Some Considerations for Comparing Risk of Radiation and Chemicals

YANG Huating
China Institute for Radiation Protection, P.O. Box 120, Taiyuan, Shanxi, P.R. China

Abstract

Some basic concepts, used in radiation protection, are tried to be applied to the assessment of risks of environmental chemicals with the necessary variations. Dioxins may serve as an intermedium for the comparison of radiation and other chemicals. The death risk of dioxin induced cancers in life is 4.7×10^{-4}, based on the intake of 1pg/kg/day by using additive model and extrapolating linearly the results of the epidemiological study. And the risk is 2.6×10^{-4}in life by multiplicative model. The death risk of radiation induced cancer is 4×10^{-5}/a to the effective dose of 1mSv/a for adult. Ingestion of 1Bq of ^{239}Pu will give rise to a committed effective dose of 2.5×10^{-7}Sv, therefore, yearly ingestion of 1.47×10^{-6}g of ^{239}Pu is corresponding to 1mSv/a. A definition of *risk per year over mass ingested per year (1/μg)* may be suitable for the comparison of yearly risk of yearly-ingested masses of dioxins and ^{239}Pu. The life expectancy and a reference body weight (averaged weights of man and woman adults) are chosen as 70 years and 64kg respectively. The risks caused by ingestion of unit mass dioxin and ^{239}Pu are given as follows:

2.87×10^{-4}/μg (2,3,7,8-TCDD, additive model),
1.69×10^{-4}/μg (2,3,7,8-TCDD, multiplicative model)
and 2.3×10^{-5}/μg (^{239}Pu).

These results show that dioxins are even riskier. The comparison among dioxins and other chemicals may be relatively easier.

Key words: dioxin risk radiation compare chemical

1. Introduction

As to nowadays knowledge, some macroscopic biological effects, for example, cancer caused by chemical compounds and radioactive materials, are very difficult to be distinguished [1]. Therefore, it would seem unwise to isolate the assessment of the risk from chemicals and radiation. On the contrary, it seems operationally desirable to develop as far as practicable an integrated approach to the problems of the risk assessment for the better protection of human health against these hazardous environmental pollutants. Various efforts of comparing the effects of ionizing radiation and chemicals are coming the observations that many chemical compounds are able to result in biological effects that are similar to or identical with those caused by radiation. Especially, so-called stochastic effects (heritable damage, cancer) are interested in. There are many objects and targets for risk assessment. As far as the importance and feasibility are concerned, human as the object and cancer incidence as target value for the risk assessment could be suitable.

As a real fact, ionizing radiation is the first and so far sole environment factor that has been intensifiedly studied so as to produce the quantitative risk estimation. The advanced situation of study of biological effects of ionizing radiation may originate from the facts of the disastrous consequences of nuclear weapons and extremely sensitive measurement technique for the ionizing radiation.

The common ionizing radiation phenomena are eventually summarized to only a few kinds of particulates' (α, β, γ ,n and so on) interaction with materials, but there are over 10 millions of chemical compounds with even no toxicity data and environment limits for the overwhelming majority of the chemicals.[2] Obviously, it is not easy to find a united methodology of evaluation of effects of chemicals and radiation. If some of substances are chosen as a reference of comparison, say photon and dioxins, their results of the assessment might be served as a bridge of the risk assessment between chemicals and radiation. For the purpose of radiation protection, the biological effect of photons is appointed as the standard in ionizing radiation, and the effects of other kinds of ionizing particulates are weighted by radiation weighted factors, $W_{R.}$[1] The same skill is also used for weighting the toxicities of the congeners of dioxins. The comparison among dioxins and other chemicals may be relatively easier.

2. Difference and similarity

The apparent difference between radiation and chemicals is that some of chemicals are beneficial and sometime indispensable for man's health at low-level exposure. In other words, there must be a threshold of "dose" for chemicals above which the chemicals will do more harms than benefit to human health. For ionizing radiation, such a threshold might exist.

Which kinds of health effects are more suitable for assessment of the risk caused by chemicals and radiation? There should be a criterion of judgement that is objective and diagnosable on clinic examination without psychological interference. Cancer incidence may be a good candidate. It can be expressed as yearly deaths among 10^6 persons. The death of cancer avoids the uncertainty caused by using life quality and the like as the criterion that is extremely difficult to express in mathematical models.

Different chemicals have their own abilities inducing damage to DNA that could progress into a cancer later. The ability can be figured out by using a sort of weighting factor as radiation weighting factors, W_R, for ionizing radiation. Similarly, effecting degrees on different tissues or organs by different chemicals can be described by introducing the concept of tissue weighting factors, W_T, also for radiation.[1]

Generally speaking, the damage can't occur until chemicals are taken into or made contact with the body. However, radiation is able to make damage to the body through external radiation. Chemicals have very complicated metabolism in human body and vary with the nature of the different chemicals. It is understandable by looking at the picture of radiation protection. There are many thick volumes of ICRP's publications that give the metabolistic models and data for calculating doses. It is impracticable to construct such a sophisticated system for so many chemicals at present. The study of dioxin's effects on human can be the first step to go.

The effects of radiation or chemicals can be quantified by the concept of "dose". The absorbed dose, D, is defined as $D= d\varepsilon/dm$. That is the mean energy imparted by ionizing radiation in unit mass of the matter. Because the chemical energy imparted by chemicals to the matter is much less than radiation, the dose may be defined as chemical's mass over the mass of an organ or tissue, then multiplied by functioning time. That is $D=t*dm/dM$. The SI unit for the dose can be second (s). The definition of *D=(chemical's quantity(mol)*time(s))/(organ's volume(l))* may be more practical for some chemicals.

3. Properties of Dioxins

The polychlorinated dibenzo-para-dioxins (PCDD) and polychlorinated dibenzo-furans (PCDF) are two series of tricyclic aromatic compounds almost with the same properties. Their structural formulae are given in Fig.1.The number of chlorine atoms and their positions can be different. And there are 75 PCDD and 135 PCDF isomers. The PCDDs and PCDFs

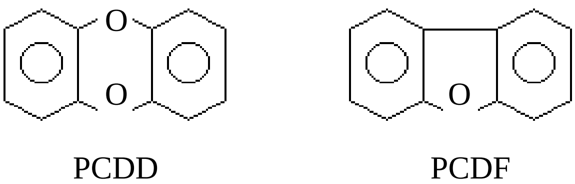

Fig.1

are always mixed together when produced, and their chemical, environmental and biological characteristics are similar, both of the PCDDs and PCDFs are usually called dioxins for short. Different from most of chemicals, dioxins are never intentionally produced commercially in quantity, but formed as by-products during many of manufacturing or processing procedures, such as pulp industry, pharmaceutical synthesization and incinerator etc.

In recent years, dioxins are paid great attention to worldwide for their environmental biological enrichment, serious toxicity and difficulty to be degraded in biosphere. For assessment of their risks and dose responses, a concept of Toxic-Equivalent Factors is introduced, which is similar to Radiation Weighing Factor in ionization radiation protection. The toxic levels of the entire individual PCDD and PCDF are normalized as the values of Toxic Equivalents (TEQ) in which the toxicity of 2,3,7,8-TCDD is used as unit. Often it is also call TCDD

Equivalents.

$$\mathrm{TEQ} = \sum_i \mathrm{concentration(i)} \times \mathrm{TEF(i)}$$

With the help of TEF, toxicity of different PCDDs and PCDFs can be converted for comparison and additive. The most accepted factors are jointly issued by EC, NATO and US EPA, they are listed in Table1. It is worth noticing that all of 17 congeners listed are fully chlorinated in the 2,3,7,8-positions because the most concerned object is human beings and only 2,3,7,8-subsituted congeners are detected in higher animals such as fish and mammals. However it is not excluded that the other congeners are taken into and transformed in the body, for people definitely take in the other congeners through inhalation and ingestion pathways. The caution must be taken because TEFs are gained through the short-term experiments of animals both in vivo and in vitro, long-term effects on human can only be known for further investigation in the future.

Dioxins are lipophilic compounds. They concentrate at liver and other liporous tissues. Their solubility is 0.59g/l, 0.04g/l and 0.2μg/l respectively in benzene, plant oil and water. The pathways from environment to the people are ingestion of food and drinking water, inhalation of air and contact with soil. And the main contribution is from the ingestion.

Table 1 TEFs for PCDD and PCDF

Congener	TEFs
2,3,7,8-TCDD	1.0
1,2,3,7,8-PeCDD	0.5
1,2,3,7,8-subst HxCDDs	0.1
1,2,4,6,7,8-HpCDD	0.01
OCDD	0.001
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.5
2,3,7,8-subst HxCDFs	0.1
2,3,7,8-subst HpCDFs	0.01
OCDF	0.001

4. Comparison of risk

It is well known that dioxins are extremely toxic chemicals to mammals. We can get a feeling of dioxin's toxicity compared with the best-known toxic chemical, potassium cyanide (KCN). The half lethal dose, LD_{50}, of KCN for mouse is 15mg/kg (body weight). Whereas LD_{50} of 2,3,7,8-TCDD is 0.6 μ g/kg, which is 25000-fold more toxic than KCN.

For the carcinogenesis risk, a comparison between 2,3,7,8-TCDD and ^{239}Pu is made below. Among radioactive nuclides, plutonium-239 is the riskiest nuclide except for actinium-227 and curium-250. The latter two nuclides are seldom met. The death risk of dioxin induced cancers in life[5] is 4.7×10^{-4} ,which is based on the intake of 1pg/kg/day by using additive model and extrapolating linearly the results of the epidemiological study. And the risk is 2.6×10^{-4}in life by multiplicative model.

The death risk of radiation induced cancer is 4×10^{-5}/a to the effective dose of 1mSv/a for adult. Ingestion of 1Bq of ^{239}Pu will give rise to a committed effective dose of 2.5×10^{-7}Sv, therefore, yearly ingestion of 1.47×10^{-6}g of ^{239}Pu is corresponding to 1mSv/a.

A definition of risk per year over mass ingested per year (1/μg) is needed for the comparison of yearly risk of yearly-ingested masses of dioxins and ^{239}Pu. The life expectancy and a reference body weight (averaged weights of man and woman adults) are chosen as 70 years and 64kg respectively. According to the definition, the assumed values and the known values above, the risks caused by ingestion of unit mass dioxin and ^{239}Pu are given as follows:

$2.87 \times 10^{-4}/\mu g$ (2,3,7,8-TCDD, additive model),
$1.69 \times 10^{-4}/\mu g$ (2,3,7,8-TCDD, multiplicative model)
and $2.3 \times 10^{-5}/\mu g$ (^{239}Pu).

These results show that dioxins are even riskier. "Tuning pale at the mention of ^{239}Pu " has to give the place to the dioxin!

5. Conclusion

Dioxins are the most dangerous substances for both their acute and chronic effects. Dioxins may serve as an intermedium for the comparison of radiation and other chemicals. Risk comparison of radiation and chemicals is feasible if *risk/intake* is chosen as comparable quantity. The comparison at the microscopic level, such as in cell and molecule, may be more difficult. The considerations are preliminary; so many factors are excluded.

References

1. ICRP Publication 60. Recommendation of the International Commission on Radiological Protection. Pergamon Press, Oxford, 1991.
2. IAEA Bulletin Vol. 38 No. 2, 1996.
3. Rappe, Christoffer, Dioxin, Patterns and Source Identification. Fresenius J. Anal Chem 348:63-75 (1994)
4. 脇本忠明　ダイオキシンの正体と危ない話　青春出版社 1998
5. US EPA: Health assessment document for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and related compounds. EPA/600/bp-92/001 a, b, c, (1994)
6. IAEA Safety Series No.115. International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. 1996
7. ICRP Pub.30 Limits for Intakes of Radionuclides by Workers. Pergamon Press, Oxford.1979