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Food Safety and Chemical Contaminants: An Overview[a]

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سلامة الأغذية والملوثات الكيميائية: نظرة عامة

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خلاصة: تحظى سلامة الأغذية باهتمام المستهلكين في جميع أرجاء العالم. وبالرغم من أن أسباب التسمم الغذائي عزيت للتلوث البكتيري في كثير من الحالات خلال الأعوام السابقة، إلا أن المخاطر الصحية تظل كامنة في التلوث الكيميائي. وتأتي الملوثات الكيميائية من مختلف المصادر مثل المبيدات الحشرية والمواد الكيميائية الموجودة في البيئة (الدايوكسين والمعادن الثقيلة بما فيها الرصاص والزئبق) والملوثات الكيميائية الناتجة عن التسمم الغذائي (الأكريلامايد والنيتروسومينات الخ) والمواد السامة في الطبيعة (القلايكو ألكلويدات والمايكوتوكسينات ومضادات التغذية الخ) والمواد الكيميائية الناتجة عن التغليف والأدوية البيطرية والمواد الكيميائية الأخرى المتبقية. وإضافة للتلوث غير المقصود فإن نوعية وسلامة الأغذية يمكن تأثرها بمحسنات الأغذية والأغذية النباتية والتعرض للإشعاع والمواد الأخرى. ويتعرض صانعو الأغذية وجهات وضع المعايير وتطبيقها تحديات متزايدة لسد احتياجات المستهلك لأغذية سليمة لا تعرض صحتهم للمخاطر أو طريقة حياتهم للتغيير. وبزيادة تجارة الأغذية في العالم تجد سلامة الأغذية اهتماماً مشتركاً في البلدان النامية والمتطورة. وبالرغم من وجود أنظمة للتحكم في الأغذية في دول منطقة الخليج إلا أنها في أغلب الأحوال لا تكون ملائمة للمتطلبات المحلية والعالمية ولا تواكب تحديات العصر الحديث. وتكمن أنسب الطرق للتأكد من سلامة الأغذية في تقوية أنظمة المراقبة وتطوير طرق تحليل المخاطر منهجياً وتقييم المخاطر وإستراتيجيات إدارة المخاطر وتبادل المعلومات في الوقت المناسب من أجل وضع وتطبيق القوانين الملائمة عالمياً بالإضافة إلى التعاون الدولي. وتلقى هذه الدراسة نظرة عامة للتحديات والحلول من اجل سلامة الأغذية من التلوث الكيميائي خاصة في منطقة الخليج..

ABSTRACT: Food safety is a major consumer's concern worldwide. Although several incidences of food poisoning have placed microbial contamination on the forefront during recent years, health risks due to chemical contamination still remain high. The most often cited chemical contaminants are derived from a variety of sources such as pesticides, environmental chemicals (PCBs, dioxin, heavy metals including lead, mercury), chemical contaminants as a result of food processing (acrylamide, nitrosamines etc.), naturally occurring toxicants (glycoalkaloids, mycotoxins, antinutritives etc.), chemicals migrating from packaging materials, veterinary drugs and other chemical residues. In addition to the presence of unintentional contaminants, the quality and safety of foods could also be compromised by the addition of certain food additives, phytonutrients, exposure to irradiation and other substances. Food processors and the regulatory and enforcement agencies are facing an ever-increasing challenge to meet the consumer's demands for safe foods that do not pose health risks or alter their lifestyle. As the food trade expands throughout the world, food safety has become a shared concern among both the developed and developing countries. Although food control systems do exist in the countries of Gulf region, in most of the cases they are not in line with national and international needs and are not able to cope with the new challenges of the modern era. The most appropriate methods to ensure the safety of food supplies are the strengthening of regular surveillance systems, developing methods for the systematic application of risk analysis, risk assessment and risk management strategies, and timely communication of information to develop and enforce the appropriate food safety laws globally as well as the development of international and national cooperation. This paper reviews issues, challenges and solutions to achieve food safety with respect to chemical contaminants, with emphasis on the Gulf region.

Keywords: Food safety, chemical contaminants, health risks, risk assessment, risk management strategies.

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Food is essential for sustenance of the human race. Availability and abundant supply of food at a reasonable cost has always remained a priority on the agenda of both developed and developing countries. In 1992 the FAO/WHO Conference concluded that "Access to nutritionally adequate and safe food is the right of each individual". Since the end of World War II, major scientific advances have been incorporated globally in the production, protection, prevention, processing, marketing, communication, and consumption of food. Although the abundant supply of food has been the major achievable goal, food safety has remained a matter of concern. Food safety is not a new phenomenon. It is a growing concern worldwide. The explosion of advances in the mode of communication has produced enhanced awareness about the supply of safe food. This has increased the need for enhancing international and national cooperation as well as towards the development and enforcement of appropriate food safety laws globally (Watson, 1992). Recent studies have shown that toxic and nutritionally important chemicals exert a far greater influence over human health than previously thought (WHO, 2002a). New chemical hazards in foods that would affect human health are continuously being identified. Illness due to the consumption of contaminated food is perhaps the most widespread transmissible health problem in the world today and an important cause of reduced economic productivity (Kaeferstein, 2003a). Food and waterborne diseases are responsible for the death of an estimated 2.2 million people annually. Greater life expectancy and increasing numbers of immuno-compromised people mean a larger vulnerable population, for whom unsafe food is often an even more serious threat (WHO, 2002b, Kaeferstein, 2003a).

More and more people are asking the question: "Is it safe to eat what is available?" People are concerned about the safety of their food because of the presence of exogenous chemicals, which find their way into food during production, processing, transportation and storage. The most often cited chemical contaminants are derived from a variety of sources: agricultural chemicals (pesticides), environmental chemicals (PCBs, dioxin, heavy metals including lead, mercury), chemical contaminants as a result of food processing (acrylamide, nitrosamines, solvent residues from extraction processes etc.), naturally occurring toxicants (glycoalkaloids, mycotoxins, antinutritives etc.), chemicals migrating from packaging materials (polyvinyl chloride), antibiotics and veterinary drugs and other chemical residues. In addition to the unintentional contaminants, the quality and safety of foods could be compromised by the addition of certain food additives, phytonutrients, exposure to irradiation and other substances. Public's food safety concerns are more focused on long-term risks that may be caused by the consumption of invisible, unknown or controllable chemicals (Fennema, 1990; Alcock, 2000; Lefferts, 2000; Peshin *et al.*, 2002). Symptoms of exposure vary with the class and dose of the compound. In many cases, some of these effects are caused by exposure to groups of different chemicals. Cancers, birth defects and brain damage are some of the main concerns cited in public. The economic, trade and health burden from these effects totals billions of dollars annually in the world.

Major Issues

CHEMICAL CONTAMINANTS AND THEIR HEALTH EFFECTS: A chemical contaminant is a substance not intentionally added to food. However, these contaminants enter food during production, protection, manufacturing, preparation, treatment, packaging, transportation, and storage as well as from environmental effluents as a result of industrialization. The levels of concern and anxiety shown by regulators and consumers are high due to the perceived potential toxicity of these contaminants, which may be hazardous to human health in short and long term exposure through diet and water. Two main sources of exposure to chemicals include: direct exposure during agricultural operations and indirect exposure ingesting foodstuffs containing the chemical in question. The role of food safety activities is to assure consumers that no adverse health effect would occur if food was processed and consumed in the manner and quantity described.

The major factors influencing food safety include: microbiological hazards such as pathogenic bacteria, viruses, and parasites, and chemical hazards such as environmental contaminants, pesticides, heavy metals, mycotoxins, residues of antibiotics and veterinary drugs, natural toxicants, food additives, toxic chemicals produced during food processing/cooking and radio-nucleotides. In recent years reporting of food poisoning incidences worldwide has placed the focus of food safety on microbiological contamination. Significant increase has been reported in the past few decades in the incidence of diseases caused by microorganisms that are transmitted mainly by foods, such as *Salmonella spp.* and *Compylobacter spp.* New serious hazards have also emerged in the food chain, such as enterohaemorrhagic *Eschericia coli* and *bovine spongiform encephalopathy* (BSE) (WHO, 2002a, b). Based on scientific criteria including severity, incidence and onset of biological symptoms, microbial contaminants are considered to be more significant food safety issues. However, consumer's perceptions identify environmental contaminants and food additives as being high on their list of priorities. The chemicals, which are added to food during modern processing, are, however, most stringently examined for their toxic effects (Clayson, 1993).

The reason for such dichotomy is that the consumption of microbiologically contaminated food produces rapid symptoms. Proper food handling and processing can eliminate or destroy about 95% of microbiological contamination. However, the same is not true for traces of chemical contaminants. Evidence of health effects due to low level exposure of chemical contaminants are not rapid, except in cases where there has been major exposure as a result of disaster such as explosions in Seveso (Italy), Bhopal (India), Veracruz (Mexico). Most often chemical contaminants produce effects after chronic exposure by imparting toxic effects such as damaging the developing fetus (teratogenicity), altering the genetic code (mutagenicity) or inducing cancer (carcinogenicity). Continued chronic exposure to certain classes of compounds can depress cell immunity, cause abnormal hormonal behaviour, disruption of mammalian endocrine systems, and can also involve mutagenicity, carcinogenicity and immunotoxicity (Berry, 1997; Davis *et al.*, 1998).

SOURCES OF CHEMICAL CONTAMINANTS: In both developed and developing countries the demands for synthetic fertilizers, pesticides and antibiotics (as veterinary medicine and growth promoters in feed) have witnessed considerable growth in their use in agricultural production over the last few decades. In addition to this, wastes and sludges, which are also being used regularly as fertilizers on farmlands, further contribute to the presence of chemicals. Most of the concerns related to health consequences, however, center around the use of pesticides in agriculture.

PESTICIDES: The term pesticide collectively refers to insecticides, herbicides, and fungicides. The major classes of pesticides are labelled together according to their chemical structures. In 1995, the worldwide consumption of active pesticide ingredients was 2.6 million metric tons, 85% of which was used in agriculture, having a total worth of US$38 billion. Japan, North America, Western Europe accounted for over 70% of the total pesticide consumption. Herbicides mostly belong to the triazene (atrazine), and chlorophenoxy (2,4-D, 2,4,5-T) families, whereas insecticides are classified as organochlorines (DDT, dieldrin, lindane, chlordane), organophosphate (diazonin, malathion, dichlorvos), carbamate (carbofuran, carbaryl) and pyrethroids (permethrin, deltamethrin). In agricultural production systems they can be applied directly on crops (from seed to germination, maturing and storage stages) to kill and control the insect population, and on soil to control weeds. They are also used in and around the food manufacturing processes to control insect and rodent populations. Pesticides also find usage in homes as well as in gardens. The use of pesticides in agricultural practices is advocated because they increase yield, a good return on investment (more food for less labour input), and improve food quality (Echobichon, 2001). However, the presence of their residues in the food chain has raised major concerns (Ames and Gold, 1990; Dittus and Hiller, 1993; FAO/WHO, 1993; FDA, 1993; Gold *et al.*, 1997; Lefferts, 2000).

Organochlorines in general have low acute toxicity (100-200 $mg.kg^{-1}$ body weight), but at higher doses can impact negatively on death. The most important member of this family is dichlorodiphenyltrichloroethane (DDT), which induces microsomal enzymes in animals and man and is shown to be responsible for increased incidence of liver tumour in mice (Ames and Gold, 1990). Although DDT, endrin, aldrin and dieldrin are not mutagenic, genotoxic or teratogenic, they are classified as "probable" carcinogens in humans because they have demonstrable clastogenic activities during *in-vitro* and *in-vivo* studies in rats (IARC, 2002). DDT and other organochlorines are degraded effectively by sunlight in tropical countries, but persist in temperate zones. Their bioaccumulation in tissues and biomagnification in food chains are the major reasons for their discontinued usage.

Wildlife and humans are exposed to organochlorines directly or indirectly. They are persistent in the environment, bioaccumulate in fatty tissues and are termed persistent organic pollutants (POP). They have been shown to implicate interrupted sexual development, thyroid system disorders, inability to breed and reduced immune response in wildlife and, as such, act as endocrine disruptors. A recent study on methoxychlor, a DDT substitute, has shown this to block the male hormone system, affecting mating behaviour, and sperm counts (Colborn *et al.*, 1999). The effects of endocrine disruptors on animals vary, ranging from alligators born with abnormally small penises, and birds with crossed beaks, to sudden disappearance of entire populations. In humans, premature puberty in girls in developing countries is supposedly due to increased level of DDT in their blood (Krstevska-Konstantinova *et al.*, 2001). In general, organophosphates (OPs) have high acute toxicity because they inhibit acetylcholinesterase (AChE) in nervous tissues of both man and insects. The inhibition is, however, reversible. A few OPs also induce delayed forms of neurotoxicity. In general, all esterified alkyl phosphates; phosphonates and their thio derivatives are suspected carcinogens. Further, dimethyl vinyl phosphates (tetrachlorvinhos, dichlorvos) are carcinogenic in at least one animal species (Colosio *et al.*, 2003; Farahat *et al.*, 2003; Holstege and Baer, 2004).

Carbamates behave like organophosphates (OPs) since they can also inhibit AChE, which is reversible, and as such exhibit similar toxicity. However, carbamates do not induce delayed neurotoxicity. Carbamate pesticides affect different subtypes of neuronal nicotinic receptors independently of acetylcholinesterase inhibition. This implies that neuronal nicotinic receptors are additional targets for some carbamate pesticides and that these receptors may contribute to carbamate pesticide toxicity, especially after long-term exposure (Smulders, 2003). Pyrethroids are the newer generation of synthetic insecticides with high insect and mammalian toxicity. Deltamethrin, cypermethrin and permethrin are important members of this class of insecticides. They are easily metabolized by warm-blooded animals, including man, and do not accumulate in the environment, but are highly toxic to fish. Cyano-pyrethroids, such as deltamethrin, cypermethrin, and fenvalerate, exhibit CNS syndrome due to release of HCN during their metabolism. Pyrethroids are however, eliminated from the animals quite rapidly and completely, undergoing oxidation and ester hydrolysis followed by various conjugations with low tissue residues (Miyamoto *et al.,* 1995).

ANTIBIOTICS AND VETERINARY DRUGS: Synthetic chemicals have become an integral part of animal production systems and are given different names according to their functions or effects, e.g. growth promoters, feed efficiency enhancers, etc. FAO defines veterinary drugs as "Any substance applied or administered to any food producing animal, such as meat or milk-producing animals, poultry, fish or bees, whether used for therapeutic, prophylactic or diagnostic purposes or for modification of physiological functions or behaviour". These include a wide spectrum of compounds including antibiotics, growth hormones, sulfonamides, dimetridazole and carbadox (FAO/WHO, 1993, FAO, 2003). It is estimated that about 80% of all Canadian and United States livestock are treated with drugs, sometimes during their lifetime. The most frequently used drugs in animal production systems are antibiotics, which are also used regularly in humans to treat diseases. The routine use of these drugs in animal production systems and fish farming has potential for residues in products from these animals. The use of drugs in animal and fish production systems is a growing concern with researchers, regulatory officials and with the public because the animals act as biological filters and deposit residues in their products such as meat, milk, egg and fish flesh (Boxall *et al.*, 2004; MacNeil, 2003). There is a growing concern that the consumption of animal products and fish containing traces of antibiotics would give rise to resistant bacteria and in turn the commonly available antibiotics will become ineffective in treating diseases putting the populations at greater risk. There is already some evidence for the presence of "super bugs" which are resistant to the currently available antibiotics (Coast *et al.*, 2002, WHO, 2003).

NITRATE, NITRITE AND N-NITROSAMINES: The main dietary source of nitrate and nitrite are the fertilizers and the preservatives used in treating the meat to inhibit the production of botulinum toxins. Nitrate, which is an inactive compound, is produced in plants from nitrogenous fertilizers. Nitrate undergoes reduction to nitrite which then, under appropriate conditions of pH and temperature, can react with endogenous primary and secondary amines to form N–nitrosamines, some of which have been shown to be carcinogenic in experimental animals (Verhagen, 1997). Nitrosamines are found in a large number of food products, but N–nitrosodimethyl-amine (NDMA) has caught much attention because it induces cancer in a wide variety of laboratory animals and is a suspected cancer agent for humans. Nitrosamines are routinely found in cured meats and alcoholic beverages (National Academy of Sciences, 1981; Hill, 1988).

INDUSTRIAL/ENVIRONMENTAL CHEMICALS: These are diverse in structure, but can broadly be classified into two categories: i) inorganic (metals), organometallic, and ii) organic substances (PCBs, Dioxins). The human body needs a variety of trace elements for various metabolic processes. However, beyond tolerance levels these elements are detrimental to human health and can lead to adverse effects. Lead and mercury are the most undesirable elements in foods because of their well-documented negative health effects. The main dietary source of lead, in addition to its absorption from soil and water run off from mining operations, is through leaching from lead-soldered food cans, appliances used in cooking (specially in developing countries), transfer from water pipes and storage. Mercury is used in mining and industrial operations. It can be released into the environment, deposited in watersheds and can in turn contaminate fish and wildlife. People consuming such contaminated fish can suffer from neurological diseases (Chan and Egeland, 2004). Methyl mercury was used as seed dressings for a long time. The consumption of mercury-treated seeds has caused considerable serious illness, including death (National Research Council, 2000).

In addition to environmental inorganic compounds, agricultural produce can also be contaminated with organic chemicals that are not intentionally applied during production, protection and preservation. They are produced during municipal incineration, domestic coal fires, vehicle exhausts and metallurgic processes. They can then be deposited on soil, water and agricultural produce. They form a class of compounds which are commonly referred to as environmental organics. Important members of this class are polychlorobiphenyls (PCBs), polychloro dibenzo-p-dioxins (PCDDs, dioxins) and polychloro-dibenzofurans (PCDFs, furans). All these compounds are highly chlorinated and are resistant to biological degradation. The degree and position of chlorination determines the retention, stability and the acute toxicity of these compounds. The greater the number of chlorine atoms, the higher is the toxicity. A variety of adverse mental and physical abnormalities have been observed in infants when exposed *in-vitro* to elevated levels of heat degraded PCBs. Although the observed neuro-developmental deficits have been described as subtle, there could be unknown consequences related to future intellectual functionality (Feeley and Brouwer, 2000). Based on estimated daily human intake range (14-37 $pg.kg^{-1}$ body weight) for the most sensitive responses from animal studies, and applying a composite uncertainty factor of 10, a tolerable daily intake of 1-4 $pg.kg^{-1}$ body weight for dioxin was established by WHO (Rolf van Leeuwen *et al.,* 2000).

There is convincing evidence to show that industrial chemicals like PCBs and their condensation products, dioxins and furans, contaminate the food chain (Berry, 1997). Whole day food rations were found contaminated by various pollutants with variable quantities in different regions of the world (Singh and Chawala, 1988; Saeed *et al*., 2001, Skibuiewska, 2003). This has provided valuable information on health quality of foods as well as trends in their concentration changes in total diet samples.

NATURAL TOXICANTS INCLUDING ANTINUTRIVES: Higher plants produce substances, mostly for their protection from predators, which may act as antinutritives as well as being toxic to animals and humans. Higher plants produce weakly estrogenic compounds such as isoflavones or their glycosides, coumestans (genistein, glycetein, daidzein) and a variety of other compounds. Animals grazing on certain forages, like subterranean clover and alfalfa that contain such estrogenic compounds, have shown toxic symptoms. However, epidemiological studies suggest that isoflavones in soybeans play an important role in reducing the incidences of cancers and hot flushes in oriental women. Fungal attacks on grains, fruits, and nuts produce toxic substances, which are collectively called mycotoxins. The formation of mycotoxins is highly dependent on climatic conditions. Wet, humid, and hot climates are the optimum conditions for mycotoxins production. Aflatoxins B1, M1, zearelenone, vomitoxin (commonly known as DON, deoxylivanenol),and fumonisin are the major mycotoxins that are known to be toxic to animals. FAO has estimated a worldwide loss of about one billion metric tons of foodstuffs per year as a result of mycotoxins (Bhat and Vasanthi, 2003).

FOOD PROCESSING: Although food processing improves the safety and quality of foods, there are examples of adverse effects from the chemical point of view. A recent Swedish study disclosed the presence of high levels of acrylamide, a known animal carcinogen, in potato crisps and biscuits. The source of acrylamide was found to be a Maillard reaction between asparagine and sugar in potatoes produced during cooking and baking (Mottram *et al.,* 2002; Stadler *et al.,* 2002; Wenzel *et al.,* 2003). It would not be surprising if other analogues of acrylamide are detected and identified in many other baked and cooked foods. It is interesting to note that similar concern also prevailed when high levels of N-nitrosamines were detected in baked bacon strips (Sugimura, 1986; Vecchio *et al.,* 1986).

CHEMICALS MIGRATING FROM PACKAGING MATERIALS: The risk of chemicals migrating from packaging materials is not very great. Nevertheless, there is some concern regarding potential contamination. Since the introduction of plastic as a packaging material, a number of chemicals have been added to it, to improve its strength and elasticity. In addition to this, potential contamination for recycling of polyethylene terephthalate (PET) containers has also been evaluated (Jetten, 1999; Bayer, 2002; Begley *et al.*, 2002). Over the years a number of toxic compounds have been identified which migrate from the packaging materials into the food. These include styrene, benzene, toluene and phenol. There are potential problems of leaching of such chemicals from plastics to the foods that come in contact with the packaging material (Grob *et al.,* 1999). Several volatile compounds were found present in the ozonated water that had been in contact with polypropylene (PP) caps, ethyl vinyl acetate (EVA) liners, and high-density polyethylene (HDPE) bottles. These compounds are not hazardous but could cause off-taste and off-odours and low organoleptic thresholds (Song *et al.,* 2003a). Paper containers are commonly used in packaging liquids such as milk. Since the containers are made from wood chips, they may contain polychlorinated propylene (PCP) and other chlorinated compounds such as dioxins and benzofurans. There is a potential risk that these highly toxic chemicals may leach from paper cartons to milk. Song *et al.* (2003b) concluded that over an extended period of time at 100 °C, polypropylene (PP) film would not be an acceptable barrier to the migration of contaminants from the paper/paper board to the food material.

Challenges

Globally, consumers are demanding safe and wholesome food at affordable prices. They are becoming more and more knowledgeable in understanding the relationship between diet and health. Unfortunately, recent well-publicized events have eroded their confidence in safe food supply. The globalization of food trade offers many benefits to consumers, as it results in a wider variety of high quality foods that are accessible, affordable and meet the consumer's demand. However, the safety of such foods remains a big challenge as the extensive food distribution systems raise the potential for rapid, wide spread distribution of contaminated food products. The risk posed by chemicals and microbiological hazards is ever increasing.

Traditional food safety measures have not been efficient in preventing food borne diseases over the last decades. It is a challenge for the governments in developed as well as in developing countries to accept this reality and take steps to ensure the consumers that industrialization and modernization of food production systems as well as the globalization of food trade will not compromise food safety. Government officials need to be seen as good housekeepers of safe food. Consumers also need to be assured that modern agricultural production systems do not impact negatively on the environment. Sustainable agricultural practice is, however, highly desirable. Foods produced using sustainable practices are in great demand in developed countries. As most of the potential effects of these chemicals are chronic in nature, assessing the actual intake of these chemicals by humans over a lifetime is of great significance in food safety and human health. New understanding about the potential effects of chemicals on the immune, endocrine and nervous systems should continue to be incorporated into hazard characterization of chemicals in food. The biggest challenge is to meet the consumer's demand for safe food that does not pose health risks or alter their lifestyle. Safe food will not only reduce health care costs but will also aid a productive and enjoyable lifestyle.

Solutions

Consumers demand food, which is safe, nutritious and can support a healthy lifestyle. Strengthening of food safety and quality control systems, promoting good manufacturing practices and educating the food retailers and consumers about the appropriate food handling procedures are essential for proper health and good nutrition. It has been suggested that food safety must be integrated along the entire food chain, from farm to table, with all the three sectors - government, industry and consumers - sharing the responsibility (Kaeferstein, 2003b). Although food control systems exist in the countries of Gulf region, in most cases they are not in line with the national and international needs and are not able to cope with the new challenges of the modern era (WHO, 1999). The importance of raising the nutrition literacy among the Middle Eastern population has also been highlighted (Galal, 2001).

Risk assessment as a tool for monitoring food safety has gained rapid acceptance recently. It is based on both the toxicological information and estimates of exposure of the population to the chemicals. The major steps in the risk assessment process are: (1) hazard identification (collection, organization, and evaluation of information), (2) dose-response assessment (relationship between a toxicant and any adverse effects), (3) exposure assessment (distribution/ total daily toxicant intake), and (4) risk characterization (evaluation of risk).

There could be two complimentary approaches for risk assessment: (i) commodity oriented assessment - to monitor the individual foods for their compliance with national and international regulatory standards in relation to maximum residue level (MRL), and (ii) Total Diet Studies (TDS) - to maintain the actual dietary consumption of chemicals by populations and to compare intake with toxicological reference points, such as acceptable daily intake (ADI), or provisional tolerable weekly intake (PTWI).

TDS answers the fundamental question of whether or not the national diet is safe (Egan *et al.*, 2002). The accuracy of such studies depends on two basic data components, the quantity of each individual food consumed (usually collected through surveys) and the background concentration of toxic chemicals in foods when ready for consumption. WHO has initiated such studies under the Global Environmental and Monitoring System/Food Contamination Monitoring and Assessment Program -GEMS/Food (WHO, 2002a).

In feudal days rulers used tasters to ensure that the food was not poisoned. Today such practices are neither ethically nor legally acceptable. In view of the ever increasing number of chemicals that need to be monitored, *in-vitro* models are being used as bioassays, hereby detecting the compounds and groups of compounds by their biological activity rather than by their physicochemical properties (Hoogenboon and Kuiper, 1997). Currently, we rely heavily on sophisticated analytical techniques to provide information on the nature and quantity of toxicants present in the diet. Application of standard operating procedures (SOP) are important in helping to identify and assess risk. The common steps required for all types of trace analysis include:

a) *Collection of representative samples, storage and sub-sampling:* It is a critical part of risk assessment and must be planned and managed effectively. The heterogeneity of food samples sometimes makes it difficult to get samples which are really representative of the bulk samples. A valid sample is made up of some random samples that are representative of the food/ produce being analyzed. Sampling should be as representative as possible and be coordinated with sample preparation and analysis. Thus 5 or 6 one-gram portions of a bulk sample is statistically a better representation than a 5 or 6 gram piece. Storage could also cause degradation of chemicals under investigation that would give inaccurate and false values. Designing a study requires the services of a biometrician (statistician) who will advise on location, quality and quantity of samples as well as the need for the sensitivity and accuracy of analytical techniques.

b) *Extraction of chemical residues:* Extraction of chemical residues from food matrices with appropriate solvents (isolation, cleanup and enriching) followed by analysis; identity confirmation, quantification, tabulation and validation, are effective procedures. This is the step on which the accuracy of the results depends. Choice of solvents is greatly dictated by the chemical properties of the analytes as well as the matrices of the samples. In the first step crude extracts can be analyzed directly for screening/semi qualitative purposes using thin layer chromatography, enzyme inhibition, and immunoassay techniques. Other precise analytical techniques, such as gas chromatography (GC), high performance liquid chromatography (HPLC) and combination of GC and HPLC with mass spectrometry (MS), require samples that have undergone cleanup and/or enrichment steps to remove particulate matter and other undesirable residues as well as to concentrate the chemical being investigated. Selective ion monitoring (SIM) is an effective technique to eliminate the undesirable matrix responses, but with the trade-off of selecting specific analytes for analysis. Currently, gas chromatographs are using capillary columns with efficiencies upward 10^6 theoretical plates. In recent years, supercritical fluid extraction methods and microwave assisted extraction techniques have been employed to minimize the steps in sample preparation (Akhtar, 1998; Turnipseed and Long, 1998).

c) *Analysis of data and looking for variations:* The difficult task begins after the analyst has provided the data on the nature and quantity of chemical residues. The question arises as to what do all these values mean? How do the residues fit in with local/national or international threshold criteria such as maximum residue levels (MRL), average daily intake (ADI), and potential tolerable weekly intake (PTWI), which have been set earlier? Has the situation improved or declined since the last survey? If yes, then what are the reasons and what remedial measures should be adopted?

d) *Communication of results:* Reporting of surveillance data to appropriate regulatory agencies/compliance enforcement authorities is important for further actions, including the development of guidelines for future surveillance. Risk communication strategies should also be developed for the public, based on risk rather than on hazard, in an understandable language. Summaries of the information could be given to the public through various forms of communications.

Conclusions

Rapid industrialization and introduction of new farming and food processing techniques have brought forward new challenges for both scientists and the food regulatory and enforcement agencies. Food safety programs are increasingly focusing on a farm to table approach as an effective means of reducing foodborne hazards. Successful and creditable regulation should be based on sound scientific knowledge. Rapid screening methods and their validation through confirmatory analysis should be developed for multi-residues measurements. Improvement of food hygiene and control of chemical contaminants must become the integral part of national plans of nutrition and health. Open communication including education, proper surveillance systems, developing methods for systematic application of risk analysis, improving risk assessment, development of risk management strategies, timely communication of information and improving national and international cooperation, would go a long way towards ensuring the safety of our food supply.

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