Pollution and Its Control: A Historical Perspective

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Abstract This chapter aims to trace the history of environmental pollution which, in all probability, began some 300,000 years ago when humankind discovered fire. After establishing seminal definitions of pollution, pollutant, and pollution control, the chapter dwells upon the factors which caused increasing pollution across the world and which eventually triggered a global awakening toward perils of pollution till the awakening began to occur in the early 1970s. The chapter concludes with highlighting the reasons due to which pollution continues to rise throughout the globe despite enormous research and development in the field of pollution control that has been done in recent decades.

Keywords History of pollution · Environmental consciousness · Water pollution · Air pollution · Solid waste

1 The Post-modern Consciousness of Environment and Its Pollution

In India development of a post-modern consciousness for environment and its pollution was signalled when the words 'environment' and 'pollution' came to be featured in academic discussions during the early 1970s [1]. At about that time, the department of Civil Engineering, Indian Institute of Technology (IIT) Kanpur, became the first academic unit in India to offer a degree course in environmental studies when it began offering environmental engineering as a super-specialization in civil engineering. The first-ever stand-alone academic unit in India which was related to environmental studies began functioning as School of Environmental Sciences at the Jawaharlal

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Nehru University in 1974. It was followed by the establishment of the Centre for Environmental Science & Engineering at IIT Bombay. The Central Public Health Engineering Research Institute of the Council of Scientific and Industrial Research, situated at Nagpur, was renamed National Environmental Engineering Research Institute (NEERI) to become the first stand-alone *institution* in India devoted to the cause of protecting the environment. Another event to mark the national awakening toward protection of environment occurred in the form of setting up by the Government of India a Department of Environment within its Ministry Of Science & Technology, which was later elevated to a stand-alone ministry, currently named Ministry Of Environment, Forests, and Climate Change (MoEFCC). In yet another initiative the government established a *Central Board for the Prevention and Control of Water Pollution* which was later re-christened Central Pollution Control Board to encompass pollution of forms other than water pollution. The states of India were prompted to set up similar institutions at their level, which they began doing, by and by [1, 2].

Coinciding with these developments occurred several instances of public uprising against destruction of the environment, especially by polluting industries. Of these, two movements attracted the most attention, not only in India but across the globe: the campaign for the protection of the *Silent Valley* (Fig. 1), and the *Chipko Movement* (Fig. 2). The former was to protect a large swathe of tropical rain forest from getting submerged by a then proposed hydropower project. The *Chipko movement* was to halt deforestation by loggers at Tehri-Garhwal.

Fig. 1 The Kunthipuzha river in the *Silent Valley*, which, if dammed, would have submerged large areas of tropical rainforests existing around it [3]

Fig. 2 Village ladies (right) sticking to the trees to prevent contractors from cutting the trees during the *Chipko movement*. At left is Gaura Devi who was one the prime-movers of that uprising [4]

The foregoing is a recapitulation of the happenings in India. Similar happenings took place in most of the developing countries with a little variation in dates—some countries rose alongside India while some others took a few years longer.

From the foregoing a general impression may be emerging that environmental pollution is something that has hit the world only since last 4–5 decades. But is it indeed so?

As for the USA, environmental concerns entered public consciousness a decade earlier than they did in India and other developing world. There it was prompted by a book *Silent Spring* (Fig. 3), written by a lady scientist Rachel Carson who was employed with the US Bureau of Fisheries. Carson's book evoked the images of a future in which, upon getting up in the morning on a spring day, we will encounter mournful silence instead of bird songs and chirrups, because the birds would have died by pesticide poisoning.

Carson's book became a bestseller, attracting not only worldwide attention but also the wrath of pesticide companies. The pesticide companies accused Carson of 'sensationalizing' and 'exaggerating' the issue of pesticide toxicity. But the sympathy of the multitudes was on the side of Carson. The resulting public pressure and consequent governmental intervention led to a ban on DDT in 1972. Carson's book was followed by The *Limits to Growth*, *Future Shock*, and *The Population Bomb* [1]. Each of these books highlighted different aspects of overuse of resources, pollution, and eco-degradation that were plaguing the world and were taking it to the path of disaster. Reports of gross pollution and the resulting deformities, diseases, and deaths began to pile up [1, 2].

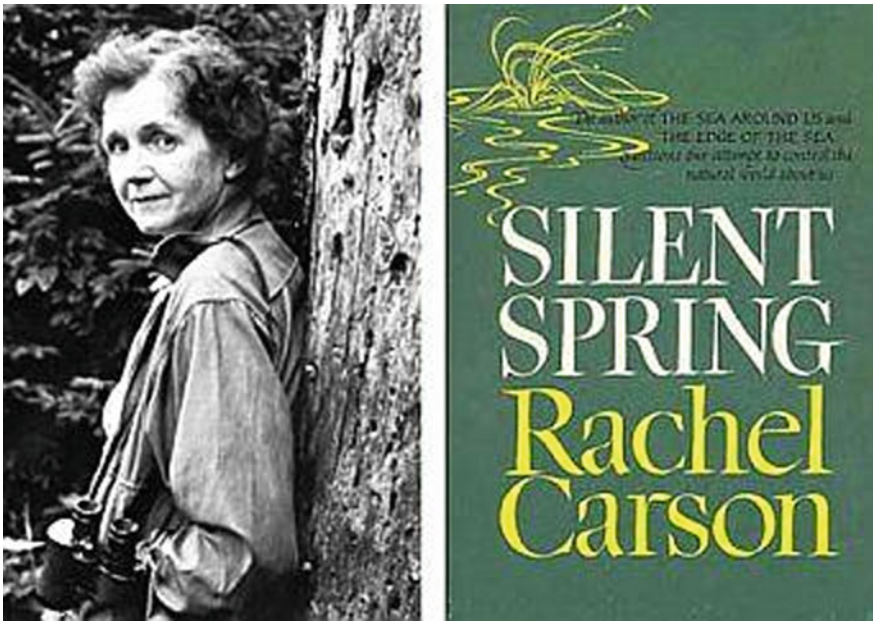

Fig. 3 Rachel Carson and her epoch-making book [5]

2 But Pollution Has Been Around Since Long

Even though the modern and the post-modern world got seized with environmental pollution from 1960s onwards, the scourge of pollution—that too severe pollution—has existed since much longer.

Before we look at the history of pollution let us first recapitulate the definitions of pollutant, pollution, and pollution control.

3 What is a Pollutant?

The terms 'pollutant', 'pollution', and 'pollution control' are very often used even by lay-persons, but are not clearly understood by most. The common perception is that a pollutant is a 'harmful substance'.

There are oft-heard statements like, *our rivers used to be clean earlier, now they are polluted.* Or such and such industry is causing pollution. Statements like these imply that when an otherwise 'clean' body of water, soil, or air receives one or more 'harmful substance', that body gets 'polluted'.

If one is to ask any gathering, name a pollutant, the typical answers would be mercury, lead, cadmium, DDT, PCB.

But is any of these really a 'harmful substance', a 'pollutant'? Without metals such as mercury, lead, and cadmium our modern society will come to a grinding halt. No hospital will have a thermometer if we eliminate mercury, no vehicle will run if you take lead out of its batteries, and no PC will be there to do so much drudgery for us if we separate cadmium from it. We will have no iPods, no cell phones, no ACs….

At one period of time (in the years following the end of the Second World War in the 1940s) DDT was hailed as a wonder chemical because it greatly boosted crop production by controlling insects, thereby saving millions of human beings from starvation. It had also saved countless lives by almost eradicating malaria. Even today pesticides are like a nectar to a farmer whose life-line, his ready-to-harvest crop, is saved in the nick of time from marauding pests by these chemicals. So no pesticide is really harmful to everyone.

Likewise when the first chlorofluorocarbon (CFC) compound was discovered in 1928 [6], it appeared a great boon because unlike other refrigerants till than—ammonia, carbon tetrachloride, and hydrogen sulphide—it was non-toxic, non-flammable, and odourless. In the following years a number of other CFCs were developed which had all the virtues of the 'parent CFC' but had still more favorable physical properties. Those compounds, the CFCs, were hailed as 'wonder chemicals'. Mankind began using those chemicals at the scale of millions of tonnes per year till it was discovered that CFCs are the prime cause of the ozone holes developing over the Antarctic (and now Arctic as well). Since then CFCs have acquired the image of deadly pollutants and the world has gone full blast to phase them out [5]. Hence the harm caused by metals like mercury and cadmium, or compounds like DDT and CFC, is not due to any intrinsic 'badness' of these chemicals.

Indeed, there is nothing in the world that is so useless that we can safely eliminate it. There are things which may be perceived as useless by some but the very same things are priceless to some others. Nor is there any 'pest' in the real sense of the term [7, 8]: insects attack crops not because there is any inherent villainy in them but because we take away their natural habitat, thereby forcing them to live on the crops we raise. We also upset their community structure due to which some of their species are suppressed and some others get multiplied in an imbalanced fashion. In fact by themselves most of the so-called pests, like locusts, are a valuable source of protein [7, 8].

Most of us love our biryani (veg or non-veg). And most of us love ice cream. But what would happen to the biryani if a few spoonfuls of ice cream are dropped into it? Or if one adds a few grains of spiced rice into ice cream? In the first instance ice cream would have polluted the biryani while the biryani would have contaminated the ice cream in the second.

Students everywhere are apt to switch on their music players at the slightest provocation. But put headphones in their ears and play their favorite number when they are bending over their answer books during the end-semester exams. The music would sound like blows of hammer on the eardrum.

Hence, there is no unequivocally 'undesirable substance' or 'pollutant' in this world which is nothing but that. In reality, what we call a pollutant is a right thing but in the wrong place. In other words a pollutant is a resource misplaced. It follows that

'pollution' is a contextual term, not an absolute one. The word pollution is derived from the Latin word *pollutionem* (to make dirty, to defile). When the purity or utility of any substance gets compromised due to contamination of other substance(s), pollution is caused.

So there is no 'pollutant' in this world which is nothing but a pollutant. Nothing that can only harm and has no value. A pollutant, in reality, is a right thing but in the wrong place: a misplaced resource.

4 Pollution Caused by Nature

A number of natural processes cause temporary or long-term contamination of the existing environment on local or regional scales. For example large forest fires of which the intensity and the extent has been increasing throughout the world, cause severe air pollution in the directly affected and nearby areas for several days. Volcanic eruptions spew enormous quantities of SO_x, NO_x and other gases besides metal-rich lava. It renders useless large areas of agricultural fields, water courses and garden lands that come in its path. The Tsunamis that originated off the Indonesian and Japanese coasts in 2004 and 2011 disrupted innumerable estuarine regions across their impact zone. Ground waters, such as the ones that occur in some parts of the eastern India, can contain harmful levels of arsenic or other minerals due to the natural process of leaching from aquifers rich in those minerals [1, 2, 9]. All these are examples of land/water/biota getting polluted by non-enthropogenic happenings.

The extinction of dinosaurs and millions of other species in the Jurassic era has been attributed to dust pollution. As per a widely accepted theory an asteroid hit the earth and so much dust was raked up due to the impact that sunlight was mostly blocked off. The temperatures fell abruptly; plants stopped growing and died, water became undrinkable. As a result species after species perished and much of the world as it then was, became extinct! In fact it has been theorized that the cycles of extinction and re-evolution may be occurring once every few billion years!

In 1908 a meteoroid of ~ 30 m diameter disintegrated near Tunguska, Siberia [10]. The impact of this happening was equivalent to 10–15 mega tone TNT explosion. It destroyed an estimated 80 million trees over an area of 2150 km^2 (Fig. 4). This is another example of 'harm' nature can cause to itself and in which human beings may not have played any role except to suffer from it.

5 Pollution Caused by Humankind

So it must be clearly borne in mind that episodes of ecosystem disruption and contamination can occur by natural processes but in most cases such episodes serve the purpose of restoring balances across larger areas. They appear as disruptions only when viewed in the limited context of the directly affected regions. Otherwise be

Fig. 4 The crator generated at Tunguska, Russia, when a meteoroid crashed above it, causing a loss of 8,000,000 trees [10]

it forest fires, or volcanic activity, or quakes, or storms, the apparently catastrophic events actually serve the cause of the earth in the larger context.

For instance, when one 'catches' fever, the raised body temperature is due to the fight of the body's immune system against an 'enemy' infection. The fever is accompanied by body fatigue which forces us to take rest thereby leaving the immune system to focus on defeating the intruder. The apparently diseased state caused by fever is only a temporary discomfort, brought about by nature for our longer-term benefit. In many ways natural 'calamities' are similar to body fever in their intents and purpose.

Anthropogenic (man-made) pollution, on the other hand, is like being hit by a stone or a bullet in a cross-fire. The body's self-healing mechanism would still try to nullify the harm caused by the injury but, if the injury is serious, it would leave a scar or, at worst, permanent disability. And if the stone or the bullet happens to hit one's brain or the heart, it can kill. Likewise if the pollution happens to be too severe it can put tens of thousands to death in a matter of a few minutes and irreversibly toxify large areas as has happened due to the leak of methyl iso-cyanate at Bhopal in 1984 [11].

Throughout this chapter, by 'environmental pollution' we will mean pollution caused due to anthropogenic activities. And by 'pollutant' we will mean a substance which is at a wrong place and/or at a wrong time.

6 Beginning of Pollution

It isn't hard to imagine that the pre-historic 'cave man' must have experienced pollution caused by his own refuse if he had used the same cave for long, or had a large family inhabiting a small cave. Likewise as soon as humankind discovered fire, some 300,000 years ago (Fig. 5), anthropogenic air pollution due to energy use began [12]. It is quite possible that some of the families of the early cave man might have suffered CO poisoning when fires were lit which were bigger than the cave's ability to ensure adequate aeration. But, by-and-large, the human population was too less, too disperse, and too nomadic to cause serious pollution in the pre-historic times. Whatever little pollution that was caused, was soon assimilated by natural processes of scavenging and biodegradation.

It was when humankind began to build primitive shelters and formation of villages began to occur wherein more than one family lived in close proximity of each other, the first 'seeds' of pollution were sown. As the humankind became more and more civilized, and the number of inhabitants per village grew, so did the quantity of human waste per unit mass of land. In proportion increased the burden on the environment to assimilate the pollution.

Yet for thousands of years this quantity was still not too large to be processed and assimilated by the nature's scavengers. Just as the pollution created by the non-human animals of a natural forest, or a pristine river/lake, gets assimilated by the

Fig. 5 Discovery of fire, some 300,000 years ago, made humankind the only species on earth who had access to energy beyond its own muscle power and other body parts [13]

action of natural scavengers, so was assimilated the anthropogenic pollution. The impact of pollution wasn't large enough to be widely noticed.

Then, as century after century the knowledge and skills of the humankind continued to grow, there was proportionate growth in the use of newer materials and development of newer processes. Humankind invented wheel, learnt the rudiments of metallurgy, developed agricultural and pastoral skills. With each step of 'progress', man became increasingly consumerist—hankering for ever more new goods. For a long while it used firewood as its source of 'subsidized' energy. Then it learnt the use of coal and became the only animal on earth capable of utilizing fossil fuels [14, 15]. This capability further fuelled humankind's consumerist instincts. And more goods we created, more scrap was also eventually generated.

With time the size of human settlements also grew which, in turn, created pockets on earth where more refuse was created than the ability of that area's natural scavengers to process that waste. Moreover man's increasing mastery of metallurgy created increasing loads of non-biodegradable scrap.

This is how humankind became a bigger and bigger polluter with time.

7 The Realization of Pollution

7.1 The Early History

The realization that impure water causes disease occurred to humankind some 4000 years ago and in all likelihood Indian scientists pioneered it. The *Susruta Samhita* (Fig. 6) written in that period is acknowledged as the earliest known record of human knowledge on the effects of impure water. The *Samhita* also gave to the world a water purification technology still acknowledged to be one of the most reliable for killing pathogens: boiling!

Several Arab medical treatises between the 9th and the thirteenth centuries (many of which were used as textbooks in West European universities including the universities of Oxford and Cambridge), have dealt with issues of air, water, and soil pollution, solid waste management and even environmental impact assessment.

Even though large-scale mining of fossil fuels began much later, in mid-eighteenth century, surface deposits of coal and kerosene extracted from shallow wells were in use since several centuries earlier [15, 17]. So much so that the use of fossil fuels had become an acknowledged source of air pollution in the cities by as early as the ninth century. In 1272 king Edward I of England issued a proclamation banning the burning of coal after its smoke had become a public menace. But, much like the many governmental proclamations of the present era, it was followed more in breach than in compliance!

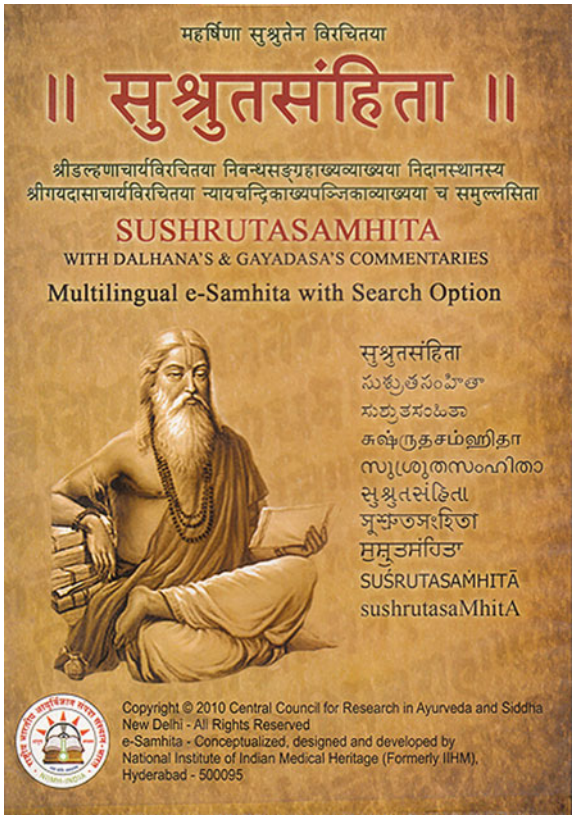

Fig. 6 *Susruta Samhita*, authored by Sage Sushruta, is one of the oldest treatises which touches upon aspects of pollution and its control [16]

8 Beginning of Central Sewerage Systems

The credit for being the first city to be brought under central sewerage (in 1859) is generally given to London but ancient civilizations of India seemed to have mastered this technology much earlier (Fig. 7). Archeological findings reveal that in the Harappan Civilization of 4500 years ago, water borne toilets were provided in each house which were linked with covered drains. The system was complete with manhole covers, chambers etc., to facilitate operation and maintenance. Existence of sitting type toilets have also been revealed in Egyptian civilizations dating back by 4100 years.

Today the cities and towns of economically advanced North American and West European countries are much cleaner and hygienic than Indian cities and towns. But it was different till the mid-nineteenth century. Prior to that India was cleaner and more advanced in every respect. While famous rivers like the Thames and the Seine were reduced to becoming carriers of sewage and floating solid waste much as Adyar in Chennai and Meethi in Mumbai have looked in recent years, the Indian rivers were much cleaner then.

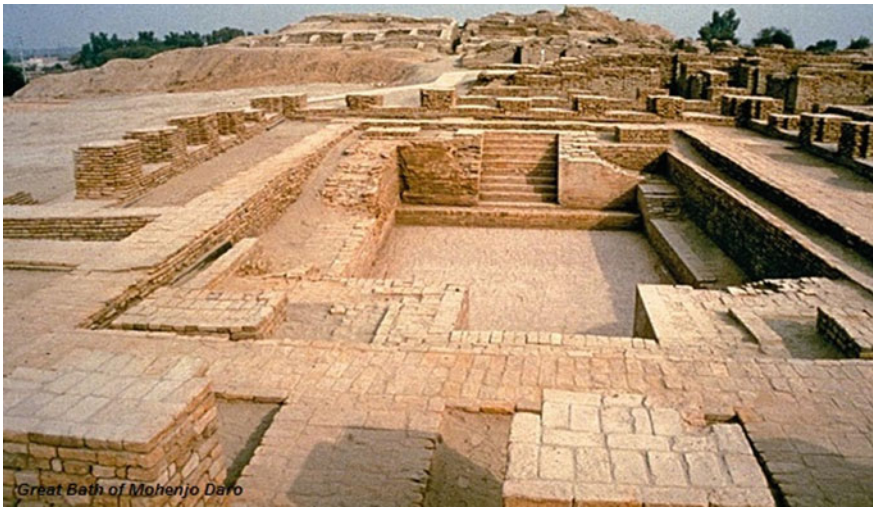

Fig. 7 The Harappan civilization presents the oldest known sanitation systems. They are distinguished by their extra-ordinarily advanced engineering [18]

Two happenings changed this situation. One was that European countries became financially strong on the basis of resources they plundered from their colonies, as Britain did from India. The other was that the industrial revolution triggered innovations leading to development of waste treatment processes and plant designs. The first happening removed the major hurdle that had till then prevented pollution control. The second showed the way to utilizing the money that had become available.

The matters were precipitated by the 'great stink' of 1858, which occurred in London when the combination of human and industrial waste being dumped into Thames resulted in the generation of an unbearable stink. It led to the development of a sewage system which is still serving London. Paris followed suit a few years later. So did, by and by, other European cities. But water pollution wasn't London's only worry—the air was no less dirty either (Fig. 8).

The sanitary situation in the USA was no better than it was in Europe. Right up till 1950 untreated sewage was dumped into rivers and canals. Even streams in public parks and cities ran polluted with untreated wastewater. Only as late as in 1957 the first comprehensive federal water pollution control legislation was enacted by the U.S. Congress. But it was confined to primary treatment. Another 15 years passed before secondary treatment was made mandatory under the Clean Water Act of 1972.

9 Air Pollution

If, for long, humankind had taken rivers, lakes, and oceans for granted, believing that we can put as much sewage and other wastewaters into them as we wish, we had

Fig. 8 The killer smog of London (1952) [22]

taken air even more for granted. Till a few decades ago all that was considered needed to escape air pollution was to "open the windows and let some fresh air come".

As a result, global awakening about air pollution began much later than it did about water pollution.

One aspect crucially separates the problems associated with air pollution from the challenges posed by wastewaters and solid waste. It is that whereas smaller streams of aqueous or solid wastes can be pooled and processed in large-scale centralized facilities—such as sewage treatment plants and sanitary landfills—it is impossible to address air pollution with such a strategy. If air pollution has to be controlled, it is necessary that each and every source that generates air pollution should be controlled. Partly due to this reason, and partly due to the much greater ability of air to disperse, consequently to dilute its pollutants with time, air pollution control came much lower down the human agenda than water pollution control did.

Till the beginning of the 1990, the standard method to 'solve' the problem of air pollution caused by thermal power plants and chemical industries was to release the polluted air off several meters tall stacks. Bigger the quantity of gaseous pollutants to dispose, taller was made the stack [17].

But just as it had happened with rivers and lakes, so it happened with air: the ability of the receptacles to dilute and assimilate pollution had limits. In case of air the limit crossed later than it did for the water-courses but when it did, the global impacts have been very severe: acid rain [19], ozone hole [6], global warming [20] and ocean acidification [21].

This very late awakening has happened despite the fact that extreme events of air pollution have been occurring ever since large-scale use of coal began during the industrial revolution. Burning of coal generated soot and contributed to smog formation. Both triggered respiratory problems. What was little appreciated by the laypersons then was that burning of coal also released acid-forming oxides of sulfur and nitrogen, besides compounds of arsenic and antimony and metal particulates. All these constituents were slow and silent, but sure killers. While millions of people must have suffered ill health and premature death due to air pollution in those times, few realized that it was air pollution that was behind their misery. Only when extreme events occurred they were talked about. One such extreme event took place in 1948 at Donora, Pennsylvania, when 20 persons were asphyxiated and 7000 were rendered very sick due to a smog which didn't disperse fast enough (Fig. 9). The Great London Smog of 1952 (Fig. 8) killed at least 4,000 people in just a few days.

Air pollution continues to be a silent killer. An estimated 7 million people worldwide die each year as a consequence of air pollution. Indoor air pollution and poor urban air quality are among the world's most widespread pollution problems. As

Fig. 9 The dreadful smog that spelt doom at Donora, USA [23]

much as 90% of the world's population breathes dirty air to some degree. Productivity losses and the burden on the medicare system due to air pollution are estimated to cost the world economy $5 trillion per year.

Interestingly when the world began taking serious note of air pollution from the early 1980s onwards, the focus was on the removal of SO_x, NO_x and SPM. Carbon dioxide was not considered a pollutant at all! Nor were any efforts made to reduce CO_2 generation or treat it after it had been generated. It was only after the emergence of undeniable and uncontestable evidence of global warming and ocean acidification in the present century that we have started viewing CO_2 as a problem! A great deal of research has gone into hydrogen energy and decarbonization of fossil fuels, with little that has made any sizable impact [24, 25].

10 The Indian Scenario

As for India, we might have been way ahead of the world till three centuries ago but from the mid-eighteenth century onwards the West European countries and then the USA gradually surged ahead and left us increasingly farther and farther behind. Slow economic growth on one hand and rapidly multiplying population on the other, have brought our cities and rivers to the kind of situation that had existed in the west prior to their great 'sanitary awakening' of 1859 onward.

When answering a starred question in the Parliament on 18 February 2009, N. N Meena, the then Minister of State (MoS) in India's Ministry of Environment, Forests and Wildlife, had revealed that in 85 cities across India, the level of respirable suspended particulate matter (RSPM) in the air is higher than the permissible levels of 60 μg per cubic meter for residential areas. In 26 of the cities it reaches double the permissible level, or higher. But RSPM is just one of the air pollutants. In innumerable studies, including several reported by us [26–28] levels of other air pollutants have been found exceeding the standards in most cities and towns of India. Meena also presented in the parliament a list of air pollutants expected in the Indian air, and their likely sources. Since then the situation has only become much worse.

Indian locations now feature in lists like 'top ten most polluted cities in the world' and 'dirty thirty' brought out from time to time by NGO's and citizens groups. The Switzerland-based IQ Air, which is a technology partner of the United Nations Environment Programme (UNEP), has ranked Delhi as the World's most polluted city. Kolkata and Mumbai occur at numbers 4 and 6 of the world's 10 most polluted cities [29]. In terms of the levels of PM 2.5, as many as 35 of the 50 worst locations, amounting to 70%, in the world occur in India. In fact 9 out of the 10 worst locations belong to India.

Make Change, and *Conservation Energy Future* both rank Ganga (Fig. 10) as the world's most polluted river. *Sustainability for All* give this dubious distinction to Yamuna (Fig. 11). Nearly all rank lists of most polluted rivers have Ganga or Yamuna featuring in top 10 slots. What is beyond doubt is that nearly all Indian rivers are

Fig. 10 Rag-pickers trying to find something value in the waste thrown in the river Ganga while a deed body floats nearby (extreme left) [30]

Fig. 11 The river Yamuna which, alongside Ganga, is regarded among the world's most polluted rivers [31]

Fig. 12 Mounds of MSW rising by the road-side is a common sight [32]

grossly polluted and quite a few are more like wastewater drains than rivers. As for municipal solid waste it is seen strewn everywhere (Figs. 12 and 13).

It is not as if technology does not exist for controlling pollution at source, or to treat pollution where it has occurred. In fact technology is available with which the most grossly polluted water can be treated to near 100% purity [34–36]. Technology exists with which any and all of air pollutants can be fully removed [37–39]. Technology exists to handle all components of solid waste. Yet all forms of pollution in India is continuously rising in terms of quantity as well as complexity [40–42]. Why is it so?

The biggest reason is economics. The available technologies are too expensive to be affordable. Another major reason is that technologies which clean one form of pollution and up creating another form of pollution. For example battery-run cars seem to prevent air pollution where they are used but they cause a lot of pollution in the course of making their bodies and their batteries.

The net result in that despite years of effort and the spending of billions of rupees to clean Indian rivers, especially Ganga, the rivers are only getting more and more severely polluted. With lop-sided and short-sighted developmental strategies infrastructure is being created in ecologically fragile regions at great costs to the public exchequer and the country's environment. A good part of it keeps getting destroyed every year in floods, fires, and similar extreme events precipitated due to climate change.

Fig. 13 Water courses being overrun by MSW [33]

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