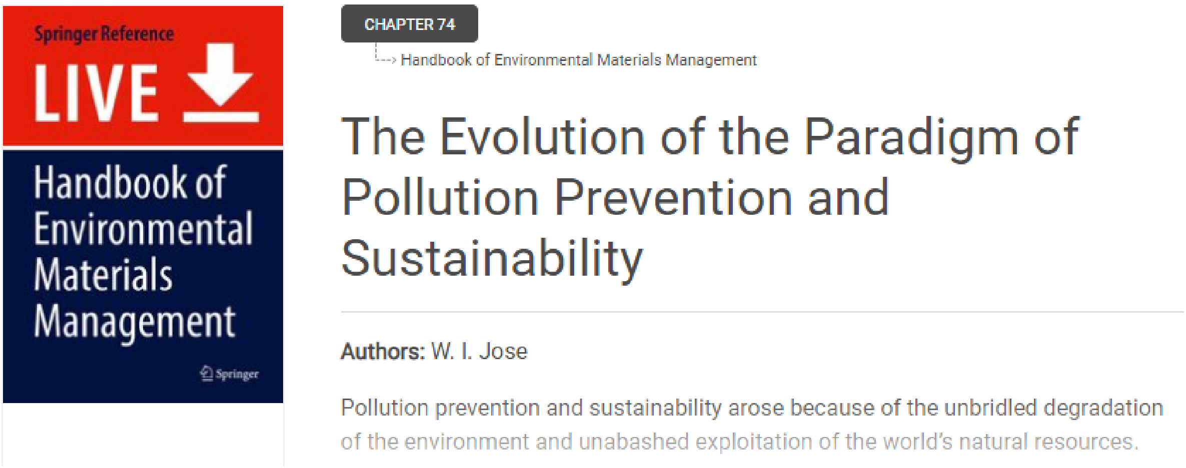

Chapter 74

The Evolution of the Paradigm of Pollution Prevention and Sustainability*   Ver. 2.0

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Abstract

Pollution prevention and sustainability arose because of the unbridled degradation of the environment and unabashed exploitation of the world's natural resources. Knowing its paradigm provides structured knowledge and information needed for understanding the intricacies, finding solutions to problems, and developing applications. Tackling problems, formulating strategies, and forming policies in this field requires the involvement of people from many disciplines. Thomas Kuhn started writing the essay, "The Structure of Scientific Revolution", using the definition of the "paradigm of a profession" as his beacon. In the end, he gave 21 different usages of the term "paradigm" without providing sufficient details about the paradigm of a profession (or a discipline or a field of study), which he referred to as the knowledge practiced by the members of a profession. From this latter concept, we can divide the paradigm of pollution prevention and sustainability into four phases: pre-/0th paradigm, 1st paradigm, 2nd paradigm, and 3rd paradigm – showing the progressive and sometimes recessive development of the field. With the problems concerning the environment and natural resources, solutions have been proposed, formulated, developed, and applied. The expectation is that an ideal green world can someday be attained. By observing the developments now and in the past, we can discern that the paradigm discussed here is somewhat independent of time and space. The heterogeneity of the world population dictates that a single road to the green world is difficult to attain. The information provided in this chapter is limited to the delineation of the development of the paradigm.

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Introduction

The field of pollution prevention and sustainability is multidisciplinary—natural sciences, social sciences, the humanities, and other areas of study are involved. While each discipline and profession can carry out studies and research on its own, many projects and activities are carried out by teams and groups consisting of people with varied disciplines and areas of interest. Hence, the members of the team must be familiar with the general and basic principles in pollution prevention and sustainability. Everyone must understand the general structure of the project, the objectives, and how each person could contribute effectively. This chapter addresses this need by providing a special technique using the concept of paradigms and probing paradigms. This is useful when people with different backgrounds meet to agree and disagree on proposed solutions and modes of action. The environmental social scientist can interact with the environmental scientist on equal terms, and together agree with the paradigm as the basis. The topic of this chapter can be a bridge to a more engaging interaction. The paradigm acts as a filter of the myriad information available in this field
Thomas Kuhn started writing his essay, "The Structure of Scientific Revolution" by defining the paradigm of a profession as "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners" (Kuhn 1962). His major objective was to show that without revolutions or paradigm shift, advancement in science is not possible. He has influenced the structure of scientific revolutions of how we understand the growth of scientific knowledge. Henry Small (2003) probed scientific paradigms with science mapping. He made a map based on citations of different authors and researchers on new ideas on branches of science. He conducted his work at a time when employing empirical methodology in research to understand scientific knowledge was the emerging trend. Contrary to Kuhn's assertion, he suggested that revolution in science should not be extremes (all or none) but instead develop as a spectrum or continuum of rate of change. The practices in pollution prevention and sustainability (henceforth referred to as PPS) has been changing and improving continuously.

Concept of Paradigms

What a Paradigm is The term paradigm comes from the Greek word "*paradeigma*" (pattern or model) derived from "*paradeiknynai*" which means "to show side by side." It now refers to a model, a theory, a concept, a map, a perception, an assumption, or a frame of reference. It used to be a simple scientific term, but because Kuhn defined it in 21 different usages (Masterman, 1970), the term has become complicated and is used in a variety of ways with the context often needing to be explained. The term sometimes becomes a source of confusion and controversy if the usage is improperly conveyed. In this chapter however, we keep Kuhn's definition of the paradigm of a profession or discipline. We refer to it as a set of knowledge that defines or guides a profession. For some professions, such as in engineering, the paradigm refers to the characteristic set of problems and systematic methods for obtaining their solutions. For pollution prevention and sustainability (PPS), it is the collection of information developed over a period from practices and data from different professions, disciplines, and fields of studies.

Determining Paradigms

The logical way to determine the paradigm of a profession or an area of study, is to trace and examine its history. We must critically note the developments, especially new ideas, themes, theses, arguments, etc., that will lead to new directions or points of views not seen before. We should carefully find paradigm shifts if any exists. Professional organizations are another source of information. The practices of the members of an organization as well as the proceedings of conferences can provide us valuable insights. Parallel to the practice of the profession is the development of the curriculum. These two aspects interact with one another and usually settle down to adapting the same paradigm. However, academic activities are sometimes not in consonance with the practices in the industry. The major reason is that the objectives or goals are different. Obtaining feedback from each other usually occurs. Textbooks, reference books, trade books, equipment catalogues, newsletters, and the patent literature, among others, all reflect data for paradigm determination. Stories, anecdotes, speeches, memoirs, biographies, recollections, etc. are good sources, too. Current events and the prevailing conditions of the world certainly affect the paradigm of a profession. The paradigms of other areas that are more specific can be determined by using other relevant parameters. For a more effective way of understanding and applying the principles discussed, the reader is advised to determine the paradigm of his/her own profession. In this manner, he/she can relate better his/her profession to the paradigm of PPS.

Visualizing Paradigms

To facilitate the understanding of paradigms and their practical use, visualization is necessary in the form of graphic plots or diagrams. Henry Small (2003) mapped the citations of authors and researchers on new ideas or different branches of science, but without a visual representation. Moreover, updating the data is slow because the actual developments are being followed from publications. Bollen et al. (2004) improved on Small's initiative by collecting and mapping clickstreams data from scholarly journals. They normalized online usage data and converted them into a map that can be used to visualize the trends in scientific research in various fields of knowledge. Real time tracking is possible. Fig. 1 shows the map of knowledge or science. The map shows both social and natural sciences. It is the equivalent of the paradigm of knowledge. Here, the paradigms of the professions and disciplines are represented by circles. We can modify the map by using areas instead, as Fig. 2 shows. Now, each profession has subdivisions of its own fields of study, with its own respective component paradigms or sub-areas. Continuing this analysis, we can imagine that a paradigm consists of component paradigms, each of which comprises paradigms, each again containing paradigms, and so on, and so forth. We can certainly design a map for the paradigm of PPS in such manner.

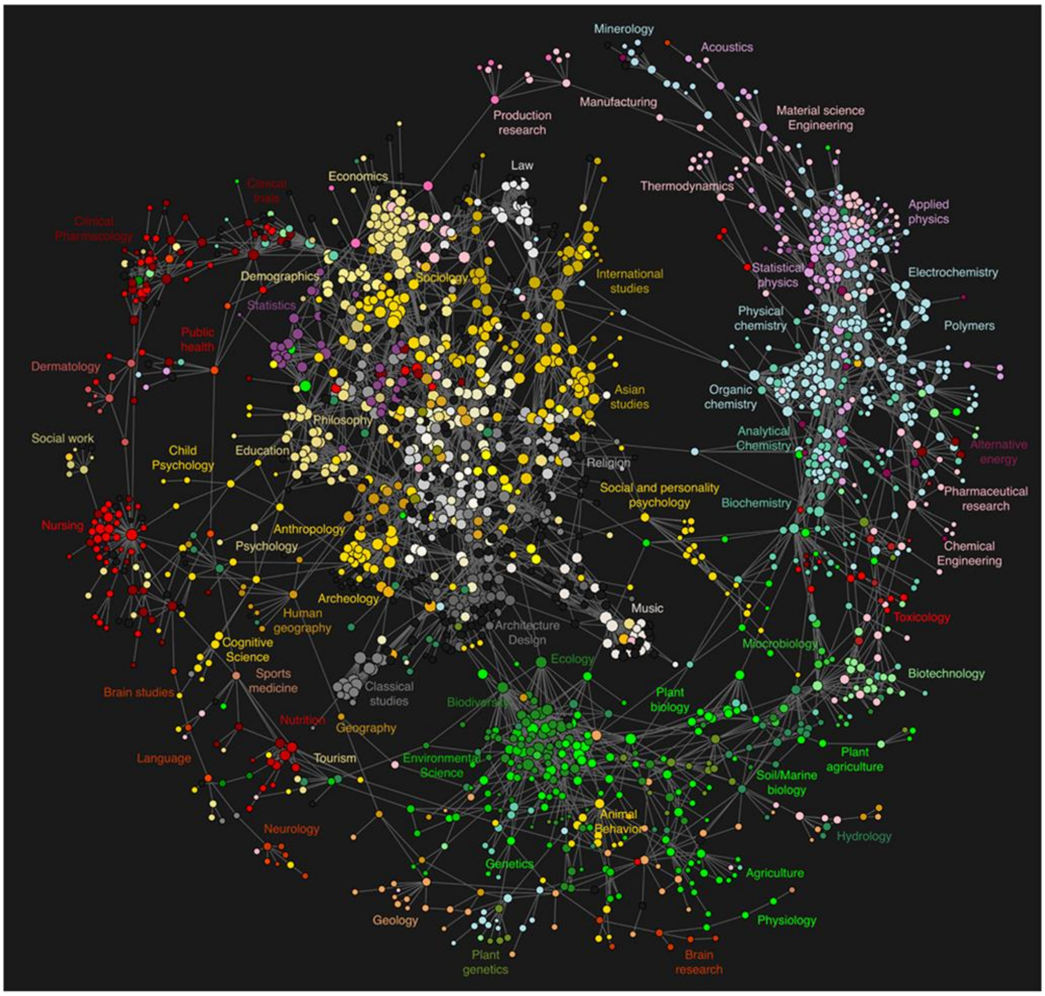

Fig. 1 Map of science derived from clickstream data. Bollen et al. (2004)
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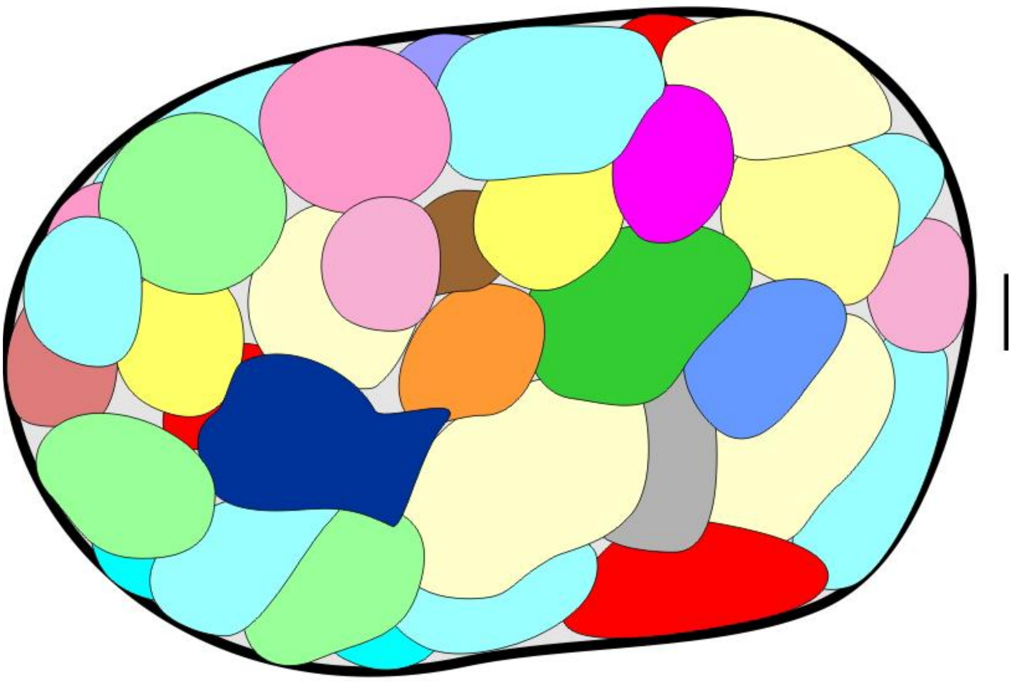

Fig. 2 The total area represents the paradigm of a profession, consists of several smaller areas that are the component paradigms, or branches of knowledge in a profession.

Using a mind map, a concept map, a Venn diagram, an Euler map, islands of information, or other graphic representation etc. can enhance the utility of the paradigm. A complete and comprehensive map contains too many information and may not be as useful as the paradigm of a small component. In this chapter, I present some diagrams which focus on the components of the paradigm.

Probing Paradigms

Plainly reading or scanning the paradigm is not gainful. We should analyze, investigate and "probe the paradigm". This means a total understanding of every aspect of the paradigm. It is equivalent to uncovering insights, observing perspectives, finding new points of view, discovering outlooks, observing attitudes, and many others. The thesaurus can provide many synonyms of the word "probe", such as contemplate, muse, ponder, brood, mull over, cogitate, ruminate, investigate, study, examine thoroughly, go deep into, and feel around, among others. After the probing, many new thoughts and ideas come out of our mind, which we might have missed before. It could be because those ideas were covered up by more prominent ones in our mind. The combination of two or more ideas may reveal another point of view. I primarily used the technique in formulating teaching strategies and developing teaching innovation in the undergraduate (Jose, 2017) and graduate (Jose, 2016) classes. PPS involves numerous principles, objectives, and applications. By considering its paradigm, we can simplify the process of understanding and unlocking its potential. We next consider how to setup its paradigm.

Setting-up the Paradigm of PPS

Having actual experience in study, coupled with an understanding of the concept of paradigms and probing paradigms is necessary in determining the paradigm. In his essay, Kuhn concentrated his discussion on paradigm shifts and its role in the advancement of science. His main argument was that "scientific activity unfolds according to a repeating pattern, which we can discern by studying its history". He did not provide a detailed description of the paradigm of any profession. As a result, only a handful of professions have explicitly discussed their paradigms. One of them is chemical engineering, which has delineated its paradigm clearly, based on the practices of its professionals around the world (Commission, 1988). Its paradigm is divided in phases: Pre-paradigm, 1st paradigm, 2nd paradigm, 3rd paradigm, and so on. The pre-paradigm or 0th paradigm phase occurred when no organized study existed. The practices relied mainly on the knowledge of other professionals such as the chemists and civil engineers, among others. Some of the practitioners became the first chemical engineers later. The first paradigm occurred during the advent of "unit operations" together with other relevant principles. The second paradigm centered on the unification of the transport processes, which consist of three subjects (mass transfer, energy transfer, and momentum transfer), into a single subject. Adopting this procedure, we can describe the 0th, 1st, 2nd, etc., and the current and future phases of the paradigm of pollution prevention and sustainability. Unlike chemical engineering, PPS is not a profession, but a field of study embraced by almost all professions. Many world gatherings, conferences, and congresses on PPS are held regularly. It is supported by the United Nations, and other world organizations, and almost all countries. With the availability of a plethora of information, we need a knowledge management system that is simple enough. The concept of paradigms provides a logical solution. By remembering or learning the paradigm of PPS by heart, we can use it as a filter in selecting the desired information from the myriad available.

The Basis of the Paradigm of PPS

Finding the appropriate definition of the phrase, “pollution prevention”, and the word, “sustainability” is the initial step in setting-up the paradigm. According to the EPA, pollution prevention is any practice that reduces, eliminates, or prevents pollution at its source, also known as source reduction, which is more desirable than recycling, treatment, and disposal. The definition and applications have expanded through time, that today, successes around the world have been documented and made available for adoption.

Sustainability, according to the World Commission on Environment and Development (1987), is development that meets the needs of the present without compromising the ability of future generations to meet their own need. Sustainability has sometimes been applied in the wrong context in environmental debates and have been exploited negatively.

Pollution prevention and sustainability arose because of the need to solve or mitigate two major problems: degradation of the environment and the depletion of resources. Certainly, we are aware that survival. human activity is the major cause of the unwanted outcomes. Here we present it as the paradigm of human activity for man’s We use the triangle created by Okada (1994) based on the description by Selvam (1990). Fig. 3 shows this. For survival and development, man has been imprudent in treating the earth. Foremost are his blatant wastage of resources and destruction of the environment. These threaten his very own survival. He must learn how to coexist with nature and the environment. Since the natural resources are finite, he must avoid its eventual depletion due to uncontrolled exploitation. He should aim to make full use of renewable resources. The key is moderation in all his activities. The graphic in Fig. 3 conveys the message effectively even without detailed explanation.

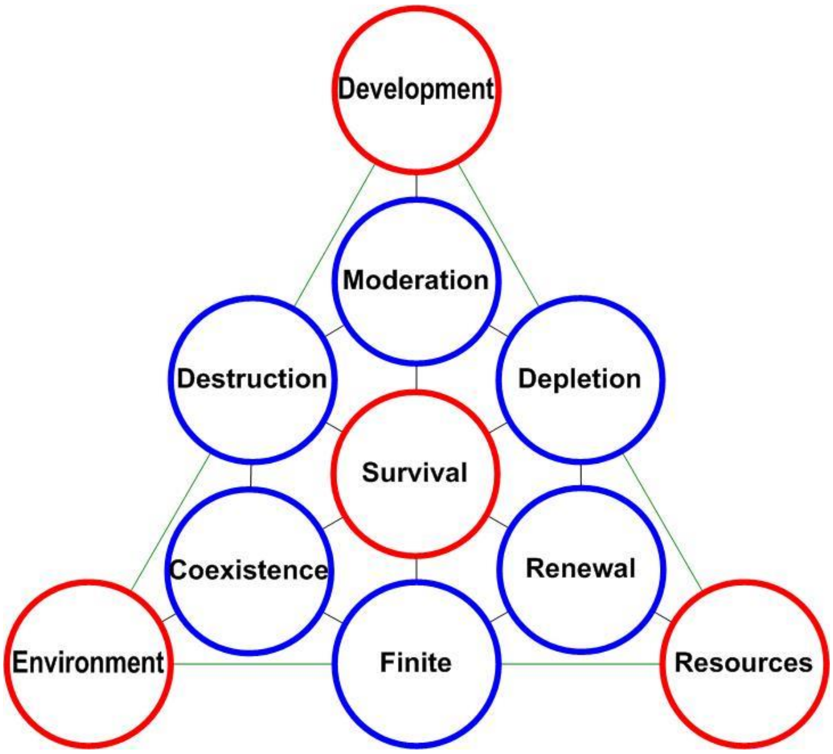

Fig. 3 The paradigm of human activity for man's survival.

Fig. 4 Global problems.

The world is saddled with problems as Fig. 4 shows. This is amidst several interacting global issues such as globalization, climate change, global warming, financial/currency crisis, energy crisis, and sustainability, among others. The concept of PPS generates different sentiments in prioritizing global issues. We must be judicious in making decisions.

Disasters, natural or man-made, could occur anytime or may be expected to ensue after some periods of time. Those caused by man can emerge because of negligence or unsafe conditions. Because man sometimes do not learn from his mistakes, these detrimental incidents can occur in any phase of the paradigm of PPS. Fig. 5 presents some man-made disasters. Preparedness, mitigation, and quick response are necessary. Today, disaster mitigation, risk reduction, and public health and safety, are significant elements in the paradigm of PPS.

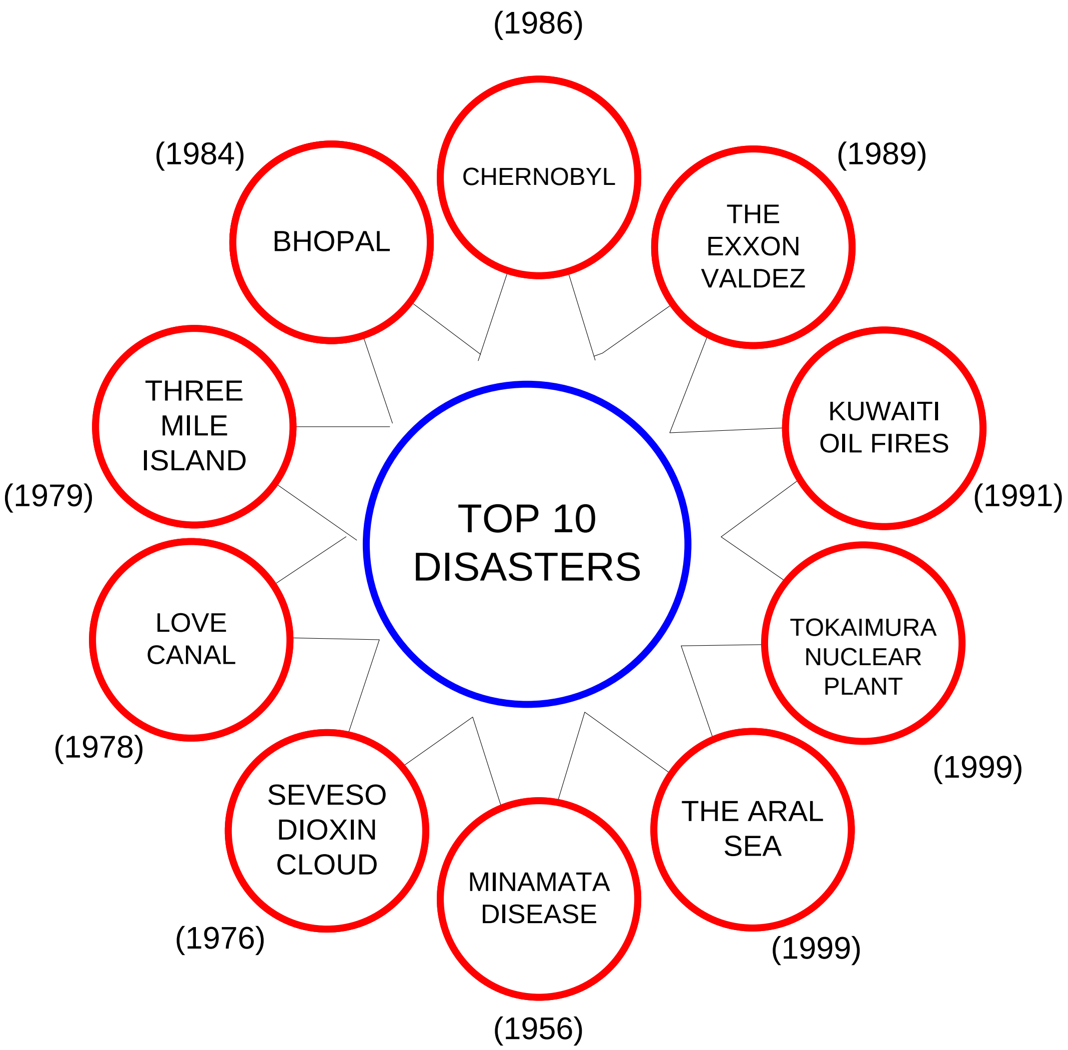

Figure 5. Top 10 man-made disasters. Time (2000)

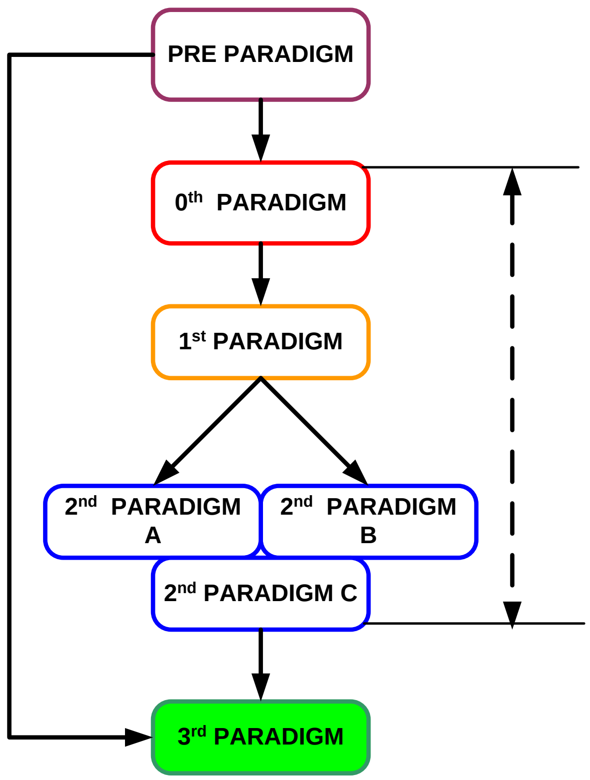

Fig. 6 The proposed phases of the paradigm of PPS. The broken lines represent that the events are independent of time.

Fig. 6 shows the arrangement of the components of the paradigm of PPS, from the pre/0th paradigm to the 3rd paradigm. Ideally, we can present the phases in a manner that depends on how events unfold chronologically based on the milestones of the development. However, these events may not evolve in such a manner because interactions, interpretations, corrections, and debates occur until a consensus settles. The demarcation between phases may not be clear because the corresponding time periods overlap. Each phase of the paradigm gradually started and proceeded in the previous phase or phases. The start of each phase is marked in accordance with a significant milestone. The time of occurrence of the phases may vary from country to country depending on the degree of development. Industrialized countries are usually in the advanced phases. In this manner, the paradigm of PPS is somewhat independent of time and space, in contrast to those of most professions and disciplines.

The pre-paradigm phase corresponds to the pre-historic times up to the start of the Industrial Revolution. The 0th paradigm phase is the period right after the pre-paradigm up to the 1960's (when problems in the environment arose.) However, we should note that problems that occurred during the 0th paradigm are still transpiring up to the present time. Practically, some parts of the world are still in that phase. The 1st paradigm provides the solutions created to remedy the problems. Although some were rashly implemented, they were improved gradually. The 2nd paradigm phase presents the improvement, refinement, and changes in the solutions, along with innovative alternatives. We can divide the 2nd paradigm into periods A, B, and C. Period A corresponds to the practice of pollution prevention in the USA in the 1970's and cleaner production in Europe and other parts of the world in the 1980's. Period B parallels the development of the concept of sustainability. Period C relates to the integration of sustainability and pollution prevention as a whole concept. The 3rd paradigm corresponds to the ideal world when the problems are solved. However, many obstacles must be overcome. The problems in 0th paradigm still occur today. Many advances have been developed but may be too costly for populations of the world. Some of the practices in the past (pre-paradigm phase) may be applicable.

Numerous graphical representations of PPS are available on the internet in the form of mind maps, concept maps, Venn diagrams, etc. One can choose the presentation that best suits him/her, since the information depends on the interest and discipline of the user. The objective is the same: effectively conveying the content of the paradigm in a compact manner.

Pre-paradigm and 0th paradigm

The pre-paradigm is included not as a historical perspective but because of its role in the development of PPS. The practices of some indigenous people today portray those in prehistoric times, which upon scrutiny depicts ideal sustainable practices. Although man has exploited the environment and the natural resources in the early days, degradation was localized because of low population. Due to the resilience of nature, the degradation apparently made it seem that nature is without limit. Referring to historical accounts, ancient civilization faced some of the same environmental problems modern society is experiencing today (Rendike, 2000). More than two millennia ago, ancient engineers and scientists began to realize and effectively address problems related with water supply and treatment, wastewater disposal, solid waste disposal, erosion, and deforestation, among others. These problems and related ones have intensified today, together with the emergence of new problems. During the Industrial Revolution in the 1800's, huge worker influx and unsanitary conditions led to problems in water supply and sewerage, causing diseases and health problems. The increased burning of coal and wood intensified air pollution, further escalating deleterious health effects. The poor health of the workers caused low productivity which hindered economic development and reduced profits. In the late 1800's, a better understanding of the scientific basis of disease and water purification somehow mitigated the problems. Some decades after 1900, health measures and waste treatment methods were being developed in the US. By the 1950's, although waste treatment techniques were available and used by industries, many either did not treat or inadequately treat their discharges. Most solid wastes were disposed in landfills, which unfortunately contaminated underground water contamination. Air pollution was uncontrolled. Nutrients from water discharges caused eutrophication of bodies of water. By the 1960's, the conditions deteriorated especially with the health effects of the unwanted environmental conditions. Continuing to the modernization of the world, the problems magnified, with the onset of new ones.

Life on earth is constantly being downgraded. This is represented by the 0th paradigm. Man's activities lead to the degradation of the environment, affecting the earth, the atmosphere, and the oceans and the seas. Refer to Figure 6. The soil and the waters are polluted. Acid rain, ozone layer depletion, marine pollution, and defoliation-desertification result. Global warming is unabated, making climate change inevitable. Solving the problems independently is not the answer. They are interconnected. Multi-disciplinary and collaborative efforts are necessary.

Water pollution

Water pollutants consist of substances that cause problems when discharged into the groundwater, rivers, and lakes. Oxygen-demanding wastes deprive fish aquatic life of dissolved oxygen (DO). Very low or minimal DO causes undesirable odor, taste, and color. Pathogens in contaminated water cause diseases. Nutrients in sufficient amounts can cause excessive growth of plant life such as algal blooms. The decomposing plant life removes oxygen in the water leading to bad taste and odors, turbidity, and color. Too many nutrients lead to eutrophication. High concentration of salts and dissolved solids in water renders it unfit to drink, even by animals. It can seriously affect agriculture. Thermal pollution affects aquatic life. An increase in temperature results in higher demand for oxygen by organisms, decreasing the DO going down. Heavy metals such as arsenic, cadmium, chromium, iron, zinc, etc. are highly toxic and usually cause damage in organs. Pesticides (insecticides, herbicides, rodenticides, and fungicides) kill organisms harmful to man, but when ingested by man, they can accumulate in the body with deleterious effects.

Air pollution

Burning of fossil fuels is the major source of air pollution which can cause many diseases such as cancer, heart disease, and respiratory infection. The major sources of air pollutants are the transportation sector, fuel combustion from stationary sources, industrial processes, and solid waste disposal (through incineration), among others. The undesired pollutants are carbon monoxide, oxides of nitrogen, photochemical smog and ozone, particulate matters, oxides of sulfur, and lead.

Solid Waste Pollution

The improper disposal of solid wastes is a health hazard, as open waste dumps become breeding places of pests and pathogenic microorganisms. Disease vectors such as rats and flies transmit many diseases to the human population. Water infiltration in waste disposal systems forms leachate, a liquid with leached-out chemical and biochemical compounds. Leachate contamination of ground water and recycling supplies are a threat to public health.

Toxic and Hazardous Wastes

Toxic and hazardous wastes that can harm the health of man, other organisms, and the environment. If they enter the cycles of the ecosystem, the harmful effects are extended. Chemical wastes for a long time have been disposed improperly with little regard to impacts on contaminating streams, lakes, groundwater. Usually, the waste products were put in containers (usually 55-gallon steel drums) and piled, dumped, or buried in convenient sites. Soon after, contamination and health problems arose.

Deforestation

Deforestation is the clearing of a forest for conversion to agricultural land, urban settlement, or other business development. Deforestation is done for many reasons: trees can be used as building materials as timber or logs; the wood can be used as fuel; cleared land can be used as farms for commercial agriculture or livestock production. Without reforestation, habitat and biodiversity are lost. Carbon dioxide in the air is not sequestered and has a profound effect on climate and weather. Soil erosion results from the absence of trees that hold the soil and causes flash flooding and landslides. The absence of forests has caused climactic changes, desertification, and displacement of people. Normal weather is disrupted by deforestation.

Energy Usage and Crises

The field of energy comprises a broad paradigm. The use of energy is a prime driving force in the activities of man. The burning of fossil fuel (oil, coal, and natural gas) contributes to global air pollution, health hazards, the greenhouse effect, and the depletion of the ozone layer. The energy demand is getting bigger because of the increasing world population and expanding needs of first world countries to enhance their standards of living (Selvam, 1991). While fossil fuels have the advantage in availability and convenience, considerable drawbacks abound such as non-renewability and uneven distribution of the resources, in addition to those mentioned above. Energy is intimately linked with the environment and economic development, and hence an important aspect in PPS.

Global Warming and Climate Change

The average global temperature has increased significantly in recent decades, that in the next century, the temperature can increase by more than 5 degrees Celsius. It is believed that human activities are responsible for the global warming phenomenon by producing too much carbon dioxide for power production from coal and fossil fuels. The transportation sector is the second largest contributor. Greenhouse gases trap the long wavelengths of the earth's radiation while allowing the short wavelength to pass through resulting in a net gain of heat energy in the earth. Getting warmer, the earth's atmosphere holds more water and storms gain more energy absorbed from the warm seas. Frequent devastating super storms are common today.

Water Shortage, Drought, Desertification

The overall effect of man's activities causes the scarcity of potable water. The earth's climate becomes abnormal and less predictable with water precipitation becoming less normally distributed in space and time. Too much precipitation occurs in some parts of the world (La Niña) resulting in worse flooding. At the same time, drought is experienced in other parts of the world resulting in death and famine. Sources of fresh water are dwindling around the world. The lists above may not be complete. Air, water, and land pollution were the primary driving forces that pushed pollution control to the forefront. We discuss the 1st paradigm next.

1st Paradigm: Pollution Control and Regulation (End-of-pipe Treatment)

The 1st paradigm was a knee-jerk reaction to the looming environmental problems in the 1970's, particularly in the United States of America. The first environmental laws were enacted, and the US Environmental Protection Agency (EPA) was established. This phase of the paradigm is concerned with averting environmental damage. With all the complications involved, and without much experience and knowledge, the concerned sectors had to search for appropriate solutions. The problems were complex with no precedence and required much learning. The EPA's first actions were the identification of all dangerous pollutants, setting of the standards for safe exposure, possible recycling of wastes, and for the protection of the environment and public health, the management of the remaining wastes. The establishment of the early regulations on the environment were more of a reflexive response to a crisis. Everybody seemed to be convinced that all the problems could be solved – that the air will become clean and that the water streams would be free of discharged pollutants within the decade. The "end-of-pipe" treatment turns out not to be the magic cure. The assessment of the levels of safety of pollutants was difficult. The end-of-pipe methods in different media—air, water, solid wastes, and toxic wastes—turned out to be a game of moving pollutants from one media to another. Using a treatment for wastewater results in the production of sludge that must be treated and disposed. Using an adsorbent to remove a toxic pollutant in the wastewater or contaminated air transfers the pollutant to the solid adsorbent that must be treated and disposed. We now discuss some of the traditional treatment schemes for the various wastes. The techniques on their own may not give a complete or suitable result. But combinations of methods, schemes, or modifications can improve the performance.

Waste Treatment Processes

The industrial processes produce gas, liquid, and solid emissions. The treatment schemes employ physical methods, chemical treatment, and biological means. Depending on the types of emission, the treatment systems can employ a combination of the above three methods, to form the primary, secondary, and tertiary treatment phases.

Physical Methods

Some common physical methods are:

- Screening – removal of solids using racks or screens
- Filtration – using a filter medium made of cloth, metal, glass fiber, or other suitable materials
- Sedimentation – allowing solids to settle at the bottom of a sedimentation tank and collected in the form of sludge
- Flocculation – promoting the aggregation of solids using a flocculant such as aluminum hydroxide with the solids separated by sedimentation or filtration
- Centrifugation – use of centrifugal force to separate the solids from the liquid or gas
- Adsorption – use of an adsorbent such as activated carbon, which possess a large surface area to attract the impurities
- Dissolved air flotation – by bubbling air in the wastewater, bubbles attach to the solid particles, which can be collected at the surface
- Air stripping – use of air to remove volatile impurities
- Steam stripping – use of steam to drive off mostly volatile components of the wastewater
- Electrodialysis – use of electric charge to separate positively charged particles from negatively charged particles

Chemical Methods

From chemistry and chemical engineering, some common chemical treatment methods are:

- Reaction to produce an insoluble solid
- Reaction to produce an insoluble gas
- Reaction of surface charge to produce coagulation of a colloidal suspension
- Reaction to produce a biologically degradable substance from a non-biodegradable substance
- Chelation
- Thermal oxidation
- Catalytic oxidation

Biological Treatment Methods

The biological treatment methods are classified into aerobic and anaerobic processes. They employ naturally occurring microorganisms that degrade biological wastes. Aerobic microbes need oxygen to survive, while the anaerobic ones die in its presence. Facultative microorganisms can live with or without oxygen. The most common aerobic method is the activated sludge process, which requires intensive aeration (and high energy requirement). The anaerobic digester represents the group of anaerobic treatment processes. These two systems are the basis of numerous variations and improvements of the waste treatment processes that have evolved through the years. Choosing the appropriate system for a particular waste requires a treatability study and judicious decision. While the rate of reaction is faster in aerobic systems, they require aeration and are energy intensive. On the other hand, anaerobic processes produce biogas that can be used as an energy source. The rate of reaction is slower, though. A major improvement in the biological processes is the use of support materials (or immobilization systems) for the microorganisms to prevent their loss, and the microbes are recycled in effect. Some biological treatment methods are:

- Activated sludge
- Aerobic attached growth
- Aerobic hybrid systems
- Aerobic lagoons
- Anaerobic digesters
- Anaerobic lagoons
- Waste Stabilization ponds and lagoons
- Trickling Filters
- Composting
- Enzyme treatment

Toxic and Hazardous Waste Treatment

These wastes can be treated by physical methods (using the usual unit operations) or chemical means (oxidation, reduction, precipitation, pH adjustment, or ion exchange). A biological process can be used for wastes of low concentration or amenable to microbial treatment. High temperature incineration is suitable for many hazardous wastes.

Solid Waste Control and Disposal

Solid waste control equipment and processes consist of physical processes such as shredding, air classification, and compacting. In air pollution treatment, the particulate control devices used are cyclone separators, electrostatic separators, baghouses and fabric filters, and venturi scrubbers. The gaseous control devices are adsorbers, absorbers, vapor incinerators, and flares.

Solid Waste Disposal

Solid wastes can be disposed at materials recovery plant, landfills, incinerating plants, or other conversion process plants such as pyrolysis or biological processes. The resource recovery plants dispose only the final residuals. Landfills can be open dumps or "sanitary" (covered compacted wastes). Open dumps were discouraged or prohibited. Incineration can be used for energy recovery but requires expensive air pollution control.

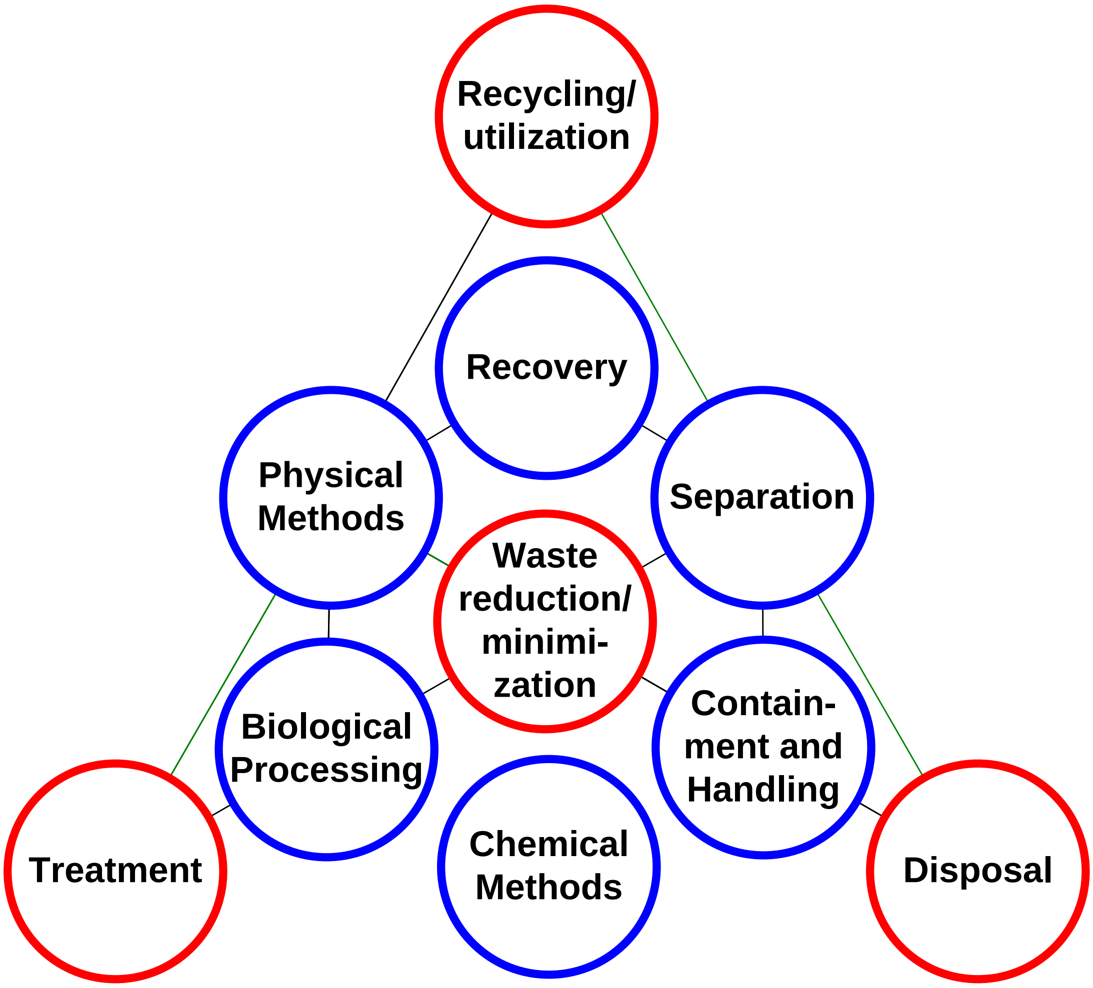

Fig. 7 The hierarchy of waste management.

During the 1st paradigm, many companies closed. Those that remained sought improvement to lower the costs. Progressive companies, on their own, devised methods to lower the treatment cost through R & D and innovation. The hierarchy of waste management was evolving then as Fig. 7 shows. This was the prelude to the 2nd paradigm.

2nd Paradigm: Practice of Pollution Prevention and Sustainability

The second paradigm consists of pollution prevention and sustainability, but these two topics must be discussed separately. Their development congruently occurred with some common milestones. While both aspects of natural and social sciences aspects are present, pollution prevention has a typical paradigm of science—the development of systematic solutions to problems. Sustainability has many social science aspects that complement pollution prevention and broadens the social, environmental, economic, political, and other applications. We must present the 2nd paradigm in three parts: pollution prevention and cleaner production; sustainability; and the integration of sustainability and pollution prevention. Pollution prevention originated and was widely adopted in the United States in the 1970's while the concept of sustainability was being elaborated. In Europe, cleaner production, which was equivalent to pollution prevention developed and was influenced by the concept of sustainability. The rise in the acceptance of sustainability is chronicled by the third part.

Period A- 2nd Paradigm: Pollution Prevention/Cleaner Production

The paradigm of pollution prevention is in the realm of many disciplines. It is typically a collection of problem-solving activities directly concerned with the environment and the lives of people. The problems are solved by scientists and engineers, in close coordination with social scientists and other people of various disciplines. The government and its different branches, public and private organizations (local, regional, and local) are all involved. The implementation can be done at different sectors and levels. At company level, the procedures have been quite developed, with many of the successes having been duplicated. Many procedures and practices for various industries are available.

Pollution prevention, as a response to the environmental problems was first practiced in industrial plants. Within a company, everybody from top management down to the lowest ranked employee must be involved. Problems are solved; solutions are validated and applied—with the involvement of the social sciences and allied disciplines. This phase of the paradigm focuses on attaining better economic efficiency in the protection of the environment. Thus, many of the programs that were undergoing a paradigm shift (1st paradigm to the 2nd paradigm) found ways to prevent or minimize the pollution that gave rise to the practice of pollution prevention. With the success of some companies, others emulated them.

Reducing the generation of waste became a benchmark in environmental programs. Some innovations were the use of wastes as ingredients in the process or in another product, or as the product itself. Pollution prevention programs have been institutionalized by private industries to cut waste management costs and lower liabilities. To encourage the practices, new regulatory and non-regulatory programs have been developed to promote pollution prevention. In the US, many federal and state programs have issued laws and regulations on pollution prevention.

All these initiatives have been duplicated worldwide. The issue regarding hazardous wastes has been raised—on clean up after the generation and treatment before disposal. Some of the laws passed were the 1997 Clean Air Act, the Clean Water Act of 1977, Toxic Substances Control Act, The Resource and Recovery Conservation Act, and the Pollution Prevention Act of 1990. Many of the States in the US have even led the way in developing laws and regulations. They have passed their own provisions on pollution prevention. The private companies have developed pollution prevention programs because of the economic benefits. Regulatory agencies instituted award programs for the success in the industry sector. As a public relations tool, many companies publicize the success of their waste reduction programs. Worldwide, governments realized the importance of pollution prevention. The UK has emulated the efforts in the US. Japan concentrated on reuse and recycling technologies. Many European countries have been leaders in pollution prevention. Non-regulatory approach was emphasized in Europe—in terms

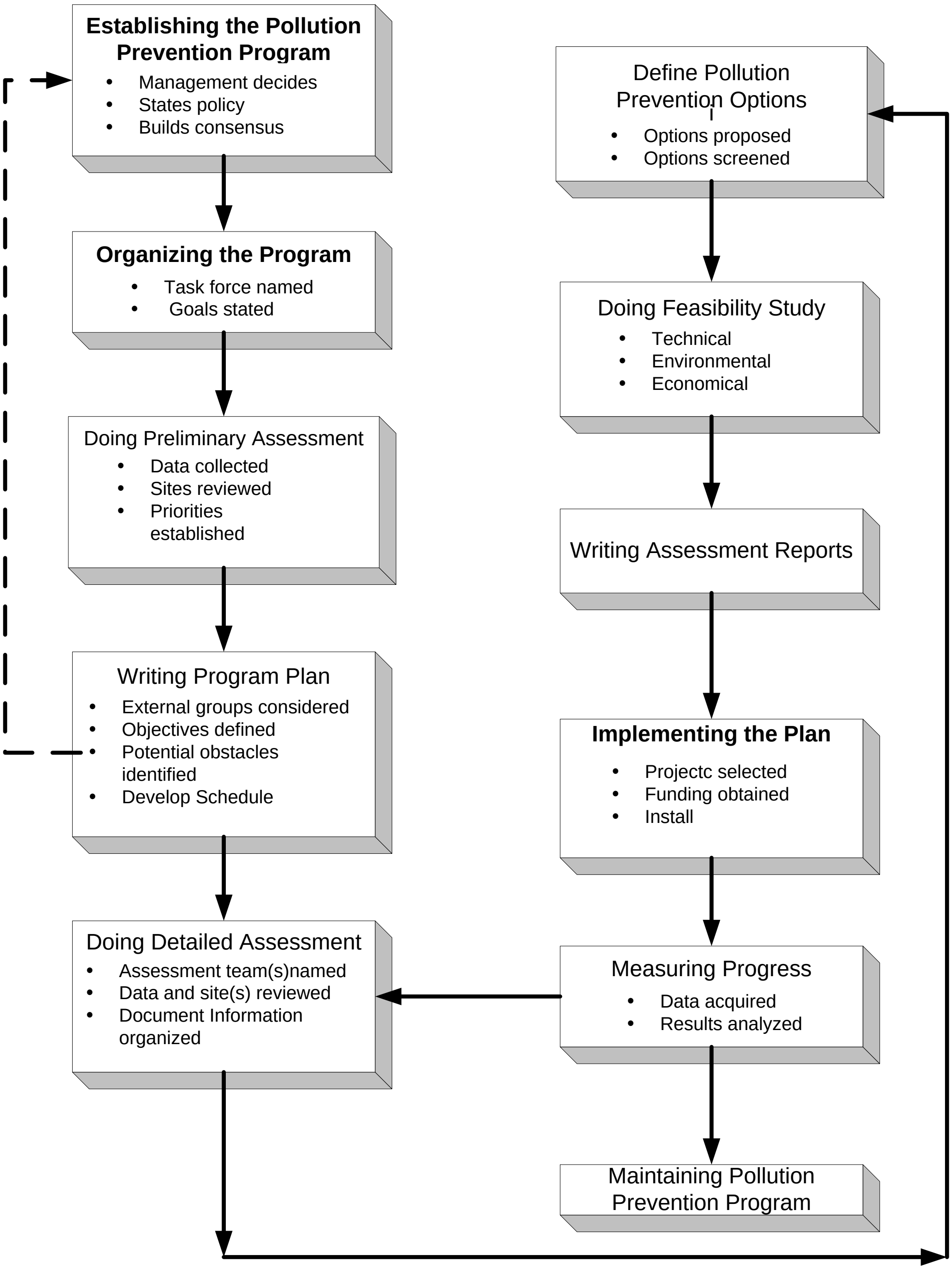

Fig. 8 Flow sheet of a typical pollution prevention plan. (Evers 1995)

of cooperation with and assistance to industries. An equivalent program, "Cleaner Production" was promoted by the United Nations Environmental Program (UNEP) and was practiced starting in the 1980's.

Conducting a pollution prevention program benefits the company not only with monetary incentives but with many other opportunities that come with the adoption. Pollution prevention changes the usual waste management practice with wide ranging methodology. Overall, it is an approach concentrated on preventing the formation of any type or form of waste (in practical terms) in the entire plant. Through the practice of pollution prevention, improved environmental protection results in the benefit of improved efficiency, profitability, and competitiveness of the business. Through legislation and regulation, the implementation of pollution prevention is straightforward. While pollution prevention translates to sound business, its implementation supports other rationales, concerned mainly with economics. They comprise the following: waste disposal costs are reduced because less waste is to be treated; the raw materials costs are reduced because the process uses and reuses these materials more efficiently; the damage costs are reduced because of the avoidance of lawsuits and insurance charges; and the public relations is improved because environmental improvements promote a good image of the industry. Moreover, savings of both time and money result due to the great reduction in the paperwork associated with the permitting regulations.

Instituting a Pollution Prevention Plan in a Plant

A pollution prevention program should proceed through sequential operations of planning and organizing, assessment, feasibility analysis implementation, and review. Fig. 8 shows a typical scheme. If these steps are followed carefully and effectively, the discharge of wastes and pollutants can be reduced to a minimum (Evers, 1995). Hence the final treatment cost becomes less also. Pollution prevention applies to hazardous and non-hazardous wastes, as well as process wastes and products. Offsite recycling, incineration, and other clean technologies were initiated.

Cleaner Production

As adopted by the UNEP, "cleaner production is the continuous application of an integrated preventative environmental strategy to processes, products, and services so as to increase efficiency and reduce the risks to humans and the environment." (UNEP Cleaner production was Europe's and other countries' version of pollution prevention with the influence of the concept of sustainability. The method for solving pollution problems on a technical basis has been transformed to scientific ones. The UNEP's definition can be reduced to prevention, continuity, and integration. Prevention is not only about source reduction but also a risk reduction strategy. Continuity applies to improving the method of discharging pollutants. With pre-set objectives and targets, success means new objectives and targets are defined on a continuing basis for the next cycle. Integration accumulates all the environmental metrics that combine all impacts from start to finish. Cleaner production reduces wastes, increases efficiency, enhances productivity, and conserves financial resources. Not to be confused with waste reduction and pollution control, cleaner production is focused on life cycle analysis, site recycling of materials, and incessant upgrade of successful results.

The ISO 9000

Quality, productivity, and efficiency are the ultimate result of pollution prevention. In this respect, the ISO 9000 complements pollution prevention and vice versa.

The International Organization for Standardization established the ISO 9000 series, a series of standards in five parts. It was firstly written as a general guide for buyers and suppliers to negotiate with one another. Today, registrars certify that a firm strictly complies with the documented quality systems and practices to the standards of the ISO 9000 series. The designation, production, installation, inspection, packaging, and marketing of the firm's products as well as services are dealt by the standards. Strictly implementing a pollution prevention is necessary for a company aiming for the ISO 9000 series certification. A pollution prevention plan on the other hand would be a good groundwork for the ISO 9000. Being ISO 9000-certified today is necessary for worldwide business. (Hockman and Erdman, 1993)

Environmental Management System

An Environmental Management System (EMS) is a system to evaluate environmental practice. It is used to improve environmental performance, make changes, and react to outcomes. As an organizational tool, it can be used to identify improvement opportunities in environmental practice to gain better results. (Haider 2011)

Period B- 2nd Paradigm: Sustainability

The 1st paradigm is focused on remediating the degradation of the environment while part A of the 2nd paradigm deals with protecting the environment in a more economical or even profitable manner. Part B of the 2nd paradigm is about elevating the concern for the environment to a higher degree, with the promotion of sustainability.

Sustainability has been a catchword in debates concerning the environment—sometimes with negative or wrong connotation. Therefore, the correct and clear paradigm of this field should be the basis of applications.

After World War II, the US initiated international pacts to promote economic development, social development, and human rights to promote peace and security. This led to human well-being, freedom, quality of life, and opportunity becoming the ultimate goals of development. Living standards and the economy rose, with people's lives becoming longer. However, this led to the mounting problems of environmental pollution and resource misuse. Because of the widespread environmental degradation and poverty issues not properly addressed in the 1970's and the 1980's, new development models had to be instituted. In 1980, the report of the International Union for Conservation and Nature (IUCN) concluded that "integration of conservation and development" was needed for "the survival and well-being of all people." This approach was adopted by the World Commission on Environment and Development in 1983, which defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The Commission recommended to the United Nations to transmute the report into an action plan.

The nations of the world convened the 1992 UN Conference on Environment and Development at Rio de Janeiro and endorsed Agenda 21, an action plan for global sustainable development, the Rio Declaration, consisting of 27 principles. It was ratified by 178 countries including the US. The US however, had a problematic relationship with the UN due to distrust. The UN perceived the US and some countries to control its affairs. The US viewed Agenda 21 as a way of reducing its influence in the world and as an intrusion in its domestic policy. Although the US has embraced sustainability, some barriers somewhat persisted. This is the reason pollution prevention and cleaner production seemed to exist in different paths although they are almost identical. This is an indication that politics and opinions affect the development of the paradigm of PPS. The direction of the paradigm has been affected sometimes subtly, or sometimes obviously, for better or for worse.

The definition of development in sustainability added a third dimension—environmental protection/restoration—to the economic and social pillars. See Fig. 9.

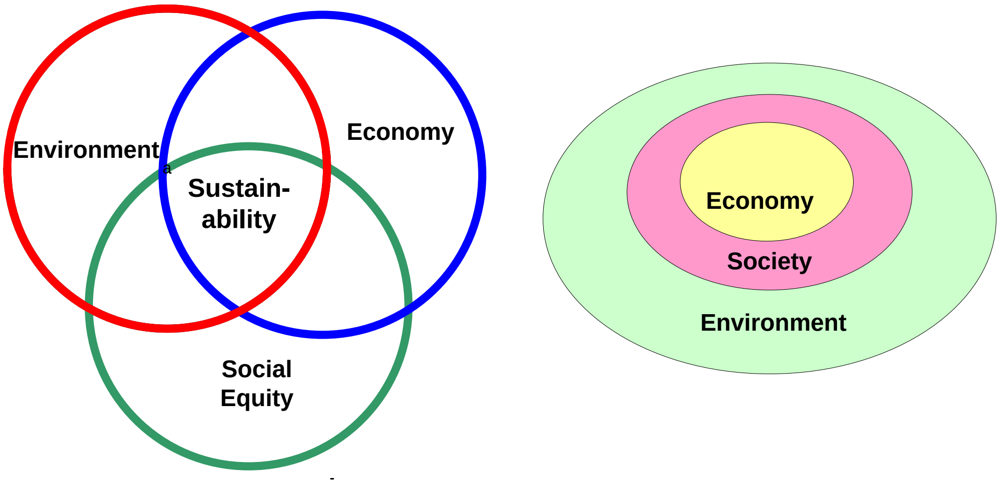

Fig. 9 Environment is the basis of the pillars of sustainability. Environment takes priority over human society and economy because they cannot exist without the environment (Adopted from Caradona, 2014).

Sustainability can only be realized by simultaneously protecting the environment, maintaining economic growth, and fostering social equity. These became the basis of different interpretations of sustainable development in the world, with ultimate aims of development as well-being of man, better quality of life, freedom, and opportunity. In the ecological system, the human society, the natural environment, and the flow of resource interact dynamically.

Environmental laws, as well as other regulations around the world, considered the above objectives to prevent harm or inequity. In the US, new forms of knowledge were acknowledged as necessary. An interdisciplinary and problem-driven field of sustainability science has arisen: a paradigm of sustainable development, drawing on the disciplines of engineering, law, natural sciences, and social sciences. Similar actions were reiterated around the world by UN member countries. In the European Union (EU), the sustainability strategies specifically addressed climate change, clean energy, sustainable consumption and production, sustainable transport, conservation/management of resources, public health, migration, and global poverty, among others. Jorgensen (2000) notes that the widely used definition of sustainability does not include reference to environmental quality, biological integrity, ecosystem health, or biodiversity. This issue should be included in the paradigm of sustainability.

Interpretations of Sustainability

As the paradigm of sustainability has a larger scope, the principles can have more interpretations

Numerous issues have been brought out. For example, according to Portney (2015), the concept of sustainability is subtle that the practical issues may not receive due attention. Efforts have been focused on explicit targets such as (1) climate change, (2) safeguarding water supplies and systems, and (3) preparation for probable changes in the environment. In relation to climate change, burning fossil fuels release carbon dioxide to the atmosphere causing its warming as evidence indicates (although with some controversies). This involves climate change mitigation and climate change adaptation. Resiliency is necessary in addressing the rise of sea level, extreme weather occurrence, and droughts. Wide-ranging issues relate to

water—health effects due to lack of access to clean drinking water, fresh water supply depletion due to rising sea levels, disappearance of rivers and bodies of water, and many others—point to the need of addressing the availability of water for the near future and the next generations. Many of the issues are included in the items below.
In 2015, the United Nations Development Summit adopted the Sustainable Development Goals (SDG) to serve as an action plan for the world to follow in the next 15 years with 17 specific goals that involve social, economic, and environmental dimensions of sustainable development: (1) no poverty, (2) zero hunger, (3) good health and well-being, (4) quality education, (5) gender equality, (6) clean water and sanitation, (7) affordable and clean energy, (8) decent work and economic growth, (9) industry, innovation and infrastructure, (10) reduced inequalities, (11) sustainable cities and communities, (12) responsible consumption and production, (13) climate action, (14) life below water, (15) life on land, (16) peace, justice and strong institutions, and (17) partnerships for the goals.

Throughout the years, sustainability has been formalized with different declarations and protocols.

Period C- 2nd Paradigm, Integration of Pollution Prevention and Sustainability

The underpinnings of the concept of sustainability based on the original definition of sustainable development initially impeded the real objectives. Through the years, however, the undeniable importance is being realized. Pollution prevention developed in the US without the outright influence of sustainability in the 1970's. It spread to the other parts of the world where the concept of sustainability was gaining popularity. In Europe and elsewhere, cleaner production was promoted as a counterpart of pollution prevention in the 1980's. Today, pollution prevention and cleaner technology are synonymous.
This phase of the paradigm of PPS is about the integration of the concepts and the available alternative methods of analysis and solutions.

Because of the complexity involved in this area of study, the systems approach or system thinking is the most appropriate method that must be used, together with engineering, natural, and social sciences. The non-technical issues are equally important as the technical ones. In this area of study, all the stakeholders must have an equal share of responsibility and contribution.

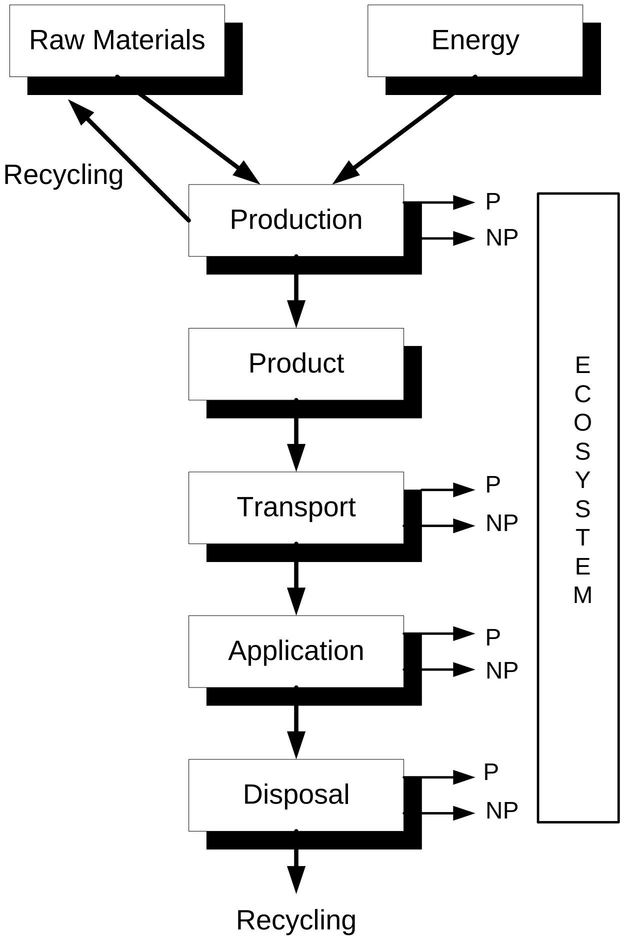

Fig. 10 The flow of mass and energy during the history of a product (agricultural and industrial). Point pollution (P) and non-point pollution (NP) enter the ecosystem. (Jorgensen 2000)

Today, environmental management has become complex. Fig, 10 shows the flow of materials and energy in how a product is made, from the raw materials to the final discarding of wastes. Several point and nonpoint pollutants are involved. In our society today, between 10^7 and 10^8 products probably exist. Several technologies are available to solve the pollution problem, such as environmental technology (to remove pollutants from the air, water, and soil), cleaner technology/pollution prevention technologies (to recycle or change/alter the production system to reduce the emission), life cycle analysis (to produce an environmentally friendly product), and eco-technology (to use the ecosystem to solve pollution problems such as use of artificial ecosystems) (Jorgensen 2000). Considering the environmental regulations and green taxes that may be imposed, we imagine the complexity involved. A unifying method should be used. To handle complex problems, the concept of systems must be used. This is discussed next.

The Systems Approach or Systems Thinking

Sustainability is about the environment, and we have seen the complexity as illustrated above. By considering all the components, conditions, and factors involved, the systems approach should be used. A system is a collection of interconnected components organized and coordinated in such a way that some characteristic properties are exhibited by the system. The system properties are not exhibited by any of the individual parts but are the result of the interaction and relationships of the parts. Systems may be nested within other systems, as for example, the human body has the circulatory system, nervous system, digestive system, etc. The Earth is a system consisting of numerous nested and interconnected systems. To deal with sustainability, the system properties of several systems must be considered, such as ecosystems, industrial production systems, agricultural production system, a country or regional system, the system involved in the life cycle of a product, and the system of the properties of chemicals used in industry, agriculture, and everyday life. Some specific examples where systems are applicable are in environmental management systems, life cycle analysis, and environmental risk assessment. The use of computer modeling makes the works accessible. (Jorgensen 2000)

The systems approach must use enormous amount of environmental data. The ongoing advances in computing and web technology provide the environmental field with the necessary resources for collecting and analyzing data. The information that has been collected fall in the category of Big Data, which is a compilation of large volumes of complex data sets that is difficult to process and manage. Fortunately, the use of web technologies can tackle this challenge, as current implementation “facilitate working with larger volumes and more heterogeneous data sources”. (Vitolo et al. 2015)

Measurement Tools, Metrics, and Measurement of Sustainability

The release of the UN Agenda 21 in 1992 created a demand for measuring sustainability results. As sustainability is an abstraction that is not measurable using the usual metrics, new assessment tools had to be built from scratch. Collection and creation of new information than can be used to rate the rate of sustainability of everything, e. g., forest management, power plants, agricultural produce, a whole country, a political unit, population growth, education, social well-being, green buildings, etc., must be done. Table 1 shows some of the metrics.
The measurement of sustainability has gone mainstream and has been used to define success not exclusively only on financial terms. The answer to the question, “Is it sustainable?” can be yes with some confidence. We can now decide how to choose “green products”. The sustainability of energy sources and the way to a low-carbon economy can now be analyzed. Programs in education and training now include the study of metrics.

Table 1 Some sustainability measurement tools (Caradonna 2014)

Ecological Footprint Analysis (EFA)	Ecolabels
Carbon Footprint	Ecolabel: Ecologo
Life Cycle Analysis	Ecolabel: Certified organic
Human Development Index (HDI)	Genuine Progress Indicator (GPI)
Triple Bottom Line	UN Millenium Development Goals (MDG)
The Sustainability Tracking, Assessment and Rating System (STARS)	Ecosystem-based Fishery Management (EBFM)

Innovation and sustainability

While unpatentable social inventions abound, innovation and invention are more often associated with technology. Advanced technologies use techniques such as TRIZ (Russian acronym of *Theory of Inventive Problem Solving*) (Altshuller 1999), OTSM (Russian acronym of *General Theory of Powerful Thinking*) (Khomenko 2010), and Kurtweil’s Law of

Accelerated Acceleration (Kurtweil 2001). When applied to social sustainability, these methods have some limitations. (Hede et al. 2015) has proposed a conceptual Multifaceted Framework, consisting of the "multilayered decision modeling methodology" in conjunction with the "comprehensive and simplified technique for sustainability evaluation using expert opinion". Pertinent criteria related to sustainability "ranging from social, emotional, environmental, technical, rational, intuitive, economical", and others, are used. The method uses the most relevant criteria for sustainability that address equitably the stakeholders' welfare. The method was developed for product development, but it is equally applicable to other aspects of sustainability since we observe the paradigms of chaos theory and complex adaptive systems in our daily lives.

3rd Paradigm: Efforts towards a Green World

The 3rd paradigm sets the picture of the result that could be expected from the various efforts exerted in the last decades. Humankind has been facing tremendous difficulties in the world with sustainability as the greater challenge. So, going on to the third paradigm of PPS, will it be a future that is green, brown (business as usual), or black (deteriorated conditions)?

The Situation Today

Man has faced many challenges, and he has always recovered. This time, he should come to his senses. The extreme carrying capacity of the earth is fast approaching. The earth's temperature is rising abnormally. The greenhouse gases have been increasing. The limitation of the end-of-pipe method of treatment have pushed pollution prevention to the forefront. We feel gloomy that despite all the advances and breakthroughs, the ideal world has not come. To find out the real situation today, we refer to the UN Millennium Development Goals (MDG) set more the 15 years ago and evaluate what our status is now.
Let us look at the 2015 review of the MDG by the United Nations (UNDP 2015) after 15 years, that of Goal No. 7: "Ensure Environmental Sustainability".

- Virtual elimination of ozone-depleting substances has been achieved since 1990, with the ozone layer set to recover by the middle of this century.
- In many regions, terrestrial and marine areas that are protected have been increasing since 1990. In Latin America, for example, the coverage rose to 23.4 per cent from 8.8 per cent from 1990 to 2014.
- For improved drinking water source, the availability rose to 91 per cent in 2015 from 76 per cent in 1990.
- Since 1990, 1.9 billion of the 2.6 billion people with access to improved drinking have piped drinking water on premises. 58 per cent of the world's population have a higher level of service.
- Worldwide, 147 countries have access to drinking water, 95 countries have gained proper sanitation, and 77 countries have both.
- Globally, 2.1 billion people have improved sanitation available. The practice of open defecation has been halved since 1990.
- In the developing regions, 39.4 per cent of the urban population living in slums in 2000 decreased to approximately 29.7 per cent in 2014.

After close to a half-century of the circumstances that triggered PPS, are we heading towards a green world? The obvious answer is that we still have a long way to go.

However, we must wake up to the reality that the attainment of a green world will involve compromises. We are living in a heterogeneous society: the north and the south; the developed and undeveloped.

The First Road to the Green World

In terms of the breakthroughs accomplished in PPS, we are progressing. Many breakthroughs have been achieved that could lead to a green world for developed countries. Some of them comes at a high cost. The developments include green buildings, advanced transportation (electric/autonomous vehicles), solar power, renewable sources of energy, robotics, automation, 3-D printing, super computers, space travel life support system applied to homes, controlled environment, etc.

The Second Road to the Green World

Back to the natural world as practiced by indigenous people. At a small cost, a green world can be attained but is not compatible to the usual lifestyle in the developed world. Accounts of practices of ancient and indigenous people show that many of their practices, customs, and traditions lean towards sustainable conditions. Two examples are given here.

The Harmonious Life of the Amazonian Indians

Calvacanti (1997) cites that evidence from anthropology and ethnoscience points that a society can have a joyous life within possible limits with the aim of discovering a knowledge of how to devise a sustainable future for the future of humanity. In terms of man-nature relationships, the Amazonian Indians exhibit a harmonious way of life without causing social or ecological distress because they are very austere. They observe sustainability with a plan that meets the needs of future generation, and they take care of other species that assures the preservation of biodiversity. They have a strong sense of community, with individual interests not pursued unrestrictedly. They have an ecological land-use planning. They manage resource use, such as in the protection of forests on the banks of a river as a resource for fish subsistence. These practices can be adapted by modern civilization but with much difficulty.

Fig. 11 The Ifugao Banaue Rice Terraces Image source: Philippine Tourism Authority http://web.tourism.gov.ph/phil_destination.aspx

Figure 12. Close-up photograph of the terraces. (Photo credit: Joel Cuello)

Sustainable Engineering Marvel

Professor Joel Cuello of the University of Arizona, in his forthcoming book, *Wonder of Sustainability: The Ifugao 's 7 Universal Laws of Sustainable Design from the Ancient World*, recommends a more practical approach based on an existing archetype that exemplifies the principles of sustainable design.

That archetype has existed for at least 2,000 years. Located at an altitude of 1,500 meters at the Cordillera Mountains of the Philippines, the Ifugao Banaue Rice Terraces stretches for a total combined length 3,204 km if connected from end to end. See Fig. 11. The cascades carry forest water from terrace to terrace starting from an elevation of 1,800 m. Recognized by the United Nations Educational Scientific and Cultural Organization) as a World Heritage Site, and by the American Society of Civil Engineers (ASCE) because of its engineering ingenuity, the archetype applies the principle of hydrology, sustainable development and efficient use of water sources and irrigation. It has produced rice for the Ifugao people without interruption for more than 2000 years. Professor Cuello has identified the seven fundamental laws of sustainable engineering design that the Ifugao's Banaue Terraces exemplify (Fig. 12).

1. Law of Availability – prescribes that sustainable design must select input resources that are readily available. The terraces were designed with available materials of mountain slopes, soil, rocks, and spring water using solar energy to grow the rice and conversion of potential energy of the water to kinetic energy, to deliver the water from the top of the mountain to the lowest terrace.
2. Law of Harmony – mandates that the design, to be sustainable, must be in harmony with the intended function and the environment. The terraces were sculpted following the natural contour lines of the mountain. The slopes allow for the simple delivery of the water.
3. Law of Knowledge – prescribes that the design, to be sustainable, must be based on solid fundamental knowledge of science, aesthetics, etc. The terraces were designed following the principles of hydraulics, allowing the diversion of 4 to 5 kilometers of stream down the mountain slopes for irrigation.
4. Law of Reuse – prescribes that the design, to be sustainable, must recycle resource that serves as the output. The stubs and the roots of the rice are mixed in the terrace soil as soil conditioner and fertilizer for the next season of planting.
5. Law of Symbiosis – prescribes that the design, to be sustainable, may incorporate the integral linking of two components such that each component both derives and supplies benefits from and to the other. Rice plants are combined with mudfish in the terrace ponds. The mudfish provide nutrients to the plants and protect them from insects, while the plant provides oxygen to the mudfish.
6. Law of Peers – prescribes that the design, to be sustainable, must benefit from the insights and inputs from peers. The ideas for the terraces are not the product of one person, but of a whole community over a long period of time.
7. Law of Community – prescribes that the design, to be sustainable, must be integrated into the daily life of the community. Aside from giving food to the community, the terraces are an integral part of the social, cultural, and religious practices of the community.

Fig. 12 The Ifugao's Seven Laws of Sustainable Design.

As an archetype of sustainable design, as well as the seven laws of sustainable design, the Ifugao Rice Terraces is a design worth emulating.

As an archetype of sustainability that embodies the seven laws of sustainable design, the Ifugao Rice Terraces' design principles are worth emulating. Professor Cuello conducts advanced research in line with sustainability, encompassing: Alternative Energy Engineering (algae, biodiesel, hydrogen, etc.), Bioreactor/Bioprocess Engineering (algae high-value products, biochemical production from cells), Water Reuse Engineering (green algae), and Controlled Environment Engineering (vertical farming, bioregenerative space life support, plant lighting, tissue culture, hydroponics, etc.).

Conclusion

This chapter describes the development of the paradigm of pollution prevention and sustainability based on historical and prevailing practices. Usually, papers about the paradigm of a subject matter suggest improvements or breakthroughs to usher a change in the paradigm. The change rarely takes place because the prevailing paradigm is the result of a consensus among practitioners. Changes in paradigms are continuous and are seldom abrupt. Progress can be attained even in the absence of a complete paradigm shift. This chapter was written with three objectives in mind:

1. To delineate the paradigm of PPS, to serve as a structured skeleton or outline for the contents of this handbook. This is also useful for those studying PPS for the first time.
2. To encourage and stimulate a paradigm shift on how we view the resources and the environment. For example, replacing the term "wastes" with "residuals" and viewing it as a resource that can have new uses.

3. To serve as a delimited set of information (only for PPS and related fields) that can be used in the brainstorming process (or similar techniques) to keep the number of output ideas manageable.

This work can serve as an aid in determining the impact of a particular environmental material in the scheme of the ecosystem.

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