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Natural laws dominate the human society

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Human evolution is governed by non-equilibrium thermodynamics of bio-systems. Natural laws are determining the ever increasing pollution, endangering to self-destroy the human race just the same way as yeast does when producing ethanol. The dominating power of natural laws is shown in the paper; it is stronger than the cultural awareness of mankind (law, religion and moral, education and ethics). Only natural catastrophes can make people act in a different way, towards lowering the pollution. Although the catastrophes are increasing at an exponential rate, it may be too late for human action, when heat waves, sea level rise, desertation, or floods will act strong enough to make the mankind respond culturally (non-naturally).

1. Introduction

Human population on the Earth is increasing and so is the living standard of most people. Simultaneous population growth and rising consumption per capita are increasing pollution at an accelerating rate. Needing increasingly more resources, the mankind is reducing diversity of species (e.g. by deforestation, draining), intensifying extraction of raw materials and fossil fuels, exhausting natural reserves of non-renewable materials and energy. The nature is responding with a climate change and natural catastrophes. Is sustainable growth or at least status quo possible?
The same natural laws are governing material-, bio- and social-systems on the Earth. These systems have the same, universal, aggregated structure in each of them, e.g.:

Atom → molecule → unit cell → crystal → phase → material
Atom → molecule → bio-cell → tissue → organ → organism
Human → family → community → region → state → union
Employee → plant → factory → company → multinational company.

Material structure has of course different levels of scale. At the pico-level atoms, ions, and molecules exist. Nano-level has nuclei, lamellae, and bacteria; micro-level contains crystals, spherullites, fibriles, domains, micro-crystallites, and cells. On the macro-level stones, tissues, organs, organisms, families, and companies exist. Global level has different populations and ecosystems, all constituting the nature. On the social level villages, cities, provinces, nations, and unions exist. Material or social structure is governing flows of material, energy, information, and innovation.
Examples showing that the same rules are governing material- (geo-), bio- and social-systems are abundant. Minimum energy tendency is characteristic for atoms, organisms, people, and companies. Big entities 'eat' smaller ones, as exercised by crystals, fishes, companies, nations. Re-crystallization of too big units takes place by destroying uncompetitive structures – nucleation and growth in materials, creative destruction in economy (big units are transformed into smaller ones, able to survive). This happens in

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companies when radical changes on the market occur, e.g. at disintegration of a state, or financial crisis. Critical extent, e.g. radius (of a nucleus), or mass (of a foetus, atomic bomb), or turnover (in an enterprise) is needed to ensure spontaneous reaction or growth.
Environmental protection is characteristic for all entities. Bubbles, drops, particles are protected by a fluid film (gas or liquid) on their surface. Solid film (oxide or adsorbent layer) is formed on the surface of a metal, peel is protecting fruits (apples, pears), and bark covers trunks and branches of trees. Cell has a membrane, egg has a shell, skin and wool is protecting animals, humans have clothing, house has walls, plant has fences, and state has frontiers.
Self-organization happens when e.g. cutting a polymer film (molecules un-coil, un-kink, and reorient to stop propagation of a crack). Strain hardening occurs when stress is applied to ductile materials. Antibodies are fighting against evaders in animals. Spontaneous resistance movement against invasion frequently happened in the human history, e.g. resistance against landlords in Middle Ages, partisan movements against Hitler's troops in Second World War. Green Alliance and voluntary agreements have been founded to protect the nature from pollution. Let us see the natural laws behind it!

2. Equilibrium and Non-equilibrium Thermodynamics

Three different types of systems are known in thermodynamics (Prigogine, 1977):

- **Isolated** systems, which cannot exchange either matter or energy – entropy (disorder) in these systems is increasing, whenever leaving the equilibrium, e.g. with time.
- **Closed** systems can exchange energy but not matter; an example of such a system is the Earth, receiving energy from the Sun but not exchanging any substantial matter with the Universe. Energy of such a system is minimized in equilibrium.
- **Open** systems exchange energy and mass – biosphere being a typical example (e.g. animal, human, or town). Spontaneous self-organization and ordering by fluctuations results from non-equilibrium taking place in such systems, causing evolution to continue. This natural law was experimentally proven by 'chemical waves' and 'chemical clock', which are similar to the biological cycles (e.g. number of mongooses and snakes) and social ones (like supply and demand).

Elements of evolution are elementary interactions (microstructure), space-time organization (macrostructure), and fluctuations, which are forming dissipative structures with their own wavelength or time constant. They have been experimentally demonstrated by Belousov-Zhabotinski's reaction (Zaikin and Zhabotinski, 1970). Time constant of the "chemical clock" (in min) and wavelength of the "chemical waves" (in mm) differ widely from the molecular ones (in ps, nm).
Non-equilibrium thermodynamics requires several conditions to be fulfilled: matter and energy exchange has already been mentioned. Feedback of information is another condition, being accomplished already in autocatalytic reactions. Evolution of mankind was a typical example of an irreversible change as the system was out of equilibrium and open, i.e. exchanging matter, energy, and information:

1. *Material* utilization has given names to historical ages (Stone Age, Bronze Age, and Iron Age). Inventions of cement, ceramics, aluminium, titanium, alloys, plastics, composites, nano- and bio-materials followed.
2. *Energy* development was explosive, too, although the Sun remained by far the most important, but not fully utilized source: wood (fire), domestic animals, waterwheels, windmills were used as additional, renewable energy sources. Later,

coal, steam, electricity, oil, gasoline, gas, fission have been satisfying the ever growing needs of mankind. Bio-refineries, photovoltaic cells, tar sands, methane hydrates, fusion, etc. are hoped to solve future energy needs of mankind.

3. Natural *information* of humans is transmitted by genes, while accumulated experience is exchanged by education and messages. Many technological means of exchanging information have been invented in the history of mankind: speech, script, print, telephone, radio, telegraph, television, computer, video, and internet are examples of exponential development rate.

The exponential growth enabled the human race to master the Earth and other species.
Self-organization of systems at equilibrium against external disturbance has been known for centuries as the Le Chatelier's Principle: »When an external force is applied to a system in equilibrium, the system adjusts so as to minimize the effect of the applied force«. Reaction at high temperature absorbs heat; exothermic reactions prefer lower temperatures, but endothermic love higher ones. Living organisms defence against any external attack occurs spontaneously. An example of spontaneous self-organization in social systems is the law of supply and demand (shifting price equilibrium to another level). Closed societies are losers, e.g. evolution in communistic Soviet Union, Central and Eastern Europe, China, Cuba lagged behind the capitalistic one, because of building on equilibrium (no difference in wages), preventing competition (borders were closed). Competition and everyday training is vital for survival of the fittest. Open societies, like USA, and European Union (EU), with free exchange of goods, capital, people, ideas have been winners; China had an explosive development after opening up to the world.

3. Is environment approaching a bifurcation?

A system near equilibrium moves in a stationary, controllable way; but when it is far from equilibrium, fluctuations, instability, stochastic development with bifurcations take place. Bifurcations (catastrophes, crises) can be handled by a mathematical theory; they introduce the concept of history into the evolution. The Earth is entering an instability period. Both, the number and severity of global catastrophes are increasing, e.g. climate change causes storms, floods, earthquakes, melting of glaciers, spreading of deserts. Number of victims caused by the climate change is increasing rapidly in Europe: 2 000 people dyed in 1990–1999 (200 per year), while 47 000 people dyed in 2000–2004 (9 400 per year). Recently, in the World there were on average: 20 000–30 000 victims, and 2 millions wounded per year; 1 million lost their homes annually, 140 millions had economic and other consequences, ten times more than hit by wars and terrorism. In the future, lack of resources and water will increase; cancer, endocrine disrupters, aids, pandemic, and other autoimmune diseases are endangering human development.
There are many frustrating news on climate change in Europe going on. Glaciers are disappearing and snow level has climbed up by 150 m – crushing stones are expected to roll into the valleys. Biomass growth in seas is following the twelve and eighteen year cycles, but modern equipment enables mankind to fish at the minimum biomass, and several species may disappear in future. The temperature of the North Sea has reached 20–22 °C in 2006, what has never been observed before; it enabled tourists to swim, but autochthonous shells were dying away, while oysters were coming into the North Sea. Climate change is enabling white wine production in Sweden, while its production is to be substituted by red wines in Germany. Because of the growing non-equilibrium, bifurcation is expected to happen on Earth in due time, and it can result in a disaster of global dimensions. In this case, nations consuming fewer resources, or having better innovation and adaptation systems have better chance to survive.

Energy is the most important resource, and burning of fossil fuels is producing the most abundant greenhouse gas (GHG), CO_2, which constitutes 82.5 % of GHGs. Therefore, it will serve as a case study in this paper. Until now, climate change resulted in a global temperature rise of 0.6 °C. Additional temperature rise of 2 °C could be expected, if achieving a 30–50 % reduction of the GHG immediately. As this is not a realistic presumption, a temperature rise of 3–5 °C is to be expected! World energy consumption is to increase by 60 % in 2030, as compared to 2002 (COM, 2006). Prices of energy will be escalating as a result. Anthropogenic CO_2 emissions are 30 Gt/a now; burning of fossil fuels is bringing 24 Gt/a, agriculture, and deforestation 6 Gt/a. On the other side, ocean sinks can handle 10 Gt/a, and vegetation 7 Gt/a. Atmospheric surplus, 13 Gt/a are accumulating, thereby influencing the climate. Geological storage possibilities are estimated to be 2 000 Gt, and expected cost of 25 €/t; cost could be reduced by enhanced oil or gas recovery.
The Kyoto agreement was signed in order to lower the CO_2 emissions, but USA, China and some other important consumers have not signed it, yet. Actually, EU is reducing greenhouse gases by 6–8 % by moving industry and thereby pollution from Europe to Asia (China, India); the same is true for all the developed countries, speeding-up global energy usage and pollution. Oil reserves are estimated to cover the needs up to 60 years, and gas reserves up to 80 years, only.

4. Evolution of ecosystems

Evidently, the human race is behaving like the yeast, increasing its population and consumption until the non-renewable energy reserves of the Earth will be exhausted. Exponential growth is not possible – logistic growth results from resource limits with all the populations on the Planet. This law has been studied by Prigogine et al. (1977). They have defined the saturation capacity of a medium as a part of the biotic potential of species, including their birth and death coefficients. Again, mankind has been broadening its food resources by reducing biodiversity, using natural and non-renewable resources: deforestation, agriculture, seed selection, fertilizers, pesticides, tools and machinery, up to the genetically modified food nowadays. The human population with its 6.5 billion people has surpassed the inflection point on the logistic curve or the maximum on its bell-shaped derivative in the early 1960s. The limit of growth is estimated to occur in 2200, at the population of 10+ billion (UN, 2006).
Mankind has been reducing its death coefficient (increasing duration of humans' life) by reduced mortality, fighting diseases by inventing medicines, hospitals, social security, etc. World life expectancy at birth is now at 65 years; it increased by a remarkable 20 years since 1950; by 2050 it is expected to exceed 76 years (COM, 2006). Birth coefficient (number of children) required the children to be as numerous as possible by natural law and religion, but it is not obeyed any more in more developed society; this is the consequence of introducing the non-natural (cultural) pension system. The world population growth rate has fallen from its peak at 2.0 % in early 1960s to 1.3 % now. The average number of children per couple has fallen from 4.9 to 2.7 in the same period. But many conflicts are arising in the World because of the very different birth coefficients of nations. Evolution of nations is a dynamic phenomenon, governed by non-equilibrium thermodynamics and kinetics where potentials (gradients) are causing flow rates. Level, velocity, temperature, electrical or chemical potential, species concentration, knowledge, salary, security are potentials (thermodynamics), which are causing dynamic phenomena. The actual flow rate (kinetics) depends on resistance/conductance of a material or social structure. Potentials like price, salary,

capital generate flows: price differences are causing money flow rate, capital (environmental, financial, human, material, organizational, social, political, technological, working) is generating profit and added value per employee flow rates. Differences in gross domestic product (GDP) and salaries (purchasing power) are causing mobility of people: from one place to another, from agriculture and industry to services and tertiary sector, from elementary to medium and higher education, from graduate to postgraduate and lifelong education. Survival and well-being of a population is the goal. The same is true for companies. The mobility of employees depends on: traffic, employment, information, housing, educational network. But all of them depend on energy available. Resistance is accompanied by a 'hysteresis' effect (oscillator with multiple outputs) in all the dynamic phenomena: spontaneous polarization of ferroelectric and ferromagnetic materials (e.g. $BaTiO_3$), reversibility of *shape-memory* alloys, oxidizer effect on an active-passive metal, ignition-extinction effect in catalysts, etc. It is valid also for social systems (political changes after elections), and climate change (reversal in the pollution of an ecosystem).
Environmental and ecological changes are typically dynamic phenomena. Eco-system is an open system, which exchanges material, energy, and information. Its gradients are: pollution (GHG, acidification), deforestation, melioration, urbanization, etc. Its flow rates are: erosion, eutrophication, warming-up, desertification, salinisation, etc. The rate is exponential, as with an autocatalytic reaction, but it is limited by the saturation capacity of the available Earth resources. Eventual backward logistic curve will differ from the forward one. In the environmental system, reducing pollution requires much lower concentrations of pollutants as when increasing it (Schurz, 1987).
The area of the hysteresis loop is proportional to the energy input needed to oscillate between the two extreme states, changing from one state to another. If the area is big, the material or structure is resilient against changes (hard), if it is small, the resilience is weak (soft). We do not know whether the resilience of the Earth ecosystem is hard or soft, yet. As an example of hard recovery consider the ozone layer, which is now optimistically hoped to recover by 2065 – nearly 100 years will be needed in spite of the severe reduction of chlorofluorocarbon emissions. How high is the resistance of atmosphere, hydrosphere, geo-sphere, biosphere, and socio-sphere to the anthropogenic changes? What can be the limit to mankind's existence – food, energy, pollution, degeneration, another species? For the yeast it is pollution, 10–12 % of ethanol secret in the fermentation broth.

5. Evolution – Systems Approach

Material, energy, and information are not enough to describe evolution of structures and bio-systems. The forth element, innovation must be included. Again, it is observed in all the systems on Earth: allotropes in materials (e.g. graphite and diamond, polymorphs in metallic phases), and genetic mutants in bio-systems. Ideas, inventions, and innovations are known in social systems. Mutations and inventions are stochastic by nature and they are created by a combination of genes or found by individual's research. Each individual is testing the surroundings by interacting with the system, and observing the response of the environment to its actions. The innovation can be accepted or rejected by the system, the response being deterministic. A positive response enables multiplication of mutants and their growth to a population. Populations are governed by statistics (as average behaviour).
People are inclined to think deterministically, but non-equilibrium can surprise them with stochastic development. Innovations, science, patents are a natural behaviour, the

must for human population to survive. History of humanity is a history of continuous innovations, e.g.: tools (axe, knife, wheel, plough, spindle), machinery (loom, steam engine, internal combustion engine, electro-motor, turbine, reactor, etc.), transportation (horse, carriage, ship, train, car, lorry, pipe, airplane, jet, space shuttle), and arms (infantry, cavalry, artillery, armour, navy, aviation, biocides, nuclear weapons, missiles). Will science find the solutions needed in future, too? There is no guarantee to find it for all the problems in time.

Evolution of biological species and populations is much the same: their bell-shaped life cycle curve is composed of distinct periods: birth, infancy, growth, maturity, aging, and death. The innovations are important for understanding the race of populations for the resources. Two populations using the same resource (food, water, land, fossil fuel, ore, etc.) are fighting for it. Competition for resources between social populations has been constant during the history of mankind. The population with a higher biotic potential (material and energy resources, information and innovations, high birth and low death coefficients) will be substituting the one with a lower potential. Evolution of species is proceeding by competition and selection, steadily increasing the exploitation of the environment with time.

Families, companies, nations, states can be in any phase of the life cycle. They can die out, like many nations did. Social populations are evolving, too: from instinct intensive (hunters), to labour intensive (peasants, craftsmen), resource intensive (blue collars), and knowledge intensive (white collars) ones. Each of these revolutions has exponentially (about ten times) increased the number of human population to a new saturation capacity limit. This behaviour is valid also for technologies, apparatuses, methods; it is governing the development of families, companies, and societies.

6. Cultural Component of Mankind

Culture is a negation of natural laws: law, religion, moral, education, and ethics are typical in this respect. Culture can be active only when primary, basic, or vital needs of humans are satisfied. Culture is a loser against evolution: socialist movement tried to ensure equity of people, while capitalistic societies kept on competition and selection, building on differences in salaries, wealth, and respect. Ecologically sound society like EU may also be a loser against the evolution oriented ones like USA, or China. Culture is effective only if accepted by all stakeholders; the Kyoto agreement and REACH initiative of the EU have shown that general agreement is difficult if not impossible to achieve.

Can the yeast stop fermentation of a juice broth? No! Can cultural behaviour stop the environmental disaster in future? Can it suppress the natural laws and change the historical human behaviour? Human is a selfish creature, first taking care of his children, than of himself and his property (house, land, and enterprise), his relatives, followed by his local community, nation. Care about the Earth and its eco-system comes at the end, as long as it does not strongly hurt himself, his family, or his property. Is, therefore, any chance for the mankind to survive? Maybe, but only if it is agreed by all the states in the world, controlled by an international body, underpinned by international laws and efficient courts, supported by social sciences and humanities, education and religions.

Wars for example, could be minimized by legal elimination of politicians, which were building on hate between nations, religions, races, and social classes. All that is hardly possible! It could happen after a fatal disaster, when it might be too late for mitigation.

Anyway, an adaptation strategy is possible, and reduced consumption is achievable. According to questionnaires, about 70 % of the respondents are ready to give advantage to 'environmental protection' over 'economic development', and they agree that 'plants and animals do not exist primarily to be used by humans'. Diesel engines are now widely used in EU cars; passive houses have a very good acceptance by population. In Europe many people eat less, fitness and slimness are appreciated. Organic and vegetarian food is acceptable to a smaller fraction of people, although it is healthier. Collective transportation (trains, buses) is not viable unless severe shortage of fuels occurs, like it happened during the energy crisis in the seventies.
An example of a possible adaptation is the EU strategy for sustainable, competitive and secure energy, aiming to reduce energy usage by 20 %. This is the so called 'first-order change' or 'shallow ecology'. Environmental management is more about managing habits and desires of humans than attempting to control nature – education is vital for it! Strategies are to be switched from the shallow ecology to a deep one (Glasser, 2004).

7. Education of future generations

Deep ecology requires education of future generations. There are three response levels to sustainability problems in education (Sterling, 2004):

- Accommodation – **doing things better** – learning about sustainability (first order or basic learning)
- Reformation – **doing better things** – education for sustainability (second order or meta-learning)
- Transformation – **seeing things differently** – re-design by using sustainability principles (third order or epistemic learning), which enable realization of a more sustainable cultural paradigm. It requires changes in values and believes through a process of re-perception and re-cognition.

Universities should be acting as agents in promoting the transformative change. Sustainable University as a first step to sustainable society has been conceptually designed from *Tallories Declaration* (1990) to UN *Decade of Education for Sustainable Development*, ESD (UNESCO, 2005). The latter deals in an integrated way with the protection of the environment, effective use of natural resources, maintenance of ecosystems, a well-functioning society, and a sound economy[9]. ESD shall be grounded and applied in the local, regional, national and global context, and integrated in all teaching and learning levels of the education process and personal development (formal, non-formal, informal, lifelong, life-wide, and continuing).
Deep Ecology is similar to Christianity and socialism – it is a highly valued cultural matter. There is no doubt about its goals and methods. But people do not behave culturally all the time; mostly they behave naturally, not respecting their cultural norms. Therefore, we have also to teach students the elements of evolution, the lessons from history, and the skills for survival. We would like to see disarmament, but we do not dare to destroy the arms, because of people like Hitler, Col Pot, Milosevic, Bin Laden, stochastically appearing every few years as a reaction to political or economic mistakes.

8. Conclusions

"We stand at a critical moment in Earth's history, a time when humanity must choose its future. The dominant patterns of production and consumption are causing environmental devastation, the depletion of resources, and a massive extinction of

species … Our environmental, economic, political, social, and spiritual challenges are interconnected, and together we can forge inclusive solutions" (Earth Charter, 2000).
Natural laws are universal and cannot be overridden by human societies during their development. Pollution prevention and education for sustainability will be important in lowering the consumption of resources, but there will be severe competition between nations and states for (better) survival. Wars for resources will continue and scale-up. Culture is negation of natural laws. Only global action and laws can slow down the negative effects of climate change, resource depletion and biodiversity reduction. Control of population, sustainable production and consumption can slow down the pollution, diminishing the increasing non-equilibrium and, thereby, uncontrolled development.
Is sustainable development a real chance or a fiction, utopia? Micro-organism population in a fermentation broth cannot stop pollution, forming the poisonous ethanol. The same is true for nations evolving in the polluted world – some of them will be perishing, with the others conquering their land and resources. The exhaustion of nature will continue. When will the humanity's Life Cycle start declining? Degeneration is threatening us all, and constantly! Can the dilemmas – cooperation vs. market competition, cultural vs. natural behaviour – be solved? Is education the promising answer to it? Will humanity, socialists' ideas, culture, ethics, and moral join to reduce the non-equilibrium we are creating, and save the nature for future generations? Science, education, technology, politics, religions, all have to join efforts and try to achieve sustainable development, better sooner than later.

References

. COM(2006) 105 final, Comission of the European Communities, 2006, Green Paper – *A European Strategy for Sustainable, Competitive and Secure Energy*.

Earth Charter, 2000, www.earthcharter.org.

Glasser, H., 2004, Learning Our Way to a Sustainable and Desirable World: Ideas Inspired by Arne Naess and Deep Ecology. See Sterling, 2004, 131–148.

Goncz, E., Wardencky, W., Namiesnik, J., 2005, Universities and their role in enhancing human and social capital for sustainability. Proceedings: *Commiting universities to sustainable development*, Technical University Graz. 90–106.

Prigogine, I., Allen, P. M. & Herman, R., 1977. The Evolution of complexity and the laws of nature. In: *Goals in a Global Community*, Vol. 1, *Studies on the Conceptual Foundations*.

Schurz J., 1987, Ökosysteme in systemtheoretischer Hinsicht. *CLB Chemie für Labor und Betrieb*. **38/9**, 461–466.

Sterling, S., 2004, Higher Education, Sustainability, and the Role of Systemic Learning. In: *Higher Education and the Challenge of Sustainability*. Corcoran, P. B., Wals, A. E. J. (Eds). Kluwer Academic Publishers, Dordrecht. 47–70.

United Nations, 2006), The World at Six Billion, www.un.org/esa/population/ /publications. September, 1–11.

United Nations Framework Convention on Climate Change, 2005. *Report of the individual review of the greenhouse gas inventory of the European Community*.

UNESCO, 2006, UN Decade of Education for Sustainable Development 2005–2014. International Implementation Scheme. http://www.unescobkk.org.

Zaikin, A. N. & Zhabotinski, A. M. *Nature*. **225**, 535 (1970).