Planetary Boundaries Must not be Crossed for the Survival of Humanity

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Abstract

At present we are living in an increasingly globalized world. The scientific impact of the planetary boundary framework is based on biological, physical and chemical structures, and also is an important item for the sustainability. During the last five decades, global population, food production, and energy consumption have increased remarkably. For the growing population, sustainable economic development and standard of living, including living space, food, fuel, and other materials by sustaining ecosystem services and biodiversity are necessary. This article tries to identify the sustainable development policy on the basis of planetary boundaries. This planet has limited natural resources but human beings are using these in unplanned and competitive ways. Since 2008 scientists have been identified nine planetary boundary processes. These provide a safe space for innovation, growth and development in the detection of human prosperity. Out of these nine boundaries four have already been passed due to human activities and two boundaries still need to be determined. If these nine boundaries passed due to unconsciousness and unplanned activities of humankind, then the living organisms of the earth will face threat for the survival. The paper analyzes sufficient theoretical analysis to make it interesting to the readers. The study stresses on sustainable development policy for the welfare of humanities. The results of the study are presented by chemical reactions and sufficient numerical scientific data. An attempt has been taken here to create consciousness among the nations of the world about the effects of the crossing of the planetary boundaries.

Keywords: Biodiversity, Environmental Sustainability, Greenhouse Gas Emissions, Nitrogen and Phosphorus Cycle, Planetary Boundaries.

1 Introduction

At the end of the 20th and at the beginning of the 21st century the concept of planetary boundaries (PBs) become a pioneer issue to the environment experts. These are common and essential items for all nations of the world. PB concept rests on three branches of scientific inquiry are as follows:

1. Earth system and sustainability science.
2. Scale of human action in relation to the capacity of the planet to sustain it.
3. Shocks and abrupt change in social-ecological systems from local to global scales.

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Different aspects of the environment, such as, biological (biotic), physical (abiotic), social, cultural, and technological factors affect the health status of human population as well as other species within the ecosystems [1]

During the past five decades, global population, food production, and energy consumption have increased approximately 2.5-fold, 3-fold and 5-fold, respectively [38, 48]. As the global human population is growing faster, the additional land will be needed for living space and agricultural production. An important issue is how to meet growing human demands for living space, food, fuel, and other materials by sustaining ecosystem services and biodiversity [80].

Global increase of fertilizer use, fossil fuel consumption and the cultivation of leguminous crops, have been doubled the rate at which biologically available nitrogen (N_2) enters the terrestrial biosphere compared to preindustrial levels [45].

Industrial and anthropogenic activities have increased air pollution that cause serious global environmental problem. As a result agricultural production and water supply has reduced, human health deteriorated, ozone depletion created serious problem in the atmosphere.

2 Literature Review

In 2009, a group of 29 internationally renowned scientists led by Johan Rockström and Will Steffen have identified and quantified a set of nine PBs [103]. The Intergovernmental Panel on Climate Change (IPCC) and N. Stern expressed that global warming is due to continuous increase of GHG emissions which causes global climate change [56, 119]. The Economics of Ecosystems and Biodiversity (TEEB) indicated that at present more than 100 species out of a million are going extinct each year. The proposed boundary is set at 10 species per million species per year [122]. Johan Rockström and his co-authors studied that the cycles of Nitrogen (N_2) and Phosphorus (P) are essential for plant growth on the earth [105]. R. J. Diaz and R. Rosenberg indicated that excess N_2 and P are liable to negative human health and environmental impacts such as, groundwater pollution and loss of habitat and biodiversity [26]. A. Webb studied that the ozone layer is natural filter and protective shield that surrounds the earth to protect human, animal fish and plants from the harmful ultra violet (UV–B) radiations [138]. M. Molina and F.S. Rowland confirmed that human produced chemicals could destroy O_3 and deplete the ozone layer [85]. WHO and UNICEF estimated that about 4,500 children die in a day for the lack of drinking water supply and sanitation facilities. About 1.8 million people die every year from diarrhoeal diseases [141]. B. Rimal indicated that land use change effects on global environmental change and landscape ascription [101]. IPCC demonstrated that ambient aerosol particles are responsible for adverse health effects, creation of haze pollution both in urban and in the rural area, visibility reduction on human and influence on climate [56]. J. C. Orr and his co-authors revealed that ocean acidification effects on food webs, fisheries (shellfish), marine ecosystems (corals, coralline algae, mollusks and some plankton), coastal erosion and tourism [91]. The US Environmental Protection Agency (EPA) estimated that there are 80,000 to 100,000 chemicals on the global market [131]. B. Lomborg stated that hundreds of tons of hazardous waste are released to the air, water, and land by industry every hour of every day and the chemical industry is the biggest source of such waste [71].

3 Methodology of the Study

The article is prepared on the basis of secondary data of previous published articles, books and various research reports of the scientists. In this study we have contributed the knowledge and experience of the present human activities that making the earth to the unsafe place for the living organisms in future. The concept of the planetary boundary comes in the beginning of the 21st century. Due to population growth there is an enormous change in global economy. At the same time with competitive economy the industrialized countries emit greenhouse gases which cause global climate change. Ocean acidification, stratospheric ozone depletion, atmospheric aerosol loading, excess use of nitrogen and phosphorus, and chemical pollution has created serious problems for the safe survival of the humankind and other creatures. Land is one of the most important natural resources and used for residential, commercial and agricultural purposes. But human beings are overusing the lands for their needs which are threat for the future generations. Water is an essential element for all living organisms. But the use and abuse of water has increased widespread water scarcity, water quality deterioration, and the destruction of freshwater resources. We need to think and act accordingly to make the earth safe and nice living place for the future generation. In 2009, a group of 29 internationally renowned scientists led by Johan Rockström and Will Steffen identified and quantified a set of nine PBs for the so-called ‘safe space for humanity’. In this study we have worked on the nine PBs to send message to all nations for the consciousness of these PBs.

4 Aims and Objective of the Study

The aim and objective of this study is to identify sustainable development policy on the basis of planetary boundaries. The scientists have been identified nine planetary boundaries. Beyond of these boundaries anthropogenic change will put the earth system outside a safe operating space for the humanity. The 21st century faces critical social and economic problems and we have to work together for the survival of the humanity by solving these problems efficiently. We hope the readers will be benefited and will be realized the importance of the planetary boundary for the sustainable development at present and in future.

5 Brief Histories of Planetary Boundaries

In 2008, an interdisciplinary group of scientists started the discussions about planetary boundaries (PBs) in a workshop convened by the Stockholm Resilience Centre, the Stockholm Environment Institute and the Tällberg Foundation. In 2009, a group of 29 internationally renowned scientists (led by Johan Rockström from the Stockholm Resilience Centre and Will Steffen from the Australian National University) identified and quantified a set of nine PBs within which humanity can continue to develop and thrive for generations to come, the so-called ‘safe space for humanity’. After 2009, the concept of PBs has gained strong interest not only throughout the scientific community but also within the world of policy-making and civil society [94, 103].

The PBs provides a safe space for innovation, growth and development in the pursuit of human prosperity. Within this safe operating space, low likelihood of harming the earth’s life support systems, such that they are able to continue to support growth and human development [102].

Earlier approaches of PB were [42]: i) human actions as embedded in earth’s life-support system [89], ii) a human-dominated planet [134], and iii) work in ecological economics on global biophysical constraints for the expansion of the economic subsystem [17, 22, 23].

Johan Rockström and his co-authors in a Nature Feature argued that "*To avoid catastrophic environmental change humanity must stay within defined planetary boundary for a range of essential Earth-system processes. If one boundary is transgressed, then safe levels for other processes would risk triggering abrupt or irreversible environmental changes*." For example, converting the Amazon rainforest to a grassland or savanna could influence atmospheric circulation globally and ultimately affect water resources in Eastern Asia through changes in rainfall [103].

The concept of PBs has recently been introduced towards the earth system, through which it becomes possible to define the biological, physical and chemical structures that enable the development of complex human societies in the last 10,000 years (the Holocene period during which we developed agriculture, villages, cities and contemporary civilizations) to define a 'Safe Operating Space for Humanity' [24]. Human societies developed since Holocene period from small groups of hunter-gatherers through larger agricultural communities to global urban-industrial society in the 21st century [60]. The Anthropocene (*anthropo* for man and *cene* for new) started around the beginning of 1800 with the Industrial Revolution in England and concluded its first stage after World War II in 1945. In the Anthropocene, human is accelerating departure from the stable environmental conditions of the past 12,000 years into a new, unknown state of the earth. This period has been characterized mainly by an enormous expansion in the use of fossil fuels, first coal and then oil and gas. The 2nd stage of Anthropocene started in 1945 and is coming to an end in these very years [21, 116]. The PBs are values for control variables that are either at a 'safe' distance from thresholds, for processes with evidence of threshold behavior or at dangerous levels for processes without evidence of thresholds [103].

The precedent era the 'Holocene' has permitted human civilizations to thrive, especially because it guaranteed a stable warm period (for 10,000 years ca.) without dramatic variations, which is not usual in the history of humans' appearance on the earth [117].

6 Nine Planetary Boundaries

Nine planetary boundary (PB) processes have been identified, which are as follows (figure 1): Climate change, stratospheric ozone depletion, ocean acidification, land use change, freshwater use, rate of biodiversity loss, interference with global nitrogen and phosphorus cycles, aerosol loading and chemical pollution have been identified [102]. A clear strength of the nine PB frameworks is that it offers a comprehensive and possibly exhaustive set of non-weighted variables to capture key global environmental challenges rather than existing single-issue indicators and footprint tools, for example, the carbon footprint as an indicator of national environmental performance. Seven of these nine were possible to quantify at present by identifying control variables (e.g., for climate change, atmospheric CO_2 concentration) and setting specific boundary values (e.g., 350 ppm CO_2) [88]. These nine boundaries are expected to lead to an increased risk to one or more aspects of human wellbeing, or would undermine the resilience of the earth system as a whole [102]. Beyond of these boundaries anthropogenic change will put the earth system outside a safe operating space for humanity [73]. The identification of the nine PBs was not based on available data and two have not yet been quantified (table 1).

Table 1: The nine planetary boundaries [103].

Earth system process	Control variables	Proposed boundary	Most recent measurement
Climate change	1. Atmospheric CO_2 concentration (parts per million).	350 ppm	393.81 ppm
	2. Change in radioactive forcing (W/m^2).	+1 W/m^2	+1.87 W/m^2
Ocean acidification	Global mean saturation state of aragonite in surface sea water.	2.75	2.90
Stratospheric ozone Depletion	Concentration of ozone (Dobson units).	276 DU	283 DU
Biogeochemical flows: nitrogen cycle	1. Amount of N_2 removed from the atmosphere for human use (millions of tons per year).	35 Mt	121 Mt
and phosphorus cycle	2. Quantity of P flowing into the oceans (millions of tons per year).	11 Mt	8.5–9.5 Mt
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis.	To be determined	To be determined
Fresh water use	Consumption of fresh water by humans (km^3 per year).	4,000 km^3	2,600 km^3
Land use change	Percentage of global land cover converted to cropland.	15%	11.7%
Rate of biodiversity loss	Extinction rate (number of species per million species per year).	10 E/MSY	>100 E/MSY
Chemical pollution	For example, amount emitted to, or concentration of persistent organic pollutants, plastics, endocrine disrupters, heavy metals and nuclear waste in the global environment, or the effect on ecosystem and functioning thereof.	To be determined	To be determined

The red areas show the position of each boundary. The safe operating spaces for the boundaries are within the green area (Figure 1). Out of these nine boundaries four have already been passed due to human activities: Climate change, loss of biosphere integrity, land-system change, altered biogeochemical cycles (phosphorus and nitrogen), whilst two boundaries still need to be determined (atmospheric aerosol loading and chemical pollution). Two of these, climate change and biosphere integrity, the scientists call 'core boundaries' [118]. It is estimated that within a very short time world will face the difficulties of shortage of freshwater, change in land use, ocean acidification and interference with the global phosphorous cycle [102].

The PBs are not fixed and they represent estimates of how close to an uncertainty zone that the global human community can act, without seriously challenging the continuation of the current state of the planet [43].

6.1 Climate Change

Global warming is due to continuous increase of GHG emissions. The current concentrations of GHG in space have increased since the industrial revolution (in 1750) from a CO_2 equivalent of 280 parts per million (ppm) to 450 ppm [84, 119]. The global surface temperature has increased ≈ 0.2^0C per decade in the last three decades. Global warming is now $+0.6^0$C in the past three decades and $+0.8^0$C in the past century, and continued warming in the first half of the 21st century is consistent with the recent rate of $+0.2^0$C per decade [50, 81]. The atmospheric concentrations of CO_2 grew 80% from 1970 to 2004, and recently exceed by far the natural range over the last 650,000 years [56].

Scientific research shows that ice loss from Antarctica and Greenland has accelerated over the last 20 years which will raise the sea level. From satellite data and climate models, scientists calculated that the two polar ice sheets are losing enough ice to raise sea levels by 1.3 mm each year and scientists observed that the sea levels are rising by about 3 mm per year. By 2006, the Greenland and Antarctic sheets were losing a combined mass of 475 Gt of ice per year. If these increases continue water from the two polar ice sheets could have added 15 cm to the average global sea level by 2050. A rise of similar size is expected to come from a combination of melt water from mountain glaciers and thermal expansion of sea water [9].

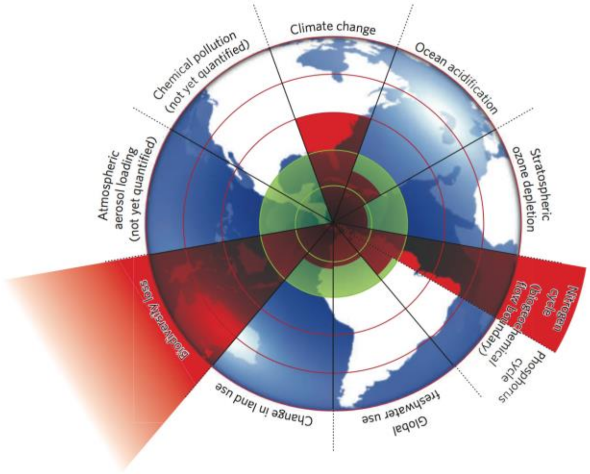

Figure 1: Planetary Boundaries [102]

Climate boundary is based on two critical thresholds parameters: Atmospheric concentration of CO_2 and radiative forcing [56]. The PB for climate change was proposed the CO_2 level as a maximum 350 ppm (table 1) and in 2014 it is crossed 400 ppm. The radiative forcing should not exceed 1 Wm^{-2} above pre-industrial levels but the change in radiative forcing is 1.8 Wm^{-2} [105, 107].

In the 21st century carbon budget of 1,456 $GtCO_2$ would result in a lower than 2°C warming at 450 CO_2eq. At the time of this analysis in 2007, this global carbon budget would correspond to annual emissions of 14.5 $GtCO_2$/y, and per capita emissions of no more than 2 tons CO_2/y [77, 126].

More recent analysis expresses that 2^0C target requires 21 $GtCO_2$eq/y in 2050, and assuming that 76% of these are CO_2 emissions give a budget of 16 $GtCO_2$/y [129]. It is true that about 50% of global CO_2 emissions produced by 11% of people.

6.2 Rate of Biodiversity Loss

Biodiversity is the natural capital we depend on to sustain ecosystem functions, which is another PB of major concern that has been passed. Before industrialization the extinction rate was less than one species per million species each year. At present more than 100 species out of a million are going extinct each year. The proposed boundary is set at 10 species per million species per year [122]. In the last 20 years, about half of the recorded extinctions are primarily due to land-use change, species introductions, and increasingly climate change [94]. Biodiversity is not only about species numbers but also concerns variability in terms of habitats, ecosystems, and biomes [90].

Biodiversity is one of the four “slow” boundaries, which seem to be associated with local-to-regional scale thresholds rather than global ones [104]. Biodiversity loss is considered as the single boundary where current rates of extinction put the earth system furthest outside the safe operating space. It is a slow process without known global-level thresholds, that there is incomplete knowledge on the role of biodiversity for ecosystem functioning across scales, and that the suggested boundary position was therefore highly uncertain [73]. Loss of biodiversity is now called ‘Change in biosphere integrity’.

Conversion of forest to cropland, increased use of nitrogen and phosphorus fertilizers, and increased extraction of freshwater for irrigation could all act together to reduce biodiversity more than if each of these variables acted independently [102].

If the corals are degraded due to temperature rise, as a consequence of climate change, not only the corals disappear but also the fish species associated with them [46].

6.3 Nitrogen and Phosphorus Cycle

Nitrogen (N_2) and Phosphorus (P) move among the atmosphere, soil, water, and organisms in a process called the nitrogen (figure 2) and phosphorus cycle, respectively. Both are biogeochemical cycles and are very important for ecosystems. This transformation can be carried out through both biological and physical processes [144]. The cycles of N_2 and P are essential for plant growth on the earth. The availability of N_2 and P in the biosphere has increased massively over the last decades [105]. The production of industrial fertilizer and the cultivation of leguminous crops are major causes to increase of large scale N_2 and P. Since the increased production of N_2 fertilizers through the Haber–Bosch process and increased mining of phosphate rock, the consumption of inorganic fertilizers in agriculture has increased exponentially. Between 1950 and 1994, there was a sustained increase in global annual consumption of N_2 and P fertilizers from 3 to 74 million tons N_2 and from 2.4 to 13 million tons P [74].

The increased use of N_2 and P fertilizers has allowed for producing the food necessary to support the rapidly growing human population [44]. On the other hand mobilized N_2 and P in watersheds enter groundwater and surface water and are transported through freshwater to coastal marine systems has resulted negative human health and environmental impacts such as, groundwater pollution, loss of habitat and biodiversity, an increase in frequency and severity of harmful algal blooms, eutrophication, hypoxia and fish kills [26, 98, 124].

6.3.1 Nitrogen Cycle

Nitrogen gas (N_2) comprises 79% of the earth’s atmosphere. There are about 5 billion metric tons of N_2 contained in the atmosphere, ocean, terrestrial and marine biota, soil organic matter and sedimentary rocks, and less than 2% is available to organisms. N_2 is present in the environment in a wide variety of chemical forms like, organic N_2, ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), nitrous oxide (N_2O), nitric oxide (NO) or inorganic nitrogen gas (N_2). Nitrogen is plentiful in the atmosphere, but limited in soils because of the strength of the triple bond that holds the two nitrogen atoms together and often constrains plant growth. To increase food production farmers use N_2 fertilizer. N_2 cycle consists of following processes: i) nitrogen fixation, ii) mineralization, iii) nitrification, iv) immobilization, v) denitrification, vi) volatilization, and vii) leaching [13].

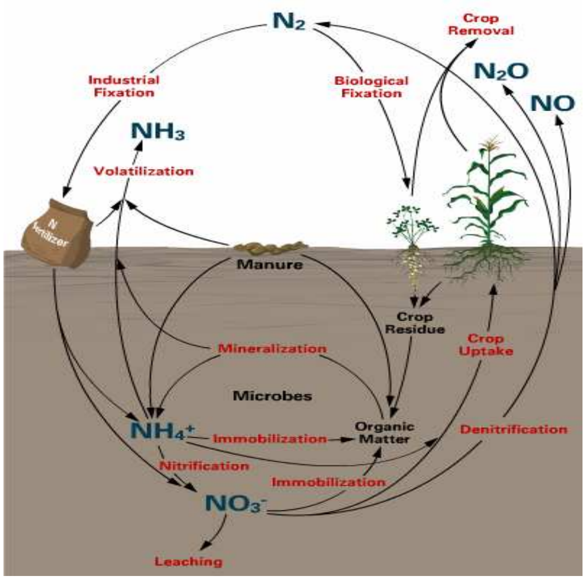

Figure 2: Nitrogen Cycle [61]

Simple interpretations of these 7 items are as follows [61]:

Fixation: Fixation is the conversion of atmospheric N_2 to a plant available form. This process is happen during the production of commercial fertilizers or during a biological process (legumes such as alfalfa, soybeans and clovers convert atmospheric N_2 with specific bacteria, to a form plants can use). For this process requires energy, enzymes and minerals;

$N_2 \rightarrow NH_3 \rightarrow R\text{–}NH_2$

where 'R' indicates hydrocarbon ion.

Mineralization: Mineralization is the process by which microbes decompose organic N_2 from manure, organic matter and crop residues to ammonium;

$R\text{–}NH_2 \rightarrow NH_3 \rightarrow NH_4^+$.

Nitrification: Nitrification is the process by which microorganisms convert ammonium to nitrate to obtain energy;

$NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$.

Immobilization: Immobilization refers to the process in which nitrate and ammonium are taken up by soil organisms and therefore become unavailable to crops;

NH_4^+ and/or $NO_3^- \rightarrow R\text{–}NH_2$.

Denitrification: Denitrification occurs when N_2 is lost through the conversion of nitrate to gaseous forms of N_2, such as nitric oxide, nitrous oxide and dinitrogen gas;

$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$.

Volatilization: Volatilization is the loss of N_2 through the conversion of ammonium to ammonia gas, which is released to the atmosphere;

$H_2N\text{–}CO\text{–}NH_2 \rightarrow NH_4^+ \rightarrow NH_3$.

Leaching: Leaching is a pathway of N_2 loss of a high concern to water quality. Soil particles do not preserve nitrate very well because both are negatively charged. As a result, nitrate easily moves with water in the soil.

Hence, in the N_2 cycle processes of fixation, mineralization and nitrification increase plant available N_2. On the other hand denitrification, volatilization, immobilization, and leaching decrease N_2 permanently or temporarily from the root zone.

N_2 is an essential nutrient for organisms as an integral part of DNA and RNA, amino acids and chlorophyll (essential for photosynthesis) [114]. N_2 is also an essential element required for the growth and maintenance of all biological tissues of all living creatures, and often limits primary production in terrestrial and aquatic ecosystems [30, 69]. When deficient of N_2 is happened, root systems and plant growth are stunted, older leaves turn yellow and the crop is low in crude protein. Without N_2 plants will not grow and we would not exist without food. N_2 fertilizers have increased supply of food; feed and other bio-based huge raw materials and also have improved the use efficiency of land and labor [109].

About 121 million tons of N_2 is used (the proposed boundary is set at 35 million tons per year or 5 kg per capita) from the atmosphere per year into reactive forms to make fertilizer for food production and other non-food cultivation [39]. According to current trajectories this figure will be more than 600 million tons per year in 2100 [40]. Finally this N_2 releases in the environment polluting waterways and the coastal zone, accumulating in land systems and adding some N_2 to the atmosphere [74].

N_2O has risen in the atmosphere as a result of agricultural fertilization, biomass burning, cattle and feedlots and industrial sources [14]. It is one of the non-CO_2 GHGs and causes global warming in the atmosphere [74]. N_2 is also associated with the formation of smog, acid rain and tropospheric ozone, depletion of stratospheric ozone and negatively affects the quality of groundwater and surface water. Hence, it has a serious impact on the health of plants, animals and men, on the quality of ecosystems and on biodiversity. It imposes a negative impact on the quality of the environment and contributes to the depletion of fossil fuel reserves [109].

Ammonia (NH_3) in the atmosphere has tripled as the result of human activities. It is a reactant in the atmosphere, where it acts as an aerosol, decreasing air quality and clinging to water droplets, eventually resulting in nitric acid (HNO_3) that produces acid rain. Atmospheric NH_3 and HNO_3 also damage respiratory systems [114].

The N_2 cycle is of particular interest to ecologists because N_2 availability can affect the rate of key ecosystem processes, including primary production and decomposition. Human activities such as fossil fuel combustion, use of artificial N_2 fertilizers, and release of N_2 in wastewater have dramatically changed the global N_2 cycle [45].

Ecosystem processes can increase with N_2 fertilization but anthropogenic input can also result in N_2 saturation, which weakens productivity and can damage the health of plants, animals, fish, and humans [133]. At present about 33% of global N_2 ‘budget’ used to produce meat for the EU.

6.3.2 The Phosphorus Cycle

The phosphorus cycle is the biogeochemical cycle that describes the movement of phosphorus through the lithosphere, hydrosphere, and biosphere. Phosphate erodes from rocks and minerals. Plants are able to incorporate phosphate found in the soil into their tissues. This phosphate is then passed on to the next trophic level when consumers eat the producers (plants). Consumers assimilate this phosphate into teeth, bones, shells, etc. As these organisms die, their phosphates, once again, become available for plants to repeat the cycle [148].

Although phosphorus (P) is of great biological importance, it is not abundant in the biosphere. P is the 11th abundant element in the crust of the earth, comprising approximately 0.1% by mass and 13th in seawater [114]. P was discovered in Hamburg, Germany by alchemist Hennig Brand in 1669 by heating urine to high temperatures [7,32,47]. The human adult body contains about 1.5 kg of P, mostly in the bones. There is no known substitute for P. It is one of the three key components of fertilizers. It is crucial for the world's food supply. About 90% of P is used globally for food production. In agriculture, P is involved in energy metabolism and biosynthesis of nucleic acids and cell membranes and is required for energy transfer reactions, respiration, and photosynthesis. Plants require highest 0.3–0.5% P in dry matter during vegetative growth [142]. Collectively, Morocco, China, South Africa, the USA, Jordan and Russia hold over 95% of known, high quality, economically-recoverable phosphate rock. The USA is fast running out of its domestic high-grade reserves and is increasingly importing rock from Morocco to process into high grade fertilizer for sale on the world market [113]. Morocco holds approximately 82–85% of global reserves, followed by China at about 12% [58].

It provides the phosphate-ester backbone of DNA (the genetic material of most life) and RNA, and it is crucial in the transmission of chemical energy through the adenosine triphosphate (ATP) molecule (the energy-releasing molecule) and adenosine diphosphate (ADP). It is found as phosphates ($H_2PO_4^-$, HPO_4^{2-} and PO_4^{3-}), (for example, as phosphoproteins and phospholipids) in cellular membranes, in bones and teeth (the biomineral hydroxyapatite) [92,97]. Phosphate is taken up directly by plants, algae and some bacteria. Other sources of phosphates are the waste and remains of animals and plants, bird and bat guano accumulations and apatite ($Ca_{10}(PO_4)_6(OH, F, Cl)_2$). Apatite is the most common naturally occurring P containing mineral in the earth's crust (over 95% of P). It is also found in high concentrations in sedimentary rocks containing the fossilized waste or sediments of marine plants or animal [57].

It is also found in the form of inorganic phosphate on land, in the form of phosphate rock containing the fossilized waste, soil minerals and sediments of marine plants or animal, as dissolved phosphate and phosphate sediments. P cannot be manufactured or extracted from the atmosphere as like N_2. P cannot be destroyed, since it has no gaseous phase. Humans excrete between 3–4 grams daily in urine but cows and hogs excrete 15–20 times that amount daily. Many tons of phosphate rock are mined each year in the production of fertilizers to replace some of the phosphates lost from farmland through erosion and crop production [20].

When rocks and sediments gradually broke, phosphate is released. Some phosphate stays on land and cycles between organisms and soil. Plants bind phosphate into organic compounds when they absorb it from soil or water. Organic phosphate moves through the foods, from producers to consumers, and to the rest of the ecosystem. Other phosphate washes into rivers and streams, where it dissolves. Some phosphate mixes to the ocean, where marine organisms process and incorporate it into biological compounds [62].

Phosphorus (P) is mined from rock and its uses range from fertilizers to toothpaste.

About 20 million tons of phosphorus is mined every year and around 8.5–9.5 million tons (the proposed boundary is set at 11 million tons per year) of it finds its way into the oceans [8]. The original definition was criticized, partly because of the uncertainty of the science [108]. Global phosphate reserves are rapidly being depleted, threatening the world's future ability to produce food. Phosphate rock, the basis for large scale fertilizer production, is a non-renewable resource. Current global phosphate reserves might be depleted in the next 50–100 years, which is very significant for humanity. The US reserves of P to be depleted in the next 25 years [64].

The original PB on the phosphorus cycle was included to reflect the risk of a global ocean anoxic event that would trigger a mass extinction of marine life [49].

At the planetary scale, the additional amounts of N_2 and P activated by humans are now so large that they significantly perturb the global cycles of these two important elements.

6.4 Stratospheric Ozone Depletion

Ozone gas (O_3) is a very small portion of the atmosphere, but its presence is vital to the welfare of the entire living organisms. O_3 is found extensively (about 91% of atmospheric O_3) in the lower part of the stratosphere of the earth's atmosphere at the ozone layer. The ozone layer is surrounding the atmosphere at an altitude between 20 and 50 km from the earth's surface and with thickness ranges of 2–8 km where O_3 is continually created from O_2, and destroyed, by absorption of high-energy radiation from the sun and chemical reactions. The ozone layer is natural filter and protective shield that surrounds the earth to protect human, animal fish and plants from the harmful ultra violet (UV–B) radiations [138].

O_3 was discovered in the laboratory in the mid-1800. It has pungent odor that helps to detect even there are very small amount in the air. The ozone layer was discovered in 1913 by the French physicists Charles Fabry and Henri Buisson. Its properties were discovered in detail by the British meteorologist Gordon Miller Bourne Dobson, who developed a simple spectrophotometer (the Dobson meter) which is used to measure stratospheric O_3 from the ground. Between 1928 and 1958 Dobson established a worldwide network of O_3 monitoring stations that operates continuously. Also the 'Dobson unit (DU)' is used to measure the total amount of ozone in a column overhead [112]. DUs are measured by how thick the layer of ozone would be if it were compressed into one layer at 0^0C and with a pressure of one atmosphere above it. Every 0.01 mm thickness of the layer is equal to one DU [4]. It is discovered in the mid-1970s that human-produced chemicals could destroy O_3 and deplete the ozone layer [85]. Since the discovery it is observed that ozone depleting chemicals are steadily increasing in the atmosphere. In the ozone layer there are up to 12,000 ozone molecules for every billion air molecules, but in the earth surface are 20 to 100 molecules in billion air molecules [34].

The most sever O_3 loss has been seen in Antarctica during spring and winter, which is called ozone hole, as the O_3 depletion is very large and localized there. In ozone hole region stratospheric ozone depletion is so severe that levels fall below 200 DU but normal concentration is 300 to 350 DU [2].

O_3 is destroyed by halogen source gases such as, certain chlorine (Cl_2) and bromine (Br_2) containing chemicals. Most halogen source gases are converted in the stratosphere to reactive halogen gasses, namely chlorine monoxide (ClO) and bromine monoxide (BrO) in chemical reactions involving ultraviolet radiation from the sun rays and destroy O_3 [34]. Cl_2 can destroy about 100,000 ozone molecules and Br_2 is more destructive than Cl_2. Use of chlorofluourocarbon (CFC) in refrigeration and air conditioning equipment, methyl bromide for storing agricultural crops and agricultural soil sterilization, fire suppression, aerosol applications, foam blowing, sterilants, and solvents are main causes of destruction of the ozone layer [59, 125].

Excess of harmful UV-B rays create skin cancer (damaging DNA) and cataracts in human, reduce crop yields and disrupt the marine food chain by destroying plankton in the ocean. Destruction of ozone layer can make abrupt changes in weather and climate, desertification and forest fires and the rise in sea level to the shores of many in the world and disrupt the ecological balance [3].

6.4.1. Destructive Reactions of O_3 Depletion

Stratospheric O_3 destruction cycle is cycle 1 (say). This cycle performs into two separate chemical reactions. The cycle starts with ClO or Cl. First ClO reacts with O to form Cl, and then Cl reacts with O_3 and reforms ClO. The cycle then begins again with another of ClO with O. Because of Cl or ClO is reformed each period, O_3 molecules are destroyed and Cl is considered a catalyst for O_3 destruction. Atomic O is formed when ultraviolet sunlight reacts with O_3 and O_2 molecules [34].

$ClO + O \rightarrow Cl + O_2$

$Cl + O_3 \rightarrow ClO + O_2$

Result: $O + O_3 \rightarrow 2O_2$.

Polar O_3 destruction cycles are cycle 2 and cycle 3 (say). As ClO abundances in Polar Regions, in cycle 2, ClO reacts with another ClO in the presence of sunlight and destroys O_3 [34].

$ClO + ClO \rightarrow (ClO)_2$

$(ClO)_2$+ sunlight (γ) $\rightarrow ClOO + Cl$

$ClOO \rightarrow Cl + O_2$

$2Cl + 2O_3 \rightarrow 2ClO + 2O_2$

Result: $2O_3 \rightarrow 3O_2$.

In cycle 3, ClO reacts with BrO in the presence of sunlight creates Cl and Br. Finally, Cl and Br react with O_3 to release O_2, consequently destroy O_3.

$ClO + BrO \rightarrow BrCl + O_2$

BrCl + sunlight (γ) $\rightarrow Cl + Br$

$Cl + O_3 \rightarrow ClO + O_2$

$Br + O_3 \rightarrow BrO + O_2$.

Result: $2O_3 \rightarrow 3O_2$.

In cycle 4 (say), O_3 reacts with OH/HO_2 and creates O_2 and OH, and this OH again start new cycle [68].

$OH + O_3 \rightarrow HO_2 + 2O_2$

$HO_2 + O_3 \rightarrow OH + O_2$

Result: $2O_3 \rightarrow 3O_2$.

6.4.2 Steps to Reduce Ozone Depletion

In 1976, the United States Academy of Sciences linked the release of ozone depleting substances (ODSs) representatives from

24 countries signed the '1987 Montreal Protocol' on 'Substances that Deplete the Ozone Layer', agreeing to start phasing out the manufacturing of ODSs in 1989 [128]. The treaty has been amended several times, and at present more than 190 countries has ratified it. In 1985, the British Antarctic Survey (BAS) reported the damage to the ozone layer above the earth's surface. Only the USA and the UK account for more than 50% research, followed by Germany and Japan for ozone depletion.

On December 17, 2014 the US Environmental Protection Agency (EPA) proposed to lower the national ambient air quality standards (NAAQS) level for O_3 to 65–70 parts per billion (ppb). The current O_3 level is 75 ppb [41].

6.5 Global Use of Freshwater

Water is an essential element for all socio-economic development and for maintaining healthy ecosystems for living organisms. It is the origin of every form of life. Fresh water is essential for healthy and safe lives of human beings. Adequate and safe water and sanitation services make strength the nation's health, education, life expectancy, well-being and social development, economy, security and ecology [87, 136].

Clean water is needed for drinking, cooking, washing, and sanitation. It is also a key element of sustainable social and economic development. Fresh water is found in lakes, rivers, and groundwater aquifers. The use and abuse of water has increased in the last few decades due to population growth and economic expansion, which will create widespread water scarcity, water quality deterioration, and the destruction of freshwater resources [63].

6.5.1 Source of Water

Less than 3% of the water of the earth is fresh; the rest is sea water and undrinkable [136]. Of this more than 2.5% is frozen, locked up in Antarctica, the Arctic and glaciers and not available to human. Hence humanity must rely only on 0.5% of all human's and ecosystems fresh water needs [130]. Of this 0.5% of world water the major use is in the following [137]:

- About 10^7 km^3 is stored in underground aquifers. Since 1950 there has been a rapid expansion of ground water exploitation providing 50% of all drinking water, 40% industrial water and 20% of irrigation water.
- About 119,000 km^3 net of rainfall is falling on land after accounting for evaporation.
- About 19,000 km^3 is in natural lakes.
- More than 5,000 km^3 is manmade storage facilities reservoirs, which has been 7 fold increases in global storage capacity since 1950.
- About 2,120 km^3 water is in rivers.

Water resources are decreasing (especially in many developing countries) across the planet. Even in the 21st century 1 person in 6 (1.1 billion people) has no access to safe drinkable water and 42% of the world's population (2.6 billion people) live in families with no proper means of sanitation. About 4,500 children died in a day for the lack of drinking water supply and sanitation facilities. About 1.8 million people die every year from diarrhoeal diseases. Most of the people of Africa (especially girls) have to collect water from far distance and struggle to survive at subsistence level [141]. Half of the urban population in Africa, Asia, Latin America, and the Caribbean suffers from one or more diseases associated with inadequate water and sanitation [65].

6.5.2 Water for Sustainability

At the beginning of the 21st century, the demand for clean water becomes a global challenge. Population growth, rapid urbanization, industrialization, food production practices, changing lifestyles, poor water use strategies and economic development have led increase pressure on water resources globally. On the other hand increasing demands for sources of clean water, combined with changing land use practices, aging infrastructure, and climate change and variability pose significant threats to the international water resources. Waterborne disease also continues to threaten drinking water supplies [19,33].

Water is not distributed evenly around the world. About 9 countries of the world, for example, Brazil, Russia, China, Canada, Indonesia, the USA, India, Columbia and the Democratic Republic of Congo possess 60% of the world's available fresh water supply [136].

Despite the advances made during the past 40 years, there are the 21st century challenges that continue to threaten the water supplies of every country. Failure to manage the water to every people in an integrated, sustainable manner will limit economic prosperity and jeopardize human and aquatic ecosystem health [33].

The hydrological projections of the world's freshwater resources have indicated that the demand of freshwater is increasing worldwide [100]. Global water scarcity is expected to grow dramatically as competition for water use increases in agricultural, urban and commercial sectors because of population growth and economic development [135]. Many countries of the world are already facing water crises; mainly (in some countries of Africa) those are in arid and semi-arid regions.

Many governments, international institutions and experts have expressed the urgent need to establish a new development agenda in the field of water management [36]. About one-third of the world's population lives in areas where experience some form of water stress that figure is likely to rise to two-thirds of the world's population by 2025 [37,65]. About 70% of global water is used in agriculture sector and it is expected the extra demand in agriculture will grow by 45% by 2030, which is equivalent to an additional 1,400 m^3 of water per year [123]. Global water consumption at the end of the 20th century becomes more than doubled since World War II. It is expected this figure will rise another 25% by 2030 [145]. A recent study led by McKinsey estimates that by 2030 global water demand will be 40%. This shortfall will hit the southwest United States, Australia, Africa, and East and Southeast Asia. The water risks in Asia are due to its vast population and economic growth [75]. Water demand is increasing in the power and energy sectors for cooling, biofuels production and for shale gas and oil extraction. The US Energy Information Administration (EIA) predicts that by 2035 that demand will be double or even triples, depending on global oil prices [29].

6.5.3. Worldwide Water Use

The daily drinking water requirement per person is 2–4 liters, but it takes 2,000 to 5,000 liters of water to produce one person's daily food [37]. Domestic use of water is 11% in high-income countries and 8% in low- and middle- income countries. Industrial use of water increases with country income, going from 10% for low- and middle- income countries to 59% for high-income countries. Water use in agricultural is 30% in high-income countries and 82% in low- and middle- income countries. But in many developing nations, irrigation accounts for over 90% of water withdrawn from available sources for use [130].

Bottled water sales worldwide have increased rapidly with global consumption now at more than 1,000 billion gallons a year. Bottled water can cost as much as 10,000 times more than tap water. The USA is the biggest consumer of bottled water. Peoples of the USA are consuming water from disposable plastic bottles at a rate of more than 10 billion gallons each year which costs $11 billion. China is the 2nd largest consumer of bottled water and it uses 7.7 billion gallons (12.5% of global use), Mexico (population is one-third of the USA) is the 3rd largest consumer and it uses 7.5 billion gallons (12.3% of global use) annually. Brazil uses 4.5 billion gallons and Indonesia uses 3.8 billion gallons of bottled water annually [106].

6.5.4 Increase of Wastewater

Urban areas are both consumers and producers of large amounts of wastewater. Wastewater is created in various ways, such as, dissolved contents of fertilizers, chemical runoff, human waste, livestock manure and nutrients [19].

The cultivation of nitrogen fixing crops and the manufacture of fertilizer convert about 120 million tons of N_2 from the atmosphere per year into reactive N_2 containing compounds. Every year about 20 million tons of P is used as fertilizer [103].

Wastewater may contain a range of pathogens including bacteria, parasites, viruses and toxic chemicals such as heavy metals and organic chemicals from agriculture, industry and domestic sources [28].

Lack of wastewater management has a direct impact on the biological diversity of aquatic ecosystems, disrupting the fundamental integrity of our life support systems. In many developing countries more than 70% of industrial wastes are dumped untreated into waters where they pollute the usable water supply [147].

6.6 Land Use Change

Land is one of the most important natural resources. Land use change affects on global environmental change and landscape ascription [101]. Land is mainly used for residential, commercial and agricultural purposes. Land can also use for recreation, wood production and biodiversity preservation. The conversion of land may impact soil, water and atmosphere which are global environmental issues. Due to the large-scale deforestation and subsequent transformation of agricultural land in tropical areas affects on biodiversity, soil degradation and the material resources to support human needs. Changes in land use may impact on the climate change [66, 67, 79].

6.7 Atmospheric Aerosol Loading

Airborne particulate matter or aerosols are found as organic or inorganic compositions and consist of solid and/or liquid particles of sizes in the range 0.01–100 μm suspended in air, which occur through natural processes such as, volcanic eruptions, windblown dust, sea spray, etc. (greater than 10 μm in diameter), or through anthropogenic sources like industrial emissions, automobile exhausts, etc. (less than 10 μm in diameter) [99].

Ambient aerosol particles are responsible for adverse health effects, creation of haze pollution both in urban and in the rural area, visibility reduction on human and influence on climate. On the other hand carbonaceous aerosols can block solar radiation and scatter visible light and play an important role in the earth’s radiative balance and in climate

[56]. They are scattered solar radiation and can act as cloud condensation and ice nuclei [111]. The main component of carbonaceous aerosol is organic carbon (OC), which is volatile while the rest is composed of black carbon (BC). Carbonaceous aerosol is produced during incomplete combustion of fossil fuels, biofuels, and biomass burning emissions [55].

Aerosol sources are classified into two types as follows [12]:

- Primary aerosols (>1 μm in diameter) are those that are emitted into the atmosphere directly as condensed solids or liquids. For example, sea salt, mineral dust, desert dust, re-entrained road dust and soot particles are clearly primary particles.
- Secondary aerosols (between 0.1 and 1 μm in diameter) are formed within the atmosphere from gaseous precursors. For example, organic particles from the oxidation of volatile organic compounds (VOC) and sulphates from the oxidation of SO_2 or other sulphur containing gases are secondary particles.

Aerosols vary in shape, chemical composition and optical properties. For example, 0.01 to 5 μm solid particles are paint pigments, tobacco smoke, dust, sea-salt particles; 5 to 100 μm solid particles are cement dust, wind-blown soil dust, foundry dust, pulverized coal, milled flower; 5 to 10,000 μm liquid particles are fog, smog, mist, raindrops; 0.001 to 0.01 μm biological origin particles are viruses, bacteria, pollen, spores and 0.001 to 100 μm chemical formation atmospheric SO_2 and metal oxides form when fuels that contain metals are burned [121].

As of 2009, the PB for 'atmospheric aerosol loading' had not yet been quantified. Although there are many assessments and indicators available for particulate air pollution, such as $PM_{2.5}$ (due to the negative influence on human health), there is not enough scientific knowledge to quantify the impact at the global scale [102].

Atmospheric aerosols influence climate directly through scattering and absorbing radiation, and indirectly by acting as condensation nuclei for clouds [93]. Aerosols may have weakened the rate of the global warming by some 30%, possibly up to 50–80% [6].

Aerosols have some effects on environment and human health as well as the life of plants or animals. According to World Health Organization (WHO), ozone, particulate, matter, heavy metals and some hydrocarbons present the priority pollutants in the troposphere. The results of the long-term studies confirm that the adverse health effects are mainly due to particulate matter, especially small particles- less than 10 μm in diameter, PM_{10} [100]. Lifetime of fine particles (diameter < 2.5 μm) $PM_{2.5}$ is from days to weeks, travel distance ranges from 100 s to >1,000 s km. Lifetime of coarse particles (diameter < 10 μm) PM_{10} is minutes to hours, and their travel distance varies from <1 km to 10 km [121].

Aerosols have deleterious health effects as they often contain toxins and/or carcinogens that contribute to cardiopulmonary diseases and mortality [96].

6.8 Ocean Acidification

The basic chemistry of ocean acidification was first described in the early 1970s, based on early models of CO_2 exchange at the air-sea interface and the thermodynamics of the carbon system in seawater. Ocean acidification is closely linked with climate change [10,35,143]. The first symposium on "The Ocean in a High-CO_2 World" in 2004 proved to be a landmark event in ocean acidification and also second symposium held in 2008 [16, 91].

When anthropocentric CO_2 increases in the atmosphere and dissolves in seawater and then creates carbonic acid (H_2CO_3), releases hydrogen ions (H^+), which increases acidity. These H^+ increase ocean acidity and reduce calcium carbonate ion (CO_3^{2-}) saturation. It is estimated that the surface waters of the oceans have taken up about 25% of the carbon generated by anthropogenic activities since 1800 and altering seawater chemistry. CO_2 is generally less soluble in warm water than in cold water. As a result, marine waters near the poles have a much greater capacity for dissolving CO_2 than do ocean waters in the tropics [11].

Shipping emissions annually release about 9.5 million tons of sulphur (S) and 16.2 million tons of nitric oxides (NO). When these dissolved in seawater converted into the strong sulphuric (H_2SO_4) and nitric acids (HNO_3) respectively [51]. Ocean acidification effects on food webs, fisheries (shellfish), marine ecosystems (corals, coralline algae, mollusks and some plankton), coastal erosion and tourism [91].

The upper layers of the ocean are now 0.7°C warmer due to global warming than they were 100 years ago [72]. Since the Industrial Revolution (1750) atmospheric CO_2 has increased. The oceans of the world are absorbing CO_2 at a faster rate than at any time in the past 800,000 years [86]. Present total human CO_2 emissions are more than 10 billion tons of carbon annually. Of this amount, 8.7±0.5 billion tons originates from fossil fuel combustion and cement production and another 1.2±0.7 billion tons from deforestation [70]. The cumulative human CO_2 emissions over the industrial era now amount to close to 560 billion tons [27]. Oceanic pH has decreased by 0.1 units, increases physiological hypercapnia, which has removed 30–40 µmol/kg carbonate ions (CO_3^{2-}) from ocean bodies like the coral sea that normally contain between 250–300 µmol/kg. Consequently, at present the ocean has become more acidic (increased by 30%) by changing the ocean's chemistry and coral reefs are in threatened position [53]. It is estimated that surface ocean pH is projected to decrease by 0.4± 0.1 pH units by 2100 relative to pre-industrial conditions [76]. If this situation happens then hundreds of thousands to millions of years will be needed for coral reefs to be re-established, based on past records of natural coral reef extinction events [132].

Increasing concentrations of atmospheric CO_2 is entering the ocean in ever increasing amounts. CO_2 combines with water to produce carbonic acid ($CO_2+H_2O \rightarrow H_2CO_3$), which subsequently converts carbonate ions ($H_2CO_3 \rightarrow 2H^+ + CO_3^{2-}$) into bicarbonate ions ($2H^+ + CO_3^{2-} \rightarrow H^+ + HCO_3^-$). Some marine organisms use bicarbonate to form the compound calcium carbonate ($2HCO_3^- + Ca_2^+ \rightarrow CaCO_3 + CO_2 + H_2O$). $CaCO_3$ builds skeletons as in coral reefs, or protective shells as in snails. Hence, the decreases in CO_3^{2-}, decreases the saturation state of $CaCO_3$ [52].

Ocean warming is implicated in mass mortality, increased disease, hypoxia, coral bleaching, species invasions, phonological shifts in planktonic food web dynamics, physiological limitation in oxygen delivery and increased costs of metabolism [54,95]. Ocean acidification is a major threat to calcifying marine invertebrates because it decreases the availability of the CO_3^{2-} required for skeletogenesis, and it exerts a direct pH effect [78]. Hypercapnia has a pervasive narcotic effect suppressing metabolism [15].

6.9 Chemical Pollution

Hundreds of thousands of different man-made and natural chemicals are harmful for ecosystem or human health. The concepts of PBs for chemical pollution are needed for developing appropriate evaluation strategies to reduce global chemical risks and the future development of sustainable chemical technologies [103].

Primary types of chemical pollution are radioactive compounds, heavy metals (steel, copper, gold etc.), and a wide range of organic compounds of human origin. Chemical pollution affects other planetary boundaries, such as, biodiversity boundary by reducing the abundance of species and climate change releasing CO_2 by the burning petroleum when chemicals are produced [102].

Hundreds of tons of hazardous waste are released to the air, water, and land by industry every hour of every day and the chemical industry is the biggest source of such waste [71].

During 1994–2008, Nigeria was the worst for gas flaring efficiency among the top eight flaring countries. At present Nigeria is the second largest gas flaring volume among the top 20 individual countries. Nigeria and Russia together account for 40% of global gas flaring and the top twenty countries account for 85% [31].

It is estimated that there are 80,000 to 100,000 chemicals on the global market [18, 131]. Of the 80,000 chemicals in commerce, 1,000 are known to be neurotoxic in experiments, 200 are known to be neurotoxic in humans, and 5 (methyl mercury, arsenic, lead, polychlorinated biphenyls (PCBs), toluene) are known to be toxic to human neurodevelopment [102]. According to the California Policy Research Center, about 2,000 potentially hazardous chemicals are introduced into commercial use each year. Global chemical production is expected to double every 25 years, even as global population increases at a much slower rate. Every day the chemists are inventing new chemicals and some of them are harmful for human life [82,146].

Twelve most dangerous Persistent Organic Pollutants (POPs) are collectively referred to as the dirty dozen. The first 9 are agricultural and landscape chemicals (pesticides) and last 3 are industrial chemicals. POPs are extremely toxic chemicals with acute and chronic effects on pests, wildlife, and humans contact. Their uses, half-life in soil (years) and effects on human health are given as follows [127]:

1. Aldrin: Uses as insecticide, half-life in soil is yet unknown and adverse health effects on human body are the development of carcinogenic, malaise, dizziness and nausea.
2. Chlordane: Uses as insect and termite control, half-life in soil is one year and adverse health effect on human body is carcinogenic creation.
3. Dichloro-diphenyl-trichloroethane (DDT): Uses as insecticide, half-life in soil is 10–12 years, and adverse health effects on human body are the development of cancer of liver and immune system suppression.
4. Dieldrin: Uses as insecticide, half-life in soil is 5 years and adverse health effects on human body are liver and biliary cancer formation.
5. Endrin: Uses as insecticide and rodenticide, half-life in soil is up to 12 years and adverse health effect on human body is the development of cancers.
6. Heptachlor: Uses as insect and termite control, half-life in soil is up to 2 years and adverse health effects on human body are the formation of

cancers, mutations, stillbirths, birth defects and liver disease.

7. Hexachloro-benzene (HCB): Uses as fungicide, half-life in soil is 2.7–22.9 years and adverse health effects on human body are the development of cancers, mutations, birth defects, fetal and embryo toxicity, nervous disorder and liver disease.
8. Mirextermiticide: Uses as insecticide, half-life in soil is up to 10 years, and adverse health effects on human body are the creation of acute toxicity and possible cancers.
9. Toxaphane: Uses as insecticide, half-life in soil is 3 months to one year and adverse health effects on human body are the development of carcinogenic, chromosome aberrations, liver and kidney problems.
10. Polychlorinated biphenyls (PCBs): Uses as industry manufacture, co-planar, half-life in soil is 10 days to 1.5 year and adverse health effects on human body are cancers mutations, births defects, fetal and embryo toxicity, neurological disorder and liver damage formation.
11. Dioxins: Uses to produce by-product, half-life in soil is 10–12 years and adverse health effects on human body are the development of peripheral neuropathies, fatigue, depression, liver disease and embryo toxicity.
12. Furans: Uses to produce by-product, half-life in soil is 10–12 years and adverse health effects on human body are the development of peripheral neuropathies, embryo toxicity and liver problems.

Pulp and paper industry is considered as one of the most polluter industry in the world. The wastewaters generated from production processes of this industry include high concentration of chemicals such as sodium hydroxide (NaOH), sodium carbonate (Na_2CO_3), sodium sulfide (Na_2S), bisulfites, elemental chlorine or chlorine dioxide (Cl_2O), calcium oxide (CaO), hydrochloric acid (HCl), etc. [120].

According to the Environmental Protection Agency (EPA), the average adult breathes 3,000 gallons of air per day. Inhaling certain air pollutants can worsen conditions such as asthma, and studies estimate that thousands of people die prematurely each year due to air pollution [115].

Sulphur dioxide (SO_2) is a poisonous gas that released by volcanoes and in various industrial processes (by roasting metal sulphide ores). It has a variety of industrial applications, from refining raw materials for preserving food. The poisonous gas SO_2 is considered as a local pollution problem worldwide. It is emitted in the atmosphere from both anthropogenic and natural sources. It is estimated that anthropogenic sources account for more than 70% of SO_2 global emissions, half of which are from fossil-fuel combustion [139]. It is considered as severe health effect ingredient, both in short-term and long-term [83].

The health effects caused by a short-term (a few minutes) exposures to SO_2 are as follows [5]:
(a) difficulty in breathing, (b) coughing, (c) irritation of the nose, throat, lungs, (d) fluid in lungs, (e) shortness of breath and (f) forms sulphuric acid in lungs.

The health effects caused by long-term exposure to SO_2 are as follows [5]:
(a) temporary loss of smell, (b) headache, (c) nausea, (d) dizziness, (e) irritation of lungs, (f) phlegm, (g) coughing, (h) shortness of breath, (i) bronchitis and (j) reduced fertility.

At present China becomes the highest SO_2 emitter in the world due to its reliance on coal for energy generation. When SO_2 combines with moisture in the atmosphere, it can form sulphuric acid (H_2SO_4), which is the main component of acid rain. Acid rain destroys various living organisms (harmful for humans, animals and vegetation) and structures (paints, buildings, infrastructure and cultural resources) [83]. The World Health Organization (WHO) estimated that acid rain seriously affects 30% of China's total land area [140].

Green chemistry and engineering (GCE) involves designing and using chemical products and processes with the aim of eliminating or reducing their negative impact on human health and the environment [82].

On 10 September 2010, California's Department of Toxic Substances Control (DTSC) submitted its Green Chemistry Proposed Regulation for Safer Consumer Products to the state's Office of Administrative Law, triggering a 45-day public comment period and formal rulemaking process, which flesh out a process for identifying and prioritizing chemicals in consumer products that may be subject to additional restrictions [25].

7 Progress in Environment Protection

The Thames in London, have been cleaned up and the air quality in major cities, such as Los Angeles, is better. Synthetic pesticides once sprayed on our crops, such as DDT, have been banned in most developed countries, and lead has been removed from petroleum-based fuels.

Even though the major 12 Persistent Organic Pollutants (POPs) have now been banned or restricted in most industrialized countries, but these chemicals continue to be produced and exported to Third World countries where regulations are negligent [1]. The USA, China and other industrialized countries agreed to reduce GHG emissions.

Six dimensions of transformation for sustainability are as follows [105]:

i. Global energy transformation (>80% reduction in CO_2 emissions by 2050).
ii. Food security transformation (+70% by 2050; sustainable intensification).
iii. Urban sustainability transformation.
iv. The population transition (aim for a 9 billion world or below).
v. The biodiversity management transformation (protect, restore, manage; sustain critical biomes).
vi. Private and public governance transformation (strengthen global governance).

8 Conclusions

In this study we have discussed the aspects of nine planetary boundaries. Beyond of these boundaries anthropogenic change will put the earth system outside a safe operating space for humanity. Four boundaries; climate change, loss of biosphere integrity, land-system change and altered biogeochemical cycles have already been passed due to human activities. Scientists estimated that within a very short time world will face the difficulties of shortage of freshwater, change in land use, ocean acidification and interference with the global phosphorous cycle. In 2014 the population of the world became 7.29 billion and world population is growing continuously. For this vast population the world faces various problems and the 21st century becomes a challenge for the survival of the mankind. At the same time industrial and anthropogenic activities have increased air pollution which affect on human health. It is the critical period that all the nations should take attempts to make the earth safe shelter for all living creatures.

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