Chapter 1
Total Diet Studies—What They Are and Why They Are Important

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Introduction

Chemicals are the building blocks of our bodies and make possible all activities associated with human life. These chemicals are obtained from the food and water that we consume everyday throughout our lives. On the other hand, human exposure to toxic chemicals in food and nutritional imbalances are known to be responsible for a range of human health problems and are implicated in many others. These problems include various cancers, kidney and liver dysfunction, hormonal imbalance, immune system suppression, musculoskeletal diseases, birth defects, premature births, impeded nervous and sensory system development, reproductive disorders, mental health problems, cardiovascular diseases, genitourinary diseases, old-age dementia, and learning disabilities. These conditions are prevalent in all countries, and, to some extent, most can be attributed to past and current exposure to chemicals in the foods we eat. Consequently, the protection of our diets from these hazards must be considered one of the most important public health functions for any country and total diet studies are the most cost-effective tools for assessing dietary exposure to a range of potentially hazardous chemicals as well as certain nutrients.

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What Are Total Diet Studies?

A total diet study consists of purchasing foods which are representative of the diet at the retail level, processing them as for consumption (often combining the foods into food composites), homogenizing them, and analyzing them for toxic chemicals and certain nutrients. Exposures through drinking water and water used in cooking are typically included in the total diet study assessment. Dietary exposures are calculated by combining the concentrations of the chemicals in the food samples with the average amounts of the corresponding food ingested by each population age/sex group or, in more sophisticated form, by using food consumption data of individuals representative of various population subgroups.

What Information Do Total Diet Studies Provide?

The primary purpose of total diet studies is to measure the average amount of each chemical ingested by different age/sex groups living in a country. The dietary exposures of the chemicals can be compared with national or international health-based reference values to assess whether or not a specific chemical poses an unacceptable risk to health. Thus, total diet studies provide a direct measure of the safety of the diet. The World Health Organization (WHO), the lead United Nations agency for public health, recommends total diet studies as the most cost-effective method for assuring that people are not exposed to unsafe levels of chemicals through food.

When conducted over several years, total diet studies provide critical information about the trends of toxic chemicals and other chemicals, such as food additives, in the diet and offer guidance about the need for targeted monitoring or possible intervention programs. They can also identify increasing or decreasing dietary intake of micronutrients that may be naturally present or due to fortification of food or animal feed.

Total diet study information often provides direct evidence on the contribution of different food items or food groups to the dietary exposure of chemicals. This information can be used to establish priorities and assure that limited government resources are used for the greatest health benefit. For example, numerous total diet studies had shown that the overwhelming contributor to the dietary intake of methylmercury is fish. As a result, risk management resources for methylmercury have been largely directed toward addressing consumption of those fish with the highest concentrations.

In addition, total diet studies, by their design, provide background concentrations of the chemicals in the foods analyzed. This baseline information is critical for quickly identifying contaminated foods when food safety emergencies arise. For example, during the Belgium dioxin incident, the availability of background concentrations of polychlorinated dioxins, -dibenzofurans, and -biphenyls in Canadian

foods facilitated the rapid assessment that foods imported into Canada from Belgium did not contain high levels of these chemicals. Also, the availability of baseline information enables rapid identification of food that significantly exceeds normal mean values. With this information, potentially hazardous contamination can be identified early and mitigated before becoming a major health or trade issue. If total diet study samples are stored, they can be used for retrospective studies if a new chemical hazard is identified, as in the case of acrylamide.

How Do Total Diet Studies Differ from Other Surveillance Programs?

Total diet studies differ from other chemical surveillance programs in several ways, namely:

(a) In most surveillance studies, a limited number of different foods are generally analyzed, so that statistically robust sampling of each food can be undertaken. In a total diet study, the focus is on exposure to chemicals from across the whole diet, so that a wide range of different foods are analyzed. With limited resources usually the norm, this often means fewer samples per food type than for surveillance surveys, but the coverage of foods is much more complete.
(b) In most surveillance studies, individual foods are usually analyzed separately. In the total diet study, individual food items from different sources (brands, regions, seasons) may be combined into composite food samples, or if resources are limited, individual food items are combined into food group composites. For example, apples, pears, and quinces are often combined into a pome fruit composite.
(c) Surveillance for trade purposes is conducted to assess whether individual commodities meet regulatory limits i.e. for pesticides, national or Codex Maximum Residue Limits. In these instances, analytical methodologies are developed to monitor these much higher regulatory concentrations. In contrast, a total diet study is conducted to measure background concentrations of these chemicals in food samples, and consequently, the sensitivities of analytical methodologies are much lower.
(d) In a total diet study, foods are analyzed after being prepared as usual for consumption. Thus, they might contain some chemicals, such as acrylamide, which are formed during food processing. On the other hand, they might not contain certain chemicals originally present in the raw foods e.g. those which are destroyed during heating or removed during washing and peeling. Thus, the chemicals in the foods analyzed in a total diet study are more closely representative of what is actually ingested by the consumer rather than what is produced e.g. raw agricultural commodities.
(e) Unlike most surveillance samples, total diet samples are usually analyzed for many different chemicals to save sampling costs. This has the additional benefit of

facilitating risk-benefit analysis for different chemicals, such as polychlorinated biphenyls, mercury, and omega-3-fatty acids in fish.

(f) Because the total diet studies are complex in nature, a high degree of expertise and organization is needed. In addition, more expensive measurement instruments, such as high-resolution mass spectrometers, are often required to measure the low levels of contaminants and nutrients that occur in food.

Why Are Total Diet Studies Important?

In most countries, food safety legislation has placed the primary responsibility for ensuring the safety of food on commercial food enterprises that produce, process, distribute or prepare food for the consumer. With varying degrees of success, governments have established regulatory and other limits for contaminants in various foods. The Codex Alimentarius Commission also had provided guidance in this regard [1]. However, most of these limits are based on Good Agricultural Practices and/or Good Manufacturing Practices and not on risk assessments themselves. Because safe or tolerable levels for chemicals, such as the Acceptable Daily Intake and the Provisional Tolerable Weekly Intake, are specified in terms of total intake from all ingested sources, contributions to exposure from many individual foods need to be taken into account to assess the aggregate risk from chemicals in food and water. The overall assessment of the safety of the food supply is one of the essential responsibilities of governments. This was recognized in the Beijing Declaration on Food Safety [2], which urged all countries to "Establish food and total diet monitoring programs with linkages to human and food-animal disease surveillance systems to obtain rapid and reliable information on prevalence and emergence of foodborne diseases and hazards in the food supply." A survey carried out in 2011 by the European Food Safety Authority in cooperation with WHO and the Food and Agriculture Organization of the United Nations (FAO) revealed that 33 countries have already conducted total diet studies [3].

In many developing countries where neither the government nor the food industry conduct testing of foods for chemical contaminants, it is all the more imperative that government authorities have a cost-effective means for ensuring that levels of chemical contaminants in the total diet do not pose a risk to the health of their populations. Because toxic chemicals in food cannot generally be detected by the senses or be removed by normal processing, consumers are not in a position to protect themselves from these types of hazards. For this reason, many consumer groups have strongly supported measures by governments to protect the population against potentially toxic chemicals in food. As a consequence, governments in most developed countries have monitoring programs for chemicals in food and conduct total diet studies. On the other hand, except for a few high-value foods for export, few developing countries have monitoring programs for chemicals in food and even fewer conduct total diet studies.

It should also be noted that in addition to contaminants, most total diet studies include selected nutrients. Although assessing the long-term exposure to potentially toxic chemicals in food as consumed is the purpose of total diet studies, the inclusion of intake assessments for certain nutrients, especially micronutrients, is extremely cost-effective, as the same samples can be used. Total diet studies have also been applied to certain food additives as well as to processing contaminants, such as acrylamide and chloropropanols.

While unsafe levels of chemicals in food may cause serious health problems, they also pose threats to trade and the environment. Food production, processing, and preparation are among the most important economic activities for almost all countries and any disruption caused by toxic chemicals in food can have a major impact on the country and on consumer confidence in the safety of the food supply chain. It is estimated that the global economic and trade burden from these contaminants in food totals many billions of dollars annually [4]. For developing countries, the foreign exchange earned from food exports is often essential for their economic development. Food exports may also be threatened by unjustified health and safety requirements, which can serve as non-tariff trade barriers. Total diet studies can also provide a scientific assessment of the risk posed by exposure to toxic chemicals as evidence of the acceptability (or not) of proposed national or Codex food standards.

In addition, total diet study results can be indicators of environmental contamination by chemicals and can be used to assess the effectiveness of specific risk management measures. For example, persistent organic pollutants, the so-called POPs, have been shown to cause adverse effects on wildlife and their endocrine disruption potential has been suggested to cause human diseases, such as cancer and behavioral disorders [5]. Given that POPs are highly fat soluble, they concentrate in the food chain. As a result, human exposure to POPs is almost wholly through food. As the upper atmospheric transport of such chemicals is well documented, the contamination of food is often remote from the source of the pollution. Therefore, it is becoming increasingly important to assess the exposure of humans to background concentrations of these as well as the other environmental pollutants that may end up in our diets.

The WHO's Global Environment Monitoring System/Food Contamination Monitoring and Assessment Programme (GEMS/Food) has encouraged all countries, and in particular developing countries, to undertake total diet studies as a matter of public health importance, while recognizing the significance of total diet studies to standards development and trade as well as environmental risk management. The overall cost of conducting a basic total diet study is much less than any other exposure assessment method available. A major part of the cost of a total diet study is the expense of analyzing samples at low limits of detection. Total diet studies can be conducted for less cost by rationalizing either the size of the food list or the range of chemicals to be analyzed. Total diet studies can also be run over a number of years to spread out the costs. In addition, for certain chemicals, the necessary analyses may be performed in other laboratories on a contract basis. If the total diet study then indicates that exposure to a chemical is well within its safe limits, there may be no need to establish expensive analytical capabilities for the

chemical. In this regard, total diet studies are useful priority-setting tools that enable risk managers and society to focus limited resources on those chemicals that pose the greatest risks to public health.

Another expense associated with conducting a total diet study (or any other exposure method for that matter) is the need to have reliable food consumption data. In this regard, countries might elect to use one of the GEMS/Food Consumption Cluster Diets [6] (See Chap. 43 – GEMS/Food Consumption Cluster Diets). However, more detailed individual food consumption data will allow specific exposure estimates for different age/sex groups as well as population groups of special interest, such as vegetarians or ethnic groups. Many countries use the 24-hour recall method that is supplemented by a food frequency questionnaire. The cost of such a food consumption survey will vary considerably depending on the local cost of labor. However, the cost can be averaged over a number of years as dietary patterns usually change slowly. The cost of such a survey may also be shared with other stakeholders with an interest in such data, including the agriculture sector and the food industry.

It should be borne in mind that the cost of a total diet study is more than balanced by the health and economic benefits that can accrue. In one developed country, a study of the economic impact on Parkinson's disease, hypothyroidism, diabetes, and nervous system and IQ effects suggested that the current negative impact of previous and current human exposure to toxic chemicals, including nutritional imbalances, likely exceeds US$800 for every man, woman, and child each year [7]. These enormous costs to countries' economies can be reduced by lowering exposure of the population to toxic chemicals and by optimizing their nutritional balance. On the other hand, the negative economic impact can be expected to continue or increase if relevant research and monitoring activities are not implemented.

While total diet studies are health-oriented and population-based, such studies can often reveal point sources of contamination, which can be corrected before actual health or trade problems occur. However, even when the health risks are assessed to be minimal, impact on trade can be severe. For example, contamination of a single batch of animal feed with oil contaminated with polychlorinated biphenyls and dioxins in Belgium resulted in economic losses exceeding US$2 billion with the majority of these losses borne by industry and individual farmers.

In regard to trade, the World Trade Organization (WTO) under its Agreement on the Application of Sanitary and Phytosanitary Measures requires that health and safety decisions be based on sound scientific risk assessments. For example, in the Czech Republic, results of a total diet study were successfully used to defend safety measures taken to halt the importation of chicken contaminated by arsenic, even though the exporting country complained to the WTO and sought damages from economic losses. In addition to hazard characterization, a risk assessment of a chemical in food requires an assessment of human exposure. For this purpose, total diet studies are considered to be one of the best means of estimating human dietary exposure and such studies are frequently included in safety evaluations performed by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) [8] as well as by national and regional expert bodies.

Where to Start?

Government policy- and decision-makers need to be aware of the importance of total diet studies for assuring the safety of the food supply. In this regard, realistic risk assessments simply cannot be performed without an assessment of exposure. As a first step, national expertise in total diet studies needs to be developed through training and participation in international networks, such as WHO GEMS/Food. At the same time, the food safety and applied nutrition communities in countries need to mobilize support for total diet studies. This includes stakeholders in government, academia, and industry as well as consumer groups. WHO has recognized total diet studies as the most cost-effective means for governments to protect public health from chemicals in the food supply. For the food industry, total diet studies provide a scientific basis for the development of standards and for the orderly development of the food industry. Consumers and their advocacy groups should recognize that total diet studies are essential public health measures that serve to safeguard the food supply from potentially hazardous chemicals and to ensure adequate levels of nutrients in the diet.

In order to promote the availability of competent people with the technical and logistical skills to conduct total diet studies, WHO GEMS/Food in cooperation with national food safety agencies periodically holds training courses at the regional and international levels. These training courses have been facilitated by WHO Collaborating Centers for Food Contamination Monitoring and particularly the one located at the Institute for Environmental Science and Research in Christchurch. However, practical experience can also be gained by placement of personnel in institutions already conducting total diet studies. Governments, particularly in developing countries, need to support the development of human and infrastructure capacities to undertake total diet studies in their countries. Once a country has completed its first total diet study, experience has shown that support for future studies is almost always assured. This is due particularly to the ability of non-technical persons to understand the concept and results of total diet studies and their significance to human health. Finally, because it is based on a transparent scientific method that is internationally accepted, total diet studies are increasingly recognized as the key to providing essential assurance that people's diets are safe and nutritionally adequate.

General information on food contamination monitoring, including total diet studies, is available in a number of WHO publications [9, 10]. In addition, the European Food Safety Authority in cooperation with WHO and FAO has developed a harmonized protocol for European Union countries that may be useful to consult [11].

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