner prior to packaging for discharging any remaining inorganic contamination or sharp objects
- Infrastructure
  - Assure good ventilation of working areas with a high load of malodours or dust (e.g. co-composting facility)
  - Install handrails and fence dangerous areas for preventing injuries
  - Respect a buffer zone between operation and community infrastructure so that ambient air quality and noise exposure standards are not exceeded. The actual distance is depending on the level of emissions
- Behavioural aspects and prevention
  - Assure that MSW is not contaminated with any medical waste!
  - Educate workers on ergonomic hazards and how to avoid musculoskeletal damage or injury due to inappropriate working practices
  - Insect vector- and rodent-control (e.g. screening or use of larvicides, insecticides) at storage sites
  - Protect workers from long term exposure to sunlight
  - Farmers using the soil conditioner should be advised to wear boots and gloves when applying the compost
  - Restrict access to the operations
  - Implement a worker well-being programme that includes regular sessions (e.g. weekly) where general health concerns are reported and health protection measures are promoted (e.g. regular hand washing, purpose of PPE and sun protection, ergonomic hazards, etc.)

4.9.1.2 *Residual risks*

By implementing all the proposed control measures, the identified health risks of Model 16 can be reduced to **low and moderate levels**. The residual risks are linked to the following processes:

- P1: pre-processing of MSW: rigorous discharging of any human, animal or chemical waste, as well as sharp objects is essential for assuring quality and safety of the organic fraction
- P2: composting: in order to avoid exposure of consumers to pathogens in the soil conditioner, it will be crucial to respect the temperature and duration indicated for the composting
- P2: composting: to ensure that workers are protected with respirators is important when handling the waste materials for the co-composting process. Otherwise pathogens, fungi and dust affect their respiratory system
- P2: composting: sharps ending up in the soil conditioner pose a moderate risk to users. Soil conditioner must be sieved before packaging and users need to be sensitised about the potential presence of sharp objects and pathogens in the soil conditioner. In addition, users need to be advised to wear boots and gloves when applying the soil conditioner.
- **Medical waste must be collected separately for keeping it out of the BM**

4.9.2 Health impact assessment

By reducing the load of MSW ending up on landfills, the business will indirectly impact people who are currently exposed to landfills (waste pickers or surrounding communities).

- **Scale of the BM:**the model ranks high on scalability as it can be implemented anywhere in communities having cooperatives visions. Hence, the HIA of Model 16 is assuming that a waste volume of 10,000 households will be collected by the business

4.9.2.1 *Impact 1: health benefits due to reduced MSW loads on landfills*

➔ For the impact definition, see Model 15, impact 2 (section 4.8.2.2).

Impact 1, assumptions:

- **Impact level:** various pathologies are associated with landfills
- **People affected:** an estimated 500 waste pickers work on the landfills that would be affected by the business
- **Likelihood:** it is very unlikely that the business will make a difference in disease incidence

Table 54 – Model 16, impact 1: health benefits due to reduced MSW loads on landfills

	Impact level (IL)	**People affected** (PA)	**Likelihood or frequency** (LoF)	**Magnitude** (ILxPAxL)
Category	Minor positive impact	Specific population group	Very unlikely	**Minor positive impact**
Score: farmers	0.5	500	0.05	**12.5**

4.9.3 Environmental Impact Assessment

Potential negative environmental impacts include: (1) accumulated waste resulting from separation of inorganic fractions from MSW prior to composting and disposed of or used improperly, and (2) leachate from the composting process, which if moisture is not well controlled can leach into the environment.. Mitigation measures to avoid negative impacts include: (1) storage, transport and disposal at a designated recycling facility or solid waste discharge site (sanitary landfill), and (2) appropriate moisture control of the compost heap and/or collection of leachate and post-treatment. Further details on technology options are outlined in the "Technology Assessment Report" [2].

Table 55 – Model 16: potential environmental hazards and proposed mitigation measures

Waste stream	**End-product**	**Technologies**	**Process**	**Pot. Env. Hazard**	**Mitigation measures**
• MSW	• Soil Conditioner	• Windrow (static/turned) • In-Vessel • Inclined step grades • Vermi-composting	• Compo-sting	• Accumulated inorganic waste • Leachate from composting	• Storage/transport/ disposal (sanitary landfill) • Moisture control • Leachate treatment

4.10 Model 17 – High value fertilizer production for profit

The difference between Model 17 and Model 15 (analysed above) are:

- the input faecal sludge is combined with animal manure; and
- nitrogen (N), phosphorus (P) and potassium (K) (NPK) are added for the co-composting in order to produce branded/certified organic fertilizer

From a health protection and health impact perspective, these two modifications to Model 15 do not make any difference. Therefore, the HRIA of Model 15 also applies to Model 17.

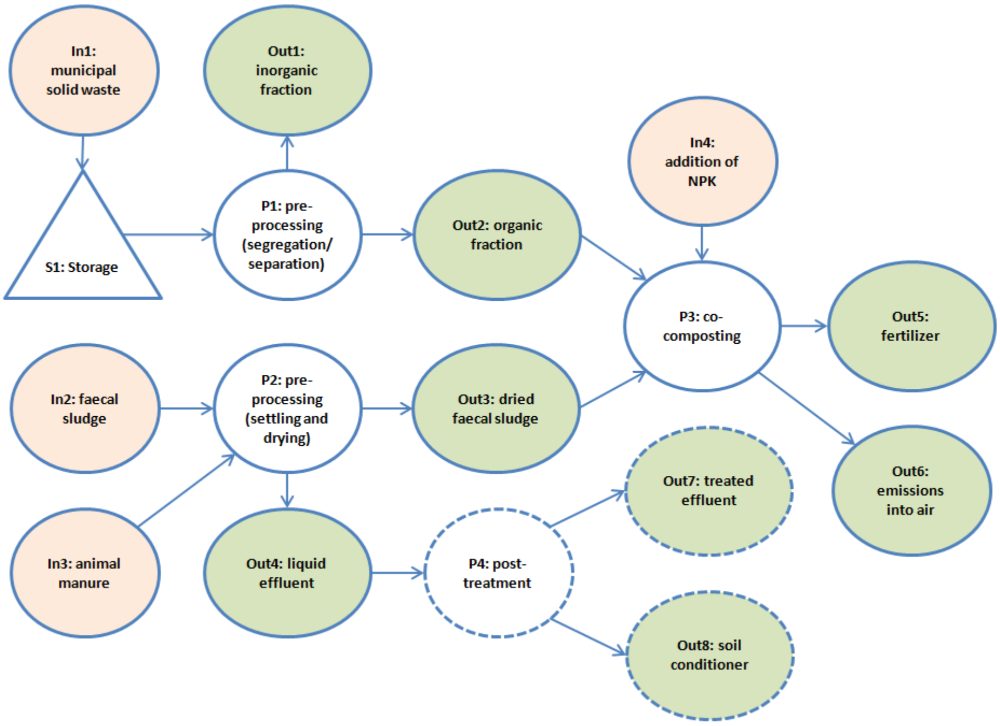

Figure 22 – Model 17: system flow diagram

Table 56 – Model 17: Inputs and associated potential health hazards

Inputs of health relevance	Potential hazards
In1: municipal solid waste	Contamination with pathogens deriving from human and animal waste (viruses and bacteria are of primary concern)
	Contamination with sharp objects
	Contamination with medical waste
	Contamination with chemical waste
In2: faecal sludge	Pathogens
	Contamination with sharp objects and inorganic waste
In3: animal manure	Pathogens
In4: addition of NPK	None

Table 57 – Model 17: Quality/safety requirements for outputs

Outputs of health relevance	Quality/safety requirements
Out1: inorganic fraction	None since considered as waste → appropriate disposal/recycling
Out2: organic fraction	N.a. (within system)
Out3: dried faecal sludge	N.a. (within the system)
Out4: liquid effluent	N.a. (within the system)
Out5: dried sludge	N.a. (within the system)
Out5: fertilizer	For agricultural use: • <1 helminthic egg per 1 gram total solids; and <10^3 *E. coli* per gram total solids • Indian quality standards for organic fertilizer are available in Annex V

Out6: emissions into air	Ambient air quality standards[a]: • $PM_{2.5}$: 10 µ/m^3 24-hour mean; 25 µ/m^3 annual mean • PM_{10}: 20 µ/m^3 24-hour mean; 50 µ/m^3 annual mean • Ozone: 100 µ/m^3 8-hour mean • NO_2: 200 µ/m^3 1-hour mean; 40 µ/m^3 annual mean • SO_2: 500 µ/m^3 10-minutes mean; 20 µ/m^3 24-hour mean
Out7: treated effluent	**Unrestricted irrigation** Root crops: • <10^3 *E. coli* per litre and <1 helminthic egg per litre Leave crops: • <10^4 *E. coli* per litre and <1 helminthic egg per litre Drip irrigation of high-growing crops: • <10^5 *E. coli* per litre and <1 helminthic egg per litre Drip irrigation of low-growing crops: • <10^3 *E. coli* per litre and <1 helminthic egg per litre **Restricted irrigation** Labour intensive agriculture: • <10^4 *E. coli* per litre and <1 helminthic egg per litre Highly mechanized agriculture: • <10^5 *E. coli* per litre and <1 helminthic egg per litre ➔ Chemical indicators in treated wastewater and receiving soils must not exceed thresholds as per WHO Guidelines (see Annex V)
Out8: soil conditioner	For agricultural use: • <1 helminthic egg per 1 gram total solids; and <10^3*E. coli* per gram total solids • Indian quality standards for organic fertilizer are available in Annex V

[a] WHO (2005). Air quality guidelines - global update 2005. Geneva: World Health Organization

4.10.1 Health risk assessment

➔ Same as for Model 15 (section4.8.1)

4.10.2 Health impact assessment

➔ Same as for Model 15 (section4.8.2)

4.10.3 Environmental Impact Assessment

Potential negative environmental impacts include: (1) accumulated waste resulting from separation of inorganic fractions from MSW prior to composting and disposed of or used improperly (2) leachate from the composting process, which if moisture is not well controlled can leach into the environment, (3) insufficient pathogen inactivation, which may occur when temperatures are not well control over a sufficient period of time, and (4) liquid effluent from FS treatment, which when leaching into the environment can have a negative impact due to high nutrient and organic matter concentrations. Mitigation measures to avoid negative impacts include: (1) storage, transport and disposal at a designated recycling facility or solid waste discharge site (sanitary landfill), (2) appropriate moisture control of the compost heap and/or collection of leachate and post treatment, (3) temperature control of the compost heap to ensure sufficient pathogen inactivation, and (4) post-treatment of the liquid effluent from FS dewatering processes. The goal of RRR based businesses should be full resource recovery of all End-products, which implies end-use of appropriately treated liquid effluent from post-treatment of liquid effluent from FS dewatering processes. If for some reason this is not feasible, only then should treated liquid effluent from FS dewatering processes get discharged into the environment presuming that it complies with local standards for discharge into the environment. Further details on technology options are outlined in the "Technology Assessment Report" [2].

Table 58 – Model 17: potential environmental hazards and proposed mitigation measures

Waste stream	End-product	Technologies	Process	Pot. Env. Hazard	Mitigation measures
• MSW • FS	• Fertilizer (NPK added)	• Solid/liquid separation • Drying beds • Co-composting	• Co-com-posting (MSW + FS)	• Accumulated inorganic waste • Leachate from composting • Insufficient pathogen inactivation • Liquid effluent (from FS treatment)	• Storage/transport/disposal (sanitary landfill) • Moisture control • Leachate treatment • Temperature control (compost heap) • Post-treatment of liquid effluent

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6 Appendices

6.1 Appendix I – Health risk assessment tables

6.1.1 Model 1a – Dry fuel manufacturing: agro-industrial waste to briquettes

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
S1: storage P1: pre-processing (handling and separation) P2: drying	Biological hazards	Pathogens	Agro-waste is contaminated with faeces or urine	Hand to mouth	PPE	3	2	Moderate	4	2	**Moderate risk (8)**
					Use of tools	3	3	High			
					Separation and discharge of any faecally contaminated agro-waste	2	3	Moderate			
				Inhalation	PPE	3	2	Moderate			
		Rodents and insect vectors	Rodents or insect vectors are attracted by agro-waste and are thus a risk for diseases transmission	Hand to mouth, vectors living on rodents	Rodent and vector control at storage sites	3	2	Moderate	2	2	**Low risk (4)**
					Use of tools	2	3	Moderate			
	Chemical hazards	Toxic gases	**At consumer level:** burning of inorganic contaminants bound in briquettes at household level	Inhalation	Separation and discharge of any inorganic contaminants	2	3	Moderate	4	1	**Low risk (4)**
	Physical hazards	Sharp objects	Skin cuts when handling agro-waste	Skin contact	PPE	3	2	High	4	2	**Moderate risk (8)**
P3: Carbonization	Chemical hazards	Toxic gases	Inhalation of toxic gases at workplace and community	Inhalation	PPE (gas mask respirators)	3	2	Moderate	4	3	**Moderate risk (12)**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures	TE	Acc	Mitigation potential	IL	LoF	Residual risk
			level		Install CO monitors around the plant	2	2	Moderate			
					Respect a buffer zone between operation and community infrastructure so that ambient air quality standards are not exceeded (see table with quality/safety requirements for outputs)	3	2	Moderate			
	Physical hazards	Heat	Worker gets in contact with fire or hot surface	Skin contact	PPE	3	2	Moderate	2	2	**Low risk (4)**
					Use of tools	3	3	High			
					Heat shields	3	3	High			
P4: Briquetting P5: Drying and packaging	Physical hazards	Dust	Long time exposure to dust	Inhalation	PPE	3	2	Moderate	2	2	**Low risk (4)**
		Injuries	Accidents while operating technical processes	Injury to the body	Education of workers handling technical processes	2	2	Moderate	8	1	**Moderate risk (8)**
					PPE	3	2	Moderate			
		Noise	Noise in exceed of OH limits	Air	PPE	3	2	Moderate	2	2	**Low risk (4)**
			Noise exposure at community level	Air	Respect a buffer zone between the operation and community houses so that noise levels at community level do not exceed 55dB during the day and 45dB at night. The actual distance is depending on the noise emitted by the operation and can easily be calculated.	3	2	Moderate	2	2	**Low risk (4)**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
Generalities	Physical hazard	Radiation	Long-time exposure of workers to direct sunlight	Environmental	Protect workers from long-term exposure to sun light	2	2	Moderate	4	2	**Moderate risk (8)**
	Various	Various	Workers are getting ill due to exposure to pathogens and chemical hazards or unhealthy working practices	Various	Implement a worker well-being programme that includes regular sessions where general health concerns are reported and health protection measures are promoted (e.g. regular hand washing, purpose of PPE and sun protection, ergonomic hazards etc.)	2	2	Moderate	4	3	**Moderate risk (12)**
	Various	Various	People from the community access the plant and get hurt, are exposed to pathogens or other hazards	Injury to the body, hand to mouth, inhalation	Restrict access to operations for external individuals	3	3	High	4	1	**Low risk (4)**
	Physical hazard	e.g. rotating parts	Workers interfere with processes they are not familiar with and get hurt	Injury to the body	Restrict access to technical processes to workers that are operating the process	3	3	High	4	1	**Low risk (4)**
	Physical hazard	Ergonomic hazards	Workers suffer of musculoskeletal damage due to inappropriate working practices	Injury to the body	Worker education for preventing musculoskeletal damage due to inappropriate working practices	2	2	Moderate	4	2	**Moderate risk (8)**

6.1.2 *Model 4 – Onsite energy generation by sanitation service providers*

					Control measures				Risk assessment		
Element of the process	**Category**	**Hazard(s)**	**Hazardous event**	**Exposure route**		**TE**	**Acc**	**Mitigation potential**	**IL**	**LoF**	**Residual risk**
P1: Toilets	Physical hazards	Sharp objects	**At consumer level:** Exposure of users of the soil conditioner to sharp object (blades, syringes)	Skin contact	Place clearly visible signs on toilets that prohibit disposal of any sharp object and inorganic waste into the toilet	2	2	Moderate	4	3	**Moderate risk (12)**
					Provide trash bins for disposal of sharp objects and inorganic waste components in each toilet	2	2	Moderate			
P2: anaerobic digestion	Biological hazards	Pathogens	N. a.	N.a.	Anaerobic digestion at >35°C for >9day (1 log reduction *E. coli* and 0 log reduction in helminthic eggs) [a]	Since anaerobic digestion is done under mesophilic conditions, it is not considered as a control measure					
			Accidental contact while handling the faecal sludge/slurry	Hand to mouth	PPE	3	2	Moderate	2	2	**Low risk (4)**
					Use of tools	3	3	High			
	Chemical hazards	Toxic gases	Inhalation of toxic gases at workplace level	Inhalation	PPE	3	2	Moderate	4	2	**Moderate risk (12)**
					Prevent gas leakage	3	3	High			
					Install CO monitors around the plant	2	2	Moderate			
					Assure ventilation of plant	2	3	Moderate			
			Inhalation of toxic gases at community level		Respect a buffer zone between operation and community infrastructure so that ambient air quality standards are not exceeded (see table with quality/safety requirements for outputs)	3	2	Moderate	4	1	**Low risk (4)**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures	TE	Acc	Mitigation potential	IL	LoF	Residual risk
	Physical hazards	Sharp objects	Exposure to sharp objects when handling the anaerobic sludge	Skin contact	PPE	3	2	Moderate	4	1	**Low risk (4)**
					Use of tools	3	3	High			
P3: gas-based generator	Chemical	Toxic gases	Inhalation of toxic gases at workplace level	Inhalation	Ensure that exhausts are released to the outside	3	3	High	4	1	**Low risk (4)**
					Install CO monitors around the plant	2	2	Moderate			
	Physical hazards	Fire/explosion	A fire or explosion occurs due to gas leakage, etc.		Develop and implement fire/explosion response plan	3	3	High	16	1	**High risk (16)**
		Heat	Worker gets in contact with fire or hot surface	Skin contact	PPE	3	2	Moderate	2	2	**Low risk (4)**
					Heat shields	3	3	High			
		Injuries	Accidents while operating technical processes	Injury to the body	Education of workers handling technical processes	2	2	Moderate	4	1	**Low risk (4)**
					PPE	3	2	Moderate			
		Noise	Noise in exceed of OH limits	Air	PPE	3	2	Moderate	4	3	**Moderate risk (12)**
			Noise exposure at community level		Respect a buffer zone between the operation and community houses so that noise levels at community level do not exceed 55dB during the day and 45dB at night. The actual distance is depending on the noise emitted by the operation and can easily be calculated.	3	2	Moderate	4	3	**Moderate risk (12)**
		Electricity	Electric shock of a worker	Skin	Use of intrinsically safe	3	3	High	16	1	**High risk**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
				contact	electrical installations; non-sparking tools and proper grounding.						**(16)**
P4: post-treatment	Biological hazards	Pathogens	Downstream exposure: - Accidental intake of contaminated liquid effluent from the plant - Ingestion of produce that is irrigated with unsafe liquid effluent or fertilized with unsafe soil conditioner	Acciden-tal ingestion	Depending on the further use of the outputs of the post-treatment, the following post-treatment options are proposed: Off-site (i.e. discharge): ➢ Drain/transfer effluents/sludge into an existing WWTP for co-treatment ➢ Discharge sludge on landfill On-site (in case of agricultural reuse of the outputs, a combination of the following options will be required for achieving the required quality standard (see table with quality/safety requirements for outputs)): ➢ Septic tank (≥1 log reduction of *E. coli* and ≥2 log reduction in helminthic eggs) ➢ Anaerobic baffled reactor (≥1 log reduction of *E. coli* and ≥2 log reduction in helminthic eggs) ➢ Anaerobic filter(≥1 log reduction of *E. coli* and ≥2 log reduction in helminthic eggs) ➢ Constructed/vertical flow wetland (≥0.5-3 log reduction of *E. coli* and ≥1-3 log reduction in helminthic eggs) ➢ Planted gravel Filter ➢ Unplanted gravel Filter ➢ Planted/unplanted drying beds (1-3 log reduction in helminthic eggs)						
			Accidental contact with pathogens while operating the post-treatment components	Hand-to-mouth	PPE	3	2	Moderate	4	2	**Moderate risk (8)**
		Disease vectors	Storage sites/treatment ponds serve as vector breeding sites	Insect bites	Prevent mosquito breeding at storage sites and/or treatment ponds	2	2	Moderate	2	2	**Low risk (4)**
	Physical hazard	Sharp objects	**At consumer level:** Exposure of users of the soil conditioner to sharp	Skin contact	Careful sieving of the sludge/soil conditioner before packaging	2	3	Moderate	4	3	**Moderate risk (12)**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
			object (blades, syringes)		Place clearly visible danger signs on the packaging, indicating the risk of sharp objects and that users need to wear gloves and boots when applying the product	2	1	Low			
Generalities	Various		People from the community access the plant and get hurt, are exposed to pathogens or other hazards	Injury to the body, hand to mouth, inhalation	Restrict access to operations for external individuals	3	3	High	8	1	**Moderate risk (8)**
	Physical hazard		Workers suffer of musculoskeletal damage due to inappropriate working practices	Injury to the body	Worker education for preventing musculoskeletal damage due to inappropriate working practices	2	2	Moderate	2	2	**Low risk (4)**

6.1.3 Model 6 – Manure to power

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
P1: anaerobic digestion	Biological hazards	Pathogens	N. a.	N.a.	Anaerobic digestion at >35°C for >9day (1 log reduction E. coli and 0 log reduction in helminthic eggs) [a]	Since anaerobic digestion is done under mesophilic conditions, it is not considered as a control measure					
			Accidental contact while handling the animal manure	Hand to mouth	PEE	3	2	Moderate	2	2	**Low risk (4)**
					Use of tools	3	3	High			
	Chemical hazards	Toxic gases	Inhalation of toxic gases at workplace level	Inhalation	PPE	3	2	Moderate	4	1	**Low risk (4)**
					Prevent gas leakage	3	3	High			
					Install CO monitors around the plant	2	2	Moderate			
					Assure ventilation of plant	2	3	Moderate			
			Inhalation of toxic gases at community level		Respect a buffer zone between operation and community infrastructure so that ambient air quality standards are not exceeded (see table with quality/safety requirements for outputs)	3	2	Moderate	4	1	**Low risk (4)**
	Physical hazards	Sharp objects	Exposure to sharp objects when handling the anaerobic sludge	Skin contact	PPE	3	2	Moderate	4	1	**Low risk (4)**
					Use of tools	3	3	High			
P2: gas-based generator	Chemical	Toxic gases	Inhalation of toxic gases at workplace level	Inhalation	Ensure that exhausts are released to the outside	3	3	High	4	1	**Low risk (4)**
					Install CO monitors around the plant	2	2	Moderate			
	Physical	Fire/explos	A fire or explosion occurs		Develop and implement	3	3	High	16	1	**High risk**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures	TE	Acc	Mitigation potential	IL	LoF	Residual risk
	hazards	ion	due to gas leakage, etc.		fire/explosion response plan						(16)
		Heat	Worker gets in contact with fire or hot surface	Skin contact	PPE	3	2	Moderate	2	2	Low risk (4)
					Heat shields	3	3	High			
		Injuries	Accidents while operating technical processes	Injury to the body	Education of workers handling technical processes	2	2	Moderate	4	1	Low risk (4)
					PPE	3	2	Moderate			
		Noise	Noise in exceed of OH limits	Air	PPE	3	2	Moderate	4	3	Moderate risk (12)
			Noise exposure at community level		Respect a buffer zone between the operation and community houses so that noise levels at community level do not exceed 55dB during the day and 45dB at night. The actual distance is depending on the noise emitted by the operation and can easily be calculated.	3	2	Moderate	4	3	Moderate risk (12)
		Electricity	Electric shock of a worker	Skin contact	Use of intrinsically safe electrical installations; non sparking tools and proper grounding.	3	3	High	16	1	High risk (16)

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
P3: post-treatment	Biological hazards	Pathogens	Downstream exposure: - Accidental intake of contaminated liquid effluent from the plant - Ingestion of produce that is irrigated with unsafe liquid effluent or fertilized with unsafe soil conditioner	Acciden-tal ingestion	Depending on the further use of the outputs of the post-treatment, the following post-treatment options are proposed: <u>Off-site (i.e. discharge):</u> ➢ Drain/transfer effluents/sludge into an existing WWTP for co-treatment ➢ Discharge sludge on landfill <u>On-site (in case of agricultural reuse of the outputs, a combination of the following options will be required for achieving the required quality standard (see table with quality/safety requirements for outputs)):</u> ➢ Septic tank (≥1 log reduction of E. coli and ≥2 log reduction in helminthic eggs) ➢ Anaerobic baffled reactor (≥1 log reduction of E. coli and ≥2 log reduction in helminthic eggs) ➢ Anaerobic filter(≥1 log reduction of E. coli and ≥2 log reduction in helminthic eggs) ➢ Constructed/vertical flow wetland (≥0.5-3 log reduction of E. coli and ≥1-3 log reduction in helminthic eggs) ➢ Planted gravel Filter ➢ Unplanted gravel Filter ➢ Planted/unplanted drying beds (1-3 log reduction in helminthic eggs)						
			Accidental contact with pathogens while operating the post-treatment components	Hand-to-mouth	PPE	3	2	Moderate	4	2	**Moderate risk (8)**
		Disease vectors	Storage sites/treatment ponds serve as vector breeding sites	Insect bites	Prevent mosquito breeding at storage sites and/or treatment ponds	2	2	Moderate	4	2	**Moderate risk (8)**
Generalities	Various		People from the community access the plant and get hurt, are exposed to pathogens or other hazards	Injury to the body, hand to mouth, inhalation	Restrict access to operations for external individuals	3	3	High	8	1	**Moderate risk (8)**
	Physical		Workers suffer of	Injury to	Worker education for	2	2	Moderate	2	2	**Low risk**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures	TE	Acc	Mitigation potential	IL	LoF	Residual risk
	hazard		musculoskeletal damage due to inappropriate working practices	the body	preventing musculoskeletal damage due to inappropriate working practices						(4)

6.1.4 *Model 8 – Beyond cost recovery: the aquaculture example*

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures	TE	Acc	Mitigation potential	IL	LoF	Residual risk
P1: duckweed pond	Biological hazards	Pathogens	Wastewater contaminated with faeces or urine	Hand to mouth	PPE	3	2	Moderate	4	1	**Low risk (4)**
					Use of tools	3	3	High			
				Inhalation	PPE	3	2	Moderate			
	Chemical hazards	Chemicals and heavy metals	**Consumer level:** Treated wastewater is used for irrigation, where heavy metals may impact on soil quality and accumulate in crops	Ingestion	In case chemical indicators of the wastewater or receiving soils exceed national threshold values (see annex IV), **the treated wastewater is not suitable for irrigation**	**Not a control measure but a pre-condition**					
	Physical hazards	Sharp objects	Skin cuts when handling sludge in subsequent processes	Skin contact	Mechanical screening of the wastewater before entering the duck-week pond	2	3	Moderate	4	1	**Low risk (4)**
					Use of PPE when handling the screened material	3	2	Moderate			
		Inorganic	Contamination of sludge	Environm	Mechanical screening of	2	3	Moderate	1	3	**Low risk**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
		waste	with inorganic waste	ental hazard	the wastewater before entering the duck-week pond						**(4)**
P2: Stabilisation ponds	Biological hazards	Bacteria, viruses, protozoa and helminths	**Downstream issue:** Fish is contaminated with pathogens Unsafe wastewater is used for irrigation	Hand to mouth and ingestion	Three stabilization ponds are needed for producing treated wastewater: 1.) Anaerobic stabilisation pond (1-3 days) 2.) Facultative pond (4-10 days) 3.) Aquaculture (→ P3)	3	2	Moderate	4	2	**Moderate risk (8)**
P3: aquaculture	Biological hazards	Pathogens	Fish is contaminated with pathogens	Hand to mouth and ingestion	Store duckweed for at least 30 days under dry conditions prior to addition to the fish pond	2	2	Moderate	4	2	**Moderate risk (8)**
					Depuration of fish before harvesting by moving fish to a clean pond for at least 2-3 weeks	2	2	Moderate			
	Chemical hazards	Chemicals	Fish is contaminated with chemicals (e.g. heavy metals)	Ingestion	Harvest fish at young age	3	2	Moderate	2	1	**Low risk (4)**
P4: drying beds	Biological hazards	Pathogens	Pathogens enter the co-composting process and ultimately pose risk to the users of the compost	Hand to mouth	Storage treatment at 2-20°C: 1.5-2 years [a]	3	2	Moderate	4	3	**Moderate risk (12)**
					Storage treatment at 20-35°C: >1 years [a]	3	2	Moderate			
					Storage treatment at pH>9 (alkaline treatment): >35°C; and moisture <25%: >6 months [a]	3	2	Moderate			
			Accidental contact while handling the sludge	Hand to mouth	PPE	3	2	Moderate	4	2	**Moderate risk (8)**
					Use of tools	3	3	High			

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
		Disease vectors	Flies feeding on faecal matter and transmitting disease	Vectors	Screening of drying beds	3	2	Medium	2	2	**Low risk (4)**
	Biological	Vector-borne diseases	Mosquitoes and flies breed in ponds and consequently increase the risk for transmission of vector-borne diseases	Mosquito bites	Prevent mosquito breeding in treatment ponds	2	2	Moderate	4	2	**Moderate risk (8)**

6.1.5 *Model 9 – On cost savings and recovery*

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
P1: wastewater treatment plant	Biological hazards	Pathogens	**Downstream exposure:** - Accidental intake of contaminated liquid effluent from the plant - Ingestion of produce that is irrigated with unsafe liquid effluent	Acciden-tal ingestion	Primary, secondary and tertiary treatment has to be applied for reducing pathogens. Different options can be combined for reaching a minimum of 7 log reduction in bacterial indicators (e.g. *E. coli*) and 3 log reductions in helminthic eggs.	3	3	High	4	1	**Low risk (4)**
		Pathogens	Accidental contact with pathogens while operating the wastewater treatment plant	Hand-to-mouth and inhalation	PPE	3	2	Moderate	4	2	**Moderate risk (8)**
					Use of tools	3	3	High			
		Disease vectors	Treatment ponds serve as vector breeding sites	Insect bites	Prevent mosquito breeding in ponds	2	2	Moderate	4	3	**Moderate risk (12)**
	Chemical hazards	Chemicals, including heavy metals	**Downstream exposure:** Treated wastewater is used for irrigation, where heavy metals may impact on soil quality and accumulate in crops	Ingestion	In case chemical indicators of the wastewater or receiving soils exceed WHO Guidelines threshold (see annex V):						
					Option A.) Apply a physico-chemical removal process (e.g. absorption)	3	1	Low	4	4	**High risk (16)**
					Option B.) Do not promote the treated wastewater for irrigation	2	1	Low	4	4	**High risk (16)**
		Heavy metals	**Downstream exposure:** Poor sludge quality results in contaminated fertilizer	Ingestion	In case the sludge does not comply with heavy metal thresholds (see	2	1	Low	4	4	**High risk (16)**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures	TE	Acc	Mitigation potential	IL	LoF	Residual risk
					Annex V) physico-chemical removal process must be applied. **Otherwise the sludge must not be further processed for producing fertilizer**						
	Physical hazards	Sharp objects	Workers are hurt or drown during operation of the plant	Injury to the body	PPE	3	2	Moderate	5	1	**Moderate risk (5)**
					Use of tools	3	3	High			
					Installation of handrails and fencing of dangerous areas	3	3	High			
P2: dewatering	Biological hazards	Pathogens	Pathogens enter the co-composting process and ultimately pose risk to the users of the compost	Hand to mouth	Storage treatment at 2-20°C: 1.5-2 years [a]	3	2	Moderate	4	3	**Moderate risk (12)**
					Storage treatment at 20-35°C: >1 years [a]	3	2	Moderate			
					Storage treatment at pH>9 (alkaline treatment): >35°C; and moisture <25%: >6 months [a]	3	2	Moderate			
			Accidental contact while handling the sludge	Hand to mouth	PPE	3	2	Moderate	4	2	**Moderate risk (8)**
					Use of tools	3	3	High			
		Disease vectors	Flies feeding on faecal matter and transmitting disease	Vectors	Screening of drying beds	3	2	Moderate	4	2	**Moderate risk (8)**
P3: co-composting	Biological hazards	Pathogens	Sludge and organic-waste is contaminated with pathogens (e.g. chicken waste → campylobacter, salmonella)	Hand to mouth	PPE	3	2	Moderate	4	1	**Low risk (4)**
					Use of tools	3	3	High			
			Downstream exposure: Those that apply the	Hand to mouth	≥45°C for ≥5 days (2 log reductions in bacteria and	3	2	Moderate	4	2	**Moderate risk (8)**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures	TE	Acc	Mitigation potential	IL	LoF	Residual risk
			compost are exposed to pathogens such as *E. coli* and helminthic eggs	and inhalation	<1 viable helminthic eggs per g dried matter)						
					Advice farmers to wear boots and gloves when applying the compost	3	2	Moderate			
		Thermophilic fungi and actino-mycetes	Inhalation of airborne spores	Inhalation	PPE	3	2	Moderate	4	3	**Moderate risk (12)**
					Moisture (>40%) control for reducing bio-aerosol emission	3	2	Moderate			
		Malodors	Exposure to malodors	Inhalation	PPE	2	2	Moderate	2	2	**Low risk (4)**
					Good ventilation of working area	2	3	Moderate			
	Physical	Dust	Long-term exposure to dust	Inhalation	PPE	3	2	Moderate	2	2	**Low risk (4)**
		Sharp objects and inorganic waste	Skin cuts when handling organic solid waste	Skin contact	Separate and discharge contaminated organic solid waste	2	2	Moderate	4	2	**Moderate risk (8)**
Generalities	Biological	Vector-borne diseases	Mosquitoes breed in ponds and consequently increase the risk for transmission of vector-borne diseases	Mosquito bites	Prevent mosquito breeding in treatment ponds	2	2	Moderate	4	2	**Moderate risk (8)**
	Physical		Physical injury of workers		Prevent the risk of drowning in ponds by means of PPE, worker education and only employ workers that know how to swim	3	3	High	8	1	**Moderate risk (6)**

6.1.6 *Model 10 – Informal to formal trajectory in wastewater irrigation: incentivizing safe reuse of untreated wastewater*

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
P1: drainage system P2: pumping station	Biological hazards	Pathogens	**Downstream exposure**: Flooding event results in exposure to pathogens	Hand to mouth and acciden-tal ingestion	Complement drainage system with a pre-treatment facility (e.g. screening and grease traps) for preventing backups and overflows.	3	3	High	4	1	**Low risk (4)**
					Regular cleaning of the drainage system for preventing clogging and overflow	2	3	Moderate	4	1	**Low risk (4)**
					Regulate the flow of the pumping station for preventing overflowing in subsequent processes	3	3	High	4	1	**Low risk (4)**
P3a: slow rate infiltration P3b: rapid infiltration	Biological hazards	Pathogens	**Downstream exposure:** - Accidental intake of contaminated liquid effluent from the plant - Ingestion of produce that is irrigated with unsafe liquid effluent	Hand to mouth and acciden-tal ingestion	**Monitor wastewater quality, which needs to comply with the following parameters given for sub-surface irrigation** $<10^6$ *E. coli* per litre and <1 helminthic egg per litre	2	2	Moderate	4	2	**Moderate risk (8)**
			Groundwater is contaminated by the infiltrated untreated wastewater	Ground-water contamin ation	Hydrology study to be done before building an infiltration technology						
	Chemical hazards	Chemicals, including heavy metals	**Downstream exposure:** Treated wastewater is used for irrigation, where heavy metals may impact on soil quality and	Ingestion	**Monitor chemical parameters in wastewater and receiving soils which must not exceed** WHO						

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
			accumulate in crops		Guidelines threshold (see annex X)						
			Groundwater is contaminated by the infiltrated untreated wastewater	Ground-water contamination	Hydrology study to be done before building an infiltration technology						
P3c: overland flow	Biological hazards	Pathogens	**Downstream exposure:** - Accidental intake of contaminated water from the plant - Ingestion of produce that is irrigated with unsafe liquid effluent - Skin penetration by pathogens transferred by water - Skin diseases	Hand to mouth, acciden-tal ingestion, skin penetration and skin contact	**Monitor wastewater quality, which needs to comply with the parameters given for root crops (**<10^3 *E. coli* per litre and <1 helminthic egg per litre) **or leave crops** (<10^4 *E. coli* per litre and <1 helminthic egg per litre).	2	2	Moderate	4	4	**High risk (16)**
					Advice farmers to wear boots and gloves when working in the irrigated fields.						
					Advice farmers to respect 2 days between last irrigation and harvesting.						
					Advise farmers to wash harvested crops with fresh water						
	Chemical hazards	Chemicals, including heavy metals	**Downstream exposure:** Treated wastewater is used for irrigation, where heavy metals may impact on soil quality and accumulate in crops	Ingestion	**Monitor chemical parameters in wastewater and receiving soils which must not exceed** WHO Guidelines threshold (see annex X)						

					Control measures				**Risk assessment**		
Element of the process	**Category**	**Hazard(s)**	**Hazardous event**	**Exposure route**		**TE**	**Acc**	**Mitigation potential**	**IL**	**LoF**	**Residual risk**
P3d: wetland application	Biological hazards	Pathogens	**Downstream exposure:** - Accidental intake of contaminated water from the plant - Ingestion of produce that is irrigated with unsafe liquid effluent - Skin penetration by pathogens transferred by water - Skin diseases	Hand to mouth, acciden-tal ingestion, skin penetration and skin contact	**Monitor wastewater quality prior to entering the wetland, which needs to comply with the parameters given for root crops (**$<10^4$ *E. coli* per litre and <10 helminthic egg per litre) or **leave crops** ($<10^5$ *E. coli* per litre and <10 helminthic egg per litre). Advice farmers to wear boots and gloves when working in the irrigated fields. Advice farmers to respect 2 days between last irrigation and harvesting. Advise farmers to wash harvested crops with fresh water	2	2	Moderate	4	3	**Moderate risk (12)**
P4a: slow rate infiltration P3b: rapid infiltration	Biological hazards	Pathogens	Groundwater is contaminated by the infiltrated untreated wastewater	Ground-water contamination	Hydrology study to be done before building an infiltration technology						
	Chemical hazards	Chemicals, including heavy metals	Groundwater is contaminated by the infiltrated untreated wastewater	Environmental							

6.1.7 *Model 11 – Intersectoral water exchange*

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
T1a: drainage system	For this business model it is assumed that the input is treated wastewater of a quality that is compliant with WHO 2006 guidelines standards				Regular cleaning of the drainage system for preventing clogging and overflow	2	3	Moderate	4	1	**Low risk (4)**
					Regulate the flow of the pumping station for preventing overflowing in subsequent processes	3	3	High	4	1	**Low risk (4)**
P1a: slow rate infiltration P1b: rapid infiltration	Biological hazards	Pathogens	**Downstream exposure:** - Accidental intake of contaminated liquid effluent from the plant - Ingestion of produce that is irrigated with unsafe liquid effluent	Hand to mouth and acciden-tal ingestion	**Monitor wastewater quality, which needs to comply with the following parameters given for sub-surface irrigation** $<10^6$ E. coli per litre and <1 helminthic egg per litre	2	2	Moderate	4	1	**Low risk (4)**
			Groundwater is contaminated by the infiltrated untreated wastewater	Ground-water contamin ation	Hydrology study to be done before building an infiltration technology						
	Chemical hazards	Chemicals, including heavy metals	**Downstream exposure:** Treated wastewater is used for irrigation, where heavy metals may impact on soil quality and accumulate in crops	Ingestion	**Monitor chemical parameters in wastewater and receiving soils which must not exceedWHO Guidelines threshold** (see annex V)						
			Groundwater is contaminated by the infiltrated untreated wastewater	Ground-water contamin ation	Hydrology study to be done before building an infiltration technology						

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
P1c: overland flow	Biological hazards	Pathogens	**Downstream exposure:** - Accidental intake of contaminated water from the plant - Ingestion of produce that is irrigated with unsafe liquid effluent - Skin penetration by pathogens transferred by water - Skin diseases	Hand to mouth, acciden-tal ingestion, skin penetration and skin contact	**Monitor wastewater quality, which needs to comply with the parameters given for root crops (**<10^3 E. coli per litre and <1 helminthic egg per litre) **or leave crops** (<10^4 E. coli per litre and <1 helminthic egg per litre). Advice farmers to wear boots and gloves when working in the irrigated fields. Advice farmers to respect 2 days between last irrigation and harvesting. Advise farmers to wash harvested crops with fresh water	2	2	Moderate	4	2	**Moderate risk (8)**
	Chemical hazards	Chemicals, including heavy metals	**Downstream exposure:** Treated wastewater is used for irrigation, where heavy metals may impact on soil quality and accumulate in crops	Ingestion	**Monitor chemical parameters in wastewater and receiving soils which must not exceed** WHO Guidelines threshold (see annex X)						
P1d: wetland application	Biological hazards	Pathogens	**Downstream exposure:** - Accidental intake of contaminated water from the plant - Ingestion of produce that is irrigated with	Hand to mouth, acciden-tal ingestion, skin	**Monitor wastewater quality prior to entering the wetland, which needs to comply with the parameters given for root crops (**<10^4 E. coli	2	2	Moderate	4	1	**Low risk (4)**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
			unsafe liquid effluent - Skin penetration by pathogens transferred by water - Skin diseases	penetration and skin contact	per litre and <10 helminthic egg per litre) or **leave crops** ($<10^5$ E. coli per litre and <10 helminthic egg per litre).						
					Advice farmers to wear boots and gloves when working in the irrigated fields.						
					Advice farmers to respect 2 days between last irrigation and harvesting.						
					Advise farmers to wash harvested crops with fresh water						

6.1.8 Model 15 – Large-scale composting for revenue generation

6.1.9 Model 17 – High value fertilizer production for profit

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
S1: storage	Biological hazards	Rodents → disease transmission	Rodents attracted by MSW	Hand to mouth, vectors living on rodents	Use of tools	3	3	High	2	2	**Low risk (4)**
		Disease vectors	Flies feeding on faecal matter and transmitting disease	Vectors	Screening of storage facility	2	2	Moderate	4	2	**Moderate risk (8)**
P1: pre-processing (segregation/ separation)	Biological hazards	Pathogens	MSW is contaminated with pathogens deriving from human and animal waste	Hand to mouth	PPE	3	2	Moderate	4	2	**Moderate risk (8)**
					Use of tools	3	3	High			
					Separation of any components that are contaminated with human and/or animal waste (e.g. diapers, sanitary products). To be discharged into the inorganic fraction and disposed of appropriately.	2	2	Moderate			
				Inhalation	PPE	3	2	Moderate			
	Chemical hazards	Chemicals	Compost is contaminated with toxic matter	Toxic matter	Separation of any waste components that contain (e.g. batteries) or are contaminated with chemicals. To be discharged into the inorganic fraction and disposed of appropriately.	3	3	High	2	2	**Low risk (4)**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures	TE	Acc	Mitigation potential	IL	LoF	Residual risk
	Physical hazards	Sharp objects	Skin cuts when handling MSW	Skin contact	PPE	3	2	Moderate	4	1	**Low risk (4)**
					Use of tools	3	3	High			
					Separation of any sharp objects (e.g. razor blades). To be discharged into the inorganic fraction and disposed of appropriately.	2	3	Moderate			
		Malodours	Permanent exposure of workers to malodours	Inhalation	PPE	2	2	Moderate	2	3	**Moderate risk (6)**
					Rapid processing of MSW after arrival	2	2	Moderate			
P2: pre-processing (settling and drying)	Biological hazards	Pathogens	High loads of pathogens enters the composting process	Hand to mouth and inhalation	Storage treatment at 2-20°C: 1.5-2 years [a]	3	2	Moderate	4	3	**Moderate risk (12)**
					Storage treatment at 20-35°C: >1 years [a]	3	2	Moderate			
					Storage treatment at pH>9 (alkaline treatment): >35°C; and moisture <25%: >6 months [a]	3	2	Moderate			
			Accidental contact while handling the sludge	Hand to mouth	PPE	3	2	Moderate	4	2	**Moderate risk (8)**
					Use of tools	3	3	High			
		Disease vectors	Flies feeding on faecal matter and transmitting disease	Vectors	Screening of drying beds	3	2	Moderate	4	2	**Moderate risk (8)**
P3: co-composting	Biological hazards	Thermophilic fungi and actino-mycetes	Inhalation of airborne spores	Inhalation	PPE	3	2	Moderate	4	2	**Moderate risk (8)**
					Moisture (>40%) control for reducing bio-aerosol emission	3	2	Moderate			
		Pathogens	Exposure to pathogens bound in the organic waste	Hand to mouth	PPE	3	2	Moderate	4	1	**Low risk (4)**
					Use of tools	3	3	High			

Note: In the header, "Control measures" spans the columns Control measures, TE, Acc and Mitigation potential; "Risk assessment" spans IL, LoF and Residual risk.

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
			Downstream exposure: Those that apply the compost are exposed to pathogens such as *E. coli* and helminthic eggs	Hand to mouth and inhalation	≤45°C for ≤5 days (2 log reductions in bacteria and <1 viable helminthic eggs per g dried matter)	3	2	Moderate	4	2	**Moderate risk (8)**
					Advice consumers to wear boots and gloves when applying the compost.	3	2	Moderate			
		Malodours	Exposure to malodours	Inhalation	PPE	2	2	Moderate	2	2	**Low risk (4)**
					Good ventilation of working area	2	3	Moderate			
	Physical	Dust	Long-term exposure to dust	Inhalation	PPE	3	2	Moderate	2	2	**Low risk (4)**
P4: post-treatment	Biological hazards	Pathogens	Downstream exposure: - Accidental intake of contaminated liquid effluent from the plant - Ingestion of produce that is irrigated with unsafe liquid effluent or fertilized with unsafe soil conditioner	Acciden-tal ingestion	Depending on the further use of the outputs of the post-treatment, the following post-treatment options are proposed: <u>Off-site (i.e. discharge):</u> ➢ Drain/transfer effluents/sludge into an existing WWTP for co-treatment ➢ Discharge sludge on landfill <u>On-site (in case of agricultural reuse of the outputs, a combination of the following options will be required for achieving the required quality standard (see table with quality/safety requirements for outputs)):</u> ➢ Septic tank (≥1 log reduction of *E. coli* and ≥2 log reduction in helminthic eggs) ➢ Anaerobic baffled reactor (≥1 log reduction of *E. coli* and ≥2 log reduction in helminthic eggs) ➢ Anaerobic filter(≥1 log reduction of *E. coli* and ≥2 log reduction in helminthic eggs) ➢ Constructed/vertical flow wetland (≥0.5-3 log reduction of *E. coli* and ≥1-3 log reduction in helminthic eggs) ➢ Planted gravel Filter ➢ Unplanted gravel Filter ➢ Planted/unplanted drying beds (1-3 log reduction in helminthic eggs)						

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
			Accidental contact with pathogens while operating the post-treatment components	Hand-to-mouth	PPE	3	2	Moderate	4	2	**Moderate risk (8)**
		Disease vectors	Treatment ponds serve as vector breeding sites	Insect bites	Prevent mosquito breeding in ponds	2	2	Moderate	4	2	**Moderate risk (8)**
Generalities	Various	Various	Input is contaminated with medical waste		In settings where medical waste is disposed of in MSW, this business model is not an option	3	2	Moderate	8	5	**40**
	Various		People from the community access the plant and get hurt, are exposed to pathogens or other hazards	Injury to the body, hand to mouth, inhalation	Restrict access to operations for external individuals	3	3	High	4	1	**Low risk (4)**
	Physical hazard		Workers suffer of musculoskeletal damage due to inappropriate working practices	Injury to the body	Worker education for preventing musculoskeletal damage due to inappropriate working practices	2	2	Moderate	4	2	**Moderate risk (8)**

6.1.10 Model 16 – Subsidy-free community based composting

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
S1: storage	Biological hazards	Rodents → disease transmission	Rodents attracted by MSW	Hand to mouth, vectors living on rodents	Use of tools	3	3	High	2	2	**Low risk (4)**
		Disease vectors	Flies feeding on MSW	Vectors	Screening of storage facility	2	2	Moderate	4	1	**Low risk (4)**
P1: pre-processing (segregation/ separation)	Biological hazards	Pathogens	MSW is contaminated with pathogens deriving from human and animal waste	Hand to mouth	PPE	3	2	Moderate	4	2	**Moderate risk (8)**
					Use of tools	3	3	High			
					Separation of any components that are contaminated with human and/or animal waste (e.g. diapers, sanitary products). To be discharged into the inorganic fraction and disposed of appropriately.	2	2	Moderate			
				Inhalation	PPE	3	2	Moderate			
	Chemical hazards	Chemicals	Compost is contaminated with toxic matter	Toxic matter	Separation of any waste components that contain (e.g. batteries) or are contaminated with chemicals. To be discharged into the inorganic fraction and disposed of appropriately.	3	3	High	2	2	**Low risk (4)**
	Physical hazards	Sharp objects	Skin cuts when handling MSW	Skin contact	PPE	3	2	Moderate	4	1	**Low risk (4)**
					Use of tools	3	3	High			
					Separation of any sharp	2	3	Moderate			

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures	TE	Acc	Mitigation potential	IL	LoF	Residual risk
					objects (e.g. razor blades). To be discharged into the inorganic fraction and disposed of appropriately.						
		Malodours	Permanent exposure of workers to malodours	Inhalation	PPE	2	2	Moderate	2	3	**Moderate risk (6)**
					Rapid processing of MSW after arrival	2	2	Moderate			
P2: composting	Biological hazards	Thermophilic fungi and actino-mycetes	Inhalation of airborne spores	Inhalation	PPE	3	2	Moderate	4	2	**Moderate risk (8)**
					Moisture (>40%) control for reducing bio-aerosol emission	3	2	Moderate			
		Pathogens	Exposure to pathogens bound in the organic waste	Hand to mouth	PPE	3	2	Moderate	4	1	**Low risk (4)**
					Use of tools	3	3	High			
			Downstream exposure: Those that apply the compost are exposed to pathogens such as *E. coli* and helminthic eggs	Hand to mouth and inhalation	≤45°C for ≤5 days (2 log reductions in bacteria and <1 viable helminthic eggs per g dried matter)	3	2	Moderate	4	2	**Moderate risk (8)**
					Advice consumers to wear boots and gloves when applying the compost.	3	2	Moderate			
		Malodours	Exposure to malodours	Inhalation	PPE	2	2	Moderate	2	2	**Low risk (4)**
					Good ventilation of working area	2	3	Moderate			
	Physical	Dust	Long-term exposure to dust	Inhalation	PPE	3	2	Moderate	2	2	**Low risk (4)**
Generalities	Various	Various	Input is contaminated with medical waste		In settings where medical waste is disposed of in MSW, this business model is not an option	3	2	Moderate	8	5	**40**

Element of the process	Category	Hazard(s)	Hazardous event	Exposure route	Control measures				Risk assessment		
						TE	Acc	Mitigation potential	IL	LoF	Residual risk
	Various		People from the community access the plant and get hurt, are exposed to pathogens or other hazards	Injury to the body, hand to mouth, inhalation	Restrict access to operations for external individuals	3	3	High	4	1	**Low risk (4)**
	Physical hazard		Workers suffer of musculoskeletal damage due to inappropriate working practices	Injury to the body	Worker education for preventing musculoskeletal damage due to inappropriate working practices	2	2	Moderate	4	2	**Moderate risk (8)**