1. Abstract

There is a worldwide interest in using pollution prevention methods to eliminate or lessen air, water, land and thermal pollution problems. Pollution prevention is designing processes that do not create pollution in the first place.

Heat exchangers play an essential role in pollution prevention and in the reduction of environmental impact of industrial processes, by reducing energy consumption or recovering energy from processes in which they are used. They are used: (1) in pollution prevention or control systems that decrease volatile organic compounds (VOCs) and other air pollutant emissions; (2) in systems that decrease pollutants in wastewater discharges, the amount of the discharge and thermal pollution; and (3) used to recover energy in facilities that incinerate municipal solid waste and selected industrial hazardous wastes. Heat exchangers are also used in the heating, cooling and concentration of process streams that are part of many other pollution prevention or control related processes.

In this paper, first presented is background information on the role of heat exchangers, their types, and a discussion of environment pollution problems. Next, the role of heat exchangers is outlined in the prevention and mitigation of the following pollution problems: air pollution from VOCs, sulfur oxides (SO$_2$), nitrogen oxides (NO$_x$); water pollution from industrial processes, thermal pollution, and land pollution resulting from municipal solid wastes or industrial hazardous wastes. Specific Research and Development needs for environmental heat exchangers are then summarized in the paper. It is hoped that this paper will challenge the heat transfer engineering community to further enhance the role of heat exchangers for pollution prevention and global sustainable development.

2. Background

Heat exchangers have found wide applications in pollution control facilities designed to mitigate various types of air, water, land or thermal pollution problems. In the past, heat exchangers have been used to help justify the use of traditional “end-of-the-pipe”
pollution control equipment because they help minimize operating costs.

In the recent years, heat exchangers have become important in implementing the concept of Pollution Prevention. The prevention approach is preferred because it is a long-term solution to pollution problems. In Pollution Prevention, engineers are challenged to innovatively develop new processes which do not generate pollution in the first place, or which make better use of available resources. Heat exchangers play an important role in helping to make these new processes economically feasible.

Heat exchangers will continue to play an important role in the foreseeable future in environmental management. Today government and business leaders worldwide are committed to a relatively new concept called Sustainable Development, which is defined as “meeting the needs of the present without compromising the ability of future generations to meet their own needs” [1]. The concept of Sustainable Development recognizes that economic growth and environmental protection are inextricably linked – goods and services must be provided in an eco-efficient manner – while progressively reducing environmental impact and resource intensity throughout their life cycle. Heat exchangers can help reduce the energy intensity of goods and services. Heat exchangers allow for the utilization of waste heat, processes to be integrated to reduce energy requirements, and energy to be exchanged between processes [2].

3. Heat Exchanger Types

A heat exchanger is a device that is used for transfer of thermal energy (enthalpy) between two or more fluids at different temperatures and in thermal contact. Typical applications involve heating or cooling of a fluid stream of concern, evaporation or condensation of a single or multicomponent fluid stream, and heat recovery or heat rejection from a system. In some heat exchangers, the fluids exchanging heat are in direct contact. In other heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In most heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix. Such exchangers are referred to as direct transfer type, or simply recuperators. In contrast, exchangers in which there is an intermittent heat exchange between the hot and cold fluids - via thermal energy storage and rejection through the exchanger surface or matrix - are referred to as indirect transfer type, or simply regenerators. Combustion and chemical reaction may take place in the process in which heat exchangers are used such as in boilers, fired heaters, and fluidized bed exchangers. Mechanical devices may be used in some exchangers such as in the scraped surface exchangers, agitated vessels and stirred tank reactors [3].

Heat exchangers could be classified in many different ways such as according to transfer processes, number of fluids, surface compactness, flow arrangements, heat transfer mechanisms, type of fluids (gas–gas, gas–liquid, liquid–liquid, gas–two-phase, liquid–two-phase, etc.) and industry. Heat exchangers can also be classified according to the construction type and process function as outlined in Fig. 1. Refer to Shah and Mueller [4] for further details.

The most commonly used heat exchangers for pollution prevention and mitigation are as follows: shell-and-tube for liquids, vaporization and condensation applications, and also for gases at high pressures and temperatures; plate-and-frame and spiral plate for liquids at relatively low pressures and temperatures; and regenerators (rotary and