WATER BALANCE MODEL FOR EVALUATION OF LANDFILL MALFUNCTION DUE TO LEAKAGE

Landfill of Mavrorachi

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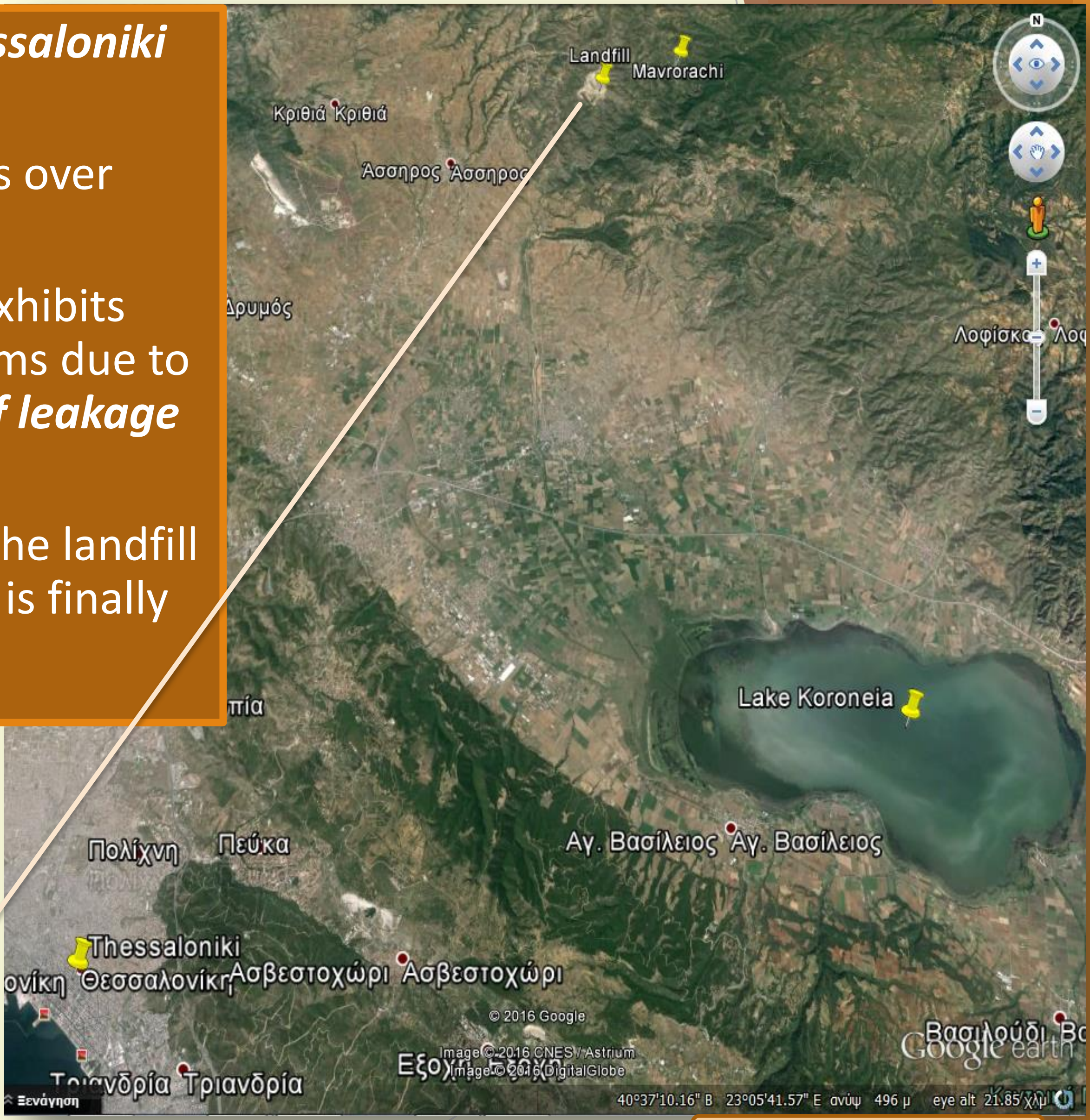
Case study : Landfill of Mavrorachi, Thessaloniki, Northern Greece

- Located in ***NW region of Thessaloniki*** at Lagadas Municipality
- Landfill area: 337 acres, spans over four cells
- From ***June 2008*** the landfill exhibits severe environmental problems due to ***systematic overproduction of leakage (+ lateral outflows)***
- The stream network around the landfill enters river Bogdanos, which is finally drained at ***Lake Koroneia***



Source: Google earth

Annual landfill data for years 2008-2014

Year	Waste disposal (tn)	Precipitation (mm)	Leachate production (m^3)
2008*	217 830	229.4	9 655
2009	525 721	490.6	65 258
2010	502 312	562.4	85 934
2011	459 685	341.2	75 567
2012	426 958	443.8	82 706
2013	401 609	420.8	94 996
2014	422 917	737.3	137 895

(*) Accounted from June 2008 (start of landfill operation).

Source: FODSA, 2015

Despite the decrease of waste disposal by 20%, an substantial increase of leachate production is observed due **accumulated moisture**, contrasted to the decreasing storage capacity of the waste mass, and the large amounts of **recycled leachate** from the WTP

The increased inflows to the WTP during 2014 resulted to important overflows – Indication that the design capacity of the plant has been underestimated.

Monthly data for year 2014

Month	Waste disposal (tn)	Precipitation (mm)	Average temperature (^oC)	Recycled leachate (m^3)	Leachate production (m^3)
Jan-14	32 816	50.0	6.5	1 812	8 314
Feb-14	30 633	79.8	8.9	1 036	7 233
Mar-14	33 254	101.2	10.9	252	5 816
Apr-14	35 690	161.8	13.8	4 571	7 837
May-14	35 871	58.0	16.4	5 439	10 753
Jun-14	35 037	27.4	24.6	4 105	9 424
Jul-14	36 469	57.0	25.5	5 342	10 270
Aug-14	33 189	42.4	26.3	6 334	9 375
Sep-14	39 266	175.6	19.8	2 409	8 473
Oct-14	40 141	65.4	15.2	2 558	6 414
Nov-14	34 010	88.6	11.4	4 799	8 348
Dec-14	36 583	204.6	6.2	5 603	8 348

- It is observed that the **peak of leachate generation** is during **summer months**, which is not straightforward to explain on the basis of available input data. In addition, significant **lateral outflows** have been observed during rainy months. In contrast to vertical leachate, these **significantly polluted waters** cannot be collected and conveyed to the treatment plant, and they are thus added to downstream surface and groundwater runoff.

Difficulties on modelling the hydrological operation of a landfill

- Inherent complexity of the associated processes and their interactions
- Dynamically-evolving system:
  - ✓ Time-varying geometry of the basin
  - ✓ Increase of overburden loads

affects

- ❑ Field capacity
- ❑ Unsaturated hydraulic conductivity

Source: D. Dermatas

Inputs - Outputs data of model

- Monthly simulation model, calibrated against the observed leachate inflows of year 2014
- Model inputs:
  - Precipitation & temperature (meteorological station of Lagadas)
  - Potential evapotranspiration (estimated on the basis of temperature)
  - Waste disposal
  - Moisture of entering solid waste (assumption)
  - Recycled inflows (from the treatment plant)
- Model outputs:
  - Surface runoff
  - Lateral runoff (leachate drained to river)
  - Evapotranspiration losses from upper layer
  - Percolation across layers (top → down)
  - Leachate generation (= percolation from lowest layer)

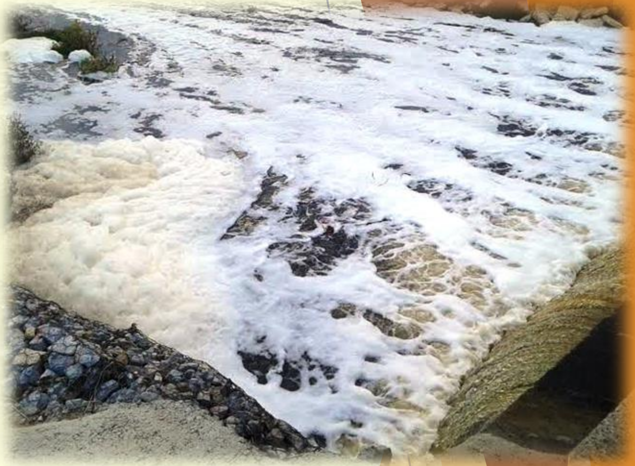
Source: Google

Field capacity (FC)

$$FC = \frac{0.60 - 0.55\,w}{\lambda \cdot 3790 + w}$$

(Tchobanoglous *et al.*, 1993, after conversion to SI units)

Correrection parameter, accounting for local characteristics of waste



Source: Google

- Associated with waste density
- It decreases as the density (waste depth) increases (time-dependent parameter)
- It's expressed in percentage units (%)
  - w: the overburden weight calculated at the mid-height of the waste column of interest
  - λ : dimensionless parameter in order to fit the model to local characteristics of Mavrorachi landfill

Infiltration model (1/2)

- The top layer receives three external fluxes: precipitation, entering waste moisture, recycled leachate
- From precipitation via equations are extracted: surface runoff, direct evapotranspiration, potential evapotranspiration
- Net inflow: $\mathbf{i_t = p_t - q_{St} - e_{Dt} + m_{Wt} + r_t}$
- The monthly precipitation occurs through few storm events at much finer time scales and precipitation usually exceeds PET, whereas on a monthly basis this may be not true.
- Lateral flow:

$$q_{Lt} = \begin{cases} 0 & i_t \leq i_0 \\ \dfrac{(i_t - i_0)^2}{i_t - i_0 + k} & i_t > i_0 \end{cases}$$

k : potential maximum retention of the top layer

i_0 : threshold for lateral flow generation

Infiltration model (2/2)

- The rest of evapotranspiration demand (PETt – eDt) is fulfilled via the available moisture of the upper layer (of the entering waste). The rate of filling depends on the saturation ratio of the upper layer.
- Actual evapotranspiration:

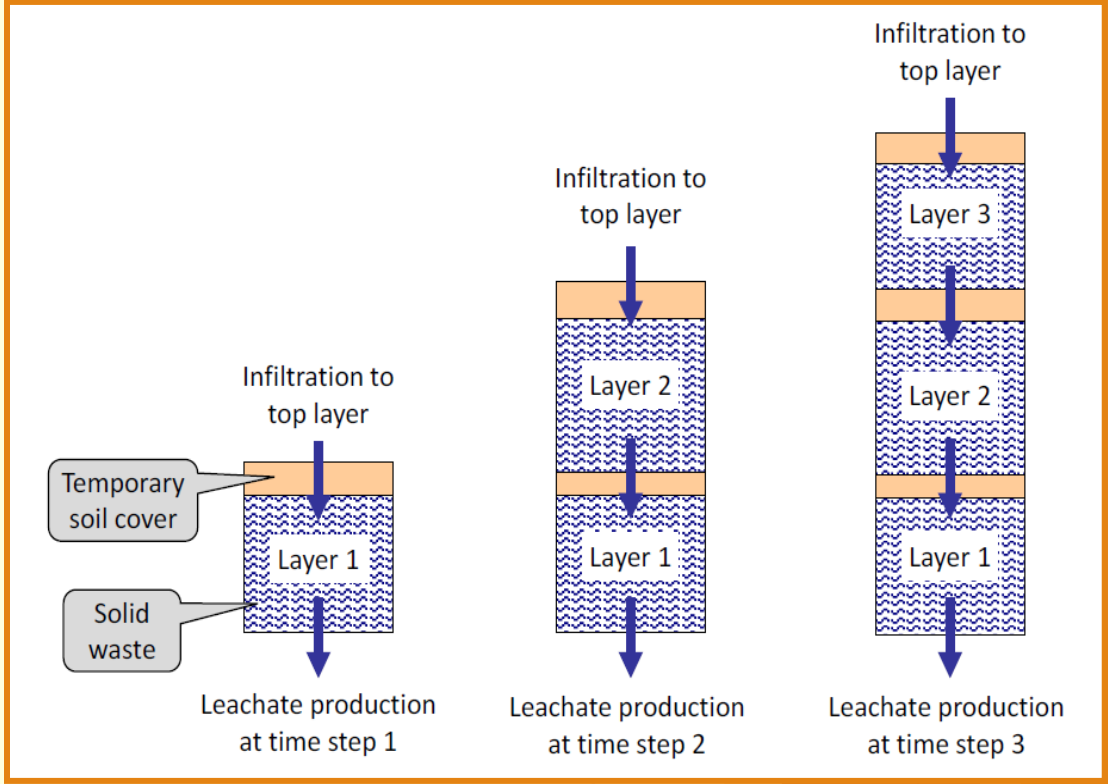
$$m_{Wt} = \frac{(PET_t - e_{Dt}) \cdot m_{Wt}}{m_{Wt} + k}$$

Source: Google

- Infiltration to top layer: **$y_t = m_{Wt} + i_t - q_{Lt} - e_{St}$**

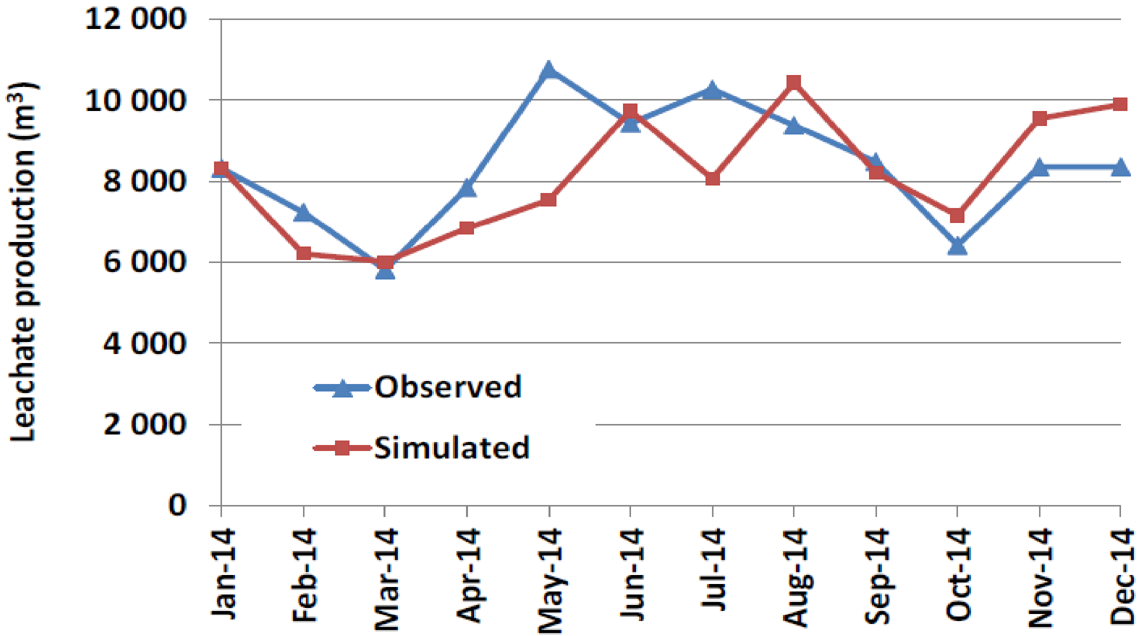
Percolation model - Schematic representation of model operation for three subsequent time steps

- The shape of the landfill is considered rectangular
- Within a monthly step, the water moves vertically across layers (percolation)
- Assumption that each layer receives the accumulated percolation from up to four upper layers
- Water balance equation is solved from top to bottom



Model calibration

- Hybrid calibration approach, ensuring physically-consistent parameter values
- The model fitting is quite satisfactory, and reproduces the unusual seasonal variation of leachate production (max at summer)
- The simulated lateral leachate losses during 2014 are estimated to reach 1700 m^3



Comparison of observed vs. simulated production of leachate for year 2014.

Conclusions

- Our modelling experiment indicated that **precipitation** is not the major source of leachate production, although it is obviously associated with **lateral outflows**.
- The **key driver is the accumulated moisture** due to the combination of the meteorological forcing, the relatively high moisture content in the entering waste and the significant amounts of treated leachate that are **recycled** within the landfill.
- An important conclusion is that while the accumulated moisture in the waste body is quite rapidly increasing, its **field capacity** decreases, thus less storage capacity is available to store all above sources of inflow.
- Next research steps:
  - Generalization of model to run in **stochastic simulation** mode
  - Investigation of the response of the landfill system against different **future operation scenarios**
  - Development of **management measures** for the mitigation of current environmental problems.

Thank you for your attention!

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