

Orica Independent Monitoring Committee

Report for Botany Groundwater Community Liaison Committee on Task 2 from the combined IMC/CLC meeting on 8 May 2006, by Professor Brian Priestly

Task 2: Professor Brian Priestly is to prepare a paper for the CLC providing an independent perspective on the incremental health risks associated with the reported dioxin emissions from the GTP compared to other potential dioxin sources in the local Botany community.

Report: This report will attempt to provide some information, in lay rather than technical language, on whether dioxin emissions from the GTP are likely to pose a health risk to residents in the local Botany community. It complements the findings in the report provided under Task 3.

What are dioxins and how are they formed?

The term “dioxin” is employed to describe a family of related chemicals which may be formed when some organic molecules containing the element chlorine combine under conditions of high temperature (usually in combustion process). The process is temperature-critical, since very high temperature combustion processes can be used to destroy dioxins. Therefore, the term “dioxins” should only apply to a family of closely related chlorinated compounds (called congeners) and some related chlorinated compounds (e.g. polychlorinated biphenyls and furans) which share common toxic properties and biological activities. Some 30 of the more than 200 individual congeners are grouped as “dioxins” and dioxin-like substances for risk assessment purposes. They differ from one another, not only in the extent and position of their chlorine substituents, but more importantly, they can differ in their toxic potential by several orders of magnitude. For example, the most toxic congener (TCDD) is up to 30,000 times more toxic than some other dioxin congeners which may be found in an environmental sample.

To account for the differing toxic potential of the many dioxin congeners, the amount of an individual congener in a mixture is adjusted by a Toxicity Equivalence Factor (TEF) derived mainly from *in vivo* data. The TEF values range from 1 to 0.00003, reflecting the different potencies for individual congeners to produce toxic or biological effects relative to a reference compound, usually 2,3,7,8-tetrachlorodibenzodioxin (TCDD). The sum of the products of the concentration of each dioxin-like compound multiplied by its TEF value is expressed as a TCDD-toxicity equivalence (TEQ) and is therefore an estimate of the total dioxin-like toxicity of the mixture.

Why are dioxins so feared as “highly toxic compounds”?

The reason that dioxins attract such dread is that they can exert toxic effects in animal studies at doses of the order of micrograms to nanograms (10^{-6} to 10^{-9} of a gram, or a millionth to a thousand millionth fraction of a gram). In contrast, the effective dose for most toxic chemicals, including some medicines, is in the milligram (thousandth of a gram) or even grams to tens of grams range. Environmental concentrations and health standards are generally expressed in terms of picograms (10^{-12} of a gram or a

million-fold lower than micrograms), or even femtograms (10^{-15} of a gram; million times lower than nanograms). The effective doses of dioxins and their presence in the environment present a significant challenge to analysts, since their measurement requires highly complex sample handling, reliable extraction and costly, sensitive analytical procedures.

Do dioxins cause cancer?

Cancer is a dread disease, so it is reasonable that if a chemical is thought to “cause cancer”, it will be feared. There is no doubt that dioxins can increase cancer incidence when animals (mainly rats) have been exposed to relatively high doses. The evidence that humans exposed to dioxins get more cancer is far less certain. Where it has been suspected that dioxins are causing increased rates of some cancers in humans, it is generally where exposures have been unusually high, as in workers exposed to relatively high sources in an industrial setting. The likelihood that levels of dioxins ordinarily found in the environment could impact on cancer rates in the general community is extremely low.

Cancer is actually a group of over 100 separate diseases where there is uncontrolled growth and spread of abnormal cells in the body. Cancer rates rise with ageing, because cells gradually accumulate changes over time which cause the normal control processes over cellular growth and division to fail. Some of these changes involve specific damage to the genetic code (DNA) of cells. This is why chemicals which damage DNA are often found to increase the incidence of cancer. Dioxins do **not** damage DNA and therefore do not appear to act on cancer rates via this mechanism.

Dioxins may influence cancer rates in animals by making it easier for cells which are on their way to becoming cancerous to complete the transformation. Unlike DNA-damaging chemicals, which may act through a single critical “hit” on DNA, it is likely that the stimulus dioxins may provide to cancer requires prolonged and relatively high exposure.

Are there safe levels of exposure to dioxins, and how are these levels determined?

It is a fundamental law in toxicology that dose (or amount of exposure) determines whether adverse effects will be seen in someone exposed to a potentially toxic chemical. People may differ in their sensitivity for a variety of reasons, including pre-existing disease and their ability to absorb, store and eliminate toxic chemicals, but there will be some dose below which there is little likelihood an adverse health effect will be seen.

Several national and international authorities have assessed the toxic potential of the dioxin family of chemicals, and have reached a degree of consensus on what constitutes a safe level of exposure. In Australia, the National Health & Medical Research Council (NHMRC) has endorsed a figure of 70 picogram dioxin TEQ per kilogram body weight per month as a tolerable monthly intake (TMI) i.e a level of intake unlikely to result in health effects even when sustained over a lifetime. It is averaged over a month, rather than a day (as tolerable intakes for most other toxic chemicals are estimated), because dioxins are difficult to eliminate once absorbed, and they accumulate slowly in the body. Therefore, fluctuating exposures averaged

over a longer period provide a better estimate of the way dioxins will accumulate in the body.

The TMI figure of 70 pg/kg/mo is derived by comparing the body burdens in animals where toxicity has been experimentally induced with body burdens in humans associated with estimated long-term intakes. It is a conservative figure, because it is driven by the most sensitive experimental indicator of toxicity in animals (hormonal and reproductive changes in monkeys). Other toxic effects of dioxins, including cancer and effects on liver and skin, occur at levels of exposure which may be orders of magnitude higher than these sensitive effects on hormonal systems. The TMI is made even more conservative by dividing the lowest dose actually found to cause toxic effects (LOAEL) or a dose shown not to cause the effects (NOAEL) by one or more safety (or uncertainty) factors to further protect more sensitive individuals. The potential for this risk assessment approach to be overly conservative is possibly compounded by current knowledge of how dioxins exert their toxic effects (see below).

How is a dioxin health risk assessment performed?

In any risk assessment, it is important to estimate exposures from all possible sources of dioxins in a community and to consider all possible routes of exposure. This means that estimates are made of how much may be breathed in from airborne sources, how much may be taken in from food and water, and whether there is potential for material to be lodged on the skin or on surfaces. Since these estimates are likely to vary substantially over time, with the nature of everyday activities, with distance from emission sources and other variables. Exposure estimates may be represented as averages, upper estimates, or other techniques based on the distribution characteristics describing the variability of exposure estimates in groups or populations likely to be exposed.

Once potential exposures have been estimated, and added together if there are multiple sources or exposures to a mixture of like chemicals, these estimates are compared with a health-based standard. In the case of dioxins, this is the TMI endorsed by the Australian National Health & Medical Research Council. The comparison may be expressed as a Hazard Index (HI), or ratio of exposure to the TMI or “target risk” level. If the exposures are less than the TMI (HI <1), there is unlikely to be a health risk. Even where the HI exceeds 1, there may still be little or no health risk because of the conservatism built into the TMI estimate.

Current scientific knowledge suggests that “dioxins” exert their toxic effects by interacting with a specific “receptor” in the body (sometimes called the Ah receptor, or AhR). The Ah receptor is found in most tissues and appears to initiate a cascade of cellular events which could result in adverse health outcomes by regulating the biological activity of enzymes and other proteins. The TEQ for dioxins and dioxin-like compounds therefore includes environmentally persistent and bioaccumulative congeners which bind to and activate the Ah receptor.

While the risk process for extrapolating the toxic effects of chemicals from experimental animals to humans generally includes safety or uncertainty factors which assume that humans are more sensitive, there is some information that the

apparent binding affinity of 2,3,7,8-TCDD to the human Ah receptor is only 1/10th that of the more sensitive rodent species. Therefore it is possible that, despite the variation in Ah receptor sensitivity likely to occur in human populations, risk assessment extrapolations based on animal data may be overly conservative. However, until more research is done to more definitively establish the human relevance of TEFs based on rodent studies this conservatism will continue to be built into the risk assessment process.

Risk assessments relating to the Botany site

A number of risk assessments based on the above approach have been conducted for the Botany site and the Groundwater Treatment Plant (GTP). The particular risk assessment relating to dioxin emissions from the GTP was prepared by URS in June 2006 and comments from Prof. Priestly and Dr Hibberd relating to this risk assessment were presented to the IMC under Task 3 at its September 2006 meeting.

The estimates of incremental exposure to dioxins and their relationship to the “target risk” are comfortably low for adults, and do not exceed unity for infants and children, even when based on dioxin emission estimates associated with more extreme operating conditions. Given the extent of the conservatism inherent in the risk assessment approach, it is reasonable to draw a conclusion that exposures to dioxin emissions from the GTP do not represent a significant incremental health risk to residents in the vicinity of the GTP.

However, it should be noted that these estimates relate to incremental risk associated with airborne emissions from the GTP source. They do not include estimates of background exposures to dioxin-like substances from diet and other sources. The National Dioxins Program conducted by the Australian Government Department of the Environment & Conservation in 2002-05 suggests that all-source dioxin exposures in the Australian population are low in comparison with other developed countries, and that there is still a comfortable margin between all-source exposures and the TMI.