Electromagnetic and informational pollution as a co-challenge to air pollution

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Abstract

The present focus on air pollution problems in a proper sense (emission of gaseous and particulate pollutants to the atmosphere) detracts, to a certain degree, attention from other growing problems of electromagnetic and informational pollution. At first glance, it appears that these problems are unrelated to the air pollution as such and may require completely different approaches for their solution (or at least, mitigation). We argue that the links between the above problems are more direct than is usually expected. Electromagnetic emissions in specific frequency bands, which are due to the exponentially increasing use of wireless communication technologies such as cell phones, satellite TV broadcasting, etc have selective effects at different elevation levels of the atmosphere and different geographical areas. Such known problems as holes in the ozone layer may be not be entirely due to chemical pollution, but may also be affected by high frequency electromagnetic effects. We discuss thermodynamical and quantum aspects of links between these three forms of pollution in the context of physics of chaotic and self-organizing systems.

Keywords: air pollution, electromagnetic pollution, informational pollution, mass communications, information density, Shannon entropy, resonance effects, quantum effects, order-disorder transitions, self-organized criticality, physics of chaos.

WIT Transactions on Ecology and the Environment, Vol 116, © 2008 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/AIR080541

1 Introduction

With all the emphasis that is presently placed on air pollution (AP) in a proper sense, it remains one of several contributing factors to the general problem of pollution and the sustainability of the environment we are living in. The main target of this article is electromagnetic pollution (EMP) and informational pollution (IP). These, newly defined forms of pollution seem at first glance unrelated to AP. Yet, a generic analysis of various physical aspects of them undertaken in this (in essence interdisciplinary) article shows numerous possible connections between AP on one hand and EMP and IP on the other hand.

While traditional methods of AP control such as emission reduction and electrostatic precipitation are part of mainstream technology, new avenues were offered for conceptualization and possible experimental development. In [1] some links between AP and quantum physics were outlined. Here we propose some other links of that nature, placing special emphasis on the relationship between AP, EMP and IP. One of our central points is to draw attention to the fact that human-produced electromagnetic emissions have a structured nature and are informationally rich. This may result in pattern-organizing (catalytic) effects on various atmospheric processes directly related to AP and sustainability.

2 Conceptual framework of pollution discourse

Like other major social and economic issues, the pollution problem in general is multi-faced and prone to all sorts of controversies and clashes of opinions. At this point public environmental discourse is dominated by the Global Warming (GW) debate. The issue of human-generated GW is highly politicized and controversial with enthusiastic supporters at both ends of the debate [2,3]. This, to a certain degree, obfuscates and overshadows pollution problem(s) as such.

2.1 From atmosphere to infosphere

The fact that we live on an (approximately) spherical planet has historically created the notion of many spheres. The number of such conceptually defined ”spheres” is now well over a dozen and keeps increasing. Without claiming completeness of such a list, we mention here *lithosphere*, *hydrosphere*, *atmosphere* (with a further subordination to *troposphere*, *stratosphere*, *ionosphere*), *biosphere*, and *magnetosphere*. These are, so to say, “naturally created” spheres. To that one can add an almost arbitrary number of “human created spheres” such as “*anthroposphere* ”, “*noosphere*” (sphere of intellectual life) and even such peculiar notions as “*pedosphere*” (sludge and pavement waste under our feet), “*garbagesphere*” or “*trashesphere*”, etc.

The concept of infosphere is presently gaining momentum [4], especially with the advent of global communication networks and, particularly, the Internet. Its precursor can be seen in the notion of the “noosphere” introduced by Vladimir Vernadsky (1863-1945) and discussed by such visionaries as Pierre Teilhard de

Chardin (1881-1955) and Nikola Tesla (1856-1943). Vernadsky considered the dynamical sequence of geosphere (non-organic Earth) to biosphere and, finally, to the noosphere. While nominally the noosphere can be defined as a sphere of human thought, it presently to some degree is merging with the notion of *infosphere*. The "thickness" of noosphere is now greatly enhanced by human-generated electromagnetic (EM) emissions and satellites. This can produce some global effects in ecosphere, e.g., EM energy fluxes can affect migratory paths of birds, or lead to a variety of genetic and ecological modifications.

2.2 Major types of human-induced pollution

With an enormous volume of pollution-related literature and documentation, below is just a mere scope of major forms of human-induced pollution.

2.2.1 Air pollution

Without detailed discussion of AP, it is suffice to say that its relationship to human health is far from a simplistic formula that AP is "always bad". In reality its effects are highly non-linear and non-monotonic. Human immune system is known to exhibit hormesis effect, that is the adaptability of organisms to moderate pollution levels. In a sense, some forms of AP can "train" immune system to be more resistive. Medical inhalations and scent therapy is just one example. Absolutely sterile atmosphere can, in fact, be less health-friendly than moderately polluted. Non-organic (2.2.2.1) and organic (2.2.2.2) forms of pollution are key aspects of contamination from air, water and ground alike.

2.2.2 Water pollution

The problem of clean water availability becomes more and more acute with population growth and general contamination of the environment [3,5]. At the same time, various facets of water purification technology, such as seawater desalination plants, bottled water industries or transportation of polar icebergs to populated areas remain in the focus of social attention. We can point here to some novel quantum development related to informational content (memory effect) in water due to it quasi-crystalline structure [6]. The latter may potentially open a route of "self-purification" of water – the effect somewhat similar to natural fractionation of phases in heterogeneous mixtures (physical effect called *spinodal decomposition* which is a spontaneous separation of phases happening in thermodynamically non-equilibrium systems).

2.2.2.1 Non-organic pollution mostly refers to chemical spills containing such allegedly toxic elements as Cd, Hg, Co, Mn, etc. Curiously, some of them are part of typical poly-vitamin supplements and hence they are thought to have some positive health action. This again brings us to the concept of hormesis (see 2.2.2.3).

2.2.2.2 Organic compounds such as car exhausts, biological wastes, numerous food industry wastes, VOC (volatile organic compounds [7]), wastes from textile

and other industries, etc all have numerous pollution control technologies associated to them. Quality, cost factors and efficiency vary in broad limits. Likewise, different geographical areas and countries have greatly different conditions and opportunities for applications of pollution control techniologies.

2.2.2.3 Hormesis effect is a medically non-standard (and still controversial) effect of allegedly bringing benefits to the immune system which is "trained" by low toxicity levels. It may manifest itself in various kinds of pollution – air, water, low levels of radioactivity, etc.

2.2.3 Ground pollution

This type of pollution is often difficult and even impractical to separate from water pollution. Such specific forms as "brown fields" (former industrial grounds which can [sometime] be reclaimed for habitable use) have special means to deal with them.

2.2.4 Electromagnetic, noise and light pollution

These forms of "pollution" are specific in their "intangible" nature. Their interaction with other forms of pollution has many consequences. For example, patterns of birds migration are influenced by urban areas and, especially, by megalopolis sites (super-cities) which unstoppably grow across the world with exponential rate.

2.2.5 Informational pollution

Informational pollution constitutes an even more special category and at this point it is only gaining grounds in terms of its recognition as a form of pollution in some general sense. We mention it here for the purpose of consistency of the list of pollution items. More on it later in this article.

3 Electromagnetic emissions and electromagnetic pollution

Apart from some minor exceptions, almost all electricity produced by humans serves two purposes – to deliver power or to facilitate information and communication systems. The first group (electrical power engineering) includes power generation plants of various kinds (coal, hydro, nuclear, wind, solar), distribution systems (power lines, residential networks, etc) and user end (electrical appliances of all kinds). To that, to a certain degree, one can include autonomous small-scale electrical systems such as automobile or aircraft electrical equipment, etc. The second group (communication and computer engineering) includes computers, radio and TV broadcasting, phone lines, cells phones, satellite communications, etc. All this has numerous (and often non-trivial) links to a variety of physical phenomena and effects.

3.1 Physical aspects of electromagnetic pollution

While the abundance and ever-growing volume of human-generated electromagnetic waves (EMW) of various frequencies is obvious, a systematic

study of electromagnetic pollution (EMP) is still relatively fragmentary. Because modern electrical, informational and communication technologies move towards atomic (and possibly soon to sub-atomic) scales [8], the quantum aspects of information [9] and its interaction with material environment are coming to the focus of environmental attention.

3.1.1 Power lines

Alleged health effects of power transmission lines is a hot topic of social discussions. While actual data on that are mixed, unreliable and controversial, there is an open (but largely unexplored) possibility that low frequencies (50 or 60 Hz) may have a complicated non-linear effect on human immune system. On a negative side there can be some increase of risk to trigger genetic-related processes (due to, e.g., polarization and/or magnetic effects on biological structures) and on a positive side it may lead to the above mentioned hormesis effect. Direct effects of power lines on AP can also take place in a variety of ways. One is the trapping effect of charge particulate due to eddy electric field as well as induced magnetism (Faraday induction) from changing alternating currents.

3.1.2 Communication satellites

Much of global communications is now based on satellites with equatorial geostationary orbits about 37, 800 km above the Earth's surface. They orbit Earth every 24 hours with orbital speed of 3.07 km/sec. Therefore, they "hang" over a fixed (equatorial) point on Earth's surface and appear immovable for an Earth's observer. Because of their distance from the Earth's surface the velocity of light limitation leads to a communication latency about 0.5 sec (both ways). One can ask what kind of a cumulative effect these satellites and their electromagnetic emissions can produce at a terrestrial scale and how these emissions can interact with AP and general environmental quality. Also, there are numerous satellites on lower orbits (a few hundred km over the ground) which rotate at about 90 min periods and may interact with ionosphere and Kennelly-Heaviside layer.

3.1.3 Magnetic effects

It is well known that the interaction of Earth's magnetic field with ion flux from the Sun produces noticeable effects such as *Aurora Borealis* (Northern Lights), disruption of radio communications, etc. One may question how the numerous satellites with their regular orbits can contribute to these effects. Because satellites have regular orbits and emit directed and informationally structured electromagnetic waves, they, in-spite of the weakness of their signals, may trigger various types of non-linear chaotic response in the ionospheric plasma as well as on dust particulates at the ground level.

3.1.3.1 Dust particles in magnetic fields are capable to exhibit a range of quantum effects. Special role of the magnetic component of the EMW may be caused by specific quantum effects characteristic for a dynamics of charged particles in a magnetic field, such as Larmour precession, Quantum Hall Effect

and other macroscopic quantum phenomena. Most of a micron and sub-micron AP particulate usually has a net charge (negative or positive) of several elementary charges. This brings us to quantum regimes and the EMW-induced symmetry-breaking which can lead to a variety of chaos related effects, such as order-disorder structural phase transitions in suspended dust systems.

3.1.3.2 Accidental energy degeneration which was originally introduced in 1935 by one of the founders of quantum physics V.A.Fock (original German term: *Zufalligen Entartung*) refers to fact that in symmetrical systems, such as hydrogen atom (spherical symmetry), there are more energy levels having the same energy than can be expected from the geometry in a 3-dimensional space. Symmetry considerations involving higher (4-dimensional) space can explain that. Although at first glance accidental degeneration may be unrelated to AP problem, at a deeper level a possible link can be established through recognition that a very small perturbation in a symmetrical system can have a drastic effect (above mentioned "Butterfly effect"). The fact that Earth's gravitational field has (approximately) spherical symmetry can have a significant bearing on the enhancement of interaction between EMW and AP in a form pertinent to a new macroscopic quantum effect.

3.1.4 Order-disorder effects

Physically speaking, various forms of pollutions are non-linear systems. Response of such systems to external factors are far more rich in possible outcomes than the response of simplistic linear systems.

3.1.4.1 Ordered electromagnetic network can be specified as one producing EM noise which is different from random EM noise. Random EM noise in circuits (Johnson noise) is used in physics-based random number generators (RNG). The latter differ from common computer-based RNG which use some deterministic mathematical procedures to generate set of numbers which still (due to the way they are produced) contain some hidden correlations. For the topic of this paper (cross-effects between EMP and AP) the opposite claim may be the case, namely a possible detrimentality of *order* in human-generated IP. Random EMW (noise) produce effects which, so to say, average out and result in self-cancellation of the effects. Ordered EM signals emitted by satellites with fixed and periodic orbits may trigger pattern-formation phenomena in Earth's atmosphere. Non-linear "telegrapher's equations" introduced by Oliver Heaviside (1850-1925) for long electrical lines admit *soliton* (localized energy packs) solutions. Thus. low frequency (50 or 60 Hz) alternating currents in power lines and complicated connectivity of power grids can lead to formation of energy nodes (beats) or running localized solitons which, in turn, may result in large scale power disruptions propagating as domino effect. Likewise, charged particles from Solar Wind and/or galactic high-energy cosmic rays can acquire some focusing and directionality which can foster accumulation of dust particulate at some specific locations. This is a macroscopic analogue of the quantum effect of *Anderson localization*.

3.1.4.2 Anderson localization is a specific quantum effect of the formation of discrete (bound) quantum states in a periodical (regular) potential with some admixture of randomness (e.g., impurities in crystal lattice). In case of human-made EMW a similar situation happens. There is some regularity (described above) and there is also some disorder (randomness and noise). Because AP in general is a non-linear complex system, it can produce nodes of energy agglomeration which then can proliferate in a variety of ways.

3.1.5 Entropy argument

In its historical development biological life on Earth (biosphere) had adjusted itself to optimize its own survivability and proliferation One example is an apparent "self-healing" of the ozone layer holes. This effect not necessarily can be fully explained by the reduction of chlorofluorocarbons (CFC) emissions alone and most likely can point to some active participation of the biosphere itself.

From the systemic point of view self-regulation implies a negative feedback which is fed on ample availability of fluctuations. This exponentially enormous "library of fluctuations" [6] allows the system (biosphere in this case) to chose the optimal path of adjustability. In physical analogy this resembles the Least Action Principle or Entropy maximization principle introduced by Jaynes [10] in the context of Bayesian (conditional) probability. This is especially relevant for the case when different forms of pollution (here AP, EMP and IP) are in the state of dynamical interaction.

In the environmental/pollution context, the imposition of the ordered human-created EM network on the system can result in truncation (diminishing) of available choices. Therefore, EMP can limit degrees of freedom and impose an outside order on the biosphere. Instead of a free rein, the biosphere now faces additional constrains and may be derailed from its natural adaptational paths.

3.1.5.1 Ergodicity principle is an important aspect of thermodynamics which states that the phase trajectory of a system passes (eventually) through all isoenergetic (energetically available) microscopic states. In other words, all fluctuations are available and potentially can be tried by the system. The ordered (or partially ordered) EMP reduces space of available fluctuations. Ergodicity principle breaks down and the system no longer has an option of "visiting" all isoenergetic states. Some, otherwise available, channels for optimization now may be blocked with drastic consequences to the biosphere. The informational side of EMP can even further exacerbate this effect.

4 Informational pollution

At the present stage of civilization we are overwhelmed with all kind of information. It is generally recognized that many of us live in a state of informational and communicational overload. Thousands of TV channels and present-day public obsession with cell phones is a vivid illustration to that. Much of this information is in a digital form and is transmitted by EMW.

4.1 Entropy and information

Here we draw attention to the fact that EMP is not a random EM noise. The genuine randomness does not admit any hidden correlations or constrains. However, as we have seen, EMP is prone to some degree of order (though sporadic and usually local) and hence is conducive to produce a number of constrains which may deprive the eco-system from full-fledged adaptability.

4.1.1 Non-randomness versus non-equilibrium

The concepts of "randomness" and "non-randomness" are largely mathematical while the tandem "equilibrium" and "non-equilibrium" are defined for physical systems. And yet, there is some inner similarity between these two dichotomic pairs. For all practical purposes the physical (thermodynamic) equilibrium is equivalent to ergodicity principle, which implies an equal probability (and potential accessibility of *all* microscopic (statistical) states within a given macroscopic (thermodynamic) state of the entire system.

In non-equilibrium systems ergodicity principle breaks down. Different microstates laying on a fixed isoenergetic surface in the phase space are no longer having equal probability. In non-equilibrium systems certain sub-sets of states and dynamical regimes are becoming preferential, that in-essence means the departure from equiprobable randomness. This (non-equilibrium condition) makes system especially prone to the outside perturbations (like EMP in this case). They exhibit even higher sensitivity to initial conditions (greater "Butterfly effect") than systems in thermodynamic equilibrium. Instead of settling into their own quasi-stable states and dynamical regimes, they are now forced to adopt a behavior dictated by the external ordering forces. In other words, non-random EMP has a tendency to deprive the eco-system from its natural adaptability. While the latter may not be completely lost, its range (freedom of choices) gets truncated.

4.1.2 Boltzmann and Shannon entropy

Since the advent of concept of entropy by Rudolf Clausius (1822-1888) and Ludwig Boltzmann (1844-1906), it was felt that it has some connection to information. One popular metaphor for that is the idea of "Maxwell Demon" (MD) which has an extensive literature. Key quest here is how MD acquires the detailed (microscopic) information about the state of a large system and how this information is used, processed and discarded. Later Claude Shannon (1916-2001) introduced alternative definition of entropy within the framework of the information theory. These definitions put a bridge between thermodynamics and information. Information about the macroscopic system can be identified with its *negentropy*. In other words, when *our* information about a physical system increases, its entropy must decrease. A similar (but somewhat later) line of thinking has emerged on the basis of quantum theory of measurement and the idea of the *implicit order* introduced by David Bohm (1917-1992). Here, a fundamental premise is that the information is not just an abstract mathematical concept but has or may have a direct action on physical systems. In-spite that such ideas are facing opposition from some skeptics, we see them as central for our discourse on the interaction between EMP/IP and AP. One might expect the "Bohm effect" to be

obscured if the electrons go around the region where a non-uniform (spatially and temporally) IP is superimposed onto the static magnetic flux.

4.1.3 Information bits as bosons

Quantum physics separates all elementary particles on two groups – fermions and bosons. From standpoint of quantum physics *bits* (quanta of information) are like bosons and hence, like physical bosons, they can exhibit the effect of the so called Bose condensation.

4.1.3.1 Bose condensation refers to the formation of the highly condensed agglomerate of bosons in macroscopic quantum systems such as superconductors, superfluids, and some biological systems. We suggest that in the modern global economy world, the said Bose condensation of high-density information bits in the informationally rich EM emissions (EMP) can amplify the pattern-forming effect on components of ecosystem and the environment (such as global AP) and lock them into some more detrimental modes. Another aspect is direct effects of EMP and IP on humans (e.g., cell phones). Collapse of communication could also be envisaged as the IP density keeps ever increasing in the modern global economy world.

4.1.3.2 Catalytic effect is another way to look at possible interaction between EMP/IP and AP. It is known that the catalyst is generally not spent in chemical reactions. Its action, therefore, is primarily informational. An example is formation of ozone holes by CFC pollutants. Here, our quest is how information carried by EMW (especially if it experiences Bose condensation of *info-bits*) can affect chemical processes in such pollutants as, say, VOC. It may appear in a form of beats (solitons), i.e., energy accumulation in localized packs when the EMW are correlated and/or coherent.

4.2 Chaos and self-organized criticality

With the advent of modern theory of chaos with all its ammunition of terms (bifurcations, Mandelbrot and Julia sets, strange attractors, sensitivity to initial conditions ["Butterfly effect"] and many others) we were exposed to the dichotomy of chaos and order [11]. There are windows of order within chaos. An example of it is bifurcation cascades revealed by iterations of the logistic equation (Mitchell Feigenbaum).

Another example of extreme sensitivity to initial conditions is the *self-organized criticality* (Per Bak) when a sudden breakdown in a large system (like a pile of sand) is triggered by a minute (but "critical") perturbation. This effect is somewhat akin to the sudden transitions in the Catastrophe Theory (Rene Thom). Such a triggering of sharp (phase) transitions by a very weak (but "threshold") perturbation is what one can expect in the interaction of IP with AP system. It should be noted that even a very small (but ordered) perturbation can often lead to drastic effects, like symmetry breaking in complex systems. One example is a weak interaction in beta-decay of some elementary particles. Likewise, a proper Fourier analysis can extract ordered information (message) buried under a much stronger noise. Thus, human-generated fluxes of EMW with its high informational

content can lead to a variety of resonance-type effects in noosphere and ecosphere the consequences of which may be unexpected and unpredictable.

5 Conclusion

In this paper we have outlined some possible links regarding the interaction of "ordinary" pollution, such as AP with information-loaded electromagnetic emissions, which we tentatively label as EMP and IP. No form of pollution can be totally controlled and even less so eliminated. Calls for a "zero tolerance" to this-or-that form of pollution are naive and unworkable. Some reasonable level of accommodation (a generalized hormesis effect) is inevitable. We see a deepening need for a development of multi-dimensional, multi-sided interdisciplinary vision of the whole range of pollution problems in order to enhance our ability to understand all the important links in this global issue.

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