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# Groundwater and Health Implications of Biofuels Production

Rosane C.M. Nobre and Manoel M.M. Nobre  
*Universidade Federal de Alagoas / IGDEMA  
 Brazil*

## 1. Introduction

This chapter presents an overview of environmental and health problems associated with ethanol production in large scale in Brazil. Brazil and the United States are the leading producers of biofuels, accounting together for almost 90% of the total worldwide production in 2009 (REN21, 2010). The main biofuel in the United States is currently ethanol derived from corn kernels, whereas in Brazil the main biofuel production is ethanol derived from sugarcane crops (approximately 99%). In both countries, biodiesel derived from soybeans and Brazilian vegetable oils comprise a very small fraction of the total production.

Brazil is the world largest producer of sugarcane and its industry is the most energy-efficient producer of ethanol. As the demand for renewable fuel production worldwide increases, concerns exist about potential environmental impacts such as deforestation, biodiversity, soil erosion and water resources contamination. Sugarcane crops are especially suitable to be mostly cultivated in tropical areas, with natural ecosystems such as tropical forests with biodiversity hotspots. These areas may be replaced by feedstock plantations in the near future. The agricultural areas currently in use for sugarcane plantations occupy around 70.000 km<sup>2</sup> or 7 million ha (União da Indústria de Cana-de Açúcar [UNICA], 2011), more than half in the state of Sao Paulo, which retains approximately 60% of the Brazilian harvest and is responsible for 62% of the ethanol production (Goldemberg et al., 2008).

Sugarcane is also grown in the northeastern Brazil, in areas previously occupied by the Atlantic rainforest, mostly deforested, and in the Cerrado, the largest savanna species in South America with high biodiversity. The Cerrado occupies a great area of the state of Goiás, the fourth greater producer of Brazilian sugarcane, in which has been observed the greatest expansion of cultivated areas in 2009, approximately 40% within one year (UNICA, 2011). Higher biofuel demands are also responsible for rainforest loss in Indonesia and other countries.

Despite being self-sufficient in petroleum oil production, almost half of the Brazilian energy, 47% in 2009, comes from renewable resources (Ministry of Mines and Energy [MME], 2010). Biofuels from sugarcane represent 18% of our national energy matrix (MME, 2010), and this figure tends to increase in the following years. In Brazil, this may be attributable to the following factors: i) high demand for sugar and ethanol worldwide due to high energy

prices; ii) the development of new vehicle models with gasoline-and-ethanol mixtures (flex fuels) representing 90% of Brazilian cars; iii) the Kyoto protocol which demands an increased reduction in CO<sub>2</sub> emissions; iv) lack of regulatory criteria for land use; v) cheap labor and cheap production, with an average cost of US\$ 0.20 per kilogram of sugar or US\$ 0.15 cents per liter of ethanol.

## 2. Environmental concerns

It is not an easy task to quantify the numerous environmental threats/impacts associated with ethanol production and use. Kusiima & Powers (2010) recommend the evaluation of these impacts in terms of their monetary values in order to have a unit of measure. The authors quantify external costs associated with ethanol production from various biomass feedstocks especially corn. The indirect impacts, such as global climate change, greenhouse gas emissions, soil erosion, regional eutrophication are usually addressed with many uncertainties.

A study conducted by the environmental protection agency in California/USA indicates that ethanol from sugarcane provides less air pollution when compared with ethanol from corn or gasoline and emits much less greenhouse gases than other biofuels during the whole life-cycle (Coelho et al., 2006). Considering both direct and indirect effects (i.e., deforestation and other effects), the amount of CO<sub>2</sub> emission per megajoule (MJ) of energy produced is around 96 g from gasoline, 99 g from ethanol (corn) and 72 g from ethanol (sugarcane), as indicated in **Figure 1** (USEPA, 2009). Mathematical models were used to simulate these indirect effects.

As currently debated by environmental parties worldwide, the risk of the Amazon deforestation may play a smaller role in the global scenario of environmental implications of biofuels production. Besides, sugarcane cultures are not suitable for production in that area. In fact, sugarcane crops are moving to areas already deforested by soybeans culture and pasture. Sugarcane plantation currently represents only 2% of agricultural areas (UNICA, 2011) and about 0.8% of the total Brazilian territory. Besides, genetic improvements to sugarcane cultures have allowed its increased production without excessive land-use expansion (Coelho et al., 2006).

The threat to food production as a consequence to biofuels increased market is also of less concern. In Brazil, it is possible to amplify cultivated areas without being a threat to food harvest. It is not a matter of land scarcity but the lack of an effective land use management and the urgent need of better policies to encourage best agricultural practices. The transformation of extensive pasture practice to agriculture land should be a possibility. In the present conditions, there is no competition for land with food in Brazil. On the other hand, biofuels production either from corn or soybean may have a negative impact worldwide, in the near future, on the availability of grain for direct consumption (Tirado et al., 2010). In the United States, about 25% of the domestic corn yield went to ethanol production (Stone et al., 2010) and Mexico has already been feeling the effects of rising US corn, since the price of tortillas suddenly doubled in 2006 (Journal of the American Dietetic Association, nov/07). Recent catastrophic weather and geological events around the globe, such as the 2011 tsunami in Japan, could put even more pressure on the cost of food (Reuters, 03/02/11), an issue that has already brought about protests across the Middle East.

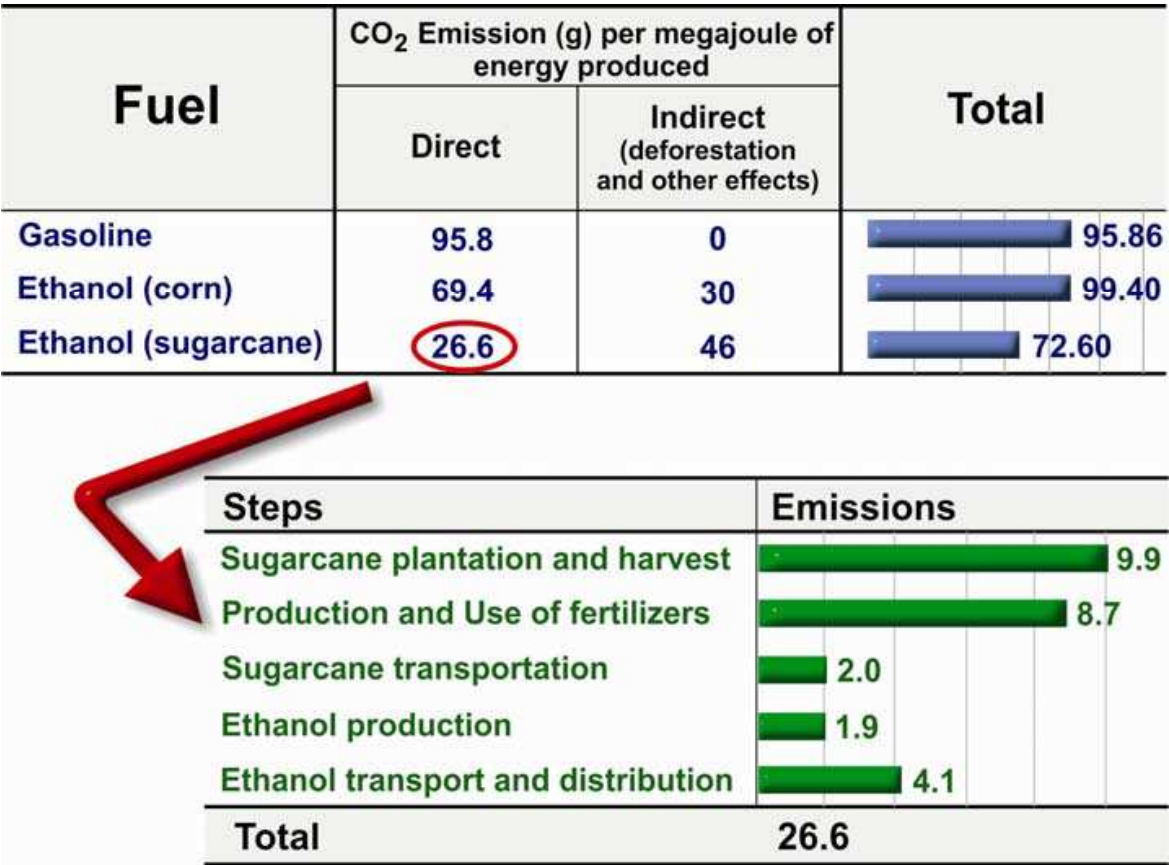


Fig. 1. Ethanol from sugarcane: less air pollution (source: USEPA, 2009)

The major environmental issues related to the sugarcane industry include watershed problems and groundwater contamination due to intensive use of agrochemicals and fertilizers. An additional concern is also deforestation of riparian vegetation and the impacts on streambank stability. Sugarcane plantations demand excess use of water, a precious resource used for many purposes. Despite elevated water availability, some Brazilian groundwater resources are already significantly stressed and vulnerable to contamination (Nobre et al., 2007).

For example, in Sao Paulo, major recharge areas of the Guarani Aquifer, the largest freshwater South American aquifer (1.2 million km<sup>2</sup> or 120 million ha), are located in extensive sugarcane fields (Queiroz et al, 2009). It has been confirmed the presence of groundwater contamination associated with pesticide use in this aquifer in the last few years due to cane plantations. Similarly, large portions of the north American Ogallala aquifer, a vast groundwater reservoir, show water table declines over 30 meters since the 1940s and is disappearing in some areas (Scientific American Earth 3.0, 2009). The Ogallala is three-quarters of the groundwater under the Great Plains region known as the High Plains Aquifer. It is the largest groundwater system in North America and over 90 percent of the extracted water is used for irrigation. In the United States, the demand for corn is such that more land is now being cultivated in drier regions of the Great Plains to the west of the corn belt where intensive irrigation is required, increasing water demand even further (The Economist, Feb 28<sup>th</sup> 2008).

In this case, the need to expand the cultivated areas to ethanol production is an additional threat, since these cultures require more water than most other crops. Since subsidies for

these crops, especially in the United States, are very high (as compared to land conservation), the choice for ethanol production, in much larger scales, has apparently been made. In Brazil, as a consequence to the present efficiency and observed cost reduction, subsidies were fully eliminated by 1997 and the industry relies exclusively on private investments (Goldemberg et al., 2008; Coelho et al., 2006). The good news is that ethanol plants are becoming more efficient and use about half as much water per liter of ethanol as they did a decade ago (The Economist, Feb 28<sup>th</sup> 2008). Moreover, the residual waste from sugarcane (bagasse) is used to provide electricity heat which results in a very competitive price. In order to be sustainable, biofuels production must preserve natural resources, including water and energy.

### 3. Water availability and demand

Agriculture is the dominant water user, and increasing the production of biomass feedstocks will certainly compete with food crops, increase water demand and change water resource allocation. Ethanol production requires much more water if compared to other fossil fuels. More than 90% of the required water is used for feedstock irrigation and a very small fraction is used in the processing of bio mass (Berndes, 2002).

Even in Brazil, where water availability is relatively high if compared to other parts of the world, there is a risk that these supplies be further depleted and deteriorated as fuel consumption increases. The United States Department of Agriculture states that about 25% of all irrigation in 2007 was for corn production (United States Department of Agriculture [USDA], 2009). The High Plains Aquifer states are to top corn produces. The natural occurrence of droughts and intensive irrigation to produce corn has caused the dramatic reduction of water levels in most regions of the aquifer (Scientific American Earth 3.0, 2009).

Water use is divided into two parts: crop production and ethanol production. The water requirement for sugarcane production is about 8-12 mm/ton of crop production (Stone et al., 2010). Sugarcane crops are historically grown in areas with total annual precipitation of 1500-2500 mm (Goldemberg et al., 2008) and irrigation is applied only during dry seasons. In Brazil, water usage in irrigation is small, around 3.3 Mha compared to 230 Mha worldwide (Coelho et al., 2006).

The crops, however, do not use all of the rainfall, some infiltrates further and some water evaporates from the soil (and leaves) of the plant during evapotranspiration. As the demand for ethanol production increases, crops are being cultivated in areas not previously suitable for grass growth and irrigation will be essential in these cases. Regardless of all, sugarcane crops, as well as corn crops, require vast amounts of water and sun. University researchers worldwide, however, are investigating new plant varieties, including genetic modified grains, so that they can tolerate lower amounts of water without affecting yields.

The water requirements to produce corn grain are much higher than water required for sugarcane. **Figure 2** depicts these figures, adapted from Stone et al. (2010) comparing three cases: world corn grain, U.S.A. corn (from the state of Nebraska) and world sugarcane production. The graph on the right shows crop water requirements for ethanol production considering conversion of 409 and 334 liters of ethanol per 1 ton of corn grain and sugarcane, respectively, from biomass to ethanol (after Stone et al., 2010). In general, it is



needed 4-5 times more water to produce the same amount of ethanol using corn instead of sugarcane.

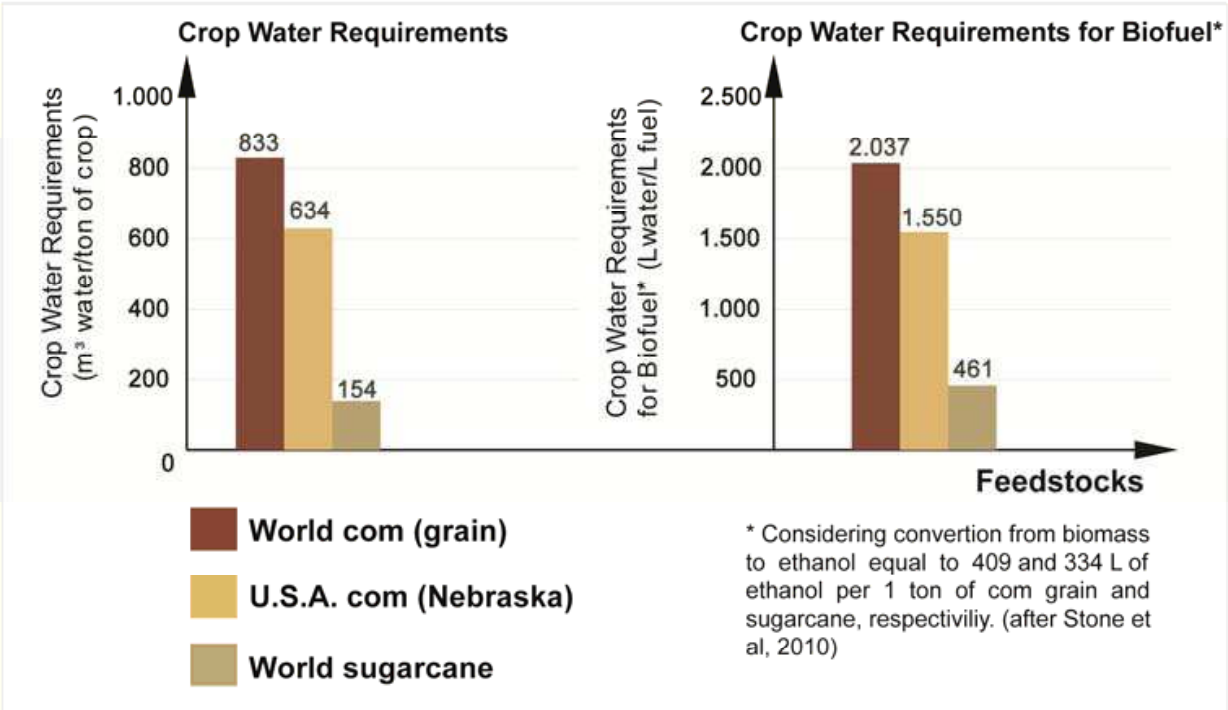


Fig. 2. Crop water requirements for corn and sugarcane cultures

Another advantage from the sugarcane production in Brazil is that farmers that own extensive lands in both northeast and southeast Brazil can concentrate their efforts in planting and harvesting their production in different periods of the year (including the seasonal migration of field workers) due to different weather conditions in both areas. In the southeast, rainy seasons occur during the summer whereas in the northeast, it happen during winter. Moreover, more than 50% of sugar-growing lands are controlled by ethanol refineries. This makes production more optimized and lucrative. However, this model contributes to workers exhaustion and other health and social related-problems. For instance, the Gini coefficient, a measure of social inequality, is very high (0.88) for export oriented crops like sugarcane (Martinelli et al., 2010).

Ethanol production facilities require large amounts of water in processing sugarcane into ethanol even though they have already improved their water efficiency over time. They currently use approximately three liters of water to produce a liter of ethanol. Ten years ago, water consumption was doubled. Some predictions due to emerging technologies simulate a reduction of water usage to two liters within a short timeframe. Water is used for four processes: cane washing, condenser in evaporation and vacuum; fermentation cooling and alcohol condenser cooling (Stone et al., 2010).

4. Water pollution and nitrogen loading

Incorporating biofuel crops into agricultural practices will affect not only water quantity but also water quality. The sugarcane industry is a great pollutant, with serious implications to

the environment and human health. These include problems associated with water pollution due to fertilizer and agrochemical loading, inadequate disposal of wastewater from the alcohol and sugar processing plants, soil erosion, among others.

In agricultural areas, groundwater has a distinct water quality signature and is usually composed of nitrate, potassium, chloride, calcium and magnesium. These compounds are originated from fertilizers, animal manure, lime and wastewater/sludge. The presence of these constituents becomes a problem when the amount present is beyond the allowable values that may pose a threat to human health.

The old-established methods of monoculture sugarcane production will probably persist in Brazilian fields, with drastic environmental side effects. Crop rotation is not practiced in these sugarcane fields, causing increased vulnerability to pests, and the need of major inputs of agrochemicals than most crops. In addition, standard agricultural practices demand the use of fertilizers such as nitrogen and phosphorus, which may bring about an increase in the loadings of nitrate to groundwater. Nitrate in contaminated water is known to cause many health problems such as methemoglobinemia in infants as well as stomach cancer in adults (Ward et al., 2005).

In the United States, in the “corn belt” of the upper Mississippi river there is the huge problem of nitrogen loss associated with annual corn plantations, due to a shallow rooting system and a short time of active nutrient uptake. This source of nutrient pollution is considered a great contributor to the “dead zone” in the plume of the Mississippi River in the Gulf of Mexico. It is argued that perennial crops such as switch grass add to much less water pollution.

In the Brazilian sugarcane fields, on the other hand, it is a standard practice to apply inorganic fertilizers as well as pesticides at high application rates. Partially treated effluents from sugarcane industry operations are also recycled and re-applied to the fields by sprinkler irrigation techniques or drip irrigation as an effective fertilizer. This waste, denominated vinasse, is nutrient rich, causing eutrophication of ecosystems and polluted runoff when discharged to surface water bodies.

The use of pesticides, which include herbicides and insecticides, is a common practice in the sugarcane industry. The Brazilian agrochemical market is the largest in the world where the major enterprises concentrate 80% of its sales in this country (Bava, 2010). The monocultures of sugarcane alone accounts for about 13% of Brazilian’s herbicide application. Many chemicals already banished in many countries (such as the insecticides endosulfan, malathion, tamaron and gramoxone) are still used in Brazil but is now being under evaluation by the Ministry of Environment and Health.

The use of atrazine, a known endocrine disruptor (ED) compound, is still used in many areas. Low doses of ED can cause developmental harm by interfering with hormonal triggers at key points in the development of an organism. Monteiro et al. (2011), for instance, found high concentrations of herbicides, mostly triazines and hexazinone, in studies of water and sediment toxicity along the Corumbatei river basin in the state of Sao Paulo where sugarcane is cultivated. Table 1 presents a list of all products currently used in Brazilian sugarcane fields, indicating the product names, major active ingredients and related endocrine disrupting effects.

This situation follows “the Circle of Poison” in which pesticides that are banned in industrialized countries continue to be manufactured there but the production is totally exported to developing countries (Galt, 2008). For example, over 25% of the US exports in

the 70's were products that have been prohibited or heavily restricted for use in North American fields. Developing countries, on the other hand, use the imported pesticides mostly on export crops, and return to industrialized countries as pesticide residues on food. More restrictions on pesticide use, however, are being pressured by environmental parties in Brazil but the battle is far from over.

## 5. Health problems

The individual and environmental factors predisposing workers to illness were identified in this section. Also, there are the indirect health consequences to nearby communities that consume agrochemical contaminated groundwater. The main individual factors related to harvest of the sugarcane industry are the physical effort due to excess work and exhaustion. Among the environmental factors, we can enlist the intense solar radiation, respiratory problems due to smoke breathing and exposure to agrochemicals in air, soil and water. There are also situations of mental suffering and the use of drugs to alleviate pain and stimulate output performance. According to the International Labor Organization, the risk of sugarcane worker deaths at the work place is, at least, two times greater than that of workers in other industries.

Although pesticides have been used in Brazil in large scales over the last 50 years, it is not easy to establish links and connections between human environmental exposure (by different media) and diseases, due to the inherent difficulties in proving the connection. This is mostly the case with carcinogenic compounds and the incidence of cancer, a multifactor disease related to many different risk factors. It is known that either the environmental factors alone or genetic variations alone are not enough to cause cancer (McKelvey et al., 2004).

The indiscriminate use of agrochemicals in Brazil, however, has certainly contributed to the environmental impact and elevated incidence of intoxication, mostly occupational. Levels of contamination have also been detected in the living environment. In many rural areas, the plantation areas are mostly close to workers houses. Another problem is that, in some cases, pesticides are stored at home and contaminated clothing is used indoors exposing the whole family with volatile toxic compounds (Jacobson et al, 2009). This makes occupation exposure a challenging problem. **Figure 3** presents a chart with the increased incidence in cases of intoxication due to pesticides in Brazil (Sistema Nacional de Informações Tóxico Farmacológicas [SINITOX], 2011). These figures are underestimated because of sub-notification of cases in the rural areas.

The Brazilian Federal Constitution of 1988 establishes that the government is responsible to carry out actions of sanitary and epidemiological vigilance as well as those related to worker health (Banco Nacional de Desenvolvimento Econômico e Social [BNDES], 2008). This is the responsibility of the government Sole System of Healthcare (SUS). In the present scenario, this system is also responsible for preventive measures to avoid the impacts on the environment created by the intensive production of ethanol. Brazilian government is being successful in many actions related to basic healthcare actions but there is a great challenge to be faced ahead as the ethanol industry will continue to grow in the coming years, creating a substantial demand for new cultivated areas. **Figure 4** below summarizes part of the challenge faced by SUS in the regions where the sugarcane industry is more intense (adapted from BNDES, 2008).



Compound	Products	Class	Toxicological Class	Endocrine Disrupting (ED) Effects <sup>1</sup>
2,4-D	Deferon; Tinto 867 SC; U 46 D- Fluid	Selective/ Hormonal Herbicide	I	Synergistic androgenic effects when combined with testosterone.
Ametrine	Ametrina Agripec; Ametron SC; Simetrex SC; Topeze SC	Selective Herbicide / Herbicide (triazines)	III	
Atrazine	Extrazin SC; Gesaprim 500; Siptran 500 SC	Herbicide (triazines) / Selective Herbicide	III	Androgen inhibitor with a weak oestrogenic effect. Disrupts the hypothalamic control of lutenising hormone and prolactin levels. Induces aromatase activity, increasing oestrogen production.
Carbamaryl	Sevin 480 SC	Insecticide	II	
Carbaryl	Carbaryl Fersol 480 Sc	Insecticide (carbamato)	II	Weak oestrogen mimic.
Carbofuran	Furadan 350 SC / TS	Insecticide	I	Acute doses increase levels of progesterone, cortisol and oestradiol whilst decreasing testosterone levels.
Clomazone	Gamit	Herbicide	II	
Cyanazine	Bladex 500	Herbicide (triazines)	III	
Cyclanilide	Finish	Regulator of vegetable growth	I	
Diuron	Advance; Ametron SC; Cention SC; Diuron 500 SC; Fortex SC; Velpar k Grda	Herbicide / Selective Herbicide	II	Inhibits the actions of androgens.
Endosulfan	Disulfan CE, Endosulfan 350 EC; Thiodan CE	Insecticide	I	Antagonises the action of androgens via binding competitively to their receptors and inhibiting the genetic transcription they induce. Mimics the actions of oestrogens indirectly by stimulating the production of their receptors.
Ethephon	Ethephon 480; Ethrel 720; Finish	Regulator of vegetable growth	II	
Ethoxysulfuron	Gladium	Selective Herbicide	III	
Fipronil	Regent 20 g; Regent 800 WG	Insecticide	II	Disrupts the production of thyroid hormones.
Glyphosate	Glifosato 480 Agripec	Systemic Herbicide		
Hexazinone	Advance; Velpar k Grda	Herbicide / Selective Herbicide	III	
Isoxaflutole	Merlin / Karmex DF	Herbicide	II	
Methanearsonic Acid	Volcane	Herbicide	II	
Metribuzin	Sencor	Herbicide	II	Causes hyperthyroidism, alters somatotrophin levels.
MSMA	Daconate 480; Fortex SC	Herbicide / Selective Herbicide	II	
Simazine	Extrazin SC; Simetrex SC; Topeze SC	Herbicide (triazines) / Selective Herbicide	III	Induces aromatase activity, increasing oestrogen production.
Trifluralin	Prem Merlin 600 CE	Selective Herbicide	II	Interacts with the pregnane X cellular receptor, interfering with the manufacture of enzymes responsible for steroid hormone metabolism.
Trinexapac-ethyl	Moddus	Regulator of vegetable growth	III	
I - Very High Toxicity      II- High Toxicity      III- Medium Toxicity				1 – McKinlay et al (2008)

Table 1. Pesticides currently used in sugarcane crops in Brazil

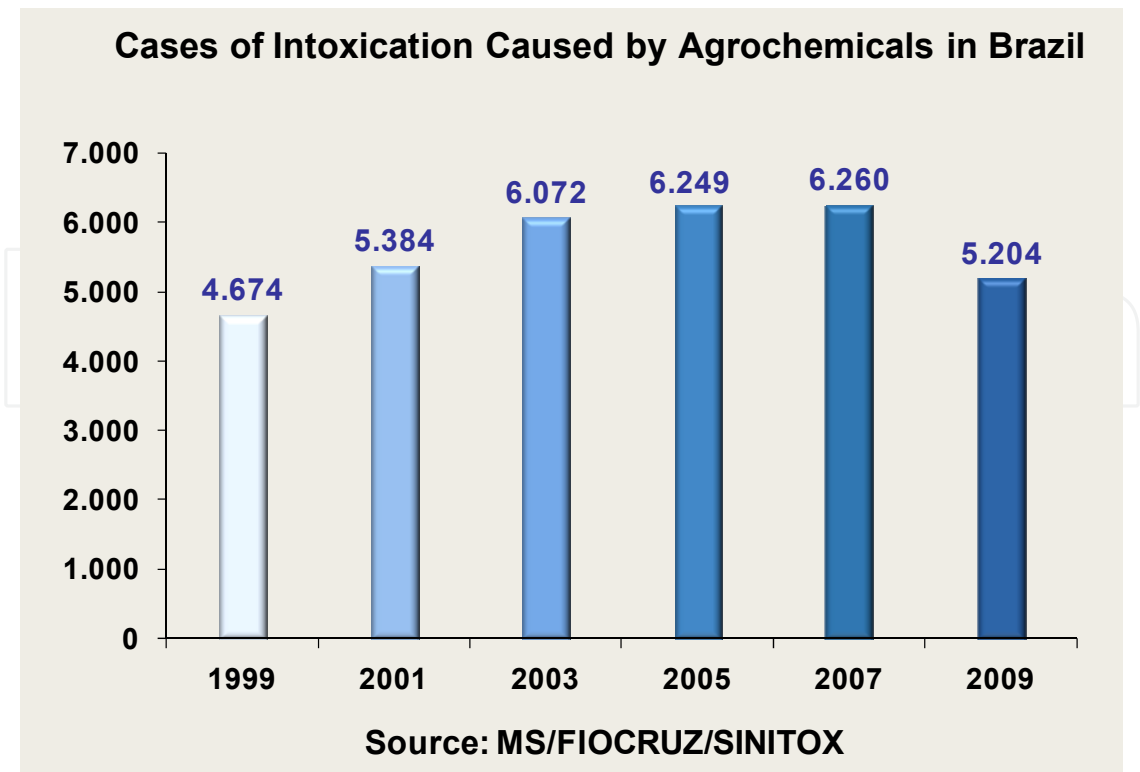


Fig. 3. Incidence in cases of intoxication caused by agrochemicals in Brazil

5.1 Respiratory problems

In many situations of sugarcane production in Brazil, burning the crops (and the sugarcane leaves) is a common practice that precedes harvesting in order to facilitate its cutting by hand. It also increases the sugar content by weight due to water evaporation. Atmospheric pollution due to the presence of particulates and gases from the burning causes many respiratory problems to workers, cardiovascular diseases and lung cancer. It also contributes to acid rain and high nitrogen deposition in soil. An increased number in hospital admissions has been observed due to asthma and other respiratory problems in the last few years. In the state of Sao Paulo, a law has been established in order to stop the burning practice completely (Goldemberg et al., 2008) and it is still under regulation. There is a great pressure to extend this law to other sugarcane producing states in the country.

When biomass burns, incomplete combustion results in the formation of toxic compounds, such as PAH (polycyclical aromatic hydrocarbons) emission, methane and fine particulates. As a consequence, food products derived form sugarcane may contain traces of pesticides, their metabolites and even the presence of PAHs.

The PAHs, such as benzo(a)pyrene, are the most harmful to health and are considered endocrine disruptor compounds. These compounds are found in a variety of food items including sugarcane juice, a common beverage commercialized in many Brazilian cities. Tfouni et al. (2009) investigated levels of PAHs in sugarcane juices for different cities and periods of time and verified that higher concentration levels of these contaminants were registered in juices collected in the harvest period. Also, Bosso et al. (2006) confirmed the present of the substance 1-OHP in the urine of sugarcane workers, a secondary indicator of the presence of PAHs in the organism. Higher concentrations were detected during the harvesting season.

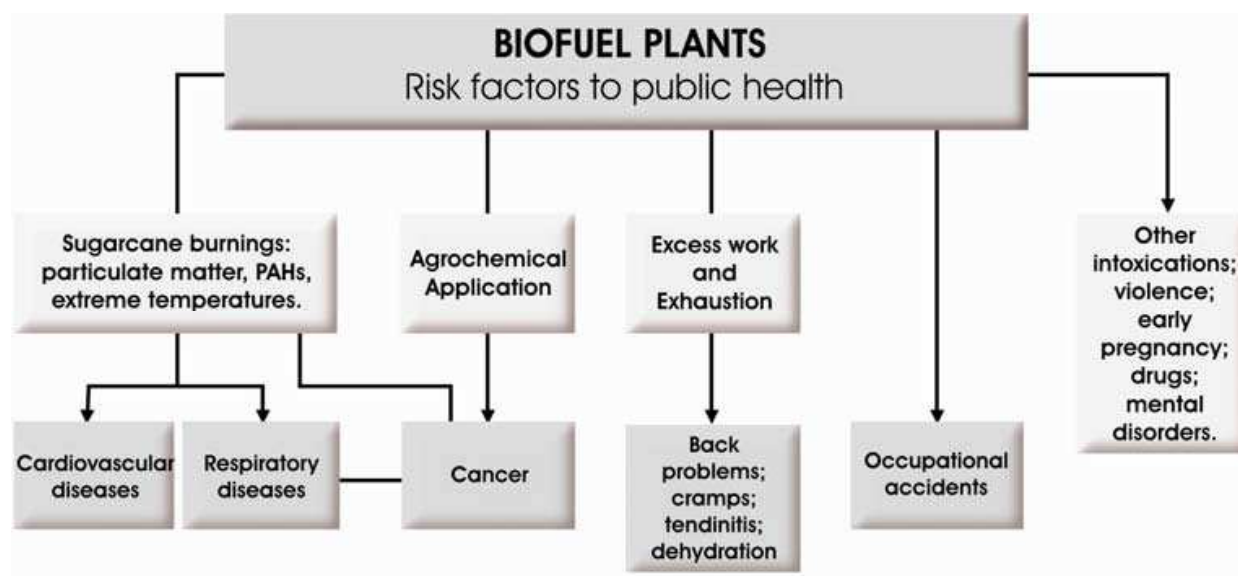


Fig. 4. Health problems related to the sugarcane industry in Brazil

## 5.2 Health problems due to groundwater contamination

In this section, emphasis is given to groundwater contamination due to nitrate and agrochemicals. Pesticides are generally over used in the sugarcane fields, presenting a serious risk to the environment. Many pesticides have already been confirmed as endocrine disruptors (ED). These compounds have estrogenic activity that may disrupt the hormonal system of mammals, causing birth defects and infertility, diabetes, cancer and even changes in behavior. The Brazilian Ministry of Health and the Environment are currently re-evaluating the use of these compounds.

Potential sources of diffuse contamination are common in agricultural areas and usually in close proximity to the population. Chlorinated organics pesticides can cause cancer by co-carcinogenic process (Vieira et al., 2005). For example, DDT and its metabolites (DDD, DDE) are the substances most cited in the literature for their roles as endocrine disruptors and impacts on human health and the environment (Wolff & Toniolo, 1995). For persistent compounds like DDT, human milk is the most contaminated of all human foods. Although these compounds have been prohibited in many countries, they still have an important role in many hormone-dependent cancers such as breast and prostate. This is possible due to high recalcitrance in soils and groundwater that may persist for many decades. This is also true to other organochlorine pesticides and triazine herbicides.

The herbicide 2,4-dichlorophenoxyacetic acid (2,4-D), still used in sugarcane plantations in Brazil (see **Table 1**), is an endocrine disruptor organophosphate pesticide. Human epidemiological studies have already linked this compound to endocrine related cancers (McKinlay, 2008). The compound diuron, an herbicide commonly present in many pesticides formulas used in sugarcane fields, is known to inhibit the actions of androgens. The insecticide carbaryl, on the other hand, is a weak oestrogen mimic. **Table 1** also includes the known endocrine disrupting effects related to many other pesticide contaminants currently used for sugarcane production in many parts of Brazil such as atrazine, carbofuran, endosulfan, fipronil, metribuzin, simazine and others.

There are studies that indicate that nitrate, derived from nitrogen, a plant nutrient supplied by inorganic fertilizer and animal manure, raises the risk of several types of cancer, especially colon and stomach (Ward et al., 2005; Irigaray et al., 2007). Beneath agricultural lands, nitrate is the primary form of nitrogen. It is soluble in water and can easily pass through soil to the groundwater table. Nitrate can persist in groundwater for decades and accumulate to high levels, as it is very stable in its oxidative form. Infants under six months of age are susceptible to nitrate poisoning in water. The resulting condition is referred to as methemoglobinemia, commonly called "*blue baby syndrome*." High concentrations of nitrate are a risk factor in developing gastric and intestinal cancer. Due to these health risks, great efforts are made on treatment processes to reduce nitrate concentrations to safe levels. Prevention measures should be applied to avoid the leaching of nitrate from the soil. Some suggest that reducing the amount of fertilizers used in agriculture will help alleviate the problem.

O'Leary et al. (2004) investigated a site contaminated by pesticides on the island of Long Island (NY) and its association with breast cancer incidence. Brody et al. (2006) conducted a similar study with women diagnosed with cancer in the peninsula of Cape Cod (Massachusetts) and the correlation between the etiology of cancer and the exposure to pesticides contaminated groundwater. Nitrate-N was used as the main tracer of contamination levels. The same database was used by Vieira et al., (2008), considering the use of statistical techniques and geographic information system for the visualization of spatial trends of breast cancer, aiming to identify the possible environmental exposure pathways.

The incidence of skin and digestive cancers among a group of rural workers in the central part of Sao Paulo State has also been verified to be correlated with the intensive use of agrochemicals in sugarcane plantations (Stoppelli & Crestana, 2005). The study indicated an almost two fold increase in the probability of cancer incidence among rural workers. Nobre et al., (2011), on the other hand, conducted a quantitative risk analysis related to groundwater contamination in a city located in northeastern Brazil that has a long history of sugarcane monoculture and a high incidence rate of breast cancer. For the last 40 years, the community consumed groundwater as the sole water source. The intensive use of fertilizers and inadequate solid and waste water disposal were considered the main environmental risk factors. The results presented high values for the carcinogenic and non-carcinogenic risk indices.

## 6. Final remarks

Biofuels are becoming widely used as a viable alternative to petroleum-based fuels. Higher demands for ethanol worldwide are compelling some countries, both developed and developing, to revise their plans in terms of increasing production in order to avoid future shortcomings related to food shortage, threat to biodiversity and environmental degradation.

Although Brazil is the biofuel industry leader, and the most successful and energy-efficient producer of ethanol, many concerns exist in terms of potential environmental impacts including water quality and depletion, health associated problems and social inequity as discussed earlier in this chapter. These are the major restrictions for the sustainable and certified sugarcane production in Brazil, considering the increase in sugarcane industry (and

ethanol production) in the following years. These concerns must be addressed by independent parties and better understood based on current scientific knowledge.

Since the first release of the bestselling *Silent Spring* from Rachel Carson in 1962, there is a consensus that chemical substances in the environment may pose profound effects in animals and that the environmental preservation is inexplicable associated to human health. In her book, chapter 3 (Elixirs of Death), Rachel says "For the first time in the history of the world, every human being is now subjected to contact with dangerous chemicals ...residues of these chemicals linger in soil to which they may have been applied a dozen years before... they have been found in fish in remote mountain lakes, in earthworms burrowing in soil, in the eggs of birds and in man himself.... All this has come about because of the sudden rise and prodigious growth of an industry for the production of manmade or synthetic chemicals with insecticidal properties. This industry is a child of the Second World War." (Carson, 1962). It is hoped that the new generation industry of biofuels production does not cause new environmental impacts as those predicted by Rachel Carson 50 years ago.

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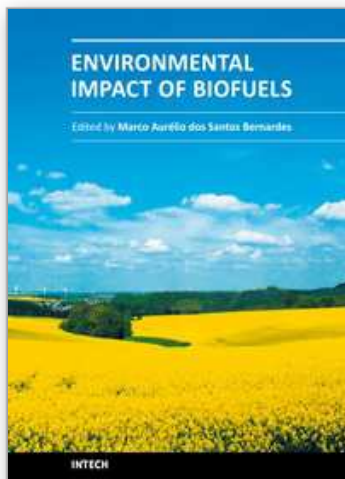
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## **Environmental Impact of Biofuels**

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This book aspires to be a comprehensive summary of current biofuels issues and thereby contribute to the understanding of this important topic. Readers will find themes including biofuels development efforts, their implications for the food industry, current and future biofuels crops, the successful Brazilian ethanol program, insights of the first, second, third and fourth biofuel generations, advanced biofuel production techniques, related waste treatment, emissions and environmental impacts, water consumption, produced allergens and toxins. Additionally, the biofuel policy discussion is expected to be continuing in the foreseeable future and the reading of the biofuels features dealt with in this book, are recommended for anyone interested in understanding this diverse and developing theme.

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Unit 405, Office Block, Hotel Equatorial Shanghai  
No.65, Yan An Road (West), Shanghai, 200040, China  
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元  
Phone: +86-21-62489820  
Fax: +86-21-62489821

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