DIETARY EXPOSURE ASSESSMENT OF CHEMICALS IN FOOD

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Summary

The contamination of food by chemical hazards is a worldwide public health concern and is a leading cause of trade problems internationally. Contamination may occur through environmental pollution of the air, water and soil, such as the case with toxic metals, PCBs and dioxins, or through the intentional use of various chemicals, such as veterinary drugs, pesticides and other agrochemicals. Food additives and contaminants resulting from food manufacturing and processing can also adversely affect health. Scientists and public-health agencies have developed risk assessment methods to derive human safe levels of exposure. Risk assessment has been divided into four sequential steps: hazard identification, hazard characterization, exposure assessment and risk characterization.

Dietary exposure assessment is a crucial component of risk assessment applied to chemical substances in foods and beverages. In order to calculate reliable estimates of...
the amounts ingested through the diet for a specific chemical substance, three elements have to be taken into account: levels and fate of the chemical in food; food consumption patterns and integration of these elements to determine exposure. In all areas the limitations of the approaches currently used lead to uncertainties that can either cause over- or underestimation of real intakes and thus of risk.

1. Introduction

There are different views on usefulness and adequacy of individual animal and plant species as a source of food and these opinions are changing under the influence of scientific knowledge, production conditions, possibility of breeding of individual animal species, economical potential of individuals or community, religions, habits and even prejudices.

Harmful residues in food include a series of chemical compounds, which could be different food additives, processing aids, pesticides, polychlorinated biphenyls, nitrates and nitrites, heavy metals, mycotoxins, and in food of animal origin also veterinary-medicinal products. Food-borne disease remains a real and formidable problem in both developed and developing countries, causing great human suffering and significant economic losses. Up to one third of the population of developed countries may be affected by food-borne diseases each year, and the problem is likely to be even more widespread in developing countries, where food and water-borne diarrheal diseases kill an estimated 2.2 million people each year, most of them children. Chemical hazards in foods occasionally cause acute illnesses, and some food additives, residues of pesticides and veterinary drugs and environmental contaminants may pose risks of long-term adverse effects on public health. New technologies such as genetic modification of agricultural crops have raised additional food safety concerns. In order to reduce those negative trends, international organizations like Food and Agriculture Organization of the United Nations, World Health Organization, Codex Alimentarius and World Organisation for Animal Health are involved with numerous activities in this field. A key discipline for further reducing food-borne illness and strengthening food safety systems is risk analysis, a systematic, disciplined approach for making food safety decisions developed primarily in the last two decades, includes three major components: risk assessment, risk management and risk communication. Risk assessment at the international level provides the scientific basis for the establishment of Codex standards, guidelines, and other recommendations and includes dietary exposure assessments as an essential component. The role of dietary exposure assessments has grown significantly in light of the World Trade Organization’s “Agreement on the Application of Sanitary and Phytosanitary Measures”. Paragraph 16 of this agreement requires that sanitary and phytosanitary measures be based on sound scientific risk assessment. The agreement also states that sanitary measures that are consistent with standards, guidelines, and recommendations of the Codex Alimentarius Commission are considered to comply with the requirements of the agreement.

Dietary exposure assessments combine food consumption data with data on the concentration of chemicals in food. The resulting dietary exposure estimate is then compared with the relevant toxicological or nutritional reference value. Assessments may be undertaken for acute (short-term) or chronic (long-term) exposures, where acute
exposure covers a period of 24 h and long-term exposure covers average daily exposure over the entire lifetime. Dietary exposure assessments of nutrients use default assumptions that tend to underestimate exposure, whereas dietary exposure assessments of potentially toxic food chemicals use default assumptions that tend to overestimate exposure. For some nutrients, two assessments may be necessary because of the specific need to look at both nutrient adequacy and the potential to exceed upper safety levels. Ideally, dietary exposure to hazardous substances can be assessed by combining data on concentration in all food products with data on their consumption. However, it is considered to be neither cost-effective nor necessary to collect detailed data for every substance, and a stepwise procedure is commonly used to focus resources on the most important issues. Screening methods, designed to look for ‘worst case’ situations, are first used to target chemicals that might be of health concern for the general population or for certain at-risk groups. The quality of the dietary exposure assessments not only depends on the quality of the data collected, but also on the integration tools used for initial screening or for the eventual more precise estimations.

2. Role of Risk Assessment

The first risk analysis paradigm for public health was proposed by the U.S. National Academy of Sciences - NAS and focused on assessing the risk of cancer from chemicals in food.

![Risk Analysis Paradigm](image)

Figure 1: The risk analysis paradigm

Risk assessment is the central component of risk analysis and provides a scientific basis for risk management decisions on measures that may be needed to protect human health. Risk assessment consisting identification of the agent causing adverse health effects (hazard identification), evaluation of the intake of the agent (exposure assessment), evaluation of the nature of the adverse health effects (hazard characterization), and estimation of occurrence and severity of the adverse health effects (risk characterization).
Figure 2: Generic Codex description of the components of risk assessment

It is a conceptual framework that, in the context of food chemical safety, provides a mechanism for the structured review of information relevant to assessing possible health outcomes in relation to exposures to chemicals present in food. The risk assessment is used to develop and evaluate risk management strategies, such as introducing measures to control the use or release of the chemical, restricting human contact, or introducing compliance testing or surveillance.

Risk management is process, distinct from risk assessment, of weighing policy alternatives, in consultation with all interested parties, considering risk assessment and other factors relevant for the health protection of consumers and for the promotion of fair trade practices, and, if needed, selecting appropriate prevention and control options.
The functional separation of risk assessment from risk management helps assure that the risk assessment process is unbiased. However, certain interactions are needed for a comprehensive and systematic risk assessment process. The relationship between risk assessment and risk management is an interactive, often iterative, process.

Risk communication is an integral part of risk analysis and helps to provide timely, relevant and accurate information to, and to obtain information from, members of the risk analysis team and external stakeholders, in order to improve knowledge about the nature and effects of a specific food safety risk assessment. It contributes to transparency of the risk analysis process and promotes broader understanding and acceptance of risk management decision.

Risk assessment of chemical substances present in or on food forms the core work of Joint FAO/WHO Expert Committee on Food Additives (JECFA) and Joint FAO/WHO Meeting on Pesticide Residues (JMPR). Based on the advice from these two committees, food safety measures are taken in the risk management executed by countries nationally and by the Codex Alimentarius Commission (CAC) internationally. Whereas JECFA and JMPR base their evaluations on scientific principles and ensure necessary consistency in their risk assessment determinations, CAC and its respective committees that deal with chemicals in food are responsible, as risk managers, for the final decisions on establishing maximum limits for pesticide residues, veterinary drug residues, contaminants and additives in food and adopting other related measures.

2.1. Hazard Identification

Hazard identification is the first stage in hazard assessment and the first of four steps in risk assessment. Hazard identification is defined as the identification of biological, chemical and physical agents capable of causing adverse health effects and which may be present in a particular food or group of foods.

The purpose of food chemical hazard identification is to evaluate the weight of evidence for adverse health effects, based on assessment of all available data on toxicity and mode of action. It is designed to primarily address two questions:
1) the nature of any health hazard to humans that an agent may pose and
2) the circumstances under which an identified hazard may be expressed.

Hazard identification is based on analyses of a variety of data, ranging from observations in humans or domestic animals and studies in laboratory animals and in vitro laboratory studies through to analysis of structure–activity relationships. From the range of studies and observations available, the nature of any toxicity or adverse health effects occurring and the affected target organs or target tissues are identified.

2.2. Hazard Characterization

Hazard characterization is defined as the qualitative and, wherever possible, quantitative evaluation of the nature of the adverse health effects associated with biological, chemical and physical agents, which may be present in food. For chemical agents, a dose–response assessment is performed.
Hazard characterization describes the relationship between the administered dose of, or exposure to, a chemical and the incidence of an adverse health effect. The critical effect - that is, the first adverse effect observed as the dose or exposure is increased is determined. In cases where the toxic effect is assumed to have a threshold, hazard characterization usually results in the establishment of health-based guidance values for example, an acceptable daily intake (ADI) for additives or residues of pesticides or veterinary drugs, or a tolerable intake (TI) for contaminants. For some substances used as food additives, the ADI may not need to be specified; in other words, no numerical ADI is considered necessary. This may be the case when a substance is assessed to be of very low toxicity, based on the biological and toxicological data, and the total dietary intake of the substance, arising from the levels used in foods to achieve the desired function, does not represent a hazard.

2.3. Exposure Assessment

The Codex Alimentarius Commission’s Procedural Manual defines exposure assessment as “the qualitative and/or quantitative evaluation of the likely intake of biological, chemical, and physical agents via food as well as exposures from other sources if relevant”.

In the case of food chemicals, dietary exposure assessment takes into consideration the occurrence and concentrations of the chemical in the diet, the consumption patterns of the foods containing the chemical and the likelihood of consumers eating large amounts of the foods and of the chemical being present in these foods at high levels. Usually a range of intake or exposure estimates will be provided (e.g. for average consumers), and estimates may be broken down by subgroup of the population (e.g. infants, children, adults).

Estimates of dietary intakes of food additives, residues of pesticides and veterinary drugs and contaminants require information on the consumption of relevant foods and the concentrations of the chemical of interest in those foods. In general, three approaches are available in exposure assessment:

1) total diet studies;
2) selective studies of individual foods, and;
3) duplicate portion studies.

Guidelines for the study of dietary intakes of chemical contaminants are available from WHO (1985). The GEMS/Food international databases include several important streams of data related to food contamination and food consumption:

- The level of chemicals is measured in raw food commodities as well as in food as consumed by final consumer.
- A list of the WHO 13 cluster diets that have been created to cover the average food consumption in 13 regions of the world. These levels of consumption are used to serve as a basis for assessing the exposure to chemical contaminants from food, but can also be used for other purposes like nutritional evaluation.

GEMS/Food currently maintains a database of five regional diets as well as a composite "global" diet. Daily dietary intakes of nearly 250 individual primary and semi-processed
food commodities are available. The African, Asian, East Mediterranean, European and Latin American regional diets are based on selected national data from FAO Food Balance Sheets. Consumption data derived using this approach provide no information on extreme consumers.

Dietary intake determinations can be relatively straightforward for additives, pesticides and veterinary drugs as the relevant foods and their use levels are specified by their approved conditions of use. However, the actual levels of additives and residues of pesticides and veterinary drugs present in foods are often well below the maximum levels permitted. In regard to residues of pesticides and veterinary drugs, levels on or in food are often totally absent because only a portion of the crop and animal population is usually treated or as consequences of withdrawal period.

Data on the levels of food additives in foodstuffs can be obtained from the manufacturers. The dietary intake of contaminants requires information on their distribution in foods that can only be obtained by analyzing representative samples of foods with sufficiently sensitive and reliable analytical methods. Maximum Residue Limits (MRLs) for pesticides and veterinary drugs and Maximum Levels for additives can be established from their conditions of use. In the simplest case, a food additive used at a specific level would be stable in the food until consumption. The Maximum Level would then equal the intake level. However, in many cases, the amount of the chemical of interest may change prior to consumption. For example, food additives may degrade during storage or react with the food. Pesticide residues in raw agricultural products may degrade/accumulate during further processing. The fate of veterinary drug residues in food products is influenced by metabolism, kinetics, distribution and withdrawal periods required for treated animals.

The establishment of MRLs must take into account any changes in the nature or level of the residue that may occur prior to a commodity entering commerce or that may occur under any anticipated conditions of subsequent use. Contaminants have no intended technological effect in the food and guideline levels are usually set as low as reasonably achievable.

The theoretical total dietary intake of additives, pesticides and veterinary drugs must be below their corresponding ADIs. Setting guideline levels for contaminants present special problems. There is usually a paucity of data to establish a provisional tolerable intake. On occasion, the levels of the contaminants are higher than what an established provisional tolerable intake would permit. In these cases, the guideline levels are set on economic and/or technical considerations.

Within the Codex Alimentarius Commission, the chemical contamination of food is addressed by the Codex Committee on Food Additives and Contaminants (CCFAC) and the Codex Committee on Pesticide Residues (CCPR). Risk management decisions are highly dependent on comparable and reliable exposure assessments and GEMS/Food has provided assistance on a range of chemical issues to CCFAC and CCPR as well as to their scientific advisory bodies, namely JECFA and JMPR.

Reliable food intake data are essential for exposure assessments based on measuring levels of chemical agents in food. Detailed food consumption data for the average
consumer as well as for different population groups are important for assessing exposure, particularly by sensitive groups. In addition, comparable food consumption data, particularly with respect to staple foods from different regions of the world are essential for developing an international risk assessment approach to food safety.

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Biographical Sketch

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Natalija Vragović, received her Degree and Ph.D in Veterinary Medicine (Veterinary Public Health and Food Safety) at the University of Zagreb (Croatia) in 2006 and 2010, respectively. Since 2006 she is in the research staff at the Department of Residues Analysis of the Center for Food Control, Croatia where she developed her expertise on risk assessment of veterinary drug residues in food of animal origin. Research interests: food safety, risk assessment, dietary exposure, chemicals in food, residues analysis. Author of about 20 research papers in international journals and numerous presentations in international scientific meetings on food safety.