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Review

Implications of leading crop production practices on environmental quality and human health

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ABSTRACT

Globally, much weight is currently being placed on agriculture to provide food for the growing population as well as feedstock for the bioenergy industry. Unfortunately, the intensification of agricultural operations to satisfy these growing needs has been associated with a number of environmental and human health risks. A review of publications on the subject was conducted and emphasis was placed on articles focusing on agriculture, environment, and public health as well as their interactions. Supporting information was also gathered from publications of various agricultural and environmental agencies. Agricultural practices with potential negative implications on the environment and human health were identified broadly as: (a) utilization of biosolids and animal manures, (b) use of agricultural chemicals, (c) management of post-harvest residue, (d) irrigation, and (e) tillage operations. Soil, water, and air contamination by nutrients, heavy metals, pathogens, and pesticides, as well as air contamination by particulate matters, noxious gases, and pathogens were among the leading environmental impacts. Some of the human-health impacts identified included neurological and reproductive defects, cardiovascular risks, cancers and other diseases (of kidney, liver, lung, and skin), skin allergies, gastroenteritis, and methemoglobinemia. Continual awareness on the impacts of the reviewed agricultural practices on environmental quality and human health and the implementation of experimentally-backed best management practices in agricultural systems remain indispensable.

1. Introduction

Environmental quality and human health are issues of global concern, particularly in this era of rapid industrialization, intense agricultural operations, and climate change. Of interest, the quest for alternative energy sources has led to the intensification of agricultural operations to offset the demand on energy crops such as sugarcane, corn, and soybean, thus, deepening the adverse impacts of agricultural activities on climate change and human health (Alcamo et al., 2005; De Fraiture et al., 2008). In most agricultural settings, management practices are often evaluated based on their economic benefits with less attention given to the environmental and public health perspectives. Attempts at addressing such shortcomings surely warrant an understanding of producers' preferences for any given crop and soil management approach since studies have shown that producers are motivated by a combination of financial, environmental, and personal incentives (Ecker et al., 2012). In the Unites States (US), efforts are being made by federal agencies such as the United States Environmental Protection Agency (USEPA) and United States Department of Agriculture (USDA) as well as their state counterparts, to create awareness of the implications of agricultural activities on environmental quality (USEPA, 2005; Elrashidi et al., 2010). Likewise, the World Health Organization (WHO) has also identified critical links between

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agriculture and human health (Hawkes and Ruel, 2006). However, current data and future projections suggest the need for implementation of best management practices in agricultural systems to curb the environmental degradation and human health risks associated with modern-day agriculture (Alcamo et al., 2005; De Fraiture et al., 2008; Costello et al., 2009).

A variety of pollutants discharged from agricultural sources are notably associated with environmental pollution (USEPA, 2003; Gerba and Smith, 2005). Commonly documented pollutants from agricultural sources include nutrients, trace metals, organic carbon (OC), pesticide compounds, noxious gases, and pathogens (USEPA, 2005; Gerba and Smith, 2005; Menzi et al., 2010). Certain agricultural practices such as the application of organic amendments (animal manures and biosolids), inorganic fertilizers, and pesticides; crop residue handling; and irrigation water use have often been cited as sources as well as facilitators of the transport of the aforementioned pollutants within the environment (USEPA, 2003; Udeigwe et al., 2010).

Various health-related issues in humans have also been attributed to a number of agricultural pollutants. For instance, linkages between cancer and certain agricultural pesticides (Alavanja et al., 2003) and between respiratory diseases and particulate matters ($PM_{2.5}$ and PM_{10}) (Arbex et al., 2007), have been widely documented. Likewise, a number of human health issues relating to trace element ingestion have been noted (Uriu-Adams and Keen, 2005; Boxall et al., 2009). Pathogens present in animal manure and biosolids have been shown to cause a number of health problems in humans (Mathis et al., 2005; Sidhu and Toze, 2009), while environmental contamination by nutrients from agricultural sources has also been tied to health risks in humans (Fawell and Nieuwenhuijsen, 2003; Kalantar-Zadeh et al., 2010). Current findings have also highlighted the relationships between human exposure to agricultural contaminants and climate change; projecting that the risks of these contaminants to humans could increase considerably in the future (Boxall et al., 2009).

The intensification of agricultural practices to provide feedstock for the biofuel/biodiesel industry and food for the growing world population further deepens the aforementioned challenges. Thus, the aim of this paper was to highlight current perspectives on the impacts of key crop production practices on both environmental quality and human health. The first part of this work will discuss the key crop production practices of environmental and human health concerns, followed by a description of the principal contaminants from agricultural sources, and their impacts on the environment and human health.

2. Principal crop production practices of environmental and human concern

2.1. Biosolids and animal manure utilization

Biosolids (aerobically and/or anaerobically digested sewage sludge) and manure are historically used on agricultural soils as sources of plant nutrients, with a growing use of solid manures as amendments to increase soil organic matter (SOM) content especially on light soils and degraded landscapes (Kimetu et al., 2008). Biosolids, a by-product of municipal wastewater treatment plants, is characterized as a complex mixture of OM (USEPA, 1999); while animal manures are solid and liquid animal wastes that may be treated (by composting, aerobic or anaerobic digestion, or solid separation) or untreated before use. In the US alone, it is estimated that 8×10^6 tons of dry biosolids are produced annually and about half of these are land applied (USEPA, 1999; Iranpour et al., 2004). Land application of biosolids has increased over the years since many states now have more stringent laws governing landfill disposal; likewise, incineration of biosolids has also decreased since many incinerators are unable to meet the USEPA 503 regulations of the Clean Air Act (Epstein, 2002). In Europe, about 2.39×10^6 tons of dry biosolids which is equivalent to 37% of the total amount produced are reportedly land applied annually (Chang et al., 2002). It is reported that biosolids production is considerably more of an issue in Europe considering the amount of sludge produced to agricultural area available for beneficial use (Iranpour et al., 2004), thus, suggesting potential future environmental problems. Similarly, livestock production in the US generates over a billion tons of manure annually (USEPA, 2011), some of which are injected or surface applied and incorporation.

The use of biosolids and animal manures as soil amendments has often been associated with environmental contamination. Biosolids and manures contain considerable quantities of nitrogen (N), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), and phosphorous (P), as well as OC (Powers, 2004; Sullivan et al., 2006; Udeigwe et al., 2009; Stietiya and Wang, 2011). The devastating impact of the direct runoff of nutrients, particularly P and N, from land applied and stored manures and biosolids on surface water quality have also been cited (Rostagno and Sosebee, 2001; Hoorman et al., 2008). Biosolids and manures have also been cited as major sources of trace metals (e.g. copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), nickel (Ni)) (Iranpour et al., 2004; Schroder et al., 2008) (Table 1), and harmful pathogens (e.g. *Campylobacter* spp, *Salmonella* spp, *Escherichia coli*, *Cryptosporidim parvum*, etc) (Gerba and Smith, 2005; Sidhu and Toze, 2009) additions to soil and water. Direct discharge of gases such as methane (CH_4), ammonia (NH_3), hydrogen sulfide (H_2S), and carbon dioxide (CO_2) from stored and applied biosolids and manures (Chadwick et al., 2011; USEPA, 2011) especially manure stored in deep (anaerobic) but exposed lagoons, has also been noted for its environmental and health implications.

2.2. Use of agricultural chemicals

Commercial crop production is highly dependent on the utilization of agricultural pesticides (i.e., any chemical applied to control weeds, insects, plant disease, and rodents). It was estimated that over 11.5 billion kg of pesticide active ingredients (valued at $39.4 billion) were used worldwide in 2007, with over 2.5 billion kg (~$12.5 billion) used in the US alone (Grube et al., 2011). In the US, the agricultural sector accounts for over 70% of all conventional pesticide used. Estimates of pesticide used by the US agricultural

Table 1
Levels of trace elements that occur as impurities in common fertilizers added to agricultural soils.[a]

	Source			
	N fertilizer	P fertilizer	Manure	Sewage sludge
	mg kg^{-1}			
As	2–120	1–1200	3–25	2–30
Cd	0.05–8.5	0.1–190	0.1–0.8	<1–3400
Cr	3.2–19	66–245	1.1–55	8–41000
Cu	–	1–300	2–172	50–8000
Hg	0.3–3	0.01–2	0.01–0.4	<1–55
Mo	1–7	0.1–60	0.05–3	1–40
Ni	7–34	7–38	2–30	6–5300
Pb	2–27	4–1000	11–27	30–3600
Se	–	0.5–25	0.2–24	1–10
U	–	20–300	–	<2–5
V	–	2–160	–	–
Zn	15–570	50–1450	15–570	90–50000

[a] Adapted from Selinus, 2013.