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Halocarbons in a Drinking Water Supply: Forecasting Contamination Values and Population Exposure

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PLAN

The contamination of a drinking water resource:

system analysis and modelling.

The problem:

estimate and forecast population exposure to halocarbons from drinking water.

The implemented solution:

time series analysis.

Procedure and results.

Further developments:

health risk assessment.

THE DRINKING WATER SUPPLY OF MILAN

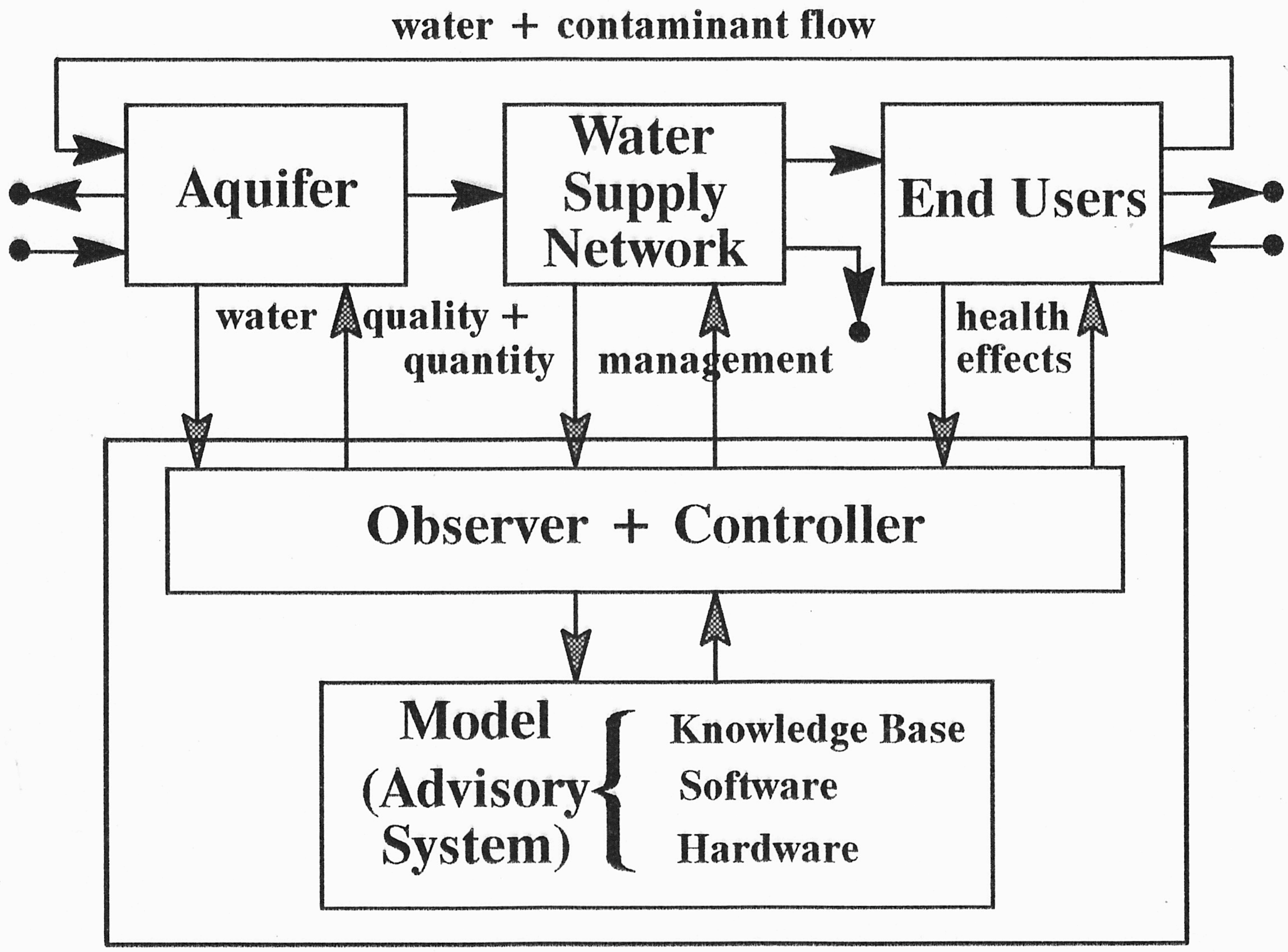
area	≈ 160 km^2
resource	quaternary (alluvial) multilayer aquifer : (top) unconfined | half confined | confined (bottom)
facilities	pumping plants: 30 since 1992 wells (40 to 160 m deep): 541 (until 1992), 544 (in 1997) well discharge rate: 20 to 40 litre/s ≤ 400 (?) privately owned wells storage tank capacity: ≈ 173 000 m^3
production	280 000 000 m^3/yr (until 1992), 250 000 000 m^3/yr (in 1996) 770 000 m^3/day (until 1992), 670 000 m^3/day (in 1996)
distribution	length of piping: ≈ 2200 km (in 1992), ≈ 2300 km (in 1997) pipe diameter: 100 to 1200 mm booster pump flow rate: .25 to .4 m^3/s 9 m^3/s average flow rate 25 m^3/s peak flow rate 5 to 8 % pressure drop
population	≈ 1 500 000 in 1992, ≈ 1 370 000 in 1996
consumption rate	
	per inhabitant: ≈ 500 l/day since 1992

EVENTS

	Milan aquifer system	**regulations**
1963	Cr^{VI} detected	
1975	volatile halocarbons (*VOC*) (TCE, chloroform, ...) detected	
1976		Advisory Board appointed by City Council sets *VOC* MAC (max admiss. concentration) in drinking water to: **250 ppb**
1980	(July 15th)	*EEC Guidelines* published
1981		*VOC* MAC set to: **200 ppb**
1983		*WHO* lists *TCE* as suspect carcinogenic in humans.
1985		Italian Government decree on drinking water quality (*DPCM 8/2/85*) issued. *VOC* MAC set to: **170 ppb**
1986	*Atrazine*, herbicides detected. Deep (< –120 m) well drilling.	
1991	(March)	Advisory Board prepares for possible emergency.
	(April)	Italian Dept. of Health grants 3 year grace period provided *VOC* MAC = **70 ppb** Emergency averted.
1991	(May 6th)	Italian water quality law becomes effective.
1992 →	Water demand keeps decreasing.	
1994	Air stripping and charcoal filtering plants operational.	Grace period expired. Water quality standards met: *VOC* MAC = **30 ppb**.

Did mathematical modelling ever play a role in the whole story ?
How and why ?

THE REAL SYSTEM
AND THE RELATED C^3I FLOW



• = Environment

SYSTEM ANALYSIS

PROCESSES	SUBSYSTEMS
water flow	*aquifer* (saturated, unsaturated) *mains*
tracer transport (diffusion + advection)	*aquifer* *mains*
reaction + adsorbtion–desorbtion + transport	*unsaturated medium* *living organisms*
plant deterioration	*wells, mains*

Well, everything eventually hangs on
$\nabla \cdot (a \nabla u) = \Phi[u]$,

but ...

THE PROBLEM

MAIN PBM. : *Estimate & forecast the exposure of population to halocarbons from drinking water.*

SUBPBM. : *Estimate & forecast the concentration of halocarbons in the water distribution* ***network****.*

QUESTIONS (originated from the SUBPBM.)

1 *How to model water flow and contaminant transport through the network ?*

2 *How to relate contaminant concentration values in the aquifer to those in the network at later times ?*

CONSTRAINTS (time and money)

Carry out the analysis & forecast

as quickly as possible

with the available data (from the network).

REMARKS

♠ Models based on PDEs are data greedy (*datengierig*).

♠ The water supply network is higly interconnected.

THE SOLUTION STRATEGY

♣ Neglect the aquifer – to – network relation.

♣ Avoid hydraulic models for the network.

⇓

✱ Use **black box** models for the time series of concentration values alone at network sampling points.

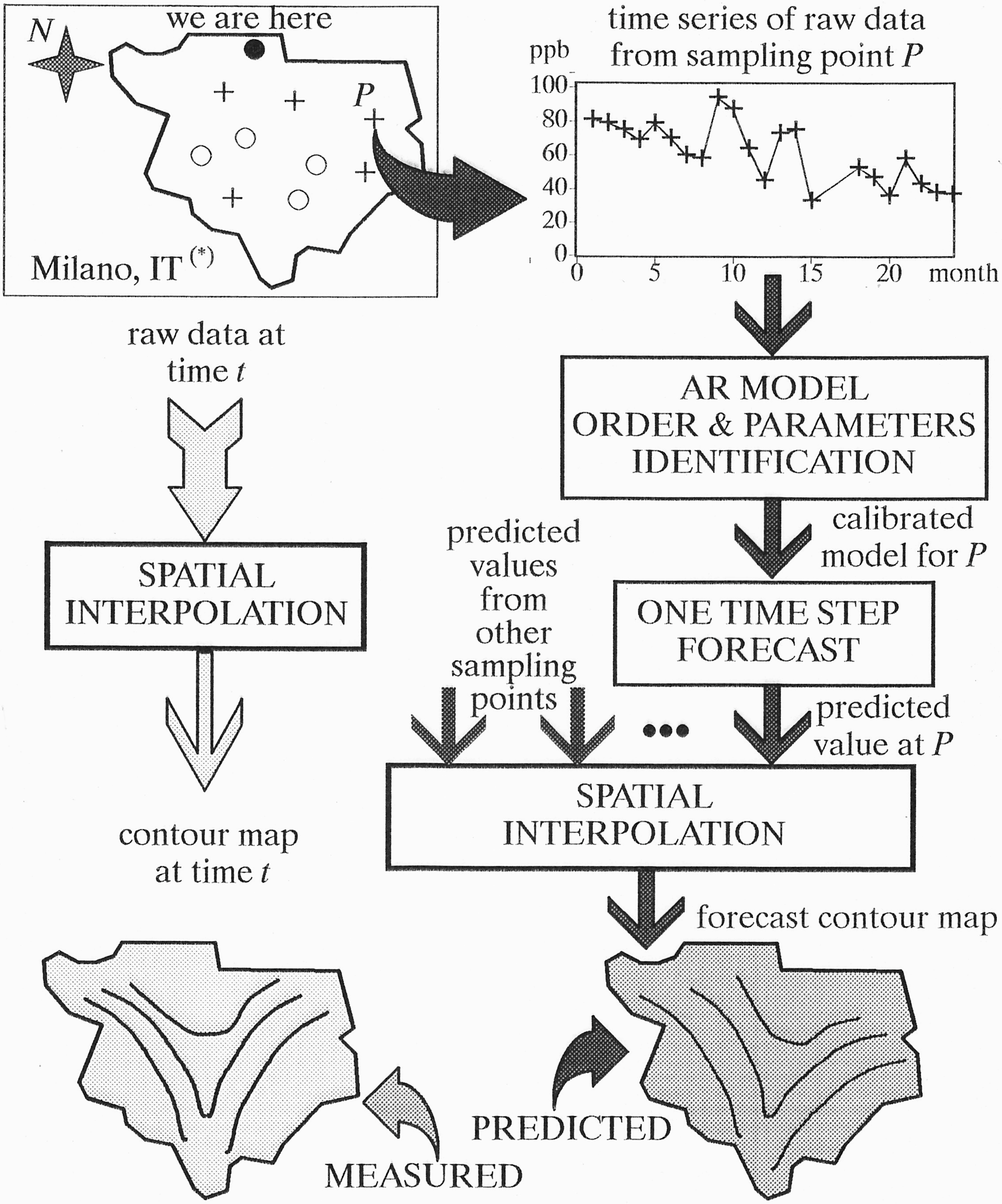
TIME SERIES:
ANALYSIS, FORECAST AND APPLICATION

"Science proceeds more by what it has learned to ignore than by what it takes into account"

GALILEO' s (*) conclusion

(*) Credit to the quoted Author has not been double checked.

PROCEDURE



(*) not to be confused with either Milano, TX or Milan, NM.