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Review

The history, genotoxicity, and carcinogenicity of carbon-based fuels and their emissions: Part 5. Summary, comparisons, and conclusions

Larry D. Claxton *

LDC Scientific Services, 6012 Brass Lantern Court, Raleigh, NC 27606, United States

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ABSTRACT

As seen through the previous reviews, each carbonaceous source of energy is associated with genotoxic and carcinogenic health risks; however, energy use is central to human society and provides many health benefits. These reviews examined the genotoxicity of carbonaceous sources of energy, focusing on the impacts due to the combustion of fuels and biomass. In previous reviews, information and data were used to examine occupational, industrial, household, and general environmental pollution as well as laboratory research. In this final summation, the effort is not only to summarize the previous reviews but to provide additional information to support any final conclusions. Included in the final observations are: (1) emissions from combusted carbonaceous fuels are very likely to include genotoxicants and/or carcinogens, and, as such, they can considerably increase the risk of adverse health effects in exposed humans, (2) environmental transformation is likely to increase genotoxicity of emissions, and (3) the world's poor households have an increased health risk because they have limited access to clean fuels and electricity. Because carbonaceous fuel emissions are highly complex, risk assessments are difficult; however, decision makers have many toxicological approaches for evaluating emissions. Although energy efficiency brings many benefits, it also involves health risks, as do renewable energy systems, if not managed carefully. The reviews do not examine climate change or non-carbonaceous fuels (e.g., nuclear fuels). Because these are not papers about the risk assessment or regulation of pollutants from carbon-based fuels, the discussions of regulations were to place research, concerns, and actions into a historical reference for the reader.

Contents

* Tel.: +1 919 839 8978.
E-mail address: ldcss@gmx.com

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1. Introduction

While doing the previous reviews [1–4], I personally came convinced that most, if not all, of the combustion emissions of carbon-based fuels are genotoxic and carcinogenic. In addition, I am convinced that many of the carbonaceous fuels themselves, especially those that have undergone heat and pressure transformation (e.g., crude oil), are genotoxic and carcinogenic. I came to this conclusion when I became certain that these substances were usually seen to give positive results in a variety of genotoxicity assays and cancer studies and contain known genotoxicants and carcinogens. Therefore, this summary details this belief mainly by providing additional evidence taken from the literature and not retelling what is found in the earlier reviews. As stated in the first paper of this series: (1) The production of energy entails both quantifiable risk and measurable benefit. (2) Depending on a person's circumstances and beliefs, individuals may put a disproportionate emphasis on either the hazard or the benefits of a substance or technology. The differences reflect differences in underlying assumptions, methodological approaches, and other factors. (3) These reviews are designed for those in multiple disciplines; however, effort is not directed toward describing and explaining genotoxicity and cancer bioassays, and (4) as our societies make choices among which fuels to use, these reviews attempt to provide a common understanding of the genotoxicity and carcinogenicity of one class of fuels.

I also believe that our decision makers are doing their best to reflect their constituents' views and to provide modern technologies and needed energy sources. A primary need is decision making that also protects the public's health and the environment. Energy policies consist of highly technical information and have many social, political, and moral implications. Because it is an almost impossible task for decision makers to filter through this quagmire of information and come to rational decisions, scientists must provide unemotional views of the information and data surrounding a topic. I hope I have done that.

The history of mankind revolves around the development of energy sources and their combustion. Most of the progress in human culture has required the exploitation of energy resources [5]. The development of carbon-based fuels has increased comfort, longevity, useable products, and the affluence of humans. Most presently used energy technologies rely on chemical bonds of hydrocarbons which are derived from solar energy and stored in the hydrocarbon bonds of plants and animals. Humans continue to exploit this hydrocarbon energy. In antiquity, principal energy sources were derived directly from the sun including human and animal muscle power, agricultural resources, wood, flowing water, and wind. About 300 years ago with the beginning of the industrial revolution, these energy sources were basically replaced by fossil hydrocarbons: coal in the nineteenth century, oil in the twentieth century, and now, increasingly, natural gas. The global use of hydrocarbons for fuel by humans has increased nearly 800-fold since 1750 and about 12-fold in the twentieth century [5].

There is a competition between the demands for more energy and the demands for the protection of life, health, and the environment; however, in these reviews, the term environment excludes dietary factors, lifestyle habits (e.g., smoking), and infectious agents. Therefore, individuals may have little or no personal control over the exposures discussed. However, environmental exposures include the air we breathe, the water we drink, the soils we contact, and the pollutants we have in our foods [6]. In industrialized, modern societies, pollutants consist of contaminants continuously added to the environment. Many of the carcinogens found in this modern society are actually complex mixtures of compounds (e.g., automotive emissions, industrial emissions). The assigning of significant carcinogenicity to these