A SUSTAINABLE ENVIRONMENT BASIS FOR EDUCATION IN INDOOR AIR SCIENCES

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1. What Is Environmental Sustainability?

It has become increasingly clear that human population growth and development activities have combined to place a growing, perhaps excessive burden on environmental resources. Consumption of natural resources, encroachment on land, and emission of pollutants have, together produced strong indicators of environmental stress. Examples of such stress include depletion of the ozone layer and of many natural resources, massive loss of topsoil and of biological diversity, and potential causes of global climate change including increased atmospheric concentrations of carbon dioxide and other greenhouse gases [1-3]. Such environmental stressors generally correlate with economic development and growth [2].

Projected population growth over the next fifty years along with extrapolation of economic development rates suggests a significant increase in environmental burdens [1]. We have used a crude model to estimate an approximate three- to four-fold increase by the year 2050. Others estimate as high as a tenfold increase over the same time period. Regardless of the exact number it is clear that increased population along with increased growth in economic activity will increasingly tax available resources and the pollution assimilation capacity of the earth [1].

The concept of ecological carrying capacity -- or ecocapacity – indicates the extent of resource depletion, pollution, and land encroachment that the earth can tolerate without degradation of the quality of the environment and the services provided by ecological systems [1]. The ecocapacity of the earth translates into the total human population and the per capita share of ecological space or "ecospace" – the amount of the earth's resources and the pollution burdens that can be sustainably supported by the earth..

The shift in awareness and interest in environmental sustainability implies several important themes in future indoor air sciences education. Among these themes is the search for more environmentally benign building materials and building maintenance products. These materials will be more easily cleanable and contain minimally toxic materials compared with dominant materials in use today. Another important theme will be low energy buildings. Such buildings will address issues of illumination, ventilation, heating, cooling, humidity control, and other building equipment using technologies that

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are more energy conserving and energy efficient. The theme of user control and involvement in building operation will be increasingly represented as a solution to many environmental problems. And finally, recycled buildings will be an important theme in renovation, re-use, and recovery of materials during demolition at the end of a building's useful life [4].

1.1. SUSTAINABLE DEVELOPMENT

Recent years have witnessed a marked increase concern over the relationship between the rates of resource consumption and the pollution emission and the carrying capacity of the earth. This resulted in the establishment of a commission to examine the level of human activity that could be supported by the earth.

1.2. WCED (BRUNTLAND COMMISSION), 1986

The term "sustainable development" was first defined in 1986 by the World Commission on Environment and Development headed by Gro Brundtland, (now head of the Wold Health Organization). The Brundtland Commission defined sustainable development as development that can meet the needs of the present generation without compromising the needs of future generations to meet their own needs [5].

> "Meet the needs of the present generation without compromising the needs of future generations to meet their own needs." – WCED, 1986

It's meaning is vague, perhaps intentionally so. Therefore, it has been interpreted differently in diverse contexts and by diverse authorities. Nevertheless, use of the term has increased since that time and some authorities report that there are more than 300 separate definitions of "Sustainable Development.."

1.3. DEFINING SUSTAINABLE DEVELOPMENT *(Dobson: Environmental Politics, 1996)*

A valuable contribution to the discussion of sustainability is the work of Andrew Dobson (who contends that most definitions of sustainability are vague and therefore, not very useful. Dobson tells us that what we mean by sustainability is defined implicitly by the decisions we make on three fundamental questions: what to sustain, why, and for whom? [6].

Dobson has presented an analysis and typology of "sustainabilities" as a means of elucidating a comparative characterization of various definitions and uses of the term. His analysis is summarized in Table 1.

Table 1. Conceptions of Environmental Sustainability [6]

	A	*B*	*C*	*D*
What to sustain?	Total capital (human-made and natural	Critical natural capital: e.g., 'ecological processes'	Irreversible natural capital	'Units of significance'
Why?	Human welfare (material)	Human welfare (material and aesthetic)	Human welfare (material and aesthetic) and obligations to nature	Obligations to nature
Objects of concern ***Primary*** ***Secondary***	 1,3,2,4	 1,2,3,4 5,6	 (1,5) (2,6) 3,4	 (5,1), (6,2) 3,4
Substitutability between human-made and natural capital	Considerable	Not between human-made capital and critical natural capital	Not between human-made capital and irreversible natural capital	Eschews the substitutability debate

Key to numbers:
1 = present generation human needs
2 = future generation human needs
3 = present generation human wants
4 = future generation human wants
5 = present generation non-human needs
6 = future generation non-human needs

Implicit questions of justice:
1. What is to be distributed?
2. Among whom?

Dobson also asserts that there are numerous problems for creation of sustainable projects or communities that are resolved implicitly in one way or another by the choices that are made. These issues are identified in Table Dobson2 along with the solutions presented.

Table 3. Issues which must be resolved in sustainability work. [6]

1	**Domain**	**Cause**	**Solution**
2	Ontological	western science	ontological shift
3	Epistemological	ignorance	precautionary principle
4 5 6 7 8 9 10 11	Social	gender inequality population growth lack of property rights in nature debt repayment western technology disempowerment poverty poverty	women's rights curbing population confer property rights in nature debt remission appropriate technology empowerment equity wealth
12 13 14	Economic	unpriced ecological services trade protectionism	marketised environment protectionism trade
15 16 17	Institutional	unsustainable resource use unsustainable resource use international disorganisation	command and control economic instruments transnational organizations

According to Dobson there are also two types of implicit questions of justice in the resolution of the issues raised in relation to the issues in Table 3: These are 1) Pattern of distribution; and 2.) Procedural or substantive.

1.3.1. *Social and Economic Issues*

Environmental sustainability must be part of a broader strategy and planning process that includes social and economic sustainability as well [2]. Sustainability must be achieved on both economic and social bases as well as environmental ones. The concept of the triangle of sustainability:includes economic, social, and environmental elements.

1.3.2. *Moral And Ethical Issues*

There are fundamental questions of moral and ethical nature that must be addressed, as suggested by Dobson [6]. These include questions of social justice, the distribution of ecospace among rich and poor within and among nations; questions of biological justice, the consideration of species other than humans; and, questions of inter-generational justice, the distribution of resources among today's and future beings, both human and non-human.

2. Buildings Contribution To Environmental Burdens

Buildings are major factors in the consumption of resources and contributors to environmental pollution and land encroachment. These results are due to the enormous amount of material consumed in building construction, maintenance and operation as well as the production of pollution from these processes as well as the consumption of energy for their construction, operation, and ultimate disposal [7]. Figure 1 shows the portion of total human burden on the environment resulting from construction, operation, use, and demolition of buildings in the United States. Results from a survey of global data show similar values.

Table 4. Buildings' share of total human burdens on the environment, data from United States [7]

RESOURCE USE	*% OF TOTAL*	*POLLUTION EMISSION*	*% OF TOTAL*
Raw materials	30	Atmospheric emissions	40
Energy use	42	Water effluents	20
Water use	25	Solid waste	25
Land (in SMSAs)	12	Other releases	13

2.1 PROJECTED FUTURE IMPACTS OF BUILDING DEVELOPMENT ON THE ENVIRONMENT

Impacts of human activities on the environment can be grossly estimated from the combination of population and per capita economic activity. The relationship between environmental impacts and the human actions responsible for them is described by Holdren and Ehrlich in 1971 and has been revisited and revised several times since that time [8]. The expression in equation 1 shows that relationship

$$I = PAT \quad (1)$$

Where I = impact
P = population
A = affluence (or consumption) per capita
T = the impact per unit of technology

While this general formulation can help us understand the implications of the rates of population and economic growth, it does not help us identify an acceptable target. Specific sustainable targets of impacts must be established for various impacts and in appropriate contexts [9].

2.2. ESTIMATED GROWTH PROJECTIONS

Table 5 presents the project population growth in industrialized and developing countries and global totals for fifty and one-hundred year horizons[9]. It is projected that the majority of growth will occur in the developing nations and that the total increase by the year 2050 will be primarily in the developing nations.

Table 5. United Nations median population projections (billions of people) [3]

Year:	1900	1950	2000	2050	2100	
Industrialized countries	0.6	0.8	1.2	1.3	1.3	Population in billions
Developing countries	1.0	1.7	5.1	8.7	9.9	
World	1.6	2.5	6.3	10.0	11.2	

In Table 6 projected growth in global consumption are projected for the next 50 years. The population growth times the economic growth rates are multiplied to give a crude indicator of projected increases in environmental burdens. Again, the majority of the growth is projected in developing nations. This is due not only to their projected increased population but also their projected continued rapid economic growth. An annual economic growth rate of 2.5% is used for the industrialized nations and 3.5% for the developing nations. This later rate is conservative in light of recent experience [9].

Table 7. Global consumption in 2050 based on population and consumption per capita. [9]

	Now	Population factor	Consumption factor	2050
Industrialized countries	75	1	2	150
Developing countries	25	2	4	200
World	100			350

2.3. ESTABLISHING SUSTAINABILITY TARGETS

Most discussions of sustainability as well as plans and projects claimed to be sustainable are not demonstrably sustainable. Sustainability means or implies the ability to go on indefinitely. Because building designers and builders do not index the environmental performance of their buildings against specific targets calculated on the basis of long-term, indefinite continuation, it is not possible to judge the sustainability of the buildings.

There have been efforts to establish sustainability targets, most notably in the Netherlands. Weterings and Opschoor presented a methodology and calculations to illustrate principles and present results of such calculations [1]. Only when quantitative target values are established and building performance is measured against some apportioned share of total consumption, pollution, and land encroachment can claims of sustainable buildings be justified. Few authors have discussed this question; none have discussed it fully except for the Dutch authors cited above.

Several Swedish researchers mostly centered around Chalmers University argued that the future impacts of human interventions in the environment are impossible to predict reliably. An important illustration is the fact that the ozone hole was only hypothesized and discovered during the past two decades. Prior to that time, humans were unaware of the significance of many pollutants released into the atmosphere. The Swedes, Azar et al, in an effort to find some surrogate or index of sustainability, have produced specific socio-ecological indicators of sustainability [10]. Table 8 shows the fundamental indicators used by Azar and Holmberg and widely promoted by the Natural Step program.. Each of these indicators can be quantified, although some of the indicators for Principle 4 depend heavily on moral and ethical considerations and values.

Table 8. Socio-ecological indicators based on socio-ecological principles [10]

Principle 1: Substances extracted from the lithosphere must not systematically accumulate in the ecosphere	$I_{1.1}$: Lithospheric extraction compared to natural flows $I_{1.2}$: Accumulated lithospheric extraction $I_{1.3}$: Non-renewable energy supply
Principle 2: Society-produced substances must not systematically accumulate in the ecosphere	$I_{2.1}$: Anthropogenic flows compared to natural flows $I_{2.2}$: Long-term implication of emissions of naturally existing substances $I_{2.3}$: Production volumes of persistent chemicals $I_{2.4}$: Long-term implication of emissions of substances that are foreign to nature
Principle 3: The physical conditions for production and diversity within the ecosphere must not systematically be deteriorated	$I_{3.3}$: Transformation of lands $I_{3.2}$: Soil cover $I_{3.3}$: Nutrient balance in soils $I_{3.4}$: Harvesting of funds
Principle 4: The use of resources must be efficient and just with respect to meeting human needs	$I_{3.3}$: Transformation of lands $I_{3.2}$: Soil cover $I_{3.3}$: Nutrient balance in soils $I_{3.4}$: Harvesting of funds

2.4. TRACKING SUSTAINABLE DEVELOPMENT

There are several important activities at the international level that encourage and even mandate sustainable development. Among the most important are the activities of the United Nations Environment Programme and the United Nations Commission on Sustainable Development. The promulgation of Agenda 21 after the Earth Summit in Rio de Janeiro has mandated local, regional, and national Agenda 21 plans. The Conseil International du Bâtiment pour la Recherch l'Étude et la Documentation (CIB) is currently proposing to prepare an Agenda 21 document for Sustainable Construction. Much of the relevant information can be found on the World Wide Web including various sites maintained by the United Nations.

3. Professional Roles In Sustainable Development

There are a number of professionals whose roles in the building environment are critical to a sustainable built environment consistent with good indoor air quality. Each of these professionals and many others will need to be educated to address sustainability issues. These include the following:

- Building designers
- Building constructors
- Building operators
- Indoor environment consultants
- Health and safety officers
- Health care professionals

3.1. LIFE CYCLE ASSESSMENT AND INDOOR AIR SCIENCES

Life cycle assessment (LCA) has become an increasingly common tool to assess the environmental performance of products and materials. More recently, even services are being evaluated using LCA methods and approaches. Only recently have LCAs been performed on building materials and no rigorous LCAs have been performed on total buildings.

LCA practitioners have not included indoor air quality, stating that such inclusion is too complicated [11]. European LCA practitioners have been more aggressive about addressing building materials than their North American counterparts. Furthermore, Europeans have been more willing to produce definitive LCA results indicating products that are preferable from an overall environmental perspective. North American practitioners have tended to limit the use of their LCA results to a set of data without definitive indications of environmental preferability [12].

There is a need to develop analytical tools that will provide assessments of life cycle environmental impacts for total building performance including but not limited to indoor air quality considerations.

3.2. THE FUTURE OF INDOOR AIR SCIENCES IS CLOSELY TIED TO ENVIRONMENTAL SUSTAINABILITY

Economic development issues in the developed and developing countries will define the role of sustainable development. Population growth, while expected to level off in the middle of the 21st Century, will contribute a multiplier to the environmental impacts of economic development in general and building construction, operation and maintenance in particular. As resource scarcity becomes more recognized as a limiting factor on development and well-being, more careful management of both natural and human-made resources will become prevalent. The increased environmental pollution deriving from development and economic growth will raise environmental consciousness throughout the world. More attention to meeting social and economic needs of the less developed nations is a likely impetus for further environmental concern and justice. Finally, political pressures will be brought to bear on all development activity.

3.3. IMPORTANT THEMES IN FUTURE INDOOR AIR SCIENCES EDUCATION BASED ON ENVIRONMENTAL SUSTAINABILITY

The push for environmental sustainability will manifest in buildings both for resource conservation and for protection of human health and comfort. There will be increased demand for buildings made of durable, easily cleanable, minimally toxic materials. These materials will result in less toxic exposure of workers who produce them, install them in buildings, clean and maintain them, and less toxic exposure of building occupants as well. Energy conservation will become an increasingly important goal of sustainable buildings since buildings use around forty percent of all energy used worldwide. Low energy buildings will find new ways to deal with problems of illumination, ventilation, heating, cooling, humidity control. Building equipment will become increasingly energy efficient and have longer useful service lifetimes. There will be increased emphasis on user control and involvement in building operation as a means to improve comfort will minimizing energy and resource consumption. Finally, recycled buildings and building materials will become more dominant. Increased attention will be paid to renovation, re-use, recovery of materials from the existing building stock. Preservation activities will be increased. Recovered building materials will be incorporated into new buildings as well as those that are being renovated or re-constructed.

4. Conclusion

It is clear that environmental sustainability will become an increasingly important societal goal in the 21st Century. For buildings this will include attention to indoor air quality. Consequently, there will be an increased demand for building professionals and building scientists who have been educated in the indoor air sciences as well as in environmental assessment methods. The resulting buildings will be more healthful – that is, they will be less damaging to the environment and more healthful for their occupants.

5. References

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