Technologies to Alleviate Pollution
Air and Water Purification

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Technologies are believed to be problem-solving. However, this may not always be true, especially in terms of their influence on the environment. The emphasis on purification technologies to solve issues arising due to environmental pollution raises the question as to whether short-term solutions, like air and water purifiers, can result in salvaging the health of people and the environment.

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The word "technology" encompasses three meanings: *tools and instruments* to enhance human ability to shape nature and solve problems, *knowledge* of how to create things or how to solve problems, and *culture* (Vergragt 2006). W B Arthur (2009) defines technology at three levels. At the level of individual technologies, he defines technology as "a means to fulfill a human purpose." In terms of the body of technology, it is described as "an assemblage of practices and components." In terms of its scope, technology is described as "the entire collection of devices and engineering practices available to a culture." Technologies provide solutions to specific issues, using the knowledge gained from understanding the sciences. Edward Tenner in his book, *Why Things Bite Back: Technology and the Revenge of Unintended Consequences* (1996), stresses on the uncertainty of technologies and their unintended, and mostly undesired, outcomes, citing the example of computers leading to wastage of paper even when they were meant to reduce consumption of paper. When we talk of technology, we seem to be prepared for its unpredictability as well. A technology can move in any direction and so could its consequences. Usually, we assume that technological change would assist in the development and progress of technology.

In recent years, purifiers have captured the imagination of people as a solution to the pollution menace despite not doing much to alleviate the situation. Two of the most prominent types of purifiers used at the household level to alleviate the influence of pollution are air and water purifiers. Since they are used at the household level, they are incapable of alleviating the influence of pollution. Rather, they shift the pollutants from inside the house to the outside, contributing to overall pollution. We convince ourselves that the outside is already highly polluted and, therefore, we are responsible only for the inside environment. Other than that, we are continuously told about the "amazing powers" of these purifier devices through advertisements in print, television, and online media. And, because they mention "science and technology" somewhere in the advertisement, we are content that the product would be "good" enough. To understand how purifiers alleviate pollution, we need to know the role of purifiers (as technologies) in alleviating the ill effects of pollution, historical data, including patents, and scientific literature explaining their functionality. The article details a history of air and water purifiers while trying to understand their usability as a solution to the pollution hazard.

Air Purifiers

The utility of air purifiers to asthma patients, children, and the elderly cannot be denied, even when they might not serve well to prevent pollution or saving people from the harmful effects of pollution. The first air purifiers were devised for firefighters, divers and miners in the 19th century in the form of masks containing activated carbon to adsorb impurities in air. The oldest patent documents, however, reveal that these were initially invented "for purifying the air admitted to the carburettors of internal combustion traction engines" in 1923 (United States Patent and Trademark Office [USPTO] 1444384). It was in 1925 that the first "air purifier and moistener," with a "fan structure adapted … for collecting and diffusing the air within a room or building," came into existence (USPTO 1543760). The most recent version of air purifiers called the HEPA (high efficiency particulate air) purifier seeks to remove all the particulate matter below three micron in size, which includes most of the air pollutants, bacteria, fungi, volatile organic compounds (VOCs), etc.

It is evident from Table 1 that all the purifiers developed after the invention of HEPA purifiers have consisted of some combination of HEPA along with other technologies or interventions. As HEPA was developed by the United States (US) Army Chemical Corps and the US Atomic Energy Commission as part of Manhattan Project during World War II, it was a secret for about 20 years. The specifications were standardised during the 1960s and the term HEPA was officially coined by the Department of Energy (DoE). HEPA filters can remove at least 99.97% of dust, pollen, mold, bacteria and any airborne particles with a size range of 0.3 micron at 85 litres per minute. It does not work as a membrane or sieve that can remove particles below a particular size range—it removes particles which fall in the range of 0.3 micron through the processes of intersection, impaction and diffusion. It is evident that HEPA filters were employed to filter out highly hazardous aerosols, toxic carcinogens, radioactive particles, and biohazardous contaminates from the start. The US Congress passed the Clean Air Act of 1963 to set standards for the reduction of air pollution through fuel emissions standards (USEPA nd).

The demand for air purifiers due to growing awareness among people about the hazards of air pollution led to innovations in this field, especially after 2000. There are various kinds of air purification systems available for households now, the best of which still contain HEPA. Some of the prominent types of air purifiers in use these days are those based on UV, HEPA, activated carbon, ioniser, ozone generation, photocatalytic oxidation, etc. The history of air purifiers and recent innovations in this field clearly show that most of the progress in this field was made because of public and government intervention. Although this could not be substantiated by primary data in India, it could safely be argued that HEPA is emerging as the most favourable technology for air purification. Therefore, we come back to the question of whether these different kinds of purifiers or any one of them help in alleviating pollution. Other than shifting the pollutant from inside the house to the outside, adding to overall pollution, air purifiers still cannot solve the problem of air pollution because of the following reasons.

Table 1: Evolution of Air Purifiers

Year	Inventor	Invention/Development
1799	Alexander von Humboldt	Primitive respirator used by miners
1823	John and Charles Dean (US)	Mask for firefighters
1848	Lewis P Haslett	"Haslett's Lung Protector" used moistened wool or a similar material, along with a one-way clapper valve, to filter dust from the air (patented)
1854	John Stenhouse (US)	Mask for divers and coal miners (charcoal-based filter design)
1871	John Tyndall	Upgraded the original firefighter masks created by the Deans, introducing a respirator to aid in breathing for firefighters
1879	Hutson Hurd	A cup-shaped mask used widely for industrial use (patented)
1940s	US Army Chemical Corps and the US Atomic Energy Commission (Manhattan Project, World War II)	"Collective protector filters," known as "HEPA (high efficiency particulate air) filters"
1963	Manfred and Klaus Hammes (Germany)	Air filtration system using a fiberglass pad with small magnets attached to the air outlet of a residential oil oven to filter soot from the air. First air cleaner to be utilised in homes (patented)
1971	Hammes brothers (Incen AG Co)	Moved to Switzerland and started developing and manufacturing air purifiers
1990	Frank Hammes (son of Klaus Hammes)	Cabin air filters as add-on accessories for Mercedes-Benz automobiles
1991	Frank Hammes	IQAir North America
1991	Richard Taylor	Combined True Medical HEPA and Activated Carbon to create a filter that addressed the issues of environmental particulate contamination, chemical toxicity, and odours
1991	Richard and Joyce Taylor	Founded Austin Air Systems; introduced a pre-filter that increased the life of HEPA filters
1992	Alley Air Company (Sam Teitelbaum and Wayne Martin)	Combined true HEPA filters and a MAC-B (mass activated carbon bed) filter to safely and effectively remove chemicals, gases, and odours from the air
1994	Frank Hammes (with engineers from Switzerland and Germany)	Highly effective consumer compact air purifiers
1996	Blueair (Sweden)	Combination of mechanical and electrostatic filtration
1998	Incen AG Co	"IQAir HealthPro Plus"
2000	Incen AG Co	"IQAir HealthPro Plus" introduced in US
2002	IQAir Co	IQAir air purifiers became the first air cleaners to incorporate H13 class certified HEPA filters, which capture up to 100 times more particles than conventional HEPA filters

Sources: (i) https://www.achooallergy.com/learning/the-history-of-air-purifiers/. (ii) http://www.airpurifierguide.org/tech/the-history-of-air-purifiers. (iii) https://homeairguides.com/about-air-purifiers/the-complete-history-of-air-purifiers/.

First, purifiers have a threshold of clearing the air depending on their size, size of the room, pollutant levels, etc, leading to their usage being restricted to specific environs. Second, there may also be certain contaminants, dangerous, but not being removed by the purifier that one uses. Third, the purifier might also not work efficiently all the time leading to contamination. In such a case, there is no way for the user to know if the purifier is working properly or not, other than the clarity of the air around them. Fourth, one cannot remain indoors all the time. Therefore, one is bound to get infected by harmful contaminants that one is trying to save oneself from. The problems of leakages will always be eminent. Finally, being in an overly purifier environment might lead to reduction in the adaptability to endure one's outside environment.

From the above discussion, we can understand that the only solution to the current air quality problems is an improvement in the ambient air quality. Use of air purifiers at the personal level does not alleviate pollution, either at the household level, or at the level of the environment. Therefore, we see the need for regulations in this field. The US established the National Ambient Air Quality Standards in 1963 and further revised these in the 1970s and 1990s. The Air (Prevention and Control of Pollution) Act was introduced in 1981 in India. The following are certain kinds of private certificates available to purifiers to ensure their quality.

(i) Certified asthma and allergy friendly: This certification is awarded to air cleaning products that have scientifically demonstrated their contribution to the goals of allergen reduction.

(ii) AHAM (Association of Home Appliance Manufacturers) Certified*:* AHAM has three clean air delivery rate (CADR) numbers which indicate the volume of filtered air delivered by the air purifiers. There are three CADR ratings, namely, for smoke, for pollen, and for dust. The higher the number, the faster the air purifier filters the air.

(iii) Energy Star Certified: Energy star-qualified air purifiers are 40% more energy-efficient than non-qualifying models.

(iv) CARB (California Air Resources Board) Certified: All portable indoor air cleaning devices sold in California after 18 October 2010 must be certified by the CARB. To be certified, air cleaners must be tested for electrical safety and ozone emissions, and meet an ozone emission concentration limit of 0.050 parts per million.

(v) UL Listed: UL is a world leader for over 100 years in product safety testing and certification.

No such standards were found with the Bureau of Indian Standards (BIS), the national standard-making body in India. Surprisingly, the purifiers sold in India boast of some of the aforementioned certifications. In the absence of regulation or standardisation of any kind in India, it is very difficult to ascertain the quality and usability of these devices, which are quite popular, especially after the increase of pollutants in air to dangerous levels in most parts of India (Dahiya et al 2017).

Water Purifiers

Purification of water for drinking is different from the purification of air as we have the liberty to purify as much as required, unlike aquatic animals. From the plethora of technologies available for purification of water at the household level, including methods such as boiling, chlorination, ultra violet treatment, ozonation, ion exchange, reverse osmosis, etc, it has been observed that reverse osmosis-based purifiers (popular as RO, RO plus, etc) are the ones that have a definite lead in terms of usage in India (Talat and Bhaduri 2017). Purifiers have evolved gradually towards RO as it is a better solution for water treatment. However, the history of RO and its comparison with other purification technologies shows that this is not true. When we look at the history of RO, we find that, just like the HEPA technologies discussed in the previous section, RO technologies were used initially by the US navy to get potable drinking water from non-drinkable sources such as sea or brackish water (Table 2).

The earliest patent documents (USPTO 1968) which talked about providing potable drinking water through RO purifiers was for use with sea water and in areas where there was scarcity of potable drinking water. B Penate and L Garcia-Rodriguez (2012) find that most of the technological advances and innovations in this technology tried to reduce energy consumption and harmful effects of scaling and fouling on membranes, and to obtain membranes with higher water flux. These advances include developments in membrane materials and module design, process design, feed pretreatment, and energy recovery, or reduction in energy consumption (Lee et al 2011). K P Lee et al (2011) argue that continuous

Table 2: Evolution of Reverse Osmosis

Year	Inventor	Invention/innovation
1748	Abbe Nollet	Studies on osmosis (discovered the phenomenon that pig bladder can permeate water)
1861	Graham	Discovered osmosis and developed it
1876	Traube	First inorganic membrane
1903	Morse and Pierce	Introduced electrodes in dialysis and furthered dialysis research
1950	S Souriranjan	Developed "artificial simulation bio selection osmosis membrane," the principle of RO
1953	CE Reid	Demonstrated that cellulose acetate RO membranes were capable of separating salt from water
1960	Loeb and Suriranjan	Asymmetric cellulose acetate membranes with relatively high water fluxes and separations
1964	North Star (predecessor of Film Tech)	Used cellulose tri acetate as a layer in thin film composite flat sheet configuration
1970	Israel Desalination Company	Proposed the terminology "of Hybrid filtration" as the earliest ultrafiltration concept
1971	Dow Chemical Company	Developed a cellulose tri acetate membrane
1980s–1990s	Dupont	The Permasep B-9 and B-10 Permeator became the leading elements in the market
1990s	Film-Tech (Dow Company)	Polyamide thin film composite (TFC-RO)
2005	Samsung SDI	Polymer nano composite membranes

Sources: (i) Johnson and Busch (2009). (ii) Development history of RO at http://aquavision.co.in/?page_id=185, https://en.wikipedia.org/wiki/Thin-film_composite_membrane, (Rao 2011). (iii) USPTO and WIPO patent search.

process improvement and the consequent cost reductions have augmented RO's commercial success. However, the above discussion also demonstrates that most of the innovations are directed towards increasing the efficiency of RO in terms of energy use or life of the membrane. Not much has taken place to reduce the rejection of water from RO, which is a serious environmental threat—because it wastes water (scarce resource) and this rejected water is highly concentrated with impurities. Indeed, rejection of water amounts to around 30%–40% of feed water in industrial units, and up to 80% in household systems (Perez-Gonzalez et al 2012; fieldwork). This trajectory of innovations in RO, which has neglected the dimension of water rejection, may be because RO was initially conceived to treat ocean water, where rejection of water is not an issue. Nor does the rejected water, which is put back into ocean, enhance any environmental hazards there.

In the case of RO, it has been found that the technology wastes much of the water (Perez-Gonzalez et al 2012; field survey), consumes electricity, and produces water that might be bad for health (Kozisek 2004). Despite these shortcomings, it is highly popular among the households in India. RO is the optimum choice in cases where households do not get water from municipal sources, which supplies already treated water, or when their supply is intermittent, which is true for most of India. But, the adoption of RO in Indian cities is not influenced by what their source of water is.

The BIS has specified certain limits to the presence of contaminants in drinking water to ensure the quality of drinking water. There are standards for ensuring the quality of packaged drinking water as well, but no such standards are available for purification devices. This leaves the users in a dilemma as they cannot test the quality of the water that they get from source or even after purification from the device. They can only test the taste and appearance of the water that they get. Like the air purifiers, water purifiers also have some private certifying organisations such as the Water Quality Association (WQA), American Water Works Association (AWWA), NSF, etc. Purifier manufacturers prominently use these certificates to popularise their products. We can see that, even in the case of water purifiers, it is the intervention from the policymakers that may solve the problem, and not the use and spread of high-end technologies.

Concluding Remarks

Although technologies are assumed to solve certain issues, they might not do so quite often, and may, in some cases, pose environmental threats as well. We see that the evolution of air and water purification technologies do not show much concern for environmental degradation. The use of these technologies are context specific; they do not help when alleviation of environmental issues is a concern, but may help to give immediate and localised benefits in some cases. Governmental regulation for purifiers is required to ensure the quality of product as well as prevent their misuse.

REFERENCES

Arthur, W B (2009): *The Nature of Technology: What It Is and How It Evolves*, Simon and Schuster.

Dahiya, S, L Myllyvirta and N Sivalingam (2017): "Airpocalypse: Assessment of Air Pollution in Indian Cities," Greenpeace, India, https://secured-static.greenpeace.org/india/Global/india/Air-poclypse--Not-just-Delhi--Air-in-most-Indian-cities-hazardous--Greenpeace-report.pdf.

Johnson, J and M Busch (2009): *Engineering Aspects of Reverse Osmosis Module Design*, Lenntech BV.

Kozisek, F (2004): "Health Risks from Drinking Demineralised Water, Rolling revision of the WHO Guidelines for Drinking-water Quality," World Health Organization, Geneva.

Lee, K P, T C Arnot and D Mattia (2011): "A Review of Reverse Osmosis Membrane Materials for Desalination—Development to Date and Future Potential," *Journal of Membrane Science*, Vol 370, pp 1–22.

Penate, B and L Garcia-Rodriguez (2012): "Current Trends and Future Prospects in the Design of Seawater Reverse Osmosis Desalination Technology," *Desalination*, Vol 284, pp 1–8.

Perez-Gonzalez, A, A M Urtiaga, R Ibanez and I Ortiz (2012): "State of the Art and Review on the Treatment Technologies of Water Reverse Osmosis Concentrates," *Water Research*, Vol 46, pp 267–83.

Rao, A P (2011): *Handbook on Water and RO,* Health point Services (India) Private Ltd, New Delhi, October.

Talat, N and S Bhaduri (2017): "Incremental Innovations, Information Contagion, and Path Dependence: The Case of Drinking Water Purification Technologies in Urban India," *Industrial and Corporate Change*, Vol 26, No 6, 1 December, pp 1089–108.

Tenner, E (1996): *Why Things Bite Back: Technology and the Revenge of Unintended Consequences*, New York: Vintage Books.

USEPA (nd): "Evolution of the Clean Air Act," United States Environmental Protection Agency, viewed on 20 November 2017, https://www.epa.gov/clean-air-act-overview/evolution-clean-air-act.

Vergragt, P J (2006): "How Technology Could Contribute to a Sustainable World," Great Tranition Initiative Paper Series 28, Tellis Institute, Boston.