Environmental Monitoring: What, How and To What End?

Martin von Allmen

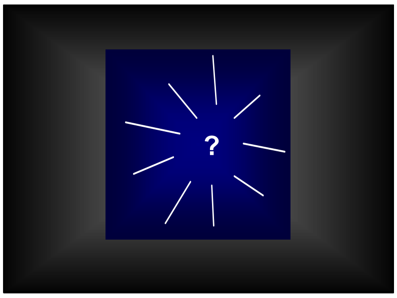
Abstract – I start by reviewing a few basic facts illustrating the uniqueness of our planetary environment and the extent of the human impact on it. Quantifying and assessing this impact is the purpose of Environmental Monitoring. After discussing some of today's monitoring practices and methods, I argue that monitoring technologies will play a key role in managing the impending historic crisis in mankind's development. This Workshop's aim - to promote the application of novel sensing and data processing technologies in environmental monitoring - opens exciting prospects for fostering progress in this crucial field.

I. A LOOK FROM OUTSIDE

The universe

seems to have had a *beginning*, known as the Big Bang. It's pictured as an infintely dense spark of pure energy at t = 0, thereafter exploding and cooling adiabatically. After some hundred thousand years a small part of the energy began condensing into hydrogen. For a long time there was nothing else.

Today, 14 billion years later, the spark stretches a volume 10^{26} m accross and has cooled to a mere 2.7°K.



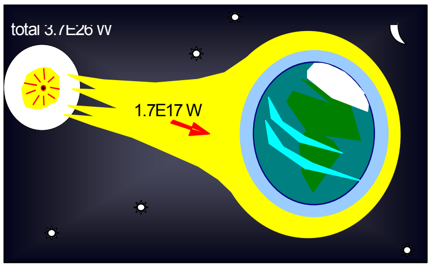
The explosion continues, apparently still accelerating.

Braving the expanding void, a small part of the hydrogen atoms managed to hold together by their gravity, forming clouds that eventually collapsed into dense bodies. In the process many of these bodies got hot enough to ignite, becoming stars. Others remained too small to heat up appreciably. Some became planets, circling stars.

The author is with TECHNIK-UMWELT Neosys AG, Privatstrasse 10, CH-4563 Gerlafingen, Switzerland (visit us at www.technik-umwelt.ch).
Phone 0041 32 674 4501, Fax 0041 32 674 4510,
E-mail martin.vonallmen@technik-umwelt.ch

The solar system

Our star formed 4.5 billions years ago. It has a mass of $2 \cdot 10^{30}$ kg and a surface temperature of 5785°K. Second for second, it radiates away an energy of $3.7 \cdot 10^{26}$ J.

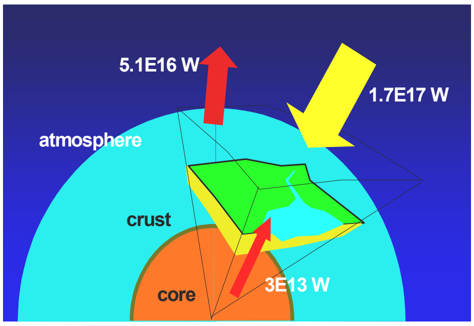


The sun is circled by 9 planets. The third, Earth, orbits at a radius of 150 million km and a speed of 10^6 km/h. Also spinning slowly around a tilted axis, it maintains a relatively steady surface temperature of 285°K or +10°C. Of Earth's direct neighbours, sunward Venus is a hellish 450°C, sunway Mars a frigid -150°C.

This happy situation is not forever: Whithin another billion years, the current era of stability will come to an end. The sun will start expanding and eventually engulf all its planets.

Earth

is basically a rocky sphere of $6 \cdot 10^{24}$ kg with a radius of 6370 km. 71% of its surface is covered by water. The whole thing is clad in a gas cover many tens of km thick.



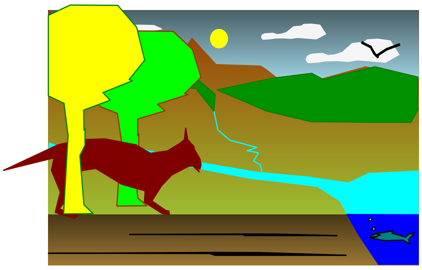
As a result of radioactive decay in its interior, Earth's iron core remains hot and largely molten. The solid crust is just 2 km thick and in constant motion. The heat from below adds about 150°C to the surface temperature. The molten core creates a magnetic field that deflects energetic particles from the sun.

This improbable combination of circumstances conspires to create a stable ambient in which water is liquid but molecular bonds remain firm, Free Energy is plentyful but hard radiation is kept away.

Life

Once the earth was in place, it took no more than a few 100 million years for simple lifeforms to appear. Their creation apparently relied on spontaneous chemical reactions and self-organized steps, guided only by the competition for resources:

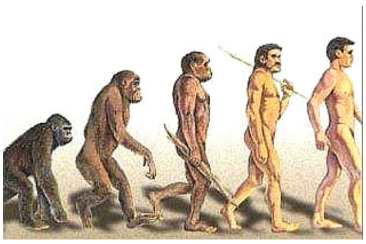
- Synthesis of organic compounds from simpler building blocks
- chance appearance of self-replicating molecules, immune to oblivion, giving rise to
- photosyntetic and other energy-producing reaction chains,
- their segregation in metabolizing compartements,
- *their* self-organisation as „living“ cells (archaea, bacteria), and
- *their* integration into collective organisms - plants and animals.



Since its materialisation on earth, life has reshaped the planet profoundly, creating a thermodynamical - ly instable oxydizing atmosphere, an uv-absorbing ozone layer, extensive weathering of rock, a global plant cover and a biomass exceeding a trillion tonnes (10^{15} kg).

Homo sapiens

Lifeforms exhibit a tendency towards increasing complexity. The genus *Homo* exists for 6 million years, the species *Homo sapiens* for 60’000±20'000 years. Most of this time the Homos lived in small groups as hunters and gatherers.



10’000±2000 years ago they made a discovery with vast consequence, agriculture. This triggered a transition from nomadic to sessile lifestile, apparently starting in Mesopotamia and conquering the globe in just a few thousand years.

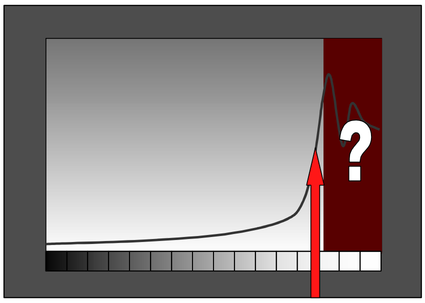
The new lifestyle had lasting consequences for H. sapiens - exploding population, division of labor, social stratification, politicians, epidemics, ABO-blood groups - but also led to science and technology, space travel, mass production and ultimately a runaway increase in consumption.

The consequences for life on earth are dramatic:

- 50% of the fertile soils, as well as
- 40% of all ocean yields

are being consumed by one single species [2]. Their domesticates dominate the biosphere:

- Wheat, rice and corn, delivering 60% of human food calories, are the most numerous plants
- 6 domestic animals (sheep, cow, goat, pig, horse, dog) constitute the majority of higher lifeforms
- wild animals and plants are going extinct at a unprecedented rate.



This is our crisis. Today 6 billion of us consume half of the planet‘s renewable resources. Whithin 50 years we might reach 9 billion.

Moreover,

- fossile fuels accumulated over millions of years are being consumed within 300 years (roughly 1800-2100). 15 generations will have benefitted, out of 3000
- man-made greenhouse gases will probably affect the climate for a long time to come, in ways not yet understood
- there is a bizarre disequilibrium in the distribution of the world‘s wealth, with 10% of the population owning or consuming 80 or 90% of all goods. A more balanced distribution will not come without losses for some. Conflicts and wars are unavoidable.

II. Measures of Impact

The follwing is a list of the main parameters of interest in environmental monitoring today:

- Pollutant concentrations in air, water and soil
- climate indicators (temperature, snow cover, permafrost, desertification..)
- rain and soil acidity
- topsoil quality (nutrients, water, biomass, erosion)
- wildlife status (abundance, diversity, turnover..)
- land and water use
- material and energy (primary, secondary, „grey“) uses
- noise and radiation levels
- compound eco-indicators
- entropy ..

Entropy

Earth is an open system that, according to thermodynamics, remains stable as long as it manages to keep its entropy in balance [1].

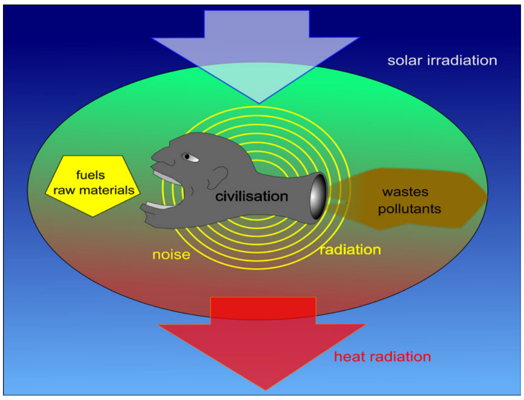
The earth has a powerful entropy pump, as it receives low-entropy visible solar radiation while reradiating high-entropy infrared. The net entropy flux is approximately

$$J_s \approx \frac{J_*(1-A)}{3}\left(\frac{1}{T_*}-\frac{1}{T_\bullet}\right)$$

(J_*: incident solar flux, A: albedo≈0.3, T: radiative temperature of ∗ sun and •earth, respectively). This gives $J_s = -6 \bullet 10^{14}$ W/°K or, as a

global average: -1.2 W/K•m^2.

On the other hand, entropy is an unavoidable byproduct of all we ever do.



Typical rates of entropy production per adult person:

- body metabolism 0.5 W/K
- total consumption: global average 10 W/K (India 2, USA 35).

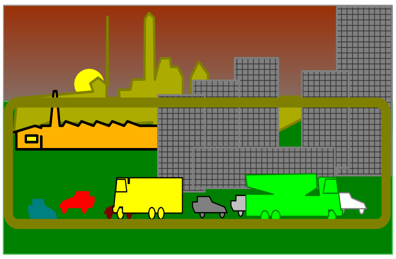
Typical rates per m^2:

- plant photosyntesis: 0.001 W/K•m^2
- modern agriculture: 0.1 W/K•m^2
- metropolitan area: 4 W/K•m^2.

Some straightforward conclusions are that

➔ cities need large hinterlands
➔ less insolated habitats are more vulnerable
➔ there is a maximum population size for entropic stability, inversely related to the level of consumption.

III. The Artificial Habitat

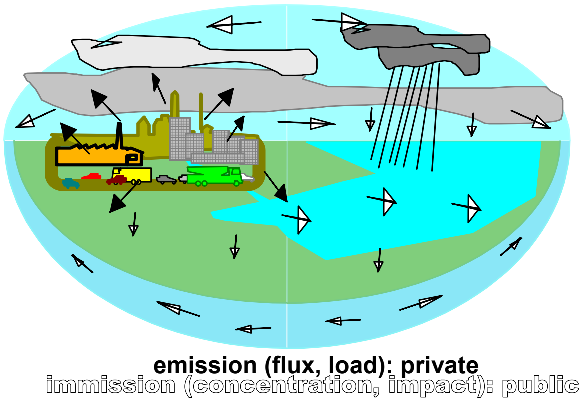


We spend most of our lives in a synthetic habitat of buildings, machines and traffic ways. It acts as an „embedded" environment with its own hazards and irritants that deserve monitoring:

- Building poisons: Asbestos, formaldehyde, PCBs, biocides, smoke, fine dust (<10 µm), metal vapours, ozone, dioxins, pathogens..
- noise and vibrations from industry, traffic, neighbours..
- „electrosmog" from power lines, appliances, mobile phones..
- ionizing radiation from medical applications, picture tubes, Radon..
- smells from stacks, solvents, detritus, animals, grill parties..

IV. Current Monitoring Practices

Emission and immission



Emission and immission monitoring, while relying on similar technologies, serve different purposes:

monitoring	*a duty of..*	*limit violation causes*
emission	source owner	penalty, improvement
immission	community	revision of public rules

Current monitoring techniques

involve all sorts of „hard", "soft" and "fluid" technologies and procedures [1]:

- In-situ chemical and physical sensors
- sample taking followed by laboratory analyses
- airplane and satellite imaging surveys
- electromagnetic detection (emission, scattering..)
- sonar and radar tracking
- impact on indicator plants and test animals
- judgment of human subjects
- „mining" of production, trade and consumption data
- analysis of economic and financial indicators
- polls, hearings, assessments…

Examples of real-world monitoring assignments
(a selection from our mandates of the last two years)

topic	*client*	*methods*
regional immission inventory/forecast	community council	data gathering & extrapolation
lead pollution from diffuse emission	battery recycler	dust collection, lab analysis
SO2 from power plant	power corporation	CEMS, AQMS [3]
industrial waste water discharge	steel mill	weekly lab tests
electrosmog from GSM base stations	service providers	field measurements, modelling [4]
highway construction impacts	highway authority	inspections, hearings, measurements

V. Purposes of monitoring

Environmental Monitoring is a technical act. However, the information it produces can have powerful consequences far beyond the technical realm. Monitoring can serve, e.g., to

- facilitate resource use to the limit
- prospect for fishing, mining or oil industry
- protect human property, safety or comfort
- assess wildlife
- improve modelling of global systems
- rise public awareness, change attitudes
- influence politics.

It is our responsibility as scientists to put our weight and our expertise on the side that helps to restore and protect our unique planetary home.

VI. References

[1] von Allmen, M: Course in Environmental Techniques „*Umwelt-Techniken*", University of Bern, 2002/2003
[2] Pimm, S.: The world according to Pimm, McGraw-Hill, New York, 2001
[3,4] see my contributions to the 1. Workshop, Milano, 2001.