SOME PRESSING GLOBAL ENVIRONMENTAL PROBLEMS OF OUR TIME AND STRATEGIES FOR MITIGATING THEIR IMPACTS

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Summary

Human activities and interventions have impacted so comprehensively and so adversely on Earth's natural environment and life-support systems that today it is hard to find a single aspect of nature or an environmental compartment that has not been degraded by them. Some of the impacts are potentially so serious, and their alleviation apparently so intractable, that they have thrown Humankind's long-term survival on the Planet into question.

Currently anthropogenic emissions of greenhouse gases to the atmosphere have been causing the problems of global warming, climate change and ocean acidification among others. They are a top priority because of their potentially catastrophic impacts predicted to occur by around 2025 if in the meantime effective measures are not taken urgently to reduce greenhouse gas emissions, especially CO_2, to the atmosphere very significantly. Extreme poverty and hunger is another very serious global problem with

far-reaching implications for the Earth's environmental integrity. Eradication of extreme poverty and hunger is number one in the list of United Nations Millennium Development Goals, and this is indicative of the importance which the international community attaches to it.

The focus of this article is on the following priority problems of our time: global warming, climate change, ocean acidification, and extreme poverty and hunger. In each case the causes have been analysed, manifest and potential consequences described, and strategies for alleviation identified.

1. Introduction

Blessed with rationality and supreme intelligence, human beings are said to be paramount in creation. Indeed, their tremendous achievements in art, literature, music, philosophy, science, technology, medicine and so on bear ample testimony to that. So much so in fact that the *Anthropic Principle* (see Glossary) states that the Universe had to evolve in the way it has so that it could be observed and understood by an intelligent information-gathering life form—man (Barrow and Tipler, 1986). This controversial and speculative claim is a little audacious and bizarre too, considering the spatial, temporal and other limitations to which human faculties are subject in this mortal coil (Nath and Talay, 1996; section 2 of *Instilling Environmental Awareness in Undergraduate University Students*)

However, the irony is that with all his intelligence and amazing science and technology, man has been knowingly and systematically degrading the very natural environmental capital that sustains him and without which all life on Earth will surely perish. According to received wisdom, such behaviour is the defining characteristic of the proverbial "village idiot" and of the seriously demented who cuts off the branch of the tall tree he is sitting on, not of the Humankind that claims to possess supreme intelligence. It is hard to find an animal of lower species that degrades or destroys its life-sustaining environment with such gusto.

In the winter of 1997 a Polish academic colleague of the author asked him this question: "If you were Mother Earth and considering what man has been doing to this beautiful Blue Planet, the like of which we have not yet found anywhere in the unimaginable vastness of the Cosmos, what would you think of the Humankind?" The author confesses that no one had asked him such a question until then, and neither had he thought of anthropogenic pollution quite in this way before. After a pause he replied, "Probably as vermin to be exterminated in the interests of her health, integrity and welfare". The colleague agreed. Even a cursory survey of how man has been degrading Earth's natural environmental capital and life support systems with his polluting behaviour will confirm that the substance of this conversation has more than a grain of truth in it.

"What a piece of work is man!
How noble the reason!
How infinite the faculty, in form, in moving!
How express and admirable!

In action how like an angel!
In appreciation how like a god!
The beauty of the world! The paragon of animals!
And yet, to me, what is this quintessence of dust?
Man delights not me; no, nor woman neither."

Shakespeare's *Hamlet*, act 2, scene 2

The following excerpt from an old Jewish scriptural text more or less sums up human attitude to nature and her bountiful benediction that sustains us in our life's sojourn:
"We waste what we have—our food, our fuel, our wealth, our gifts,
Then we watch in surprise the destruction of our world.
What we do not explore or gouge out of the Earth, we pollute.
What we do not pollute, we kill.
We do not see, or wish to see, the damage we do.
Later we regret."

Ever since the industrial revolution of the 1860s, industrialisation based on scientific and technological developments has been the dominant if not the exclusive modality for economic development world-wide. No doubt industrial development has brought immense and wide-ranging benefits to Humankind to the extent that today it is impossible to imagine life without them. However, these benefits are not and have never been cost-free, and the price is the mounting degradation of the natural environmental capital and nature's life support systems. Indeed, today it is hard to find any aspect or compartment of the natural environment that has been immune to or benefited from Humankind's headlong drive for economic development through industrialisation in pursuit of ever higher material standards of living.

Degradation by human activities of the natural environment and life-support systems occurs imperceptibly over time until a point is reached when catastrophic and irreversible consequences can occur. Mathematically this behaviour is typical of nonlinear systems including environmental and life-support systems. The mechanics of the "Euler strut", which students of Mathematical Theory of Elasticity would be familiar with, illustrates this behaviour well (see Glossary).

Today relentless rise in anthropogenic CO_2 emissions is of particular concern. As the concentration of greenhouse gases in the atmosphere, CO_2 in particular, rises, so do the intensities of global warming and climate change, and the oceans become progressively more acidic. In this article some of these global environmental issues and problems of mounting concern, listed below, are discussed along with strategies for alleviating them and mitigating their impacts:

- Global warming and climate change;
- Acidification of the oceans; and
- Poverty eradication

Here the word "alleviate" is used advisedly instead of "solve" which is often used by some authors. It is because "solving" an environmental problem conveys the sense of restoring the contaminated environmental compartment or aspect in question to its former less polluted or pristine state. With our current knowledge and resources this just cannot be done in many of the global environmental problems. Consider the following as a typical illustration: Since the industrial revolution Earth's atmosphere has been contaminated by billions if not trillions of tonnes of man-made CO_2. Could we remove the CO_2 and restore the atmosphere to its much less polluted pre-industrial state? It is hard to see how. The best we can do is to reduce or stop further CO_2 emissions to the atmosphere and hope that somehow nature's self-regenerative processes would in time deal with the CO_2 already emitted. Clearly therefore, what our best efforts can do is to alleviate or mitigate, not solve. The same argument also applies to the global problems of stratospheric ozone depletion, ocean acidification, loss of biodiversity, species loss, etc.

2. Global Warming and Climate Change

2.1. The mechanism of global warming

Anthropogenic emissions of CO_2 and other greenhouse gases (GHGs), in excess of what Earth's self-regenerative processes (e.g. the Carbon Cycle) can deal with, causes Earth's temperature to rise (*Throughout "rise in temperature" or "temperature rise" is to be understood as rise in global mean temperature above the pre-industrial global mean temperature. The latter may be taken as global mean temperature from 1861 to 1890.*) This phenomenon is called "global warming".

Through evolutionary processes such as volcanic eruptions and bacterial activities Earth's atmosphere has acquired a "barrier" containing greenhouse gases which traps some of the solar radiation falling on Earth to warm Earth's surface. It acts like the glass in a greenhouse which retains part of the incident solar radiation as heat to promote plant growth. Without this "barrier" Earth's surface will be a sterile and inhospitable wasteland like the other planets.

Carbon dioxide (CO_2), which constitutes only 0.03% by volume of pure air, acts as the main GHG responsible for trapping solar heat. The other natural and man-made GHGs are water vapour, methane (CH_4), nitrous oxide (N_2O), and aerosols such as hydrofluorocarbons(HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). The small amount of CO_2 and even smaller amounts of some of the other GHGs naturally present in the atmosphere, like the finely-tuned physical constants in the laws of Physics, is sufficient to trap enough of Sun's heat to make life on Earth possible. The "barrier" is so constructed that over time a steady-state condition is reached when the amount of solar radiation falling on Earth becomes about the same as that which the Earth radiates back into space. As a result the temperature of the Earth remains roughly constant.

Burning of fossil fuels (coal, natural gas and petroleum) to generate electric and steam power for human activities has mainly been responsible for the exponential increase in the concentration of CO_2 in the atmosphere (above the CO_2 concentration in pure air). Today (2005) the concentration is 379 ppm by volume compared to 276 ppm by volume in 1750. Current rate of increase is more than 2 ppm by volume per annum. At this rate

CO_2 concentration of 400 ppm by volume, considered to be the "danger threshold", will be reached in just 10 years from now. World temperature is already 0.8 ^oC above the pre-industrial level caused by man-made CO_2 emissions. According to experts, if current trends continue, temperature rise will reach 1 ^oC in around 2030, 2 ^oC by around 2050, and 3 ^oC or higher by around 2070 (e.g. ISSC, 2005; McCarthy, 2005).

Though simplistic, Figure 1 facilitates an understanding of how global warming could unravel over time if present man-made CO_2 emission trends are allowed to continue. As long as global emissions of CO_2 to the atmosphere remain below that which Earth's self-regenerative processes (mainly the processes of the Carbon Cycle) can deal with, no significant problem is likely to arise. However, problems start beyond point "A" when the amount of CO_2 emitted exceeds that which those processes can deal with.

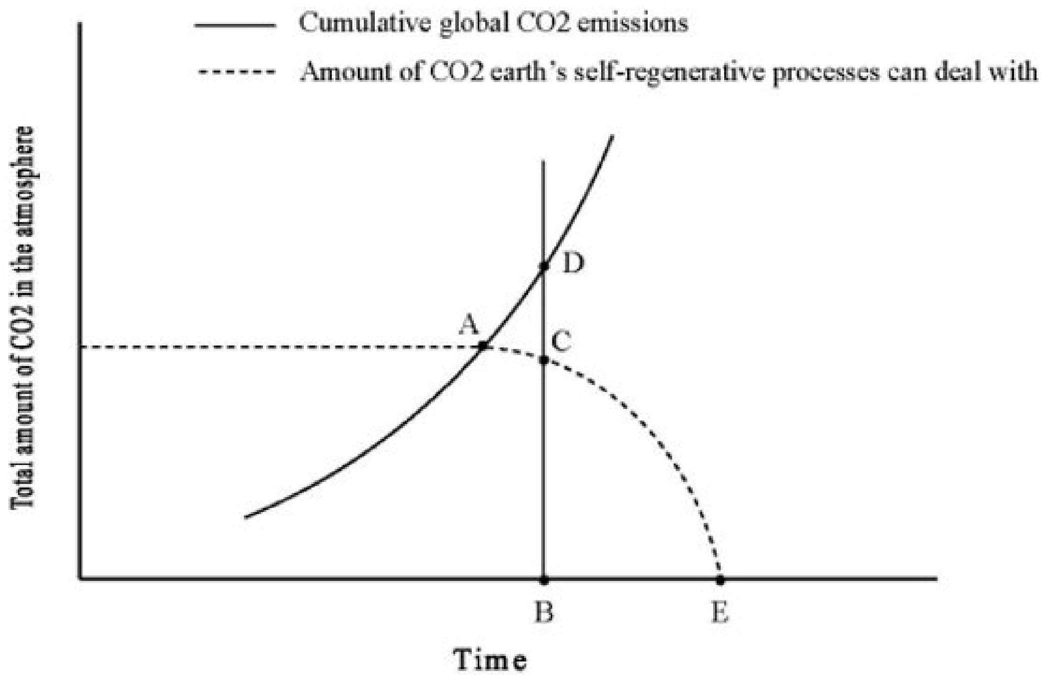

Figure 1. Schematic of how global warming could intensify over time to cause "runaway" rise in Earth's temperature

Consider a future time at point "B" when the total amount of CO_2 present in the atmosphere is represented by BD, and the amount that the slightly degraded self-regenerative processes can now deal with is represented by BC (those processes are degraded at an increasing rate between "A" and "E"). Clearly, the amount of CO_2 which those processes cannot deal with, and which will therefore remain in the atmosphere to further degrade the processes, is represented by CD. And, as Figure 1 shows, this amount, and therefore the greenhouse effect and global warming, will continue to increase rapidly over time. When those processes are completely disabled (represented by point "E"), the accumulated CO_2 plus further emissions of it will remain in the atmosphere to make the greenhouse effect (and therefore global warming) progressively more intense and at a faster rate. This would finally cause what is called "runaway" temperature rise, meaning accelerated rise in Earth's temperature without limit. Unless effective measures are taken in time to prevent it, experts predict that a "runaway" temperature rise could be catastrophic for most if not all life on Earth (Hare, 2005; McCarthy, 2005). The schematic of Figure 1 is generic in the sense that qualitatively it shows how increasing contamination of any environmental aspect or compartment affects the self-regenerative capacity of that aspect or compartment. It also shows qualitatively how increasing contamination of the Earth's natural environment as a whole affects its overall capacity for self-regeneration.

2.2. "Global dimming" and its effect on global warming

The phenomenon of what scientists call "Global dimming" was first observed by Atsumu Ohmura in 1985 when he was doing research in geography at the Swiss Federal Institute of Technology in Zurich. He observed from his measurements of sunlight levels reaching the Earth's surface in Europe that since the 1960s, when similar measurements were taken by his predecessors, the levels had declined by more than 10%. This meant that Europe, and presumably the world, was becoming a darker place over time.

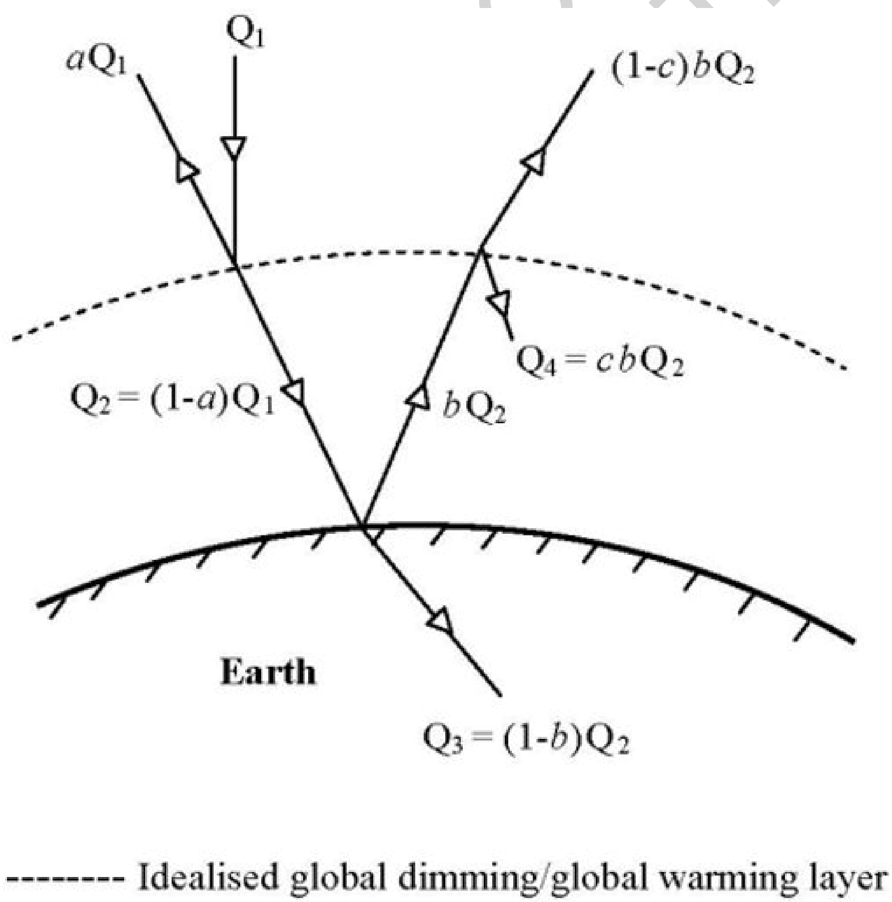

Figure 2. Simplified schematic relationship between global dimming and global warming

"Global dimming" causes partial reflection of the incident sunlight back into space before it reaches the Earth's surface (Stanhill and Moreshet, 1992). As a result, the amount of sunlight falling on Earth's surface is reduced. Water droplets in clouds coalesce around aerosols and particulates present in the atmosphere. This, it is thought, leads to the formation of clouds made of smaller droplets that scatter and reflect back incoming sunlight more efficiently than clouds made of larger droplets. The reduction caused by partial reflection varies spatially over Earth's surface depending on conditions, and temporally too. Greatest reductions occur in the mid-latitudes of the northern hemisphere. Global average reduction (i.e. global dimming) was estimated at 2.7% per decade during 1958 and 1992 (Stanhill and Cohen, 2001). On the other hand, it is thought possible that there had been a reversal of the dimming trend in the early 1990s.

For the non-scientific reader the effect of global dimming on global warming may be explained crudely with reference to Figure 2, in which for simplicity a single idealised atmospheric layer is assumed both partially to reflect incident sunlight and to trap some of the radiation reflected by the Earth. In this Figure *a*, *b* and *c* are constants determining various amounts of reflected solar radiation as shown. Clearly, the amount of incident solar radiation, Q_1, reflected back to space before it reaches Earth's surface is aQ_1; and the total amount retained by the Earth and Earth's atmosphere is $(Q_3 + Q_4)$, given by the equation

$$Q_3 + Q_4 = (1 - b + bc)Q_2$$
$$= (1 - a)(1 - b + bc)Q_1 \qquad (1)$$

The value of *b* may be taken as Earth's average *albedo* which is 0.31 (see Glossary), while that of *c* determines in part the intensity of global warming. Assuming that the sum $(Q_3 + Q_4)$ roughly represents global warming, equation (1) shows that for given values of *b* and *c* global warming is a maximum when there is no global dimming (i.e. when $a = 0$); and that it decreases as global dimming increases. Therefore, *prima facie* a small amount of global dimming, say up to 5% ($a = 0.05$), is to be welcomed as it would reduce global warming (higher global dimming may possibly cause as yet unknown harm). However, the mechanics of the global dimming phenomenon, and precisely how and the extent to which it interacts with global warming and the consequences, are far too complex to yield to such simple generalisations. Much work remains to be done in this area.

2.3. Some of the predicted consequences of climate change

Global warming causes Earth's surface temperature to rise. This, in turn, changes the global climate with serious implications for all life on Earth. Indeed, some of the predicted consequences of climate change are so menacing that they do not augur well for Humankind's survival on Earth in the long-term.

"I believe that most of the warming we are expecting over the next few decades is now virtually inevitable, and even in this time frame we may expect a significant impact."

Margaret Beckett, Environment Secretary, HM Government of the United Kingdom. In opening address to the International Conference on Climate Change, Exeter, UK, February 2005.

Although a small and dwindling number of scientists, decision-makers and others still believe that climate change is a myth, increasingly the prevailing view of the international scientific community is that it is already here, rapidly gathering pace, and that effective action must be taken to combat it before it is too late (e.g. ISSC, 2005; McCarthy, 2005; Rapley, 2005).

The global climate is a product of the complex, dynamic and mutual interactions that occur among a variety of the Earth's natural features and processes including the oceans and ocean currents, the atmosphere, ice and snow cover, forest and vegetative cover, impacts of living organisms, natural cycles (e.g. the Carbon Cycle) as well as human activities and interventions. Unfortunately, our current knowledge of these processes, and precisely how they interact with each other and to what effect, is woefully inadequate. Complexity, lack of knowledge, uncertainties and the sheer scale of the features and processes involved preclude the construction of a reliable and realistic analogue model with which to predict how changes in one or more of the features or processes would or could affect global climate or the consequences thereof. However, due to rapid advances in digital computer technology in the last 30 years or so, numerical system modelling to study climate change and its consequences is now the norm. Indeed, nearly all the climate change and related data and predictions available today are based on such studies.

Based on computer model studies, the IPCC reports that during the twentieth century Earth's average surface temperature increased by around 0.6 ± 0.2^{o}C and predicts a rise of between 1.4 and 5.8 ^{o}C during 1990 and 2100. *Prima facie* these numbers are too small to cause concern. But they *are and ought to be* a cause for concern because over long periods average global temperatures have been remarkably stable. And so the predicted rise, which is over a very short period, has potential for causing both significant climatic instability and the largely unpredictable but plausible consequences thereof. The following are some of the predicted consequences directly linked to global climate change:

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Biographical Sketch

Professor Bhaskar Nath received his Bachelor's degree in Civil Engineering from the Indian Institute of Technology, Kharagpur, India, in 1960, followed by the Ph.D. degree from the University of Wales, UK, in 1964. In 1983 he was awarded the D.Sc. degree by the University of London for his outstanding original research (according to citation) in numerical mathematics. In 2001 he was awarded the Doctor Honoris Causa (Dr.H.C.) by the University of Chemical Technology and Metallurgy, Sofia, Bulgaria, for his contribution to environmental education.

After having taught at the University of London for more than 27 years, currently Professor Nath is Director of the European Centre for Pollution Research, London; Executive Director of International Centre for Technical Research, London; Editor of Environment, Development and Sustainability published by Springer; visiting professor to several European universities, and consultant to a number of international companies and organisations. Professor Nath's research interests include Numerical Mathematics, Elasto-Hydrodynamics, Philosophy, Environmental Economics, Sustainable Development, and Environmental Education. He has more than 100 scientific publications in these and related areas including 13 books.