Time- and site-dependent life cycle assessment of thermal waste treatment processes

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New LCA Theses

Time- and Site-Dependent Life Cycle Assessment of Thermal Waste Treatment Processes

The high living standard of many industrial countries has directly led to an increase in the amount of municipal solid waste generated. Parallel to this increase in waste, there has been a raising demand for environmentally benign waste treatment processes. In Switzerland, the predominant way of treatment is incineration. Since the environmental impact of waste incineration depends on the technology used, a comprehensive assessment of the different thermal processes is necessary. In order to determine the environmental impact, the present dissertation proposes a model[1] that quantifies the emissions and resource use resulting from the incineration of waste using different technologies, the landfills for the incineration residues, the transport of waste, related infrastructure, as well as the production of ancillary products. Using the Life Cycle Assessment (LCA) methodology, we performed a case study that compares the conventional grate technology to new high temperature processes recovering metals and vitrifying the incineration residues. The results show that if the plant is equipped with a modern gas purification system the incineration process itself is not a key environmental problem of the system considered. Using the energy gained from waste incineration as the functional unit, the environmental impacts of incineration plants are comparable to that of a conventional power plant. If long-term time horizons are considered, the critical aspect is the release of heavy metals from the landfilled incineration residues. Due to the better quality of the solid outputs, new technologies have a lower potential for environmental impact than the conventional grate technology. This, however, depends on the time horizon considered. With a temporal system boundary of 100 years, the grate technology appears better, because new technologies generally use more energy and short-term emissions are of minor importance, no matter what technology is used.

The evaluation of waste incineration technologies largely depends on the assessment of heavy metal emissions from landfills and the weighting of the corresponding impacts at different points in time. Unfortunately, common LCA methods hardly consider spatial and temporal aspects. Several methodological innovations are suggested in this work. In order to quantify the impact of landfill leachates with respect to groundwater contamination, a simplified geochemical landfill model is proposed. The results indicate that slag landfills might release heavy metals over very long time periods ranging from a few thousand years in the case of Cd to more than 100'000 years in the case of Cu. The dissolved concentrations in the leachate exceed the quality goals set by the Swiss Water Protection Law (GSchV) by a factor of at least 50. The classification of the mobility of heavy metal cations in the subsoil of the landfill was performed with a generic guideline developed for this purpose. The method is easily applicable to individual landfill sites, as illustrated in three different case studies. The results indicate that the geological conditions below the landfills play an important role. Depending on these conditions, the retardation of the heavy metals ranged from a few days to many thousand years at different sites.

The long emission period of the heavy metals from landfills and the retardation of these pollutants in the subsoil raise the question whether impacts at different points in time should be weighted alike. In this work, the concept of discounting in economics and a possible transfer to LCA is discussed. It is concluded that possible future changes in the magnitude of damage should be considered in scenario analysis in the characterization phase of LCA rather than in discounting. Further discounting should only be applied in sensitivity analysis using a slightly positive or slightly negative discount rate.

The proposed methodological innovations for the assessment of heavy metal transport have been applied to the case study of Cd^{2+} and Cu^{2+} emissions from three slag landfills at different sites in Switzerland. The emissions of heavy metals to the subsoil as a function of time were calculated with the geochemical landfill model and their subsequent fate in the subsoil was assessed using the proposed soil guidelines. A scenario analysis was performed to consider possible changes in the background contamination of the groundwater influencing the magnitude of the potential damage caused by emissions of Cd^{2+} and Cu^{2+}. It was shown that landfills represent a significant risk for the groundwater in Switzerland since they accumulate large amounts of heavy metals that may be released over very long time periods. The ecological evaluation of Cd^{2+} and Cu^{2+} emissions from slag landfills per kilogram of incinerated waste largely depended on the development of the corresponding background contamination (method applied: *Swiss Ecopoints*). The site of the landfill also had a significant influence on the results. The impacts of Cu^{2+} emissions from the slag landfill to the groundwater were assessed to be 2 to 18'000 times more important (depending on the site and the assumed background contamination) than the complete system of grate incineration in the previous analysis, where the landfill emissions had been supposed to enter surface waters. These results indicate that the omission of the groundwater compartment in LCA of waste incineration can lead to misleading results. In a sensitivity analysis, discounting with four different rates, 1%, 0.01%, – 0.01%, and – 1%, was performed. The use of positive discount rates reduces the time horizon considered to between 1'000 and 100'000 years for discount rates of 1% and 0.01%, respectively. Using negative discount rates gives an extremely high impact in the case of Cu^{2+} due to the long emission period. The influence of discounting is more moderate for Cd^{2+} if a small discount rate of – 0.01% is used. These results illustrate that a site and time-dependent impact assessment of landfill emissions is crucial for a thorough assessment of different waste treatment technologies.

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[1] The software tools for grate incineration and the documentation can be ordered together with a previous report of the same project: Zimmermann et al. (1996): "Ökoinventare von Entsorgungsprozessen, ESU-Reihe 1/96, ordering number 9400131/3, ENET, Tel +41 71 440 02 55, Fax +41 71 440 02 56, E enet@temas.ch, www.energieforschung.ch.