PRESENCE OF DIOXIN IN MSW COMPOST: HUMAN THREAT? A REVIEW

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Introduction

The need to understand the effect of dioxin has long been recognised and the human exposure values are said to be lower now compared to 20 years ago (Liem et al., 2000). But, this has not stopped health effect concerns, mainly because dioxin is associated with a number of diseases such as cancer and neurobehavioral dysfunction. Sources of dioxin exposure ranges from inhalation, ingestion and food consumption. Available studies mainly focuses on inhalation due to the fact that municipal and medical waste incinerators are the major sources of dioxin emission to the environment (Dyke et al., 1997). Soils are the main sink of these emissions and relatively high soil concentrations have been found around the world especially on contaminated sites. Dyke et al., (1997) found dioxin concentrations released to land in UK to be about 1500 – 12 000 g TEQ/ year.

The presence of dioxin in both compost and sewage sludge has been reported by a number of researchers (Krauss et al., 1994; Beck et al., 1996; Grossi et al., 1998). Understanding dioxin behaviour in soils is important since it can be transferred to both humans and grazing animals through the food chain. Food contribution to exposure ranges from 20-480 pg TEQ/ day (Epstein, 1997). A number of studies have been conducted on grazing animals and breast milk, but not much literature is available for fruit and vegetables contribution after compost application. This paper aims at reporting available data on dioxin levels in compost and the resulting effect on human exposure. The objective is to understand compost-soil-plant transfer factors, bioavailability, exposure levels and health effects. This is of great significance because compost is an important soil conditioner and its maximum utility is important especially in tropical countries where topsoil might be missing or lacks essential nutrients for plant growth. Also, production of high quality compost is important in developing countries as it can support municipality and serve the community through job creation.

Discussion

The presence of dioxin in soils results from compost and sewage sludge application, waste dumping, landfilling and atmospheric deposition contributing the highest because of incinerator emissions which were uncontrolled for a number of years (Dyke et al., 1997). Concerns are being constantly raised on incinerators, mainly in developing countries, which are still emitting uncontrolled concentrations to the air. One of these countries is South Africa which has no limit in any environmental media (Bouwman, 2002), but has sugarcane soil concentrations of about 33 ngTEQ /kg (Papke as quoted by Gauss et al., 1997). This triggered an interest in determining dioxin concentration in compost from South Africa and compare with the soil concentrations Two composting plants allowed us to take samples for both the young and old compost which were analysed by our laboratory in Bolzano.

DETR (1999) found soils in Italy and Germany to contain concentrations between 1-43 and 10-30 ngTEQ/ kg while USDE (1999) found 0.13-19, 0.04-4.6 and 0.033-5.2 ng/kg for urban areas, open land and forest land, respectively. Italy has soil concentration limit of 10 ng/kg for residential land and 100 ng/kg for commercial land while Germany has 100ng/ kg, 1000 ng/kg and 40 ng/kg for agriculture, residential area and playgrounds, respectively (DETR, 1999). For both these countries there seems to be no problem of soil contamination since the observed values are lower than the limit values.

Addition of compost can increase soil concentration values. Epstein (1997) found dioxin in MSW to be <1 ng/kg while the MSW compost had 0.73 ng/kg; WSDE (1999) found 9.5-42 ng/kg in biosolid compost; Harrad et al., (1991) reported 14-41 ng/kg in yard waste compost and Grossi et al. (1998) reported 14ng/kg for biocompost and 27-57 ng/kg for unsorted compost. The differences in reported values might results from different composting material type, source and composting processes. Baden-Württemberg in Germany puts a guideline value of 17ng/kg on compost to be applied on land while Netherlands proposes 63ng/kg (DETR, 1999). In order for the other countries to see the need to implement limit values which will aid in minimising soil contamination, full understanding of compost-soil transfer factors is needed. WSDE (1999) calculated soil enrichment factors for a number of fertilizers and found 0.28 ng/kg for a soil with 1.3 g /cm^3 bulk density and 15cm mixing depth after the addition of biosolids with 37 ng/kg dioxin concentration at 15 000 kg/ha application rate. The problem with this calculation method is that it assumes zero initial soil concentration and therefore calculates initial increments and not applicable to successive increment calculations. A soilfug model developed in Milan in 1996 was run to generate soil enrichment factors for different application rates and soil conditions. For a soil with 1.4 g/cm^3 bulk density, mixing depth of 15cm addition of 14 ng/kg at 10 t/ha application rate will result in 0.033 ng kg^{-1} year^{-1} enrichment factor, which is in agreement with the results found by Fiedler (1995). This means that application of compost will not have relatively high significant effect on soil concentration. This model is very good because it considers dioxin partitioning constants, fugacity factors and the soil properties. But, the only limit is that it assumes the chemical is directly placed on the soil which is not the case with dioxin as it is bound to compost particles.

Epsteins' findings suggest that composting decreases the dioxin level present in the MSW and is in agreement with what Eduljee et al., 1997 reported. Eduljee et al. (1997) found MSW to contain 6300 ngTEQ/ton of waste while compost contained 440-3344 ng TEQ/ ton of waste. This implies that composting could be an important method for reducing dioxin levels reaching the land. Thus composting contaminated soil can decrease the PCDD/Fs present in the soil. However, this is in conflict with the findings of Laine et al. (1997) who found no significant change in PCDD/F during bioremediation. They noted an increase in PCDD/F in chlorophenol contaminated soils meaning that the presence of chlorophenol in compost material resulted in dioxin increase during composting. This has been confirmed by other authors such as Krauss et al. (1994) and Harrad et al. (1991). The extent and conditions resulting in this transformation is not fully understood, but is associated with microbial processes (Laine et al.,1997; Barkovskii et al.,1996).

Dioxin available to plants after the addition of compost will be taken up by plants through several pathways: root uptake and translocation, volatilisation and deposition onto exposed plant surfaces for plants grown next to the soil surface (Lovett et al., 1997). However, the extent of contribution of each pathway is not intensively documented and this might be caused by the fact that dioxins are stable in nature and tend to hold tightly to soil particles making them highly unavailable to plants. The presence of dioxin in plants from soil uptake has been found by a number of researchers. Lovett et al. (1997) found 0.3-0.4 ng TEQ/kg dw for carrots in Wales next to an incinerator and attributed this to root uptake. Engwall and Hjelm (2000) reported 0.2-0.6ng TEQ, 0.17ng TEQ and 0.52ng TEQ/kg dw for carrots, zucchini and cucumber, respectively after the addition of sludge on a sandy loam soil at 9 t/ha application rate with 109-38 ng TEQ/kg dioxin concentration. The interesting finding was that the sludge with less concentration produced high contaminated carrots due to its high bioavailability rate compared to the sludge with high concentration. Carrots had the highest transfer factor which was of

0.74. Also, carrots tend to accumulate dioxin more compared to the other plants because of its lipid nature.

Volatilization also contributes to plant contamination. Trapp and Matthies (1997) found a concentration of 1.8 ngTEQ/ kg dw for grass through volatilization of soil containing 600ng TEQ/kg. There aren't a number of papers available to compare with this. They also developed a volatilization model which had a number of limitations for its application. Not a lot of literature is available to understand the soil-plant and compost-soil-plant dioxin transfer factors. Availability of such information could have a significance effect in understanding dioxin effect on plants.

Consuming the fresh carrots planted by Engwall and Hjelm (2000) will yield exposure levels of 1.2-3.6 pg TEQ which constitutes 1-5% of the TDI (1-4 pg kg^{-1} day^{-1} WHO). Lovett et al. (1997) mentioned that plant contribution to ADI exposure is at maximum about 8%. This means that plants grown under low concentrations do not pose threat to human health leaving soil ingestion and dust for investigation. Déportes et al. (1995) reported that ingestion daily doses for a child and adult living in a 0.0001ng/kg contaminated site can be as high as 40-100 000 times the ADI depending on the soil use. Area under the curve (AUC) has been the method used to describe the dose-response relationship in cancer risk assessments of TCDD and other highly persistent compounds (Aylward et al., 1996). These authors suggest 100 pg kg^{-1} day^{-1} as the NOAEL in humans. Pohl et al. (1995) reported that a pica child, normal child and an adult living in a site contaminated with 0.001ng/kg TCDD, assuming 40% availability, will be exposed to 14, 2.4 and 0.16 pg kg^{-1} day^{-1}, respectively. This puts ingestion and inhalation of dust from contaminated soil as the main exposure pathway which could have detrimental effect to human health. The toxic effects observed after dioxin exposure vary with the dose and length of exposure (Mitrou et al., 2000). Mitrou et al. (2000) found 80 ng/kg TCDD concentrations in serum to affect the sex ratio of offspring of parents in Italy. This effect started at 20 ng/kg bw and changed the ratio from 0.62 to 0.38 favouring the births of girls. Brouwer et al. (1998) found infants who were breastfed by mothers with 2000-3000 ng/kg bw concentrations to have neurobehavioral changes ranging from hypotony, hyperactivity, lower mean intelligence quotients and altered latencies.

Conclusions

Using compost in commercial and agricultural land does not seem to pose threat to human health, but ingestion and inhalation from contaminated sites can have detrimental effects. Therefore, implementation of limits in compost to be used in urban areas especially playgrounds and near houses is needed since people specifically children can be exposed to high levels. There is still a lot of gap in understanding dioxin in compost and the resulting effect in human exposure. The research areas of importance ranges from bioavailability, compost-soil-plant transfer factors under different environmental conditions for different compost materials.

References

Aylward, L.L., Hays, S.M., Karch, N.J. and Paustenbach, D.J. 1996 Environ.Sci. Technol. 30: 3534-3543.

Barkovskii, A.L. and Adriens, P. 1996 Appl. Env. Microbiol. 62: 4556-4562

Beck, A.J., Johnson, D.L. and Jones, K.C. 1996 Sci. Total Env. 185: 125-149

Bouwman, H. 2002. Personnal Communication

Brouwer, A., Ahlborg, U.G., Rolaf van Leeuwen, F.X. and Feeley, M.M. 1998 Chemosphere 37: 1627-1643

Department of the Environment, Transport and the Regions UK (DETR). 1999 Compilation of EU dioxin exposure and health data: Task 2 - Environmental levels, European Commission

Déportes, I., Benoit-Guyod, J. and Zmirou, D. 1995 Sci. Total Env. 172: 197-222
Dyke, P.H., Foan, C., Wenborn, M. and Coleman, P.J. 1997 Sci. Total Env. 207: 119-131.
Eduljee, G.H., Dyke, P. and Cains, P.W. 1997 Chemosphere 34: 1615-1622
Engwall, M. and Hjelm, K. 2000 Chemosphere 40: 1189-1195
Environment Dyke, P.H., Foan, C., Wenborn, M. and Coleman, P.J. 1997 Sci. Total Env. 207: 119-131
Epstein, E. 1997 The science of composting, Technomic Publishing Co., Inc. Lancaster, USA
Fiedler, H. 1995 Chemosphere 32:55-64
Gauss, C., Papke, O., Dennison, N., Haynes, D., Shaw, G.R., Connell, D.W. and Müller, F.J. 2001 Chemosphere 43: 549-558
Grossi, G., Lichtig, J. and Krauß, P. 1998 Chemosphere 37: 2153-2160
Harrad, S.J., Malloy, T.A., Khan, M.A. and Goldfarb, T.D. 1991 . Chemosphere 23: 181-191
Krauss, T., Krauss, P. and Hagenmaier, H. 1994 Chemosphere 28: 155-158
Laine, M.M., Ahtiainen, J., Wagman, N., Öberg, L.G. and Jørgensen, K.S. 1997 Env. Sci. Technol. 31: 3224-3250.
Liem, A.K.D., Cuijpers, C.E.J. and Zeilmaker, M.J. 2000 in: Persistent Organic Pollutants: Environmental Behaviour and Pathways for Human Exposure (Harrad, S., Ed.), Kluwer Academic Publishers. London, UK
Lovett, A.A., Foxall, C.D., Creaser, C.S. and Chewe, D. 1997 Chemosphere 34: 1421-1436
Mitrou, P.I., Dimitriadis, G. and Raptis, S.A. 2001 European. J. Int. Medic. 12: 406-411.
Trapp, S. and Matthies, M. 1997 Env. Sci. Technol. 31: 71-74.
Washington State Department of Ecology-WSDE (1999) Ecology Publication no.99-309