Model-Based Diagnosis System:

Application to Constructed Wetlands

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0. INDEX

1. INTRODUCTION

1.1. CONSTRUCTED WETLANDS

Nowadays there is a limited number of appropriate wastewater treatment technologies for small communities which can be considered by a community and the designers of Wastewater Treatment Plants (WWTPs), because small community budgets become severely strained by the costs of their wastewater collection and treatment facilities. Inadequate budgets and poor access to equipment, supplies and repair facilities preclude proper operation and maintenance [Environmental Protection Agency (1999)].

Constructed wetlands (CWs), or modified natural wetlands, are used all over the world as wastewater treatment systems for small communities because they can provide high treatment efficiency with low energy consumption and low construction, operation and maintenance costs.

CWs are artificial wastewater treatment systems consisting of shallow (usually less than 1 m deep) ponds or channels which have been planted with aquatic plants, and which rely upon biological, physical and chemical processes to treat wastewater. They typically have impervious clay or synthetic liners and engineered structures to control the flow direction, liquid detention time and water level. Depending on the type of system, they may or may not contain an inert porous media such as rock, gravel or sand [Environmental Protection Agency (1999)].

CWs have been classified by the literature and practitioners into three types:

- Surface Flow (SF) CWs closely resemble natural wetlands in appearance because they contain aquatic plants that are rooted in a soil layer on the bottom of the wetland and water flows through the leaves and stems of plants (Figure 1).

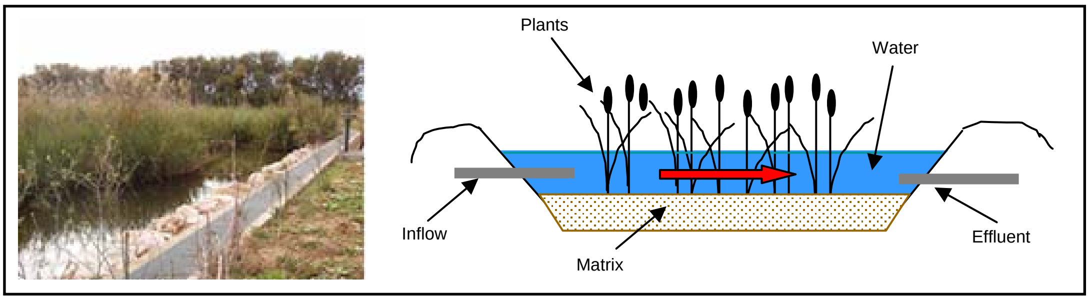


Figure 1. Surface flow constructed wetland.

- Horizontal Subsurface Flow (HSSF) CWs do not resemble natural wetlands because they have no standing water. They contain a bed of media (such as crushed rock, small stones, gravel, sand or soil) which has been planted with aquatic plants. When properly designed and operated, wastewater stays beneath the surface of the media, flows horizontally in contact with the roots and rhizomes of the plants, and is not visible or available to wildlife (Figure 2).

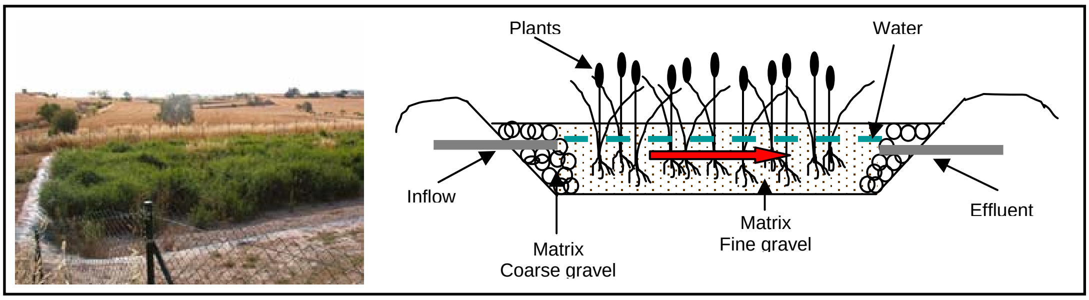


Figure 2. Horizontal subsurface flow constructed wetland.

- Vertical Subsurface Flow (VSSF) CWs, as HSSF wetlands, do not resemble natural wetlands because they have no standing water. They also contain a bed of media (such as crushed rock, small stones, gravel, sand or soil) which has been planted with aquatic plants. When properly designed and operated, wastewater flows vertically from the surface of the media to the bottom of the pool. Wastewater flows vertically in contact with the roots and rhizomes of the plants, and is visible just when it is applied, but it is not available to wildlife (Figure 3).

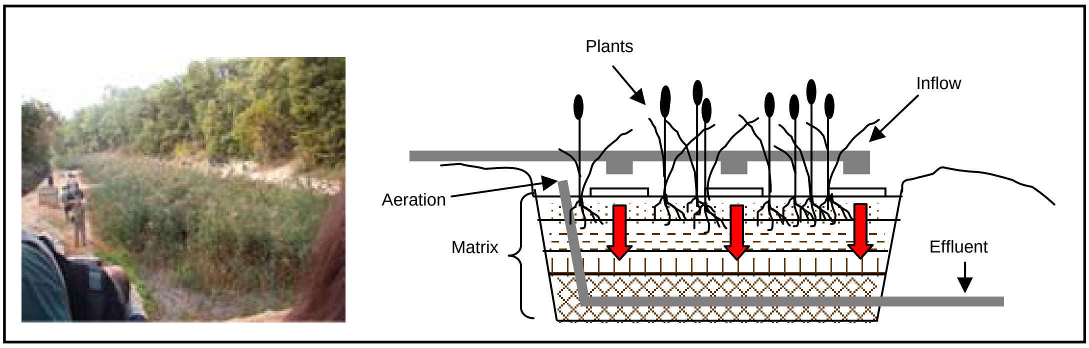


Figure 3. Vertical subsurface flow constructed wetland.

1.2. Constructed Wetlands' Performance

The CW treatment process is very complex because it includes physical, chemical and biological mechanisms like microorganism oxidation, microorganism reduction, filtration, sedimentation and chemical precipitation (Table 1). These processes can be influenced by different factors:

- CW design: Number of pools, size and shape of these ponds, gravel diameter and gravel distribution, flow direction, flow distribution system, etc.
- Weather conditions: Temperature, evapotranspiration, wind and precipitation.
- Inflow quality: Wastewater quality, pre-treatment and primary treatment performance.
- Inflow quantity.
- Presence of rodents.
- Growing of weeds, bulrushes and/or trees over or close to the CW.

- Performance of the hydraulic components: Dosing wastewater system, wastewater distribution system, wastewater collection system and wastewater level controller.
- State of the waterproofing and dikes.
- State of the gate and the fence.

Table 1. Constructed wetlands' process to remove pollutants [Huertas (2001)].

Wastewater pollutants	Pollutants removal process
Suspended solids	o Sedimentation o Filtration
Dissolved organic matter	o Biological oxidation
Nitrogen	o Biological oxidation o Biological reduction o Plants uptake o Matrix absorption o Ammonium volatization
Phosphorus	o Plants uptake o Matrix absorption o Precipitation
Metals	o Cationic adsorption and exchange o Complex formation o Precipitation o Plants uptake o Biological oxidation o Biological reduction
Microorganisms	o Sedimentation o Filtration o Microorganisms depredation o UV radiation o Antibiotic roots excretion

In order to guarantee the performance of CWs an operation and maintenance program must be defined for each WWTP. This protocol has to describe the operation procedures and ongoing maintenance needed to ensure that the wetland and the associated facilities perform to an acceptable standard; that the design objectives are met and that savings are made in operation and maintenance costs by early detection of problems [Knight (2000)]. The operation and maintenance costs are low because the procedures suggested in these protocols are simple. In spite of this, if the proposed procedures are not carried out appropriately, the CW system could fail and the following problems can appear:

- Abnormal vegetation growing during the start up
- Inappropriate vegetation density
- Accumulation of vegetation remains over the CW surface
- Weed growth
- Trees and bulrushes growth
- Chlorosis
- Rodents' damages
- Gravel clogging
- Low wastewater level

- High wastewater level
- Unsuitable wastewater distribution
- Inappropriate or clogging wastewater distribution system
- Inappropriate wastewater level controller regulation
- Inappropriate dosing wastewater system regulation
- Deficient waterproofing
- Deficient dikes structure
- Bad smells

Experience shows that the operation, maintenance activities and the frequencies of these actions and measures can be different from one CW system to another, because these aspects vary according to the factors that influence the CW performance, the wastewater treatment level required and the receiving media sensitivity.

2. OBJECTIVES

The main objective of this project is to provide a computer support to the definition of the most appropriate operation and maintenance protocols to guarantee the correct performance of CWs. To achieve this aim it is necessary:

- The identification of the CW components
- The definition of the relations among these components
- The description of the processes involved in the pollutants removal. This description has to allow (1) the diagnosis of the treatment processes under disturbances and faults and (2) the proposal of the most appropriate operation and maintenance actions.

To reach the protocols definition – in an objective, realistic and useful way – we propose the definition of models which represent the knowledge about CW: components involved in the sanitation process, relation among these units and processes to remove pollutants.

It is important to notice that HSSF CWs are chosen as a case study (mainly because almost the 90 % of Catalan CWs have this configuration) and the filtration process is selected as first modelling-process application. However, the goal is to represent the process knowledge in such a way that it can be reused for other types of WWTP where it applies.

In this document, the selected methodology to model the processes is explained (3. METHODOLOGY: PROCESS-ORIENTED MODEL). Also, this report comprises the identification of the HSSF CW' components, the definition of the relation among these components and the removal processes description (4. PROCESS-ORIENTED MODEL APPLICATION TO CONSTRUCTED WETLAND PROTOCOLS DEFINITION). In addition, section 4 includes the definition of the filtration process model.

The use of process-oriented models to represent the CW knowledge lead to study the possible reuse of the developed models to other wastewater treatment alternatives (i.e. intermittent sand filters, buried sand filters, green filters or land application). In section 5. REUTILIZATION, we discuss the possible models reuse.

3. METHODOLOGY: PROCESS-ORIENTED MODEL

3.1. JUSTIFICATION OF THE SELECTED METHODOLOGY

The definition of operation and maintenance protocols for CWs is a complex task since is necessary to take into account a lot of data and expert knowledge, as well as to reach environmental, social and economical objectives. Furthermore, the treatment processes that occur in this kind of WWTP are complex because the performance of the facility varies according to the changing structure of the system, the influent characteristics, the weather conditions, etc.

To meet this challenge, it was suggested to develop a model which can tackle the complexity of representing a dynamic interaction of several processes. At the same time, this model has to include quantitative and qualitative data and expert knowledge. Therefore, the process-oriented modelling seems to be an appropriate methodology to represent the knowledge about CWs. Moreover, this modelling method enables the model reutilization. This aspect is very important, especially taking into account that some of the dynamic processes that occur in a CW take place in other WWTPs.

REMARK: All the information presented in points 3.2. PROCESS-ORIENTED MODELLING and 3.3. THE MODELLING APPROACH, has been extracted from the thesis of Dr.Ulrich Heller [Heller (2001)].

3.2. PROCESS-ORIENTED MODELLING

The reasoning about domains with a dynamically changing structure (like WWTPs, in which a set of processes are activated and deactivated over time –i.e. organic matter biodegradation–) requires powerful and flexible modelling capabilities. Process-oriented models are a promising way to capture the laws of physic, biology, chemistry and other disciplines involved in the different dynamics. These models are based upon an explicit representation of structure in terms of (1) objects and (2) processes.

Objects are typed and quantities are associated with individual objects of each type to represent properties that can be changed by the phenomena modelled (i.e. the concentration of suspended solids is a quantity associated with the wastewater object type, and the amount of this substance can decrease in the filtration process). The occurrence of processes is determined by the presence of certain object configurations and their properties. Thus if and only if there is a configuration of objects satisfying a specified set of conditions, the process will take place (i.e. in the HSSF CW filtration process there are, at least, three objects: wastewater –flowing trough the matrix–, suspended solids –suspended in the wastewater– and a matrix –with certain granularity–). The effects of processes are given as relations and influences between the quantities of objects involved (i.e. when wastewater flows trough the matrix the amount of filtered substances on it will increase). Relations include qualitative proportionalities, and influences relate two quantities in a causal relationship. For more information see section 4.3 HORIZONTAL SUBSURFACE CONSTRUCTED WETLANDS – MODEL FOR THE SUSPENDED SOLIDS FILTRATION PROCESS.

The final constituents of the model are (1) a library: collection of generic processes specified in terms of object and relation types (i.e. filtration process), and (2) a scenario: description of specific processes aspects also, in terms of object and relation types (i.e. matrix configuration).

The composition of the modelled generic process allows the situation description for a given scenario: the identification of objects and extensions of certain predicates along with inequalities about quantity values. Moreover, this composition allows the diagnosis (to find a model that explains the observations) and the therapy (to find a model with actions that implies treatment goals).

3.3. THE MODELLING APPROACH

The basic building blocks of the modelling language are (1) the domain theory and (2) the situation description.

3.3.1. Domain theory

The domain theory consists of (1) an ontology, (2) quantities and (3) a set of behaviour constituent types, as well as (4) the basic axioms.

3.2.1.1. Ontology

Structure descriptions are composed of object instances and relations between them. All behaviour can be observed through the change of values of quantities associated with these objects. The ontology defines the entities that can be used in representing structure: object types and structural relations.

Object types: An object type is a tangible and visible entity.
The first step in the ontology description is to define the set of object types and the hierarchical taxonomy of these objects. Each type can have more than one super-type, but, of course, there should be no circularity.

Structural relations: The structural relations allow defining the connection between two object types.
The second stage in the ontology description is to identify the set of relations that allow relating objects to each other. For binary relations is possible to specify special properties such as: symmetry, completeness, uniqueness and introducible.

3.2.1.2. Quantities

A second part of the domain theory is the definition of quantity types and the association of the quantities to the objects. The quantities can be used in specifying observations, conditions or effects of behaviour constituents. Quantities cannot be associated with relations or groups of objects, rather with simple object instances only.

3.2.1.3. Behaviour constituent types

All observable behaviour, as expressed in the values of quantities, is determined by the set of occurring behaviour constituents. Behaviour constituents are typed and a behaviour constituent type is basically a deterministic law of behaviour made up of structural conditions, quantity conditions, structural effects and quantity effects with the following semantics:

IF structural conditions AND quantity conditions
THEN structural effects AND quantity effects

↓

For each configuration of objects and relations matching the structural and quantity conditions, the structural and quantity effects will result.

Structural conditions: The structural conditions of a behaviour constituent type are expressed as a set of objects and the relations among them.

Quantity conditions: The quantity conditions are statements about values of quantities. The specification of quantity conditions enables the modeller to specify constraints to be fulfilled.

Structural effects: Creation or possible even elimination of objects and relations.

Quantity effects: The quantity effects of a behaviour constituent are what actually cause changes in quantity values. They can be specified similar to quantity conditions, by employing quantity specifications, but, of course, the constraint is enforced rather than tested.

3.2.1.4. Axioms

The basic axioms are the formal representation of the semantics of the modelling primitives (i.e. the laws governing type hierarchies and quantity values assignments, or the rules for behaviour constituent effects).

3.3.2. Situation description

Diagnosis starts with what is known of the situation. This includes an initial system structure and observations of quantity values. In our modelling language, the basic elements are objects and relations, as well as assignments of quantity values. However, this situation description is open to change (by the diagnostic task) in two important respects:

a) On the one hand, it is usually incomplete, for instance only a partial description of the situation as characterized by objects, relations and quantity values. It is impractical and very often impossible to measure or observe all of the quantities in the system model; they can only be predicted from other sources of knowledge. But also unexpected objects and relations might be present, which is left for the diagnosis procedure to discover. So in this respect, the situation description is incomplete and open to completion.

b) On the other hand, the user can want to describe an assumed or "default" situation and specify observations with limited confidence. It is allowed supplying structural elements (objects and relations) and also quantity value assignments with user-defined assumptions. This distinguishes these specifications from facts. A user-defined assumption is identified by a constant that can be used in more than one location (i.e. for supplying multiple values with the assumption that the common measurement unit providing them is working correctly). The diagnostic system is able to retract assumptions, if they contradict facts or other assumptions.

Figure 4 provides an overview of the modelling sections as well as the specificity of them. The domain theory is specific to a class of systems in a common domain, while the situation description has a system specific part, assumed to be true for the entire history of the system or at least the relevant part of it, and a situation specific part. The basic axioms are completely generic and, thus, invariably the same for any models expressed in the described modelling language. This is to say that not all parts of the model can be specified by the user of an implemented system for reasoning about such models. Most notably, the basic axioms can be “hard-wired” into the reasoning system in the form of algorithms.

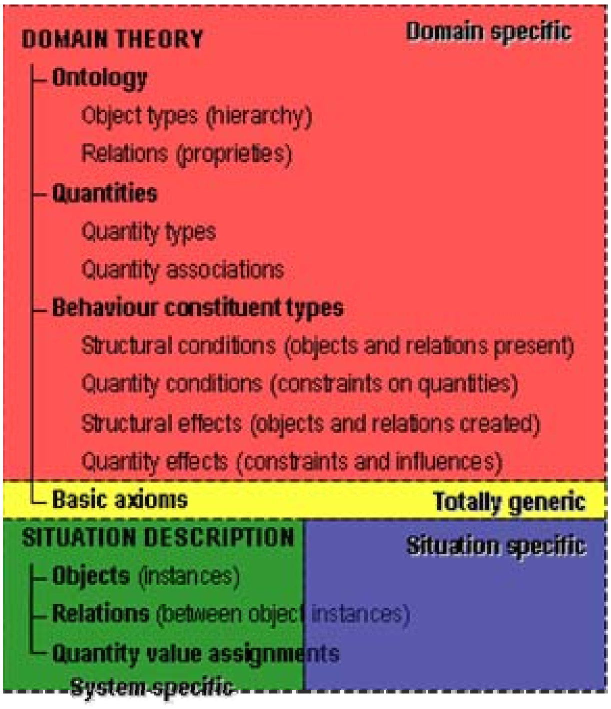


Figure 4. Overview of the modelling sections and specificity of them.

4. Process-Oriented Model Application to Constructed Wetland Protocols Definition

4.1. Introduction

The final objective of this project is the creation of a computer system that help to determine the ongoing (possibly disturbing) processes and the definition of the most appropriate operation and maintenance protocols to guarantee the correct performance of CWs, but the HSSF-CWs were chosen as a case study (mainly because almost the 90 % of Catalan CWs have this configuration). In point 4.2. Horizontal Subsurface Constructed Wetlands Component the components of this wastewater treatment system are defined.

The wastewater treatment processes of this kind of CW are focussed on the suspended solids filtration and the organic matter biodegradation. The filtration process was selected as the first modelling-process application. In point 4.3. Horizontal Subsurface Constructed Wetlands – Model for the Suspended Solids Filtration Process there is the domain theory description (except the basic axioms), and in point 4.4. Horizontal Subsurface Constructed Wetlands Scenario there is the description of specific process aspects.

4.2. Horizontal Subsurface Constructed Wetlands Components

The main HSSF-CW components are (Figure 5): (1) wastewater entrance, (2) wastewater dispenser mechanism, (3) wastewater distribution system, (4) matrix, (5) plants, (6) wastewater collection system, (7) waterproofing, (8) wastewater level controller, and (9) wastewater outlet.

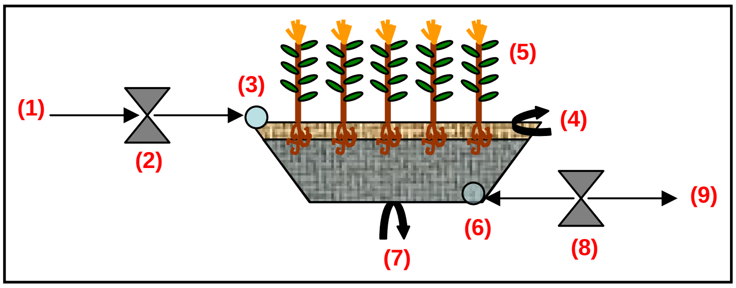


Figure 5. Schema with the HSSF-CW components.

4.2.1. Wastewater entrance

Wastewater that comes from the sewer is treated in a pre-treatment and in a primary treatment. Normally the pre-treatment units are filters (Figure 6a) or sedimentation tanks, which allow removing sand, scum, gravel, plastic, etc. Then, the wastewater flows through the primary treatment. In this unit, part of the suspended solids are removed. At least there are 3 types of primary treatment: septic tank, Imhoff tank (Figure 6b) and primary settler.

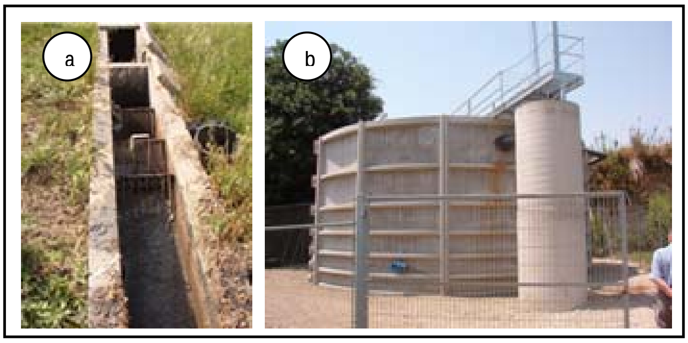


Figure 6. (a) Filters of the Sant Martí Segueïoles pre-treatment unit.
(b) Imhoff tank of the Corbins primary treatment unit.

The wastewater entrance is the pipeline or the channel that communicates the primary treatment and the HSSF-CW (Figure 7). In this treatment unit there isn't any kind of processes to remove pollutants; only the wastewater transportation takes place.

Figure 7. Channel that transports the wastewater from the septic tank (a) to the wastewater distribution point (b), in the HSSF-CW of Verdú.

4.2.2. Wastewater dispenser mechanism

In some HSSF-CW there is a wastewater dispenser mechanism between the inlet and the wastewater distribution system. This mechanism permits to dose the wastewater on the HSSF-CW. Therefore, in several cases the wastewater flows directly from the primary treatment into the HSSF-CW and in other situations the wastewater is contained in a reservoir until it is "pumped" into the HSSF-CW (Figure 8). In this unit there isn't any kind of processes to remove pollutants; only the wastewater transportation takes place.

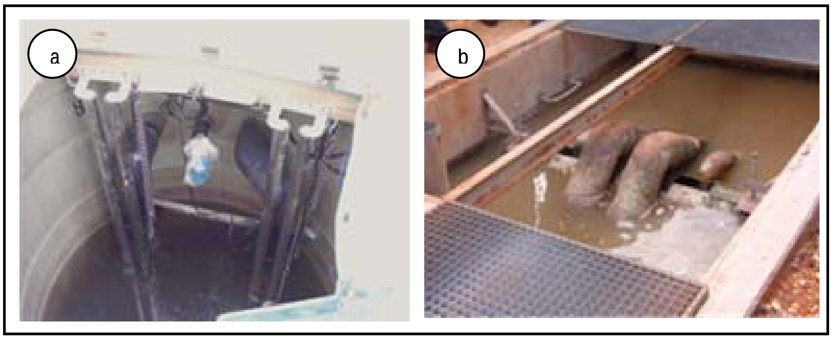


Figure 8. Photographs of wastewater dispensers mechanisms: (a) pump and (b) siphon.

4.2.3. Wastewater distribution system (Inlet)

The distribution system objective is to distribute the wastewater as homogeny as possible over the HSSF-CW inlet. There are two types of distribution systems: Tub (Figure 9a) or channel (Figure 9b). In both cases there isn't any kind of processes to remove pollutants; only the wastewater transportation takes place.

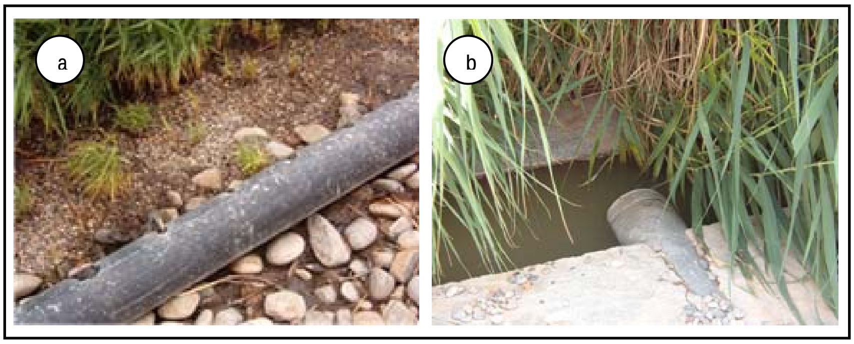


Figure 9. Photographs of wastewater distribution systems: (a) tub and (b) channel.

4.2.4. Matrix

The matrix consists of 3 layers of gravel distributed as in Figure 10. In the entrance and in the outlet of the matrix there is coarse gravel (diameter: 20-100 mm) and in the middle there is fine gravel (diameter: 8-20 mm). These gravels have to resist corrosion or to be dissolved by wastewater.

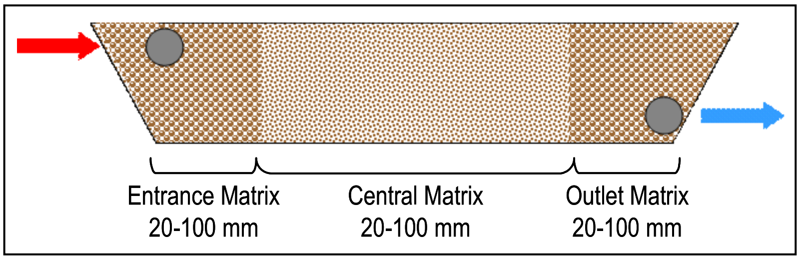


Figure 10. Schema of the gravel distribution in a HSSF - CW.

Wastewater flows through this matrix and always beneath the surface. In this step pollutants are removed, mainly suspended solids and organic matter. In addition, some nitrogen, phosphorus, metals, microorganisms and viruses can be removed.

4.2.4.1. Suspended solids removal

The suspended solids are removed by a filtration process when wastewater flows through the matrix. The gravel and the plants (more specifically the roots of the plants) contribute to this filtration process.

The great majority of the suspended solids are accumulated in the first meters (1-1.5 m) from the wastewater distribution system. If the suspended solids are inorganic, they remain in the matrix. On the other hand, if they are organic, they will be degraded by a biological process.

4.2.4.2. Organic matter removal

The organic matter is removed by a biological process. Microorganisms (aerobic, anaerobic or facultative) growing over the gravel or the roots' plants transform the organic matter into CO_2 (aerobic process – Figure 11) or CH_4 (anaerobic process – Figure 12). If there is enough oxygen takes place the aerobic process (quick and complete reaction). When the dissolved oxygen decreases takes place the anaerobic process (slow and incomplete reaction).

$$CH_6O + O_2 \rightarrow CO_2 + H_2O$$

Figure 11. Reaction for the aerobic organic matter removal.

$$C_6H_{12}O_6 \rightarrow 3\ CH_3COOH$$
$$CH_3COOH \rightarrow CO_2 + CH_4$$
$$CO_2 + CH_4 \rightarrow 2\ H_2O + CH_4$$

Figure 12. Reactions for the anaerobic organic matter removal.

4.2.5. Plants

Phragmites australis (Figure 13) is the most common planted macrophyte in HSSF-CWs. This plant contributes in the depuration process of different ways:

- Can take nutrients, organic matter and metals, dissolved in wastewater.
- Provides oxygen.
- Contributes in the filtration process.

Figure 13. *Phragmites australis* planted in HSSF-CWs.

4.2.6. Wastewater collection system (Outlet)

The objective of the collection system is to collect wastewater treated along the matrix. This system consists of a perforated tub (Figure 14), located at the bottom of the outlet matrix. In this unit there isn't any kind of processes to remove pollutants; only the wastewater transportation takes place.

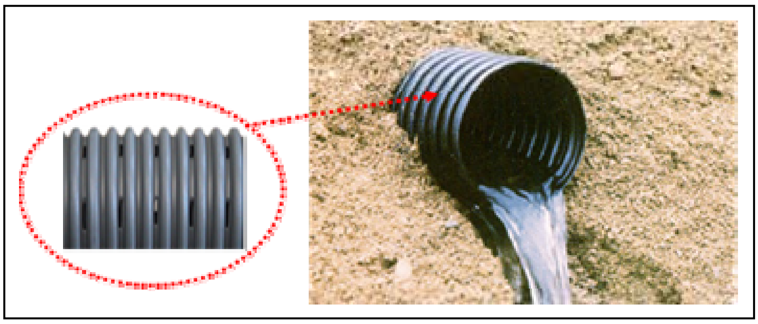


Figure 14. Perforated tub to gather the wastewater treated in the HSSF-CWs.

4.2.7. Waterproofing

The waterproofing is the liner capable of making the surface of a HSSF-CW waterproof, avoiding the percolation of wastewater in the soil, as well as preventing the infiltration of water from the soil to the HSSF-CW. In this unit there isn't any kind of processes to remove pollutants.

There are two types of waterproofing:

- Membrane: Synthetic liner made with PVC or polyethylene, resistant to the ultraviolet radiation, and 5-10 mm thickness (Figure 15).

Figure 15. Waterproofing: membrane.

- Compacted soil: Clay or other compressed soil until to be waterproofing. It is recommend a minimum of 300 mm thickness (Figure 16).

Figure 16. Waterproofing: compacted soil.

Sometimes, these waterproofings are covered with another liner. This second layer can be made with fabric and aims to protect the waterproofing from the ultraviolet solar radiation (Figure 17).

Figure 17. Textile layer to protect the waterproofing.

4.2.8. Wastewater level controller

The wastewater level controller it is an optional component in HSSF-CWs, but the great majority of the systems have this element. This controller allows modify the wastewater level in the HSSF-CW in order to: modify the hydraulic retention time, improve the *Phragmites australis* growing, avoid the weeds growing, makes easy the collection of *Phragmites australis*, evade rodents, etc. In this unit there isn't any kind of processes to remove pollutants. Figure 18 shows some of the different types of wastewater level controllers:

Figure 18. Wastewater level controllers: (a) rigid tub, (b) valve and (c) flexible tub.

4.2.9. Wastewater outlet

Connection or tub which allows spilling wastewater treated in a HSSF-CW. This wastewater has to fulfil the concentration of pollutants specified in the European Directive 91/271.

4.3. Horizontal Subsurface Constructed Wetlands – Model for the Suspended Solids Filtration Process

4.3.1. Ontology

4.3.1.1. Object types

From Figure 19 to Figure 25 there is the representation of the identified objects. Figure 19 includes the *SpatialLocators* or the objects identified as locators: constituents of the system that can be limited and defined as a space and that can be considered homogeneous. The rest of the Figures contain the *SpatialEntity* or the objects identified as entities: elements involved in the system that can change and are "contained" in a *SpatialLocator*.

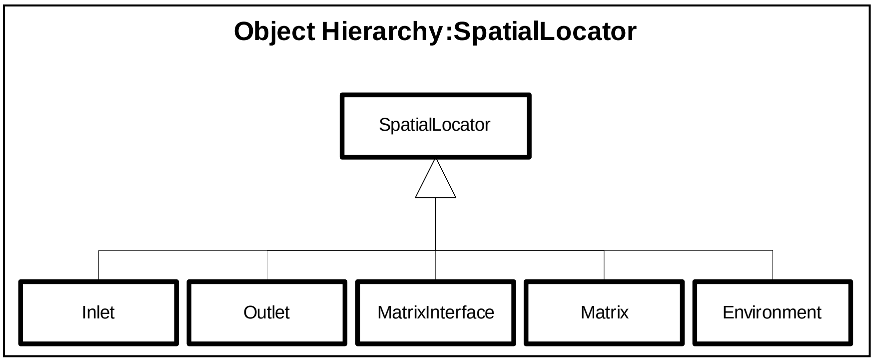


Figure 19. *SpatialLocators* identified in the HSSF-CW systems.

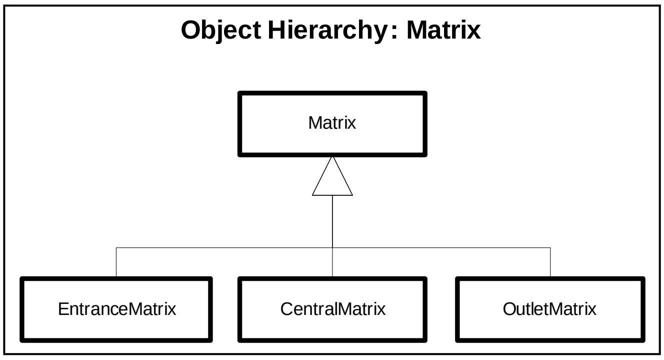


Figure 20. Matrix objects.

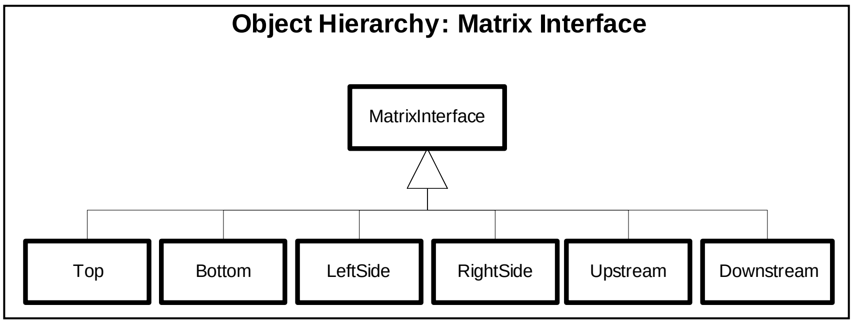


Figure 21. Matrix interface objects.

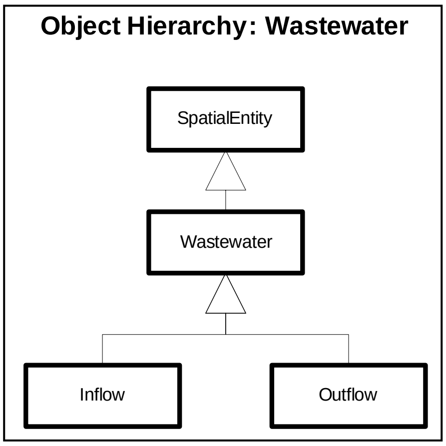


Figure 22. Wastewater objects.

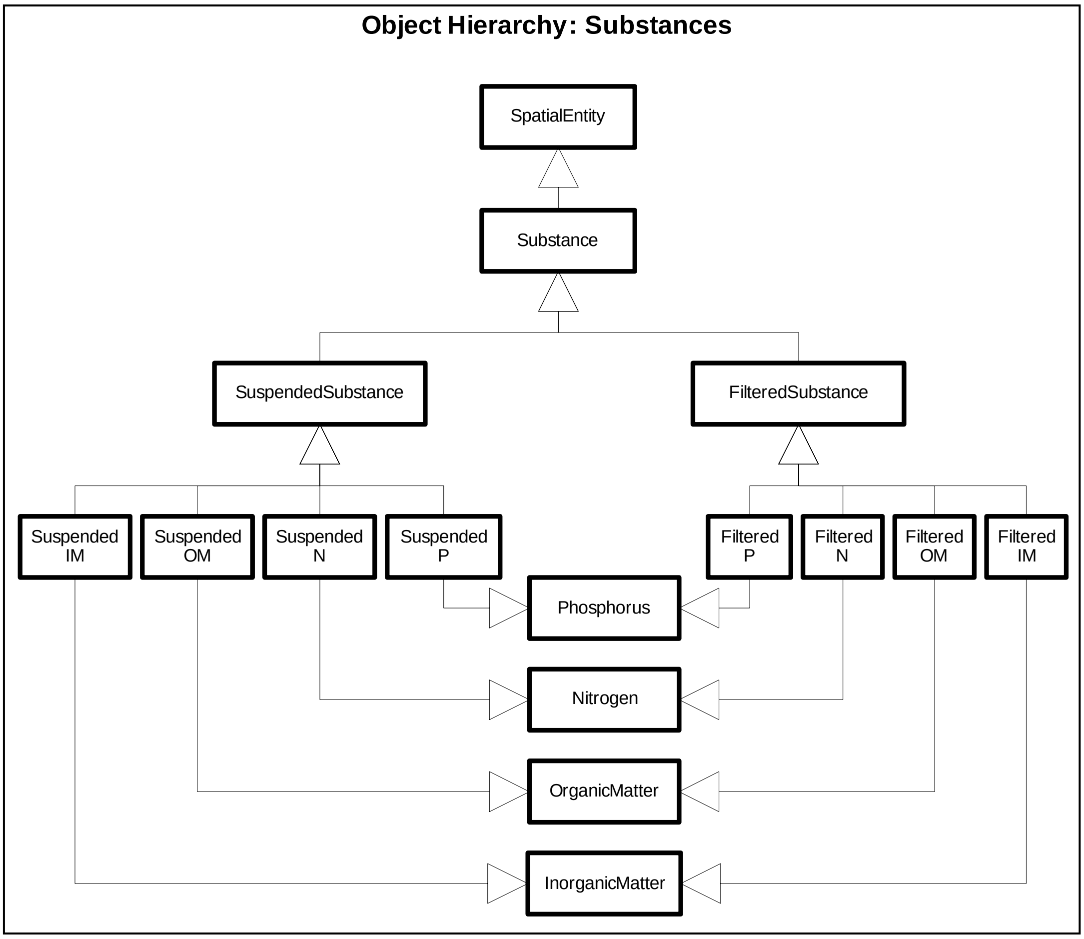


Figure 23. Substance objects.

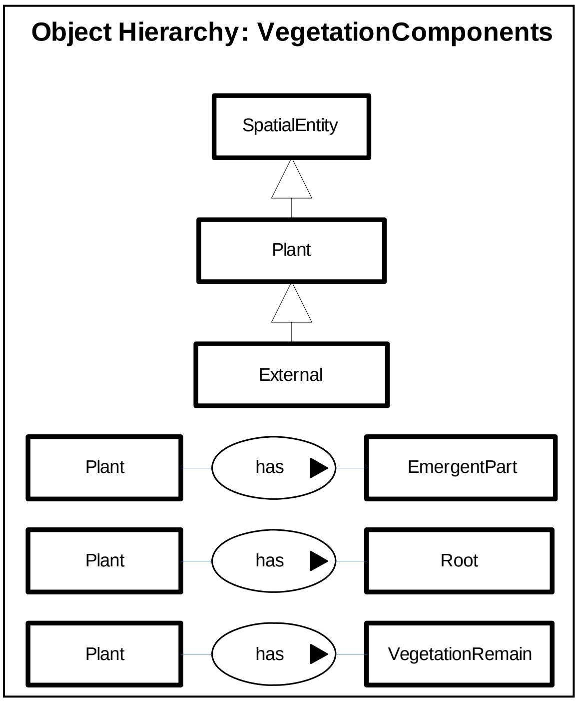


Figure 24. Vegetation objects.

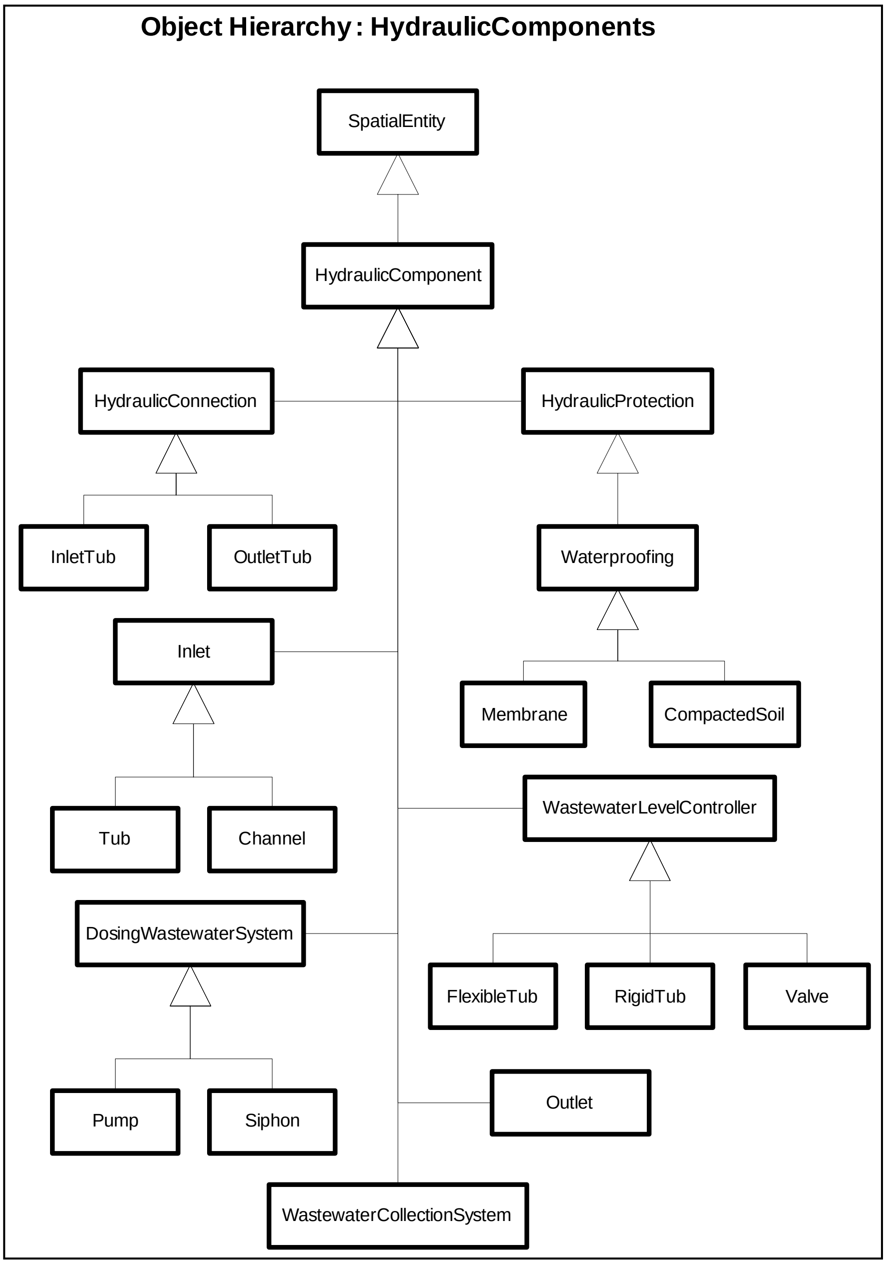


Figure 25. Hydraulic objects.

4.3.1.2. Relations

In Figure 26 there are the relations among *SpatialLocators*; Figure 27 shows the relations of *SpatialLocators* along with *SpatialEntities*, and last, but not least, Figure 28 includes the relations among *SpatialEntities*.

4.3.2. Quantities

All the quantities identified in the filtration process can be classified as signs; all of them can be expressed as a number. Figure 29 presents the association of the quantities to the objects.

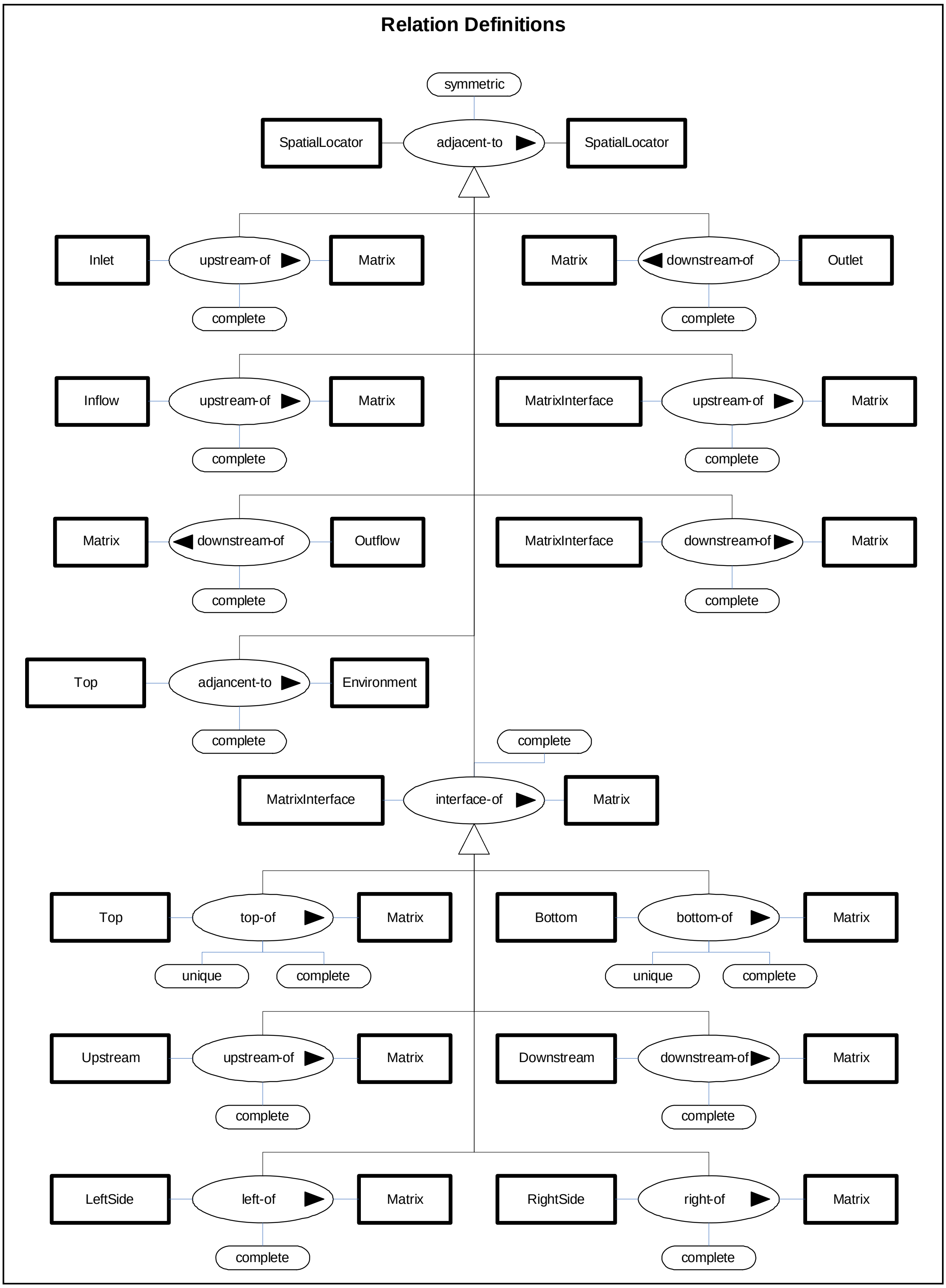


Figure 26. Relations among *SpatialLocators*.

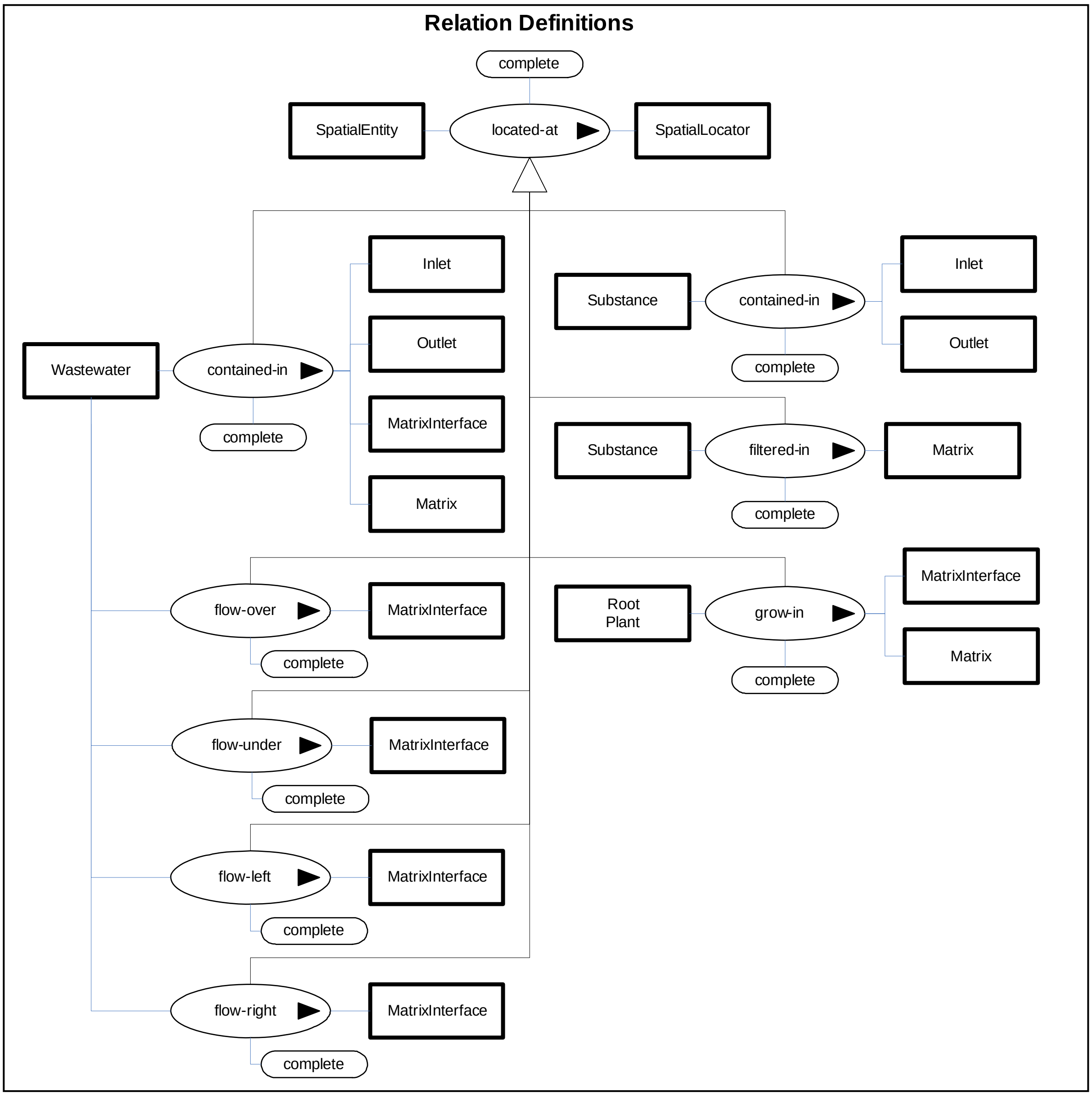


Figure 27. Relations of *SpatialLocators* along with *SpatialEntities*.

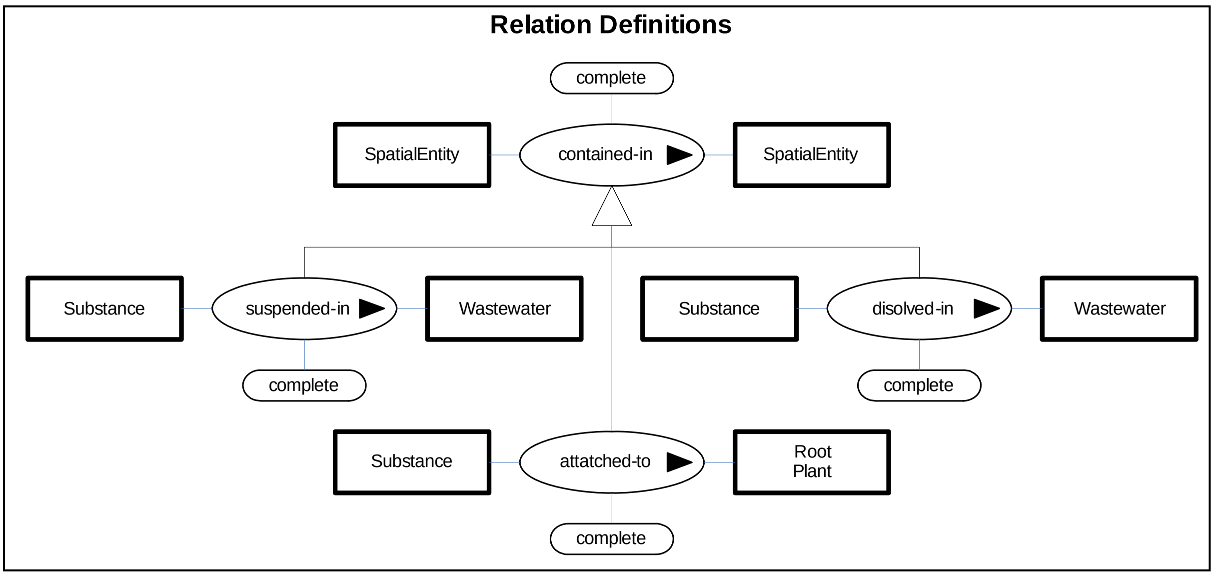


Figure 28. Relations among *SpatialEntities*.

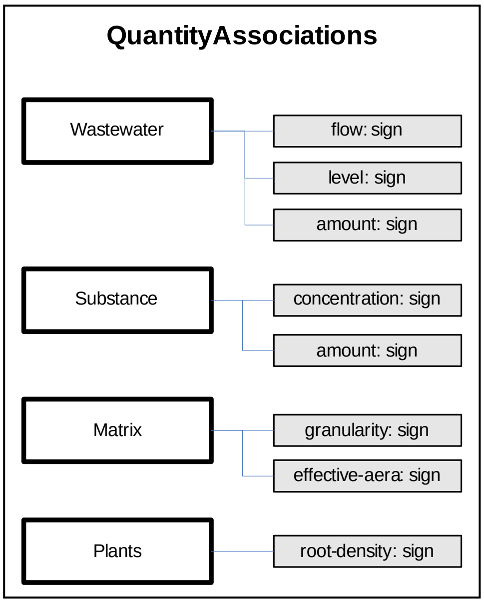


Figure 28. Association of the quantities to the objects.

4.3.3. Behaviour constituent types

The filtration process model involve three behaviour constituents: Clogging (Figure 29), suspended solids removal without plants (Figure 30) and suspended solids removal with plants (Figure 31). These schemas allow the definition of the filtration process.

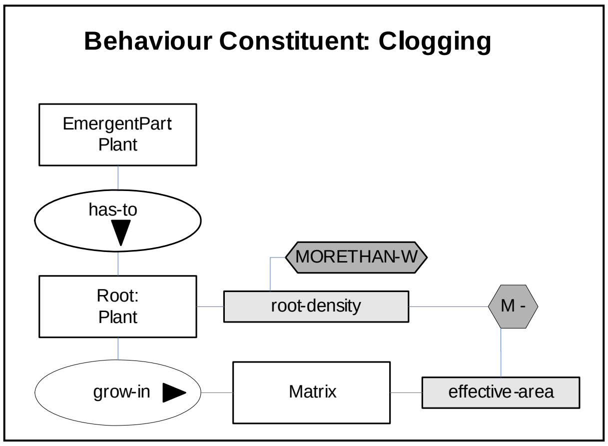


Figure 29. Clogging process.

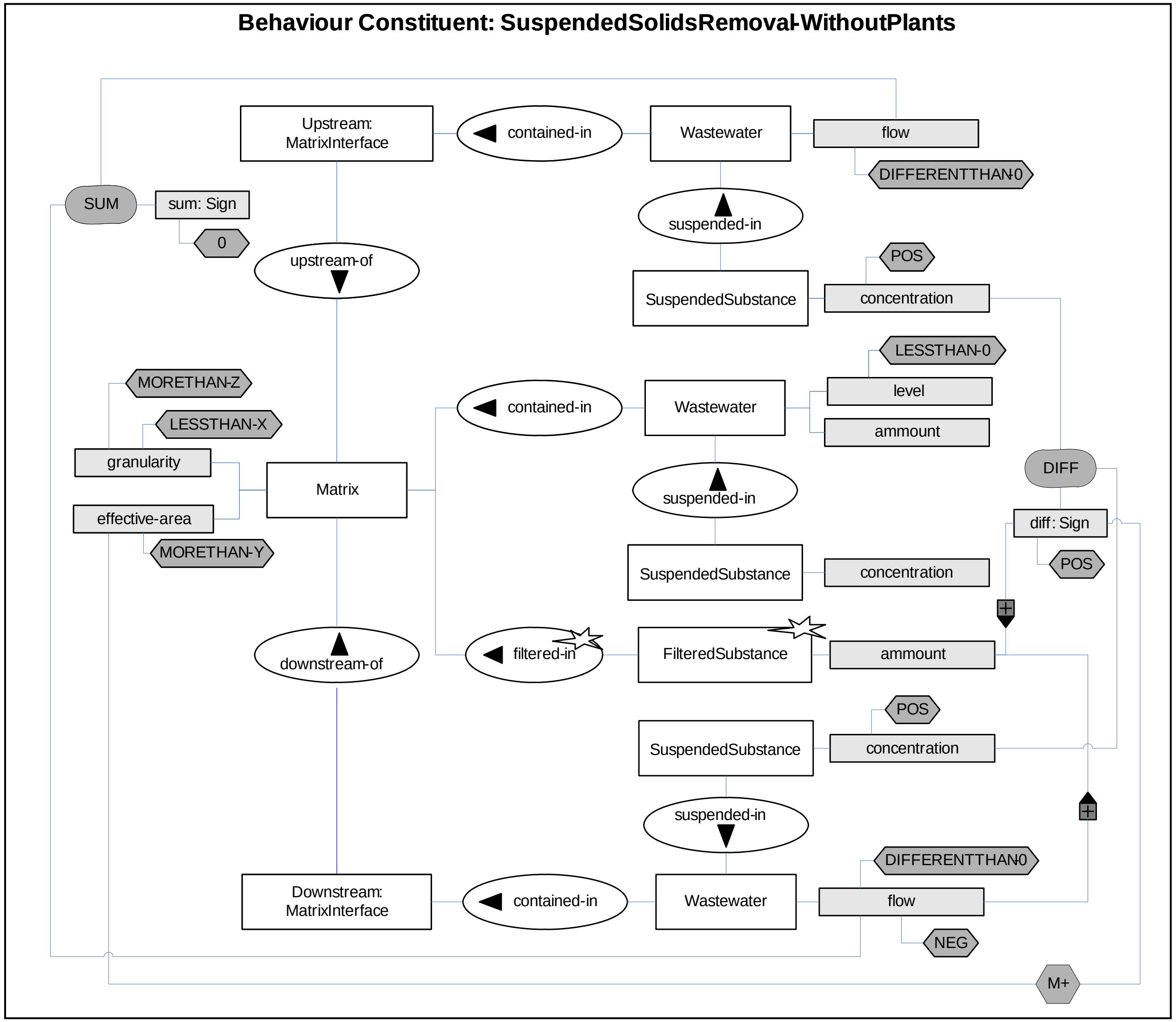


Figure 30. Suspended solids removal without plants.

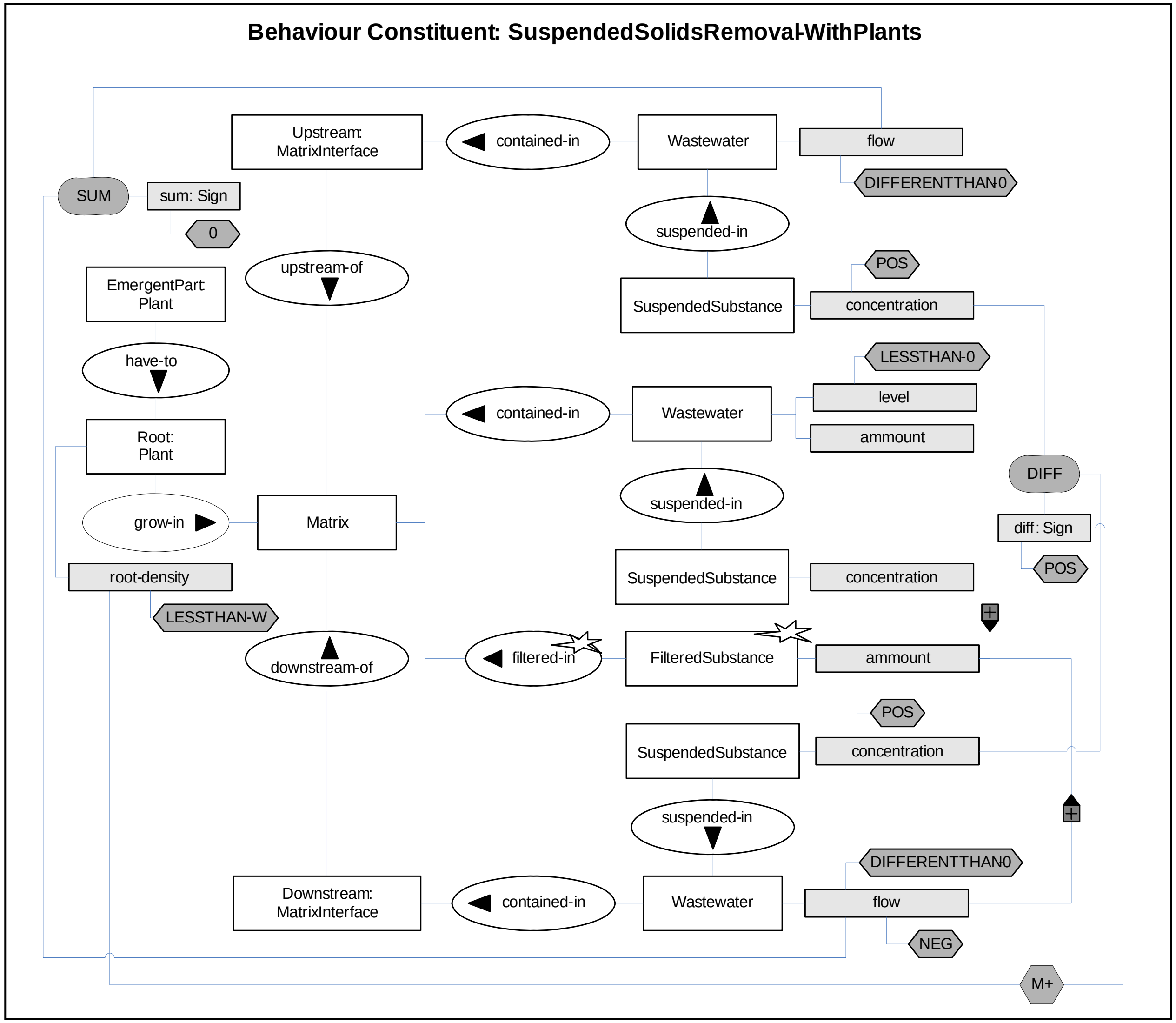


Figure 31. Suspended solids removal with plants.

4.4. HORIZONTAL SUBSURFACE CONSTRUCTED WETLANDS - SCENARIO DESCRIPTION

In the scenario description we explain the configuration of the matrix of a common HSSF-CW, just to can specify the structure of the system and define the wastewater flow through the bed of gravel (Figure 32).

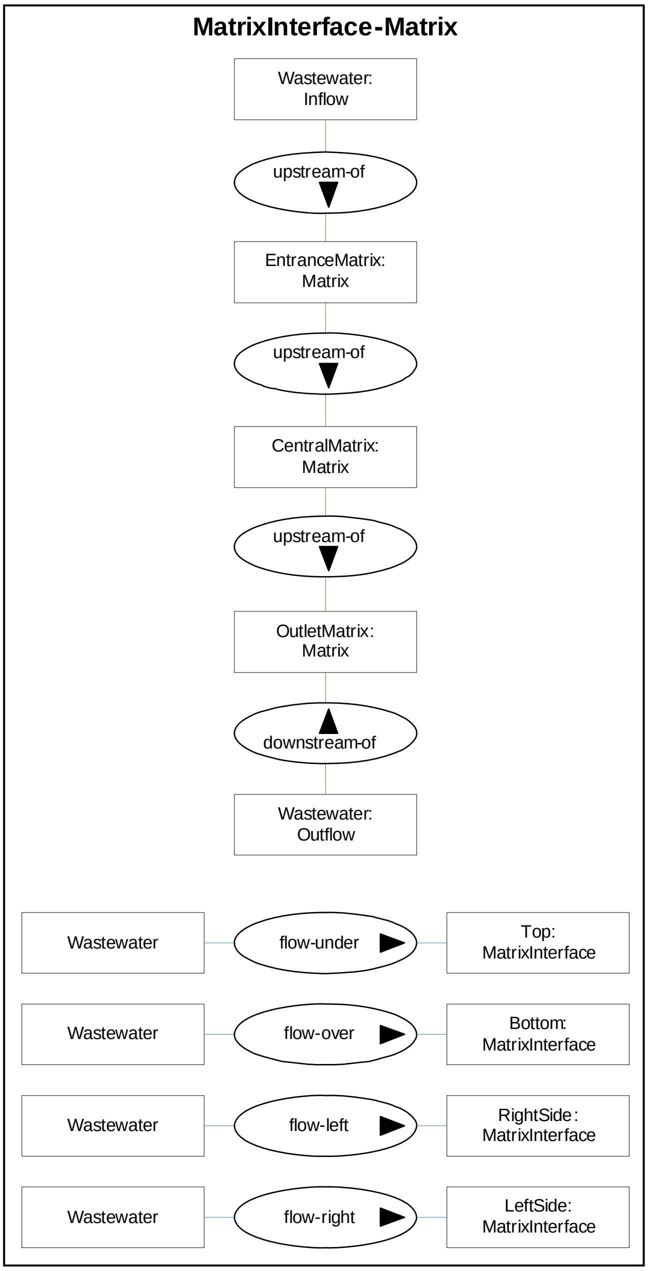


Figure 32. HSSF-CW scenario description.

5. REUTILIZATION

The filtration process described for HSSF-CWs is similar to the filtration process in other WWTP alternatives based on soil treatment (i.e. VSSF-CWs, intermittent sand filters, buried sand filters, green filters and land application). A common objective in all these technologies is to remove the suspended solids (organic or inorganic) from wastewater. The main objects involved in this removal process are the same (wastewater distribution system, matrix (and in some cases plants) and wastewater collection system). Moreover, the role of each one of these components is equivalent.

The methodology used to model the filtration process in HSSF-CW is based on the representation of the process in terms of objects and the relations among of them. Therefore, this leads to think in the reutilization of the filtration process to HSSF-CWs in other WWTPs technologies based on soil treatment.

It is necessary to note that while the reutilization of the diagnosis model seems to be possible, there are few expectations for the therapy model reutilization, because the system configuration in the other technologies can limit the application of some actions proposed for solving filtration disturbances in HSSF-CWs.

6. FUTURE WORK

Since the filtration process have been modelled and successfully evaluated, the future works have to be done in two directions:

1) Develop the diagnosis models for the others processes happening in a HSSF-CW: organic matter, nitrogen, phosphorus, metals, microorganisms and viruses removal. In the same way, construct the therapy models.

2) Study the HSSF-CW models reutilization in other WWTPs based on soil treatment.

7. GLOSSARY

➔ Clogging: Substances accumulation that limits the flow of wastewater through the matrix.

➔ Effective area: Surface of the matrix able to accomplish the following purposes: filtration, to support the microorganisms' growth, particles adsorption, etc.

➔ Environment: The totally of the WWTP surrounding conditions: meteorological conditions (temperature, wind, rain, snow and evapotranspiration), atmosphere composition, etc.

➔ Granularity: The quality of being composed of a gravel of certain size.

➔ Inlet: Perforated tub or channel to distribute the wastewater in the matrix (entrance matrix). The perforated tub can be located over or below the matrix surface, and the channel is placed over the matrix.

➔ Matrix: Volume of gravel that fills up a basin (or a channel). This gravel can be any porous material that resists corrosion or being dissolved by wastewater, and has to have a homogeneous size:

Entrance matrix (first 0.50-1.50 m): Diameter of 20-100 mm

Central matrix (between the entrance and the outlet matrices): Diameter of 8-20 mm

Outlet matrix (last 0.50-1.50 m): Diameter of 20-100 mm

➔ Matrix interface: Contact gravel surface with:

Two matrices: Upstream and downstream

The atmosphere and the matrix: Top

The bottom of the basin and the matrix: Bottom

The lateral sides of the basin and the matrix: Sides

➔ Outlet: Perforated tub to collect the treated wastewater. It is located in the bottom of the matrix (outlet matrix).

➔ Plants: There are two possible kinds of plants:

Wastewater treatment plants: Vegetation planted in the WWTP and involved in the depuration process.

External plants: Emergent plants that grow in the WWTP or close to the system. These plants (or part of them: roots and vegetation remains) can be the cause of several malfunctions.

➔ Root density: The roots are the part of the plant that grow in the matrix and support the plant, as well as provide water and nutrients. The root density is the concentration of this part of the plant in the matrix.

➔ Wastewater: Water mixed with waste matter. The wastewater comes from houses or can be a mixture of domestic wastewater, industrial wastewater or rain.

Inflow: Wastewater coming from the sewer and enters in the WWTP. This wastewater has a certain concentration of pollutants (organic matter, nitrogen, phosphorus, metals, microorganisms, viruses, etc.).

Matrix inflow: Wastewater that enters in the matrix (or in a part of the matrix).

Matrix outflow: Wastewater that flows out of the matrix (or in a part of the matrix).

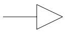
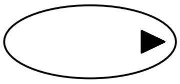
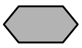
Matrix flow: Wastewater flowing through the matrix.

Outflow: Wastewater coming from the WWTP and is spilled in the receiving environment. This wastewater has to have a pollutants concentration below certain thresholds in order to satisfy the 91/271 European Directive limits.

➔ Waterproofing: Liner capable of making a surface waterproof.

Membrane: Synthetic liner made with PVC or polyethylene, resistant to the ultraviolet radiation, and 5-10 mm thickness.

Compacted soil: Clay or other compressed soil until to be waterproofing. It is recommend a minimum of 300 mm thickness.

Symbol	Name	Description
	Object	A tangible and visible entity. It can be defined by an object role and an object type.
	Object (or relation) subclass	This arrow indicates that an object (or a relation) related to a preceding one is a subclass of it. In other words, that this object (or relation) has the same properties of the object (relation) of whom is related.
	Object relation	To specify the relation between two objects.
	Relation properties	Properties of the relation: ▫ Unique: If Object-A relation Object-B is unique, then there exists at most one Object-B, e.g. the relation between of a substance and a container is unique, because a substance can only be at one place. ▫ Symmetric: Object-A rel Object-B ⇔ Object-B relObject-A ▫ Introducible means that all other structural additions can only appear in a system description if they are named by the user or created as the effect of an occurring behaviour constituent. Introducible elements are accepted as ultimate causes without further explanation. ▫ Complete: “Completeness” of a binary relation denote the property that for any instance of an object type A, there has to be an instance of an object type B, for instance for any instance of substance, it must be specified where it is located.
	Quantity type	Object characteristic that can be quantified.
	Quantity condition	Required amount of a quantity type.
	Constraint	Process restriction.
	Effect	Structural effects: New objects or relations. Quantity effects: Changes in the quantity values.
	Positive influence	Object that tends to have an increasing effect to another object.
	Negative influence	Object that tends to have a decreasing effect to another object.

8. References

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http://www.epa.gov/ordntrnt/ORD/NRMRL/Pubs/2001/wetlands/625r99010.pdf (08/10/03)

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