

Greening Automatic Dishwashers

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A water-using, energy-demanding contraption with forty to fifty component parts fashioned out of different materials, the automatic dishwasher has evolved over the last 70 years as a white good which has enhanced comfort, provided convenience and saved time in kitchens of modern urban households, especially in the western world. It has not yet established itself in Indian households, where manual dishwashing prevails and will continue to, into the foreseeable future, with studies putting the percentage at less than 10% for Asia and Latin America. Let's get to grips with some techno-environmental aspects of this contraption.

Dishwashing — be it manual or otherwise — is a frequent, unavoidable, quotidian kitchen task. Like all technological gadgets and contraptions, the automatic dishwasher has by now entrenched itself in households of the western world (over 80% penetration rate in the USA for instance), and is very slowly making a foray into the developing world's societies. While affordability and a rise in the purchasing power of households will increase demand for dishwashers in the years to come, energy prices, environmental considerations and water scarcity issues will call for stricter norms and regulations which in turn will lead to technical improvements in design and production.

Effective life-cycle management of machine dishwashers, with contributions from both the upstream producers and the downstream users — is a *sine qua non* in a world which strives to reach as many of the sustainable development goals as possible by 2030. Over the years, researchers have studied and analyzed different aspects of machine dishwashers — politico-legal and regulatory, social, economic, techno-functional and environmental. The last two will be dwelt upon in this short article.

Techno-functional things to know

Automatic dishwashers take tableware (dishes and cutlery in other words) on a journey from 'dirty and soiled' to 'wet, de-soiled and very warm' to 'dry, visually-clean and at-room-temperature', by using electrical energy which gets converted to mechanical and thermal energy during the washing-drying cycle. It is an invention that blends together applied thermodynamics, fluid mechanics and material sciences. Quite like all technological inventions, it has evolved over time, and will continue to, driven by market demands (including competition) and top-down regulations.

Over the last two decades, there has been an emphasis on design for disassembly and recyclability, reinforced by a need to make sure that dishwasher-repair technicians have

a stock of 'second-hand' spare parts (especially in cases where obsolescence affects the accessibility and availability thereof in the market), so that the equipment do not have to meet a premature end to their useful functional lifetimes. Industrial designers have to constantly stay tuned to customer requirements, and translating these into design requirements which would then be inputs to the fabrication/assembly processes, is a challenge.

The average energy use per cycle (of the so-called Eco – eco-friendly – program) of a dishwasher was as high as 1.43 kWh in 1998 (and obviously much higher for the other programs). Over the last 23 years, this has decreased conspicuously to less than 0.9 kWh. 'Much higher' even meant 3.7 kWh way back in 1977.

A dishwasher may of course account for a very small share of household electricity usage — as low as 2% in the USA and 3.5% in Turkey, but that is certainly not a deterrent to improve its energy efficiency by incorporating waste heat recovery (from the greywater which is discharged) subsystems. Indeed, on the one hand, a drop in electricity usage would mean lighter electricity bills for the consumer – a reduction of around 57 kWh per year, with a fin-and-tube heat exchanger. On the other hand, it is also true that the intense thermal radiation emanating from the electrical resistance heating element (which reaches red-hot temperatures as high as 1000°C) can be detrimental to the plastic tub materials, and also pose fire hazards.

Design optimisation of heat pumps has attracted attention during the last decade. While Chinese researchers have propounded a multi-functional, dual-refrigerant, air-source heat pump system supplying hot water for washing, hot air for drying, very hot water for disinfection and cold air for rapid cooling, and accomplishing an 80% reduction in primary energy requirements, Swedish academics have tested different refrigerants.

While decreasing the need for electricity to heat the water by recovering heat from greywater is indeed good, how about replacing electricity altogether with solar energy, especially in instances where solar heat is already being availed of for interior heating, providing hot water for bathing, etc.? Here we are thinking about not merely energy efficiency but 'renewable energy efficiency' — both a qualitative and quantitative improvement in the energy footprint. However, researchers in Greece are of the opinion that the high temperatures reached in solar water heaters may damage the elastic parts of the dishwasher input line, just as the intense thermal radiation from the resistance element referred to earlier degrades the interiors.

The dishwasher may indeed enhance comfort and provide convenience, but it could also potentially harbour diverse infectious microorganisms – mycobacterial-algal colonies – which enter the dishwasher compartment through the water and the food particles on the dishes. This is critical, especially in hospitals housing immunosuppressed patients, where dishwashers are commonly used. Bacteria like *E. faecium* are highly thermoresistant.

Commercial establishments in some countries have to abide by some mandates enforced by health agencies, which for instance could be the prescribed limit of bacterial colonies per washed utensil (measured in Colony-Forming-Units or CFUs per utensil). Thermal and/or chemical disinfection thereby becomes mandatory in order to achieve substantial reduction in CFUs per utensil, even though polyextremotolerance (resistance to a variety of extreme conditions — humidity, temperature, salinity and pH), if attained by the microbes, would render such approaches futile.

The choice of detergents during the use phase is also critical — along with temperature and time — when it comes to thwarting the growth of microorganisms within the dishwasher. Activated Oxygen Bleach (AOB) detergent in concert with longer time periods and higher temperatures, has been shown in experiments to be more effective than its chlorinated counterpart in destroying dreaded antibiotic-resistant species like methicillin-resistant *Staphylococcus aureus*.

Greening the dishwashers

Along the life-cycle of any product — be it short-lived or durable — it interacts with the environmental media — land/soil, water and air — by using them as direct/indirect sources for resources and sinks for emissions. The dishwasher or for that matter, the task of dishwashing in general, if one considers the improvements in resource efficiency thanks to techno-functional upgrades, will bring down the operational expenses in the life-cycle cost of a dishwasher, and at the same time, truncate its life-cycle environmental footprint.

Quite like the electricity usage, the annual water demand for automatic dishwashing per household per year is a small fraction of the total (about 10%). Thanks to technological improvements in the contraption, the water usage per cycle (measured again, as for electricity usage, for the Eco program) has decreased, as reported in a German study, from 19.14 litres in 1998 to 10.34 litres. The stream of ‘greywater’ leaving the dishwasher (which is also a source for heat energy as referred to earlier), is loaded with organics — carbohydrates, proteins and fats — scoured out of dirty dishes, and chemicals from the detergents used. Evidently, this is a motley mix of impurities which the wastewater treatment plants at the end-of-pipe have to deal with. If there is no satisfactory wastewater treatment provided (as in many developing countries, India included), the output of dishwashers would occasion eutrophication of receiving water bodies.

However, there are always solutions to problems, as long as researchers take it upon themselves to look for them. While the uncontrolled biofilms with pathogenic mycobacterial colonies are undesirable, ‘engineered’ ones cultivated for bio-remediation of wastewater — in this case, resulting in an appreciable reduction in the nitrogen and phosphorus load — are extremely useful agents to be incorporated within a dishwasher.

Source control, which ought to go hand in hand with end-of-pipe treatment, has resulted in a conspicuous decrease in the Phosphorus (P) content of detergents in Europe and some other developed countries. One however can also take

comfort from the fact that hand-in-hand with source control, the average degree of P-removal at WWTPs in the developed world at least, has also increased significantly over time, truncating the eutrophication of the receiving water bodies. Besides, it is the developed world which accounts for the lion’s share of dishwasher-detergent use on date. Over time, more advanced detergents may perhaps enable effective dishwashing at much lower temperatures, with concomitant economic and environmental advantages.

Energy and materials

A dishwasher of any brand, consists of about 40-50 parts, excluding the fasteners. While reducing the number of parts, when possible, is a good design approach, light-weighting is another. Over 25% of a dishwasher’s mass, as gathered from literature, is plastics — encompassing a whole range of them. What happens to them at the end of the operational lifetime of a dishwasher is very vital; one of course can safely assume that a very small percentage globally would be recycled or even incinerated for energy recovery.

The steel, zinc, aluminium and copper which account for over 50% of the mass, provides a small potential stream of secondary metals for the economy. Here, it must be mentioned that reuse of disassembled modular components as spare parts, wherever and whenever possible, must be encouraged, contributing to a circular economy which is a *sine qua non* for sustainable development.

Researchers have however warned that a narrow focus on environmental footprints, to the detriment of health and well-being has to be avoided, and raised the following question to be pondered over: Are green technologies, biodegradable detergents and reduced energy usage resulting in lower temperatures, silently turning water-and-energy-using equipment like dishwashers into breeding grounds for opportunistic and extremely-resilient (antibiotic-resistant) pathogens?

Fine balance

Sustainability is all about a fine balance, a ‘marriage’ between the upstream producers and the downstream consumers, weighting up of synergies and trade-offs, making compromises where they are inevitable. Automatic dishwashers have gradually entrenched themselves firmly at least in the developed world, over the last 70 years. During this period of time, technological developments have contributed to making the contraption ‘smarter’ and ‘more efficient’, and the expectations of consumers have progressively been satisfied.

Thermodynamics, fluid mechanics, production engineering and materials sciences apart, microbiology and of late, sustainable production and consumption, intersect to make the dishwasher a perfect candidate for multidisciplinary research for scientists across the spectrum.



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