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Title of Thesis: FAILURE MODE AND EFFECTS ANALYSIS (FMEA) OF ENVIRONMENTAL SYSTEMS USING FUZZY BASED MULTICRITERIA DECISION MAKING TECHNIQUES

Findings

This research work identifies the 24 potential failure modes (FMs) of the common effluent treatment plant (CETP), 15 FMs of sewage treatment plant (STP), and 13 crucial FMs of water treatment plant (WTP) installed in humid subtropical regions. Based on the consensus among 5 experts of CETP, 8 experts of STP, and 6 experts of WTP who are the managers of CETPs, STPs, and WTPs installed at different regions of Delhi, the capital town of India. Failure mode and effects analysis (FMEA) is a commonly used technique for ranking the FMs of any equipment or system. In recent times, the fuzzy- based multi criteria decision making (FMCDM) approach for FMEA has been effectively used for the evaluation of potential FMs. However, the rank assigned to different FMs by different FMCDM methods might be different. Subsequently, it applies a combined FMCDM methods, i.e., fuzzy analytic hierarchy process (FAHP), fuzzy technique for order of preference by similarity to ideal solution (FTOPSIS), fuzzy proximity index value (FPIV), and fuzzy visekriterijumska optimizacija i kompromisno resenje (FVIKOR), to derive rank of FMs. FAHP is applied to calculate the weights of three risk factors (RFs), i.e., occurrence (O), which refers to the chance of a failure cause occurring; severity (S), which measures the extent of the effect of a failure cause on the system; and detection (D), which represents the chance of detecting the failure cause before the failure actually occurs. Then FTOPSIS, FPIV, and FVIKOR techniques are employed to determine the rank of the FMs, which signifies their criticality. The data required to implement FAHP, FTOPSIS, FPIV, and FVIKOR techniques are gathered from the experts in linguistic terms, which are subsequently converted into equivalent triangular fuzzy numbers.

Findings indicate that the most and least significant FMs of the CETP are “leakage in flex connections, seals, and valves of air diffusers” (CETPFM20) and “assembling of unexpected

or immoderate screenings” (CETPFM4), as their rank is 1 and 24. Similarly for STP, “failure of bioreactors” (STPFM6) and “sludge pumps run for a few minutes and stop unexpectedly” (STPFM14) are the most and least significant FMs, as their rank is 1 and 15. For WTP, the most and least critical FMs are “air binding of the filter beds” (WTPFM8) and “damage of air and water pipes in filters” (WTPFM4), as their rank is 1 and 13, respectively. Further, the results obtained are compared with the conventional FMEA approach based on conventional risk priority number (RPN) calculations. The fuzzy scores obtained for the evaluation of the FMs are defuzzified to obtain the crisp scores. Subsequently, the crisp scores are multiplied to obtain the conventional RPN. Consequently, each FM is ranked with decreasing values of RPN, such that the FM with the highest value of RPN is ranked first. The ranks of some of the FMs obtained using conventional RPN and the FMCDM methods used in this study are the same. In addition, a difference in the ranks of some of the FMs produced by the conventional RPN and the FMCDM methods can also be observed. However, as the FMCDM approach used in this study takes care of the inconsistency and vagueness in the human judgement while providing importance to the three RFs and the various FMs, the ranking results obtained in this study are more appropriate as compared to the conventional RPN method.

Finally, sensitivity analysis is employed to establish the robustness of the ranking results produced by FAHP, FTOPSIS, FPIV, and FVIKOR techniques. Furthermore, possible causes for the occurrence of a few of the most critical FMs and remedial measures to reduce their occurrence are suggested by the experts, which may reduce the possibility of plant failure. Therefore, the significance of the present study lies in terms of identification of the potential FMs of the CETPs, STPs, and WTPs installed in humid-tropical regions and to rank them to depict how serious they are for the failure of the whole plant. Ranking result of the FMs derived in this study may be useful to understand the degree of severity of the various FMs of the CETPs STPs, and WTPs. This study may be useful for the management and the concerned personnel in devising effective and efficient maintenance strategies to avoid occurrence of the FMs, specially the most critical ones, so as to minimize the risk for the failure of the CETPs STPs, and WTPs. Consequently, it would improve reliability of the CETPs and ensure their almost nonstop operation for longer duration enabling them to treat huge quantity of industrial effluent before being discharged which will undoubtedly protect the environment from dangerous effects of the effluent.