SUPPORTING DECISION MAKING IN RIVER BASIN SYSTEMS USING A DECLARATIVE REASONING APPROACH

AquaTerra Final Conference. Processes-Data-Models-Future Scenarios.

Scientific Fundamentals for River Basin Management.

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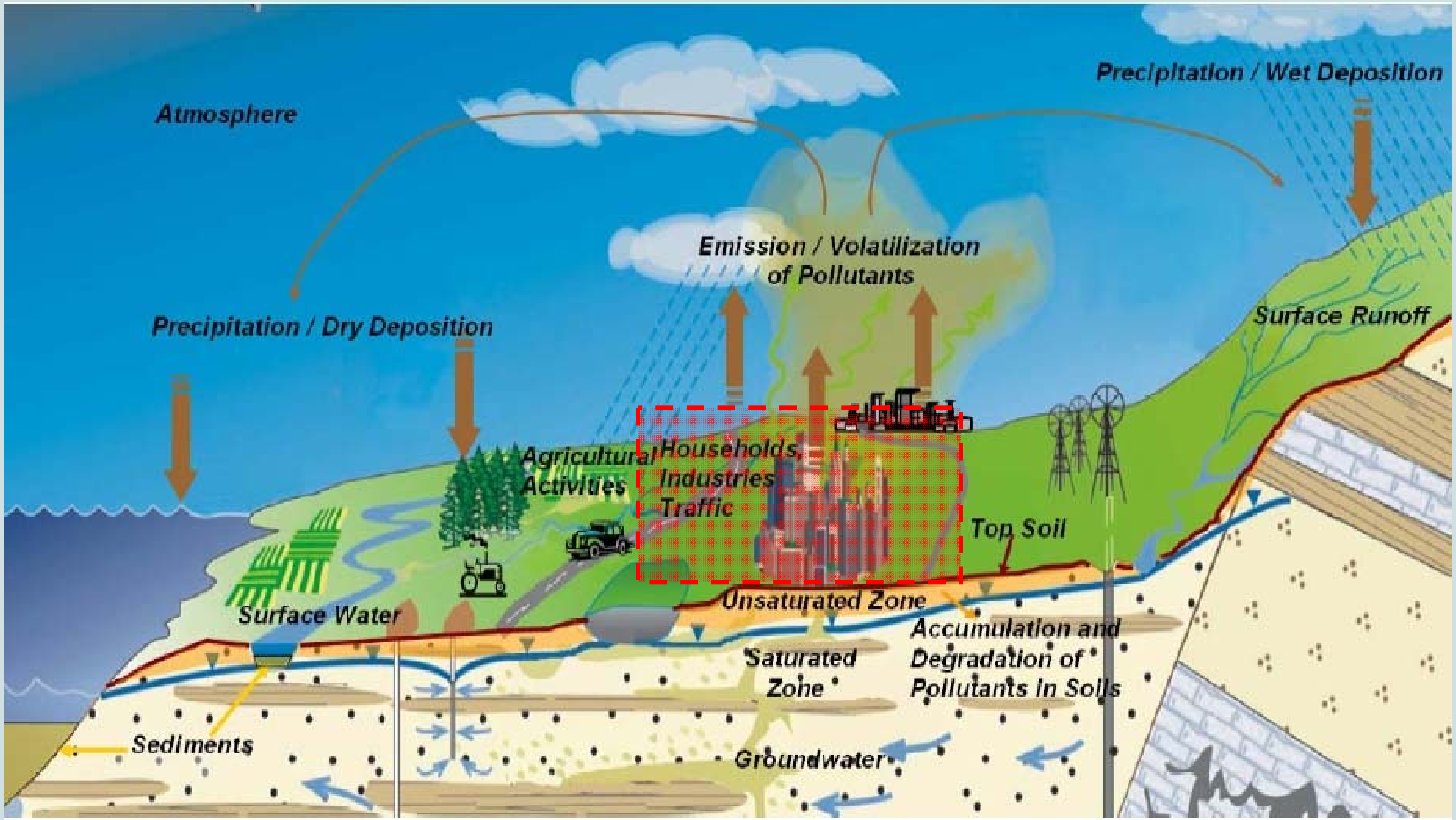
PRESENTATION OUTLINE

- Introduction:
  - Contextualizing industrial wastewater discharges in IRBM.
  - Importance of knowledge-based tools
- Methodological approach:
  - Automata (definition of 2 global automata)
  - Layered knowledge framework (how it works)
  - Possibilistic logic programming
  - Argumentation framework (evaluation)
- Results
  - Solutions (answer sets)
  - Evaluation
- Conclusions and Future work

INTRODUCTION

River Basin Management: contextualizing industrial wastewater discharges



INTRODUCTION

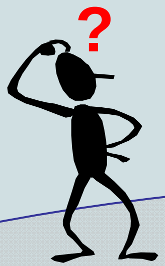
Industrial wastewater discharges management is a complex task due to:

•Quality and quantity variability of discharges

•Frequent uncontrolled discharges (changing conditions, emergence of discharges)

•Disagreement among whether a toxic or a wastewater substance is or is not safe for the final receiving media

•Different policies

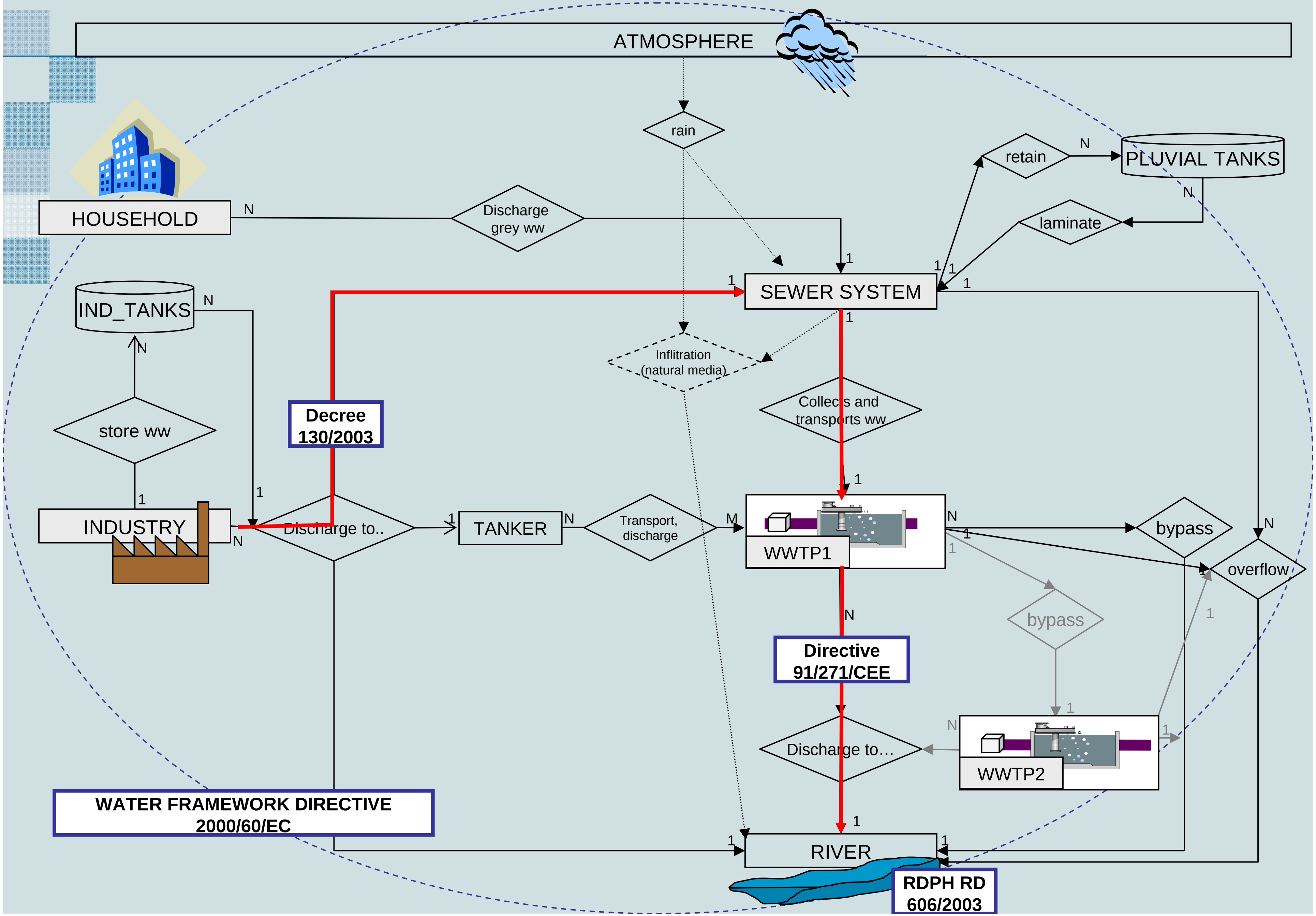


Knowledge-based modelling needed

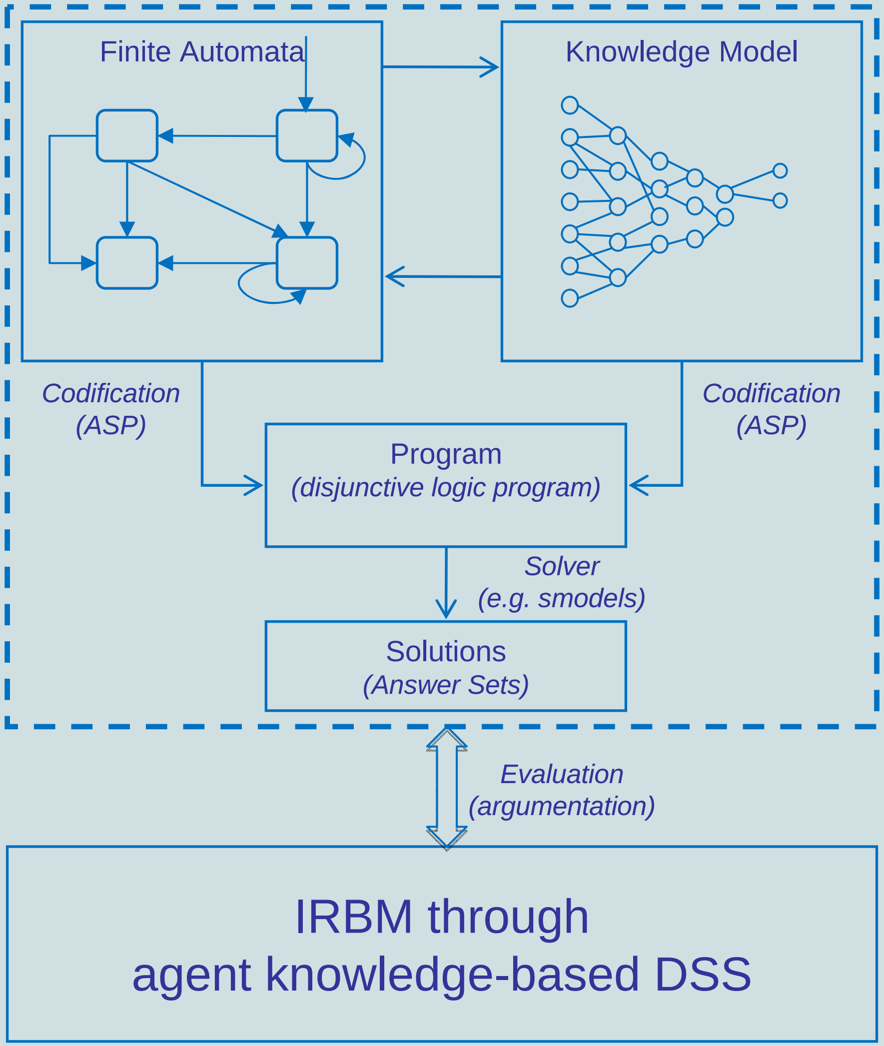
How to integrate cause-effect relationships?

How to represent the relevant knowledge to allow effective reasoning in this context?

INTRODUCTION

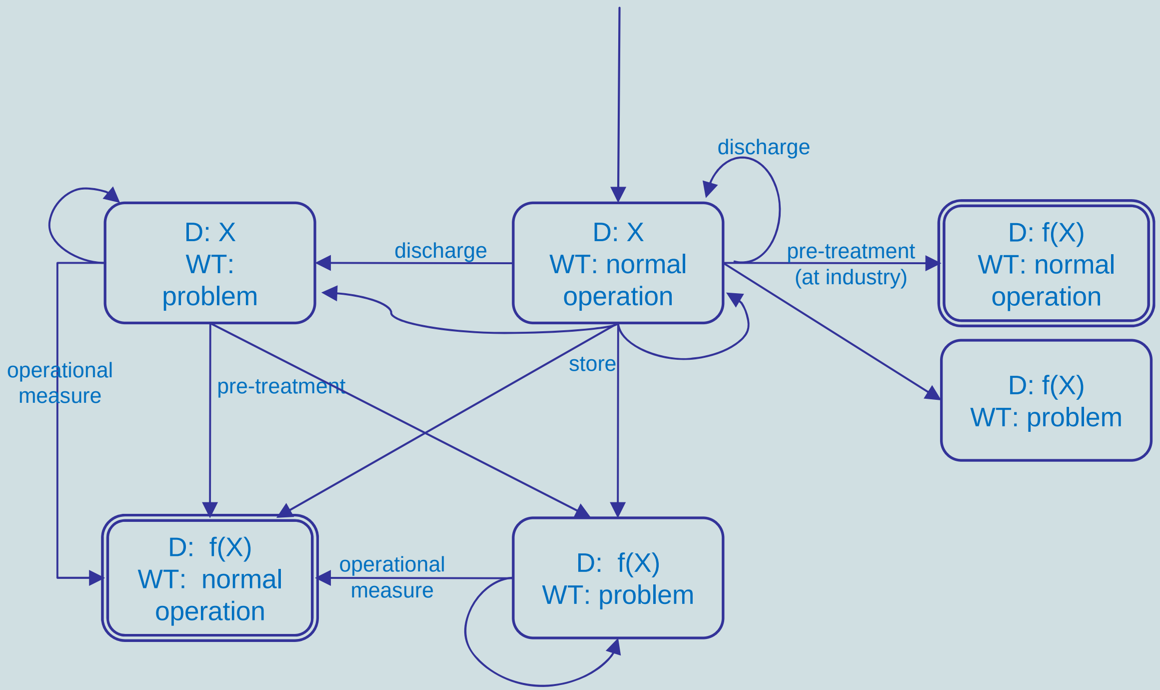


METHODOLOGICAL APPROACH



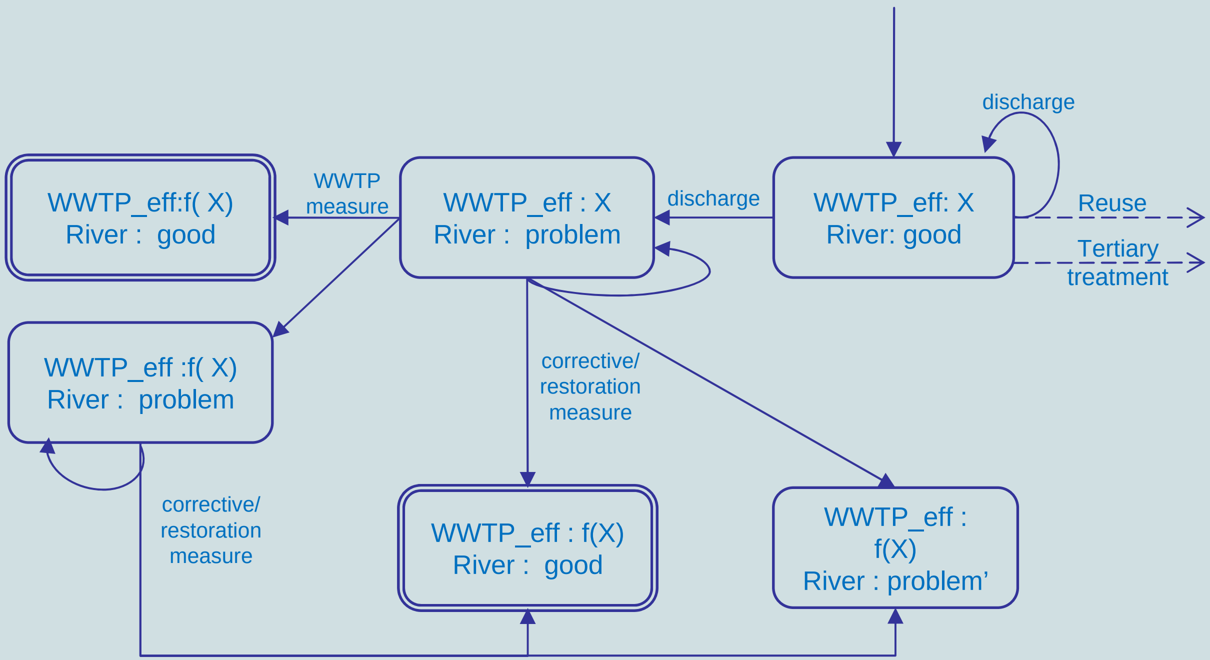
METHODOLOGICAL APPROACH

Example: automata of finite states for considering problems at activated sludge municipal WWTPs



METHODOLOGICAL APPROACH

Example: automata of finite states for considering problems at rivers given a WWTP effluent



METHODOLOGICAL APPROACH

Empiriums (e): → ***Observations (o):*** → ***Findings (f):*** → ***Facets (F):*** → ***Diagnoses (D):*** → ***Global complexes (g):***

Empiriums (e):
Dissolved Oxygen (DO)
pH
Nitrates
Biochemical Oxygen Demand (BOD)

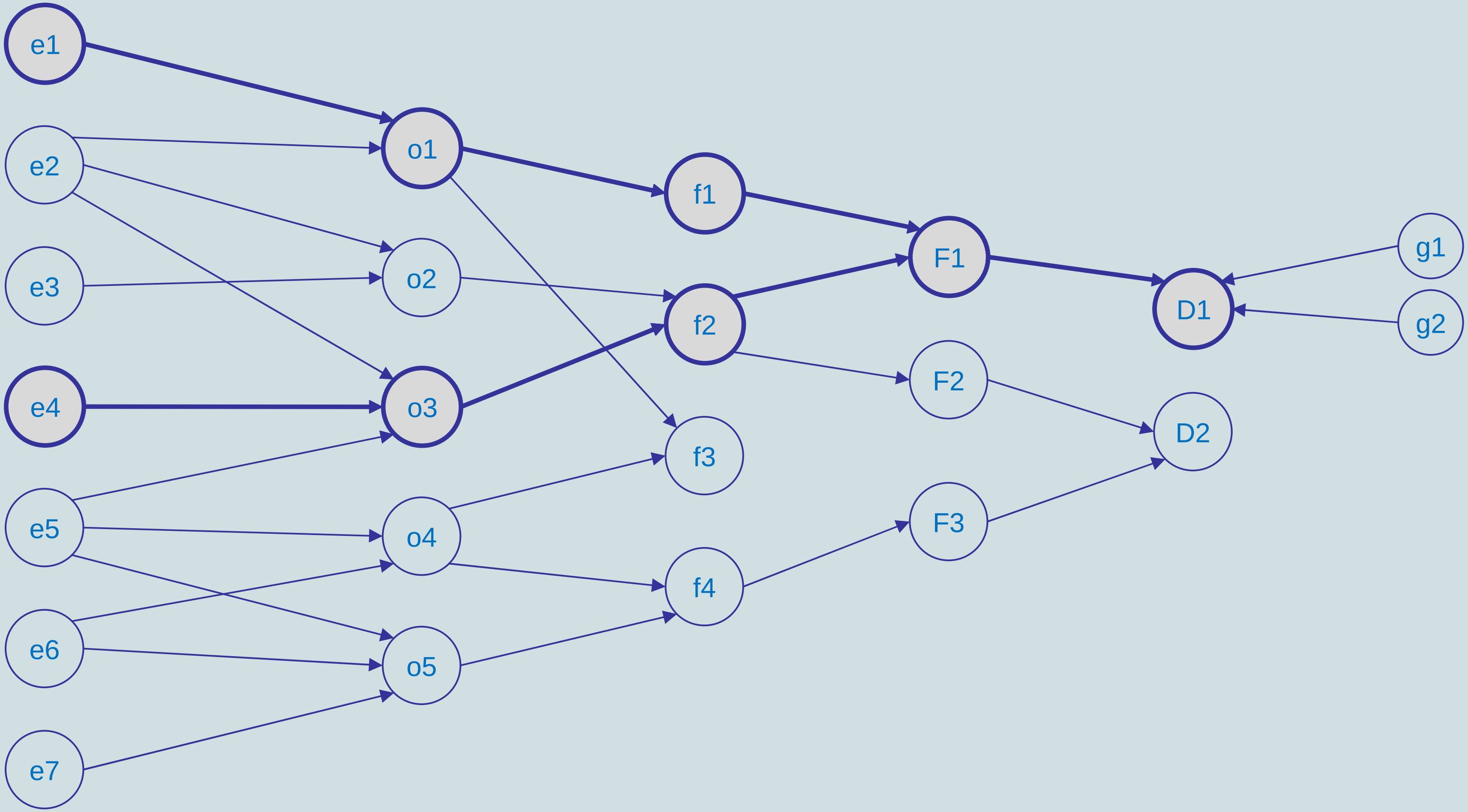
Observations (o):
pH_low
BOD_high
DO_very_high
...

Findings (f):
Biodegradability
FtoM
...

Facets (F):
Denitrification
Fungi overgrowth
...

Diagnoses (D):
filamentous_bulking
Foaming
...

Global complexes (g):
Storm
winter time (low T)
...



Knowledge-based framework (multiple layers of concept types)

METHODOLOGICAL APPROACH

The suitability of possibilistic logic programming: Answer Set Programming (ASP)

Disjunctive clause*:*

$$A \leftarrow B^{+},\ \text{not}\ B^{-}$$

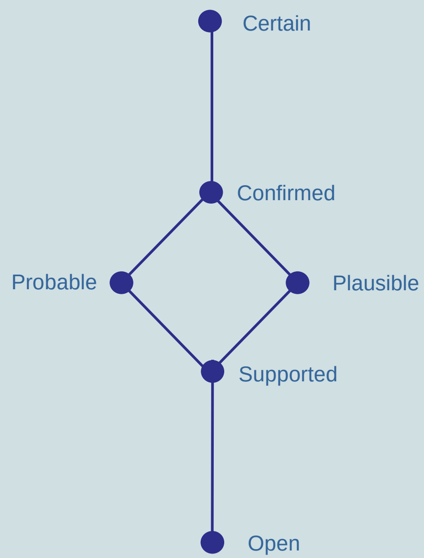
$$a_1 \vee \ldots \vee a_m \leftarrow a_1, \ldots, a_j, \text{not}\ a_{j+1}, \ldots, \text{not}\ a_n$$

Possibilistic disjunctive clause:

$$r = (\alpha : A \leftarrow B^{+},\ \text{not}\ B^{-})$$

where $\alpha \in Q$

Q={certain, confirmed, probable, plausible, supported, open}



METHODOLOGICAL APPROACH

Argumentation Framework : evaluation process

a. Argumentation construction
b. Argumentation status evaluation

✓Possibilistic arguments:

$$Arg = \langle Claim, Support, \alpha \rangle$$

✓Interaction between arguments:

$$Arg_1 = \langle Claim_1, Support_1, \alpha_1 \rangle$$
$$Arg_2 = \langle Claim_2, Support_2, \alpha_2 \rangle$$

Arg_1 *attacks* Arg_2 if one of the following conditions hold:

i. $Claim_1 = l$, $Claim_2 = complement(l)$ and $\alpha_1 \geq \alpha_2$

ii. $\exists (q{:}l \leftarrow B^+, not\ B^-) \in Support_2$ such that $complement(Claim_1) \in B^+$ and $\alpha_1 \geq \alpha_2$

iii. $\exists (q{:}l \leftarrow B^+, not\ B^-) \in Support_2$ such that $Claim_1 \in B^-$

✓Argumentation Framework and status evaluation:

$AF = \langle Args, attacks \rangle$ → Argument pattern selection → **coherent points of view**

RESULTS

In order to constraint the domain scenario the following situation is presented:

Suppose that an industry dedicated to the production of yoghurts faces a problem in the production system, and the acid lactic bacteria producing culture needs to be replaced. This implies a complete breakdown in the production, the cleaning and disinfection of all tanks with the consequent **washout of the acid lactic** producing bacteria, together with the current production of yoghurt. While common emissions from the diary industry are biodegradable, this situation will imply a considerable amount of wastewater with **high content of organic matter**, fats and greases from the milk, as well as a **low pH** due to the acid lactic bacteria.

Relevant factors considered:

Industrial discharge wastewater-related aspects: **D(X).**
WWTP operational situation: **WT(normal, problem).**
WWTP effluent characteristics: **WWTP_eff(type).**
River state: **River(good, problem).**

RESULTS

<u>Knowledge Base</u> *level* [possibility label]: `atoms`

empiriums [certain]: `BOD, COD, pH, nutrients`

observation [certain]: `discharge_characteristic(pH_very_low).`

observation [certain]: `discharge_characteristic(bod5_very_high).`

finding [confirmed]: `biodegradability(ratio_BOD:COD_medium).`

finding [confirmed]: `nutrient_availability(ratio_COD:N_medium).`

facet [plausible]: `discharge_type(organic_polluted).`

facet [plausible]: `river_situation(oxygen_depletion).`

diagnose [probable]: `problem(filamentous_bulking).`

diagnose [supported]: `problem(biological_foaming).`

diagnose [supported]: `problem(dispersed_growth).`

diagnose [probable]: `river_status(poor).`

diagnose [probable]: `river_status(good).`

global complexes [confirmed]: `weather(no_rainfall).`

global complexes [confirmed]: `environmental_temperature(temperate).`

RESULTS

Disjunctive clauses:

```
        wt(filamentous_bulking, T + 1) :- action(discharge, T),
not wt(biological_foaming, T + 1), not wt(dispersed_growth, T + 1),
not wt(normal_operation, T + 1), d(bod5_very_high, T), time (T).

        ¬wt(normal_operation, T + 1) :- action(discharge, T),
d(bod5_very_high, T), not wt(normal_operation, T + 1), time(T).

        river(oxygen_depletion, T + 2):- wwtp_eff(organic_polluted, T +
1), not river(oxygen_depletion, T + 2), time(T).

         ¬river(good, T + 2) :-  wwtp_eff(organic_polluted, T + 1),
d(bod5_very_high, T), not river(good, T + 1), action(discharge,
T), time(T).

        action(neutralize_pH, T):- d(pH_very_low, T), time(T).
        . . .
```

RESULTS

Answer Sets (solutions):

S_1={(**wt(normal_operation,1**),plausible}),
(¬wt(filamentous_bulking,1),probable),
(¬wt(dispersed_growth,1),supported),
(¬wt(biological_foaming,1),supported),
(wwtp_eff(organic_polluted,1),plausible),
(river(oxygen_depletion,2),plausible),
(¬**river(good,2),probable**)}

S_4={(¬wt(normal_operation,1),plausible),
(**wt(filamentous_bulking,1**),probable),
(¬wt(dispersed_growth,1),supported),
(¬wt(biological_foaming,1),supported),
(wwtp_eff(organic_polluted,1),plausible),
(river(oxygen_depletion,2),probable),
(¬**river(good,2),probable)**}

S_3={(¬wt(normal_operation,1),plausible),
(**wt(filamentous_bulking,1**),probable),
(¬wt(dispersed_growth,1),supported),
(¬wt(biological_foaming,1),supported),
(wwtp_eff(organic_polluted,1),plausible),
(river(good,2),probable),
(¬**river(good,2),confirmed)**}

S_n={...}

RESULTS

Arguments: *Arg = < **Claim**, Support, α >*

Arg1 = <**action(neutralize_pH, 1)**, {confirmed: action(neutralize_pH, 1) ← d(pH_very_low, 0); certain:d(pH_very_low, 0) ← ⊤}, **confirmed**>

Arg3 = <**(wt(filamentous_bulking, 1)**,{probable: wt(filamentous_bulking, 1) ← action(discharge, T), not wt(biological_foaming, 1), not wt(dispersed_growth, 1), not wt(normal_operation, 1); Certain: action(discharge, 0) ← ⊤; Certain: d(bod5_very_high, 0) ← ⊤}, **probable**>

Arg7 = <**(wwtp_eff(organic_polluted, 1)**, {plausible: (wwtp_eff(organic_polluted, 1) ← wt(filamentous_bulking, 1), not wt(dispersed_growth, 1), not wt(biological_foaming, 1); Certain: action(discharge, 0) ← ⊤; Certain: d(bod5_very_high, 0) ← ⊤}, **plausible**>

Arg8 = <**(wwtp_eff(organic_polluted, 1)**, {plausible: (wwtp_eff(organic_polluted, 1) ← not wt(filamentous_bulking, 1), wt(dispersed_growth, 1), not wt(biological_foaming, 1); Certain: action(discharge, 0) ← ⊤; Certain: d(bod5_very_high, 0) ← ⊤}, **supported**>

Arg10 = <**(river(good, 2)**, {probable: river(good, 2) ← wwtp_eff(organic_polluted, 1), not river(oxygen_depletion, 2); Certain: action(discharge, 0) ← ⊤; Certain: d(bod5_very_high, 0) ← ⊤}, **probable**>

Arg11 = <**(¬river(good, 2)**, {probable: (¬river(good, 2) ← wwtp_eff(organic_polluted, 1), not river(good, 1); Certain: action(discharge, 0) ← ⊤; Certain: d(bod5_very_high, 0) ← ⊤}, **confirmed**>

RESULTS

Argumentation Framework:

```
AF = <{arg1, arg2, arg3, arg4, arg5, arg6, arg7, arg8, arg9, arg10, arg11},
{(arg2,arg6), (arg3,arg8), (arg3,arg9), (arg10,arg11), (arg11,arg10)}>
```

Argument evaluation: preferred extensions

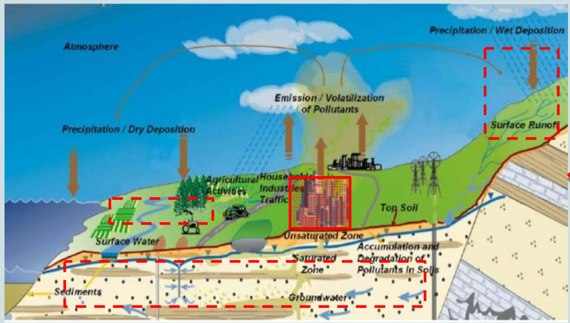
```
E1 = {arg1, arg2, arg3, arg4, arg5, arg7, arg10}
E2 = {arg1, arg2, arg3, arg4, arg5, arg7, arg11}
```

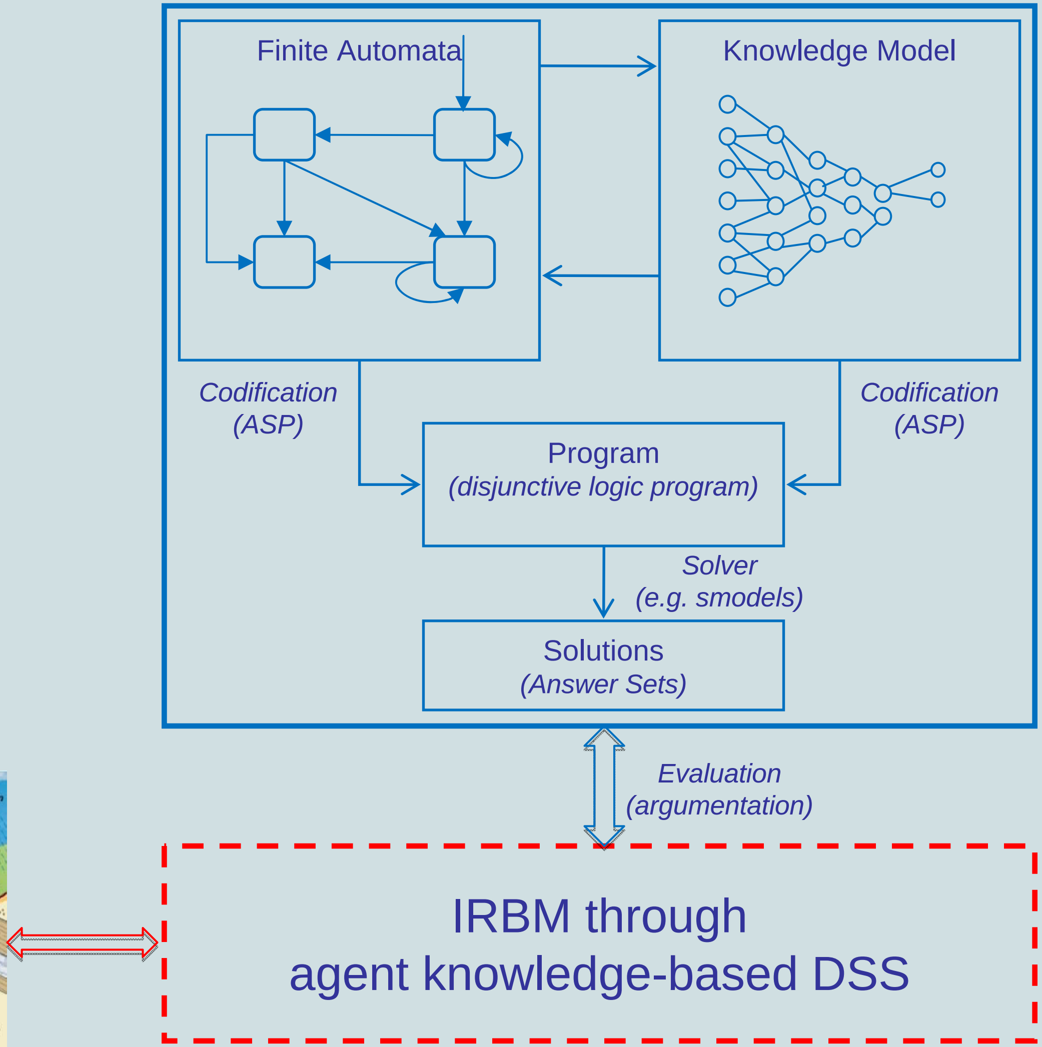
⇒ Two possible scenarios

CONCLUSIONS

- Taking decisions for the management of wastewater is a complex task.
- In order to support this task consistent knowledge is required (avoid wrong or inconvenient decisions).
- Finite state automata is useful to represent cause-effect relationships, essential in order to assess decisions in this domain.
- The proposed hierarchical structure permits to frame the degree of uncertainty related to the domain knowledge
- The codification of this knowledge in terms of a possibilistic declarative language permits to:
    - Directly execute the codified programs
    - Specify the cause-effect relations
    - Represent uncertainty degrees related to expert opinions
    - Non monotonic approach reasoning
- The overall complex diagnosis process has been automated.
- This methodological approach permits to ensure that those coherent points of view are selected, that is, that only consistent and relevant information is find out for the decision making process.

FUTURE WORK


Atmosphere
Precipitation / Wet Deposition
Emission / Volatilization
of Pollutants
Precipitation / Dry Deposition
Surface Runoff
Top Soil
Surface Water
Unsaturated Zone
Accumulation and
Degradation of
Pollutants in Soils
Saturated
Zone
Sediments
Groundwater


Finite Automata
Knowledge Model
Codification
(ASP)
Codification
(ASP)
Program
(disjunctive logic program)
Solver
(e.g. smodels)
Solutions
(Answer Sets)
Evaluation
(argumentation)
IRBM through
agent knowledge-based DSS

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QUESTIONS?

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