Available online at www.sciencedirect.com
ScienceDirect
Journal of Hazardous Materials 150 (2008) 4–20
Journal of Hazardous Materials
www.elsevier.com/locate/jhazmat

Review

Sustainable development of process facilities: State-of-the-art review of pollution prevention frameworks

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Received 3 July 2007; received in revised form 22 August 2007; accepted 23 August 2007
Available online 30 August 2007

Abstract

Pollution prevention (P2) strategy is receiving significant attention in industries all over the world, over end-of-pipe pollution control and management strategy. This paper is a review of the existing pollution prevention frameworks. The reviewed frameworks contributed significantly to bring the P2 approach into practice and gradually improved it towards a sustainable solution; nevertheless, some objectives are yet to be achieved. In this context, the paper has proposed a P2 framework 'IP2M' addressing the limitations for systematic implementation of the P2 program in industries at design as well as retrofit stages. The main features of the proposed framework are that, firstly, it has integrated cradle-to-gate life cycle assessment (LCA) tool with other adequate P2 opportunity analysis tools in P2 opportunity analysis phase and secondly, it has re-used the risk-based cradle-to-gate LCA during the environmental evaluation of different P2 options. Furthermore, in multi-objective optimization phase, it simultaneously considers the P2 options with available end-of-pipe control options in order to select the sustainable environmental management option.

Keywords: Pollution prevention; Life cycle assessment; P2 framework; P2 evaluation

Contents

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doi:10.1016/j.jhazmat.2007.08.062

1. Introduction

Until recently, end-of-pipe pollution control and management was the major practice in most of the industries to reduce the pollutants emissions, however, this is not a sustainable solution in the long term. It requires large infrastructure and manpower, which can be costly if not implemented properly [1–3]. Therefore, presently governments, environmental legislators and researchers are focusing more towards the implementation of pollution prevention techniques, where the pollution is prevented before its generation [4–6]. P2 is an important part of the environmental management system (EMS), which does not deal with offsite recycling, energy recovery, treatment and disposal. According to the US pollution prevention act, pollution prevention means "source reduction and other practices, which reduce or eliminate the creation of pollutants" [5]. It is suggested to achieve through: equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials and improvements in housekeeping, maintenance, training, or inventory control. The federal government of Canada defines pollution prevention as the use of "processes, practices, materials, products, substances or energy that avoids or minimizes the creation of pollutants and waste and reduces the overall risk to the environment" [6].

P2 has substantial benefits over end-of-pipe pollution control and management. Apart from the reduced production cost, improved competitiveness, enhanced customer trust, improved environmental performance and worker health and safety benefits, it conserves energy and materials through their optimal utilization [7]. Industries are the major source of pollution; therefore, the implementation of an effective pollution prevention methodology can lead to a cleaner and healthier environment. Some researchers and environmental organizations such as the US Environmental Protection Agency (EPA) and Environment Canada have developed pollution prevention frameworks to be used in industries. These frameworks have gradually improved the P2 methodology towards sustainable solutions. Nevertheless, some limitations and ambiguities are still prevailing, which need to be addressed. Therefore, a significant research is warranted in this area.

This paper reviews available pollution prevention frameworks and finally proposes a systematic and sustainable pollution prevention methodology 'IP2M'. The proposed methodology is built with risk-based life cycle assessment and also includes health and safety as an important parameter for P2 option selection. It is applicable to process and allied industries at early design stage as well as during any modifications to existing industries.

2. Review of the existing P2 frameworks

In the literature, pollution prevention is sometimes termed as waste reduction, source reduction, waste elimination or waste avoidance [8]. The basic elements of pollution prevention are source reduction and in-process recycling. On the other hand, waste minimization usually includes the pollution prevention with off-site recycling [9]. As pollution prevention is the preferred option of waste minimization, therefore, some waste minimization framework could also be used for practicing the pollution prevention in industries. For comparison purpose a snap shot of different pollution prevention frameworks and opportunity assessment tools are presented in Table 1.