Perspective

J Am Holist Vet Med Assoc. 2022;68:11–21.
https://doi.org/10.56641/HAVK8952

A Perspective on Glyphosate Toxicity: The Expanding Prevalence of This Chemical Herbicide and Its Vast Impacts on Human and Animal Health

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Abbreviations

AMPA	Aminomethylphosphonic acid
ARG	Antibiotic resistance gene
EPA	Environmental Protection Agency
GALT	Gut-associated lymphoid tissue
GBH	Glyphosate-based herbicide
GE	Genetically engineered
GMO	Genetically modified organism
HRI	Health Research Institute

Abstract

Glyphosate is a chemical compound initially patented as an herbicide in 1974 and sold as the main ingredient in herbicides under the trade name Roundup®, with intended use for agriculture and farming. Its use promoted the creation of genetically modified plants to allow crops to withstand this chemical, providing a more labor- and cost-efficient method for weed control.

Glyphosate usage has increased dramatically over the past several decades, extending beyond agricultural use to numerous applications, including weed control in forestry and trees, aquatic ponds, and commercial and residential lawns and gardens. The exposure rates for animals and humans are exponentially increasing through food, water, inhalation, and direct contact in the environment (skin exposure).

Cumulative research reveals that glyphosate and glyphosate-based herbicides (GBHs) have adverse effects on the microbiome, nutrient levels, and cellular health. Increasing evidence shows this chemical compound to be cytotoxic and genotoxic, with carcinogenic properties. Additional known effects of glyphosate include endocrine disruption, destruction of the gut lining (and other mucosal barriers in the body), interference with microbiota, and increased antibiotic resistance. Glyphosate also impacts the health of animals and humans by significantly decreasing the nutritive value of plants and crops.

Studies show exponentially increased exposure in humans in the United States over the past 2 decades. New information shows even higher levels of glyphosate exposure in companion animals. Veterinary studies reveal links between certain cancers (in dogs) and environmental exposure to glyphosates. More studies need to be done to determine the direct and indirect impacts of this widespread herbicide on degenerative disease, chronic disease, and cancers in humans and animals.

Introduction

Glyphosate is a chemical compound initially patented as an herbicide in 1974 and sold as the main ingredient in herbicides under the trade name Roundup® (a). All animals and humans are exposed to glyphosate at continually increasing levels. This compound is in food, soil, and water (1). Exposure to this particular herbicide is becoming an important topic because its use has exponentially increased over the last few decades (2). This has raised many concerns among the scientific community, and to date, hundreds of studies are aimed at evaluating the health and environmental consequences of glyphosates.

Glyphosate is now the most common "weed killer" used around the world, with extremely heavy use in the United States. Its original purpose was aimed at agriculture and farming to gain more yield of food crops by decreasing the competitive weed plants. Over the past few decades, however, the popularity of this chemical has grown rapidly into industrial and residential purposes, including common use on lawns and gardens. After the final patents held by Monsanto expired approximately 20 years ago, numerous glyphosate-containing products began to fill the market, with currently more than 750 different glyphosate-based herbicide (GBH) products available in the United States alone (1).

Although developed in the mid-1970s, glyphosate use increased dramatically after Monsanto introduced glyphosate-resistant "Roundup Ready" genetically modified organism (GMO) crops in 1996. Genetically modified seeds (originally corn and soy) were developed to create plants that would withstand the herbicidal effects of glyphosate, enabling farmers to kill weeds without killing their crops. However, the upward trend of GBH use continues at exponential rates, partly due to the global emergence of glyphosate-resistant weeds, requiring even higher applications of this chemical with each passing year in order to maintain its effectiveness (3).

A study conducted in 2014 by agricultural economist Charles M. Benbrook, PhD, reported alarming statistics regarding the increasing volumes of glyphosate being used in the United States. At that time, the author stated that no pesticide has come remotely close to such intensive and widespread use in the United States, adding that the dramatic and rapid growth in overall use of glyphosate will likely contribute to a host of adverse environmental and public health consequences. Benbrook reported that approximately 8.6 billion kilograms of glyphosate had been used globally since 1974, with 1.6 billion kilograms applied in the United States alone and two-thirds of that amount used in just the past 10 years (2).

Today, glyphosate is actually being used in several different ways. It is most widely recognized as a broad-spectrum herbicide to inhibit weeds, but it is also used as a desiccant to dry out the crop, facilitating harvest (4). Finally, glyphosate works as an antibiotic due to its antimicrobial properties in the soil. In other words, glyphosate has herbicide action on plants and antibiotic action on soil microorganisms, which means that it is now the most common and widespread antibiotic used globally as well (5).

At this point, GBHs are used on numerous agricultural products, many that are genetically modified and many that are not (6). Common GMO crops include corn, soybeans, alfalfa, apples, canola, cotton, papaya, potatoes, squash, and sugar beets. These crops were genetically engineered (GE) to be tolerant to glyphosate. Genetic engineering involves biotechnology that is used to alter the DNA, the genetic blueprint of the plant. These methods manipulate the expression of certain genes in plants or completely inactivate certain genes or insert new genes to confer new functions on the plant. Although the primary application of this type of genetic engineering has been to create crops that are tolerant to herbicides, a few plants have been engineered to produce insecticides, and biotechnologists are working on other applications, such as tolerance to drought (7).

When glyphosate is also applied to many types of crops that are not GE, it is used as a crop desiccant to allow for timing of harvesting and to hasten the drying of the crops to facilitate harvest. Because these non-GMO crops are sprayed with glyphosate at the end of harvest, these foods contain even higher levels of glyphosate than the GMO crops, which are sprayed while the crop is growing (4).

Non-GMO crops with the highest levels of glyphosates include many of the common ingredients in pet foods, such as oats, wheat, barley, rye, legumes, chickpeas, beans, potatoes, and peas (8). (**Figure 1**)

With continually expanding levels of use, another concerning issue is that glyphosate is water soluble. GBHs absorb into groundwater and are found in the majority of streams, rivers, waterways, and water runoffs (9).

In fact, glyphosate is reported to be one of the most problematic pesticides that repeatedly appears in drinking water (10). In the United States, the extensive agricultural use of GBHs in the midwestern and central regions of the country allows for a large concentration of this chemical to collect in the Mississippi tributary water basin. This leads to an accumulation of glyphosate funneling into the Mississippi River (11-13).

For more perspective on the vast global impacts of glyphosate, because this chemical is water soluble, it gains access into the ecosystem through all phases of the water cycle. Therefore, it is also readily found in air and rain. Through

ISSN 2474-1906

Figure 1

Sampling of Glyphosate levels founds in foods
(measured in parts per billion)

Black Beans	3000	Blackstrap Molasses	40	Beer	8
Hummus	1435	Yellow Potatoes	29	Milk Chocolate	7
Oatmeal	1254	Honey - organic	26	Dark Chocolate	7
Cheerios	624	Wine, conventional	22	Peaches	6
Roasted Soybeans	479	Orange Juice	19	Coffee	3
Whole Wheat Bread	370	Peanut Butter	12	Wine - organic	2
Honey - near GM crops	307	Chewing tobacco	10	Ice cream	1
Cranberries	243			Milk	0.2
Green Tea	208			Apples - Fuji	~0
Wheat Flour	171			Meat	~0
Lentils, cooked	94			Olive oil	~0
Blueberries	84			Orange juice - organic	~0
				Whiskey	~0

Glyphosate levels measured in common foods. Image printed with permission of Health Research Institute (HRI).

the evaporation and condensation cycle, glyphosate is absorbed and comes back down to the earth in precipitation, reportedly present now in approximately 75% of the rainfall globally (12–15). Many scientists who focus on health or environmental issues have significant concerns that earth is being saturated with a water-soluble chemical that is continually gaining access to more and more of the ecosystem. Indeed, given that the earth is 70% water and the human body is 70% water, this scenario allows for extensive delivery and distribution throughout the entire planet and all life on it.

Glyphosate Effects on the Soil

Regarding life on the planet, not only are animals and humans dependent on water for life, but they are also intricately dependent on soil as well as the microorganisms within it. The action of glyphosate is to inhibit protein synthesis via a specific enzyme pathway called the shikimate pathway. Specifically, it inhibits the enzyme 5-enolypyruvylshikimate-3-phosphate (EPSP) synthase in plants and inhibits aromatic amino acid synthesis, which functions in plants and microorganisms but not in animals (16, 17).

It is now very clear that glyphosate has antibiotic properties affecting not only microbes in the soil but also microbes in the intestines of animals and humans (5). In fact, Monsanto extended the patents on glyphosate for many years by submitting a new patent that was granted in 2010, which was based on the antimicrobial properties of this chemical (18).

Many studies are now demonstrating the effects of glyphosate on soil health and microbiome status and showing a large influence on global antibiotic resistance as well. Current research from 2021 provides evidence that, in countries where this herbicide is widely used, glyphosate could be a possible driver of antibiotic resistance due to modification of the microbial environments. The authors state that the emergence of resistant bacteria and fungi is correlated with glyphosate use in the world over the last 40 years (5). It is also correlated with a large amount of residue of glyphosate in the environment (soil, water) and plants (19). There is also an inducing or repressing effect of antibiotic resistance, which has been demonstrated in *Escherichia coli* and *Salmonella enterica* (20, 21).

Another 2021 study demonstrates that the application of GBHs increases the prevalence of antibiotic resistance genes (ARGs) and mobile genetic elements (MGEs) in soil. In addition, it is shown that herbicide exposure increases cell membrane permeability and conjugation frequency of multidrug resistance plasmids, promoting ARG movement between bacteria. Findings reveal that herbicide application can enrich ARGs and MGEs by changing the genetic composition of soil microbiomes, potentially contributing to the global antimicrobial resistance problem in agricultural environments (22).

Further studies have evaluated the potential side effects on nontarget soil organisms. One study specifically looked at the effects of GBHs on the interactions between essential soil organisms, such as earthworms and arbuscular mycorrhizal fungi (AMF). It was found that herbicides significantly decreased root mycorrhization and soil AMF spore biomass. Sizeable changes were reported, leading the authors to state that their findings provide impetus for more general attention to the side effects of GBHs on key soil organisms and their associated ecosystem services (23, 24).

The intestinal microbiome assists in the bioconversion of nutrients and detoxification and also influences host immunity, protects against pathogenic microorganisms, and promotes health. Changes in the intestinal composition can lead to dysbiosis, characterized by an imbalance between beneficial and pathogenic microorganisms. A balanced gut microbiome not only affects the functioning and health of the GI tract by defending against pathogen invasion, but also interacts with the endocrine and nervous systems, affecting the functioning and health of the whole host system (25, 26). In animals and humans, glyphosate exposure and concentrations in urine have been associated with intestinal diseases and neurological as well as endocrine problems, but cause-effect relationships need to be determined in more detail (19, 27).

Intestinal microbial communities can be affected directly by glyphosate in contaminated animal feed and the environment. Indirectly, the intestinal microbiome is also changed by the microbial communities that enter the intestinal tract on or in glyphosate-exposed plant products (28, 29). Subsequently, changes in these communities affect the immune system and can be detrimental to animal and human health. As one general example, it is known that alterations in the ratio of firmicutes to bacteroidetes in the intestinal tract of humans have been associated with irritable bowel syndrome and obesity. Pathogens that are less sensitive or even insensitive to glyphosate, such as *Staphylococcus aureus* or *Clostridium perfringens*, can emerge in the intestinal environment and cause serious disease symptoms (30).

One study evaluated the effects of glyphosate on ruminal fermentation and found that it had an inhibitory effect on select groups of microbiota but increased the population of pathogenic species. The conclusion was that glyphosate causes dysbiosis, which favors the production of the botulinum neurotoxin (BoNT) expression during in vitro ruminal fermentation (31).

In specific poultry studies, long-term exposure to GBHs administered in the feed resulted in increased oxidative stress, lower testosterone levels, and delayed development of female birds (32, 33). Chickens that were exposed to glyphosate in commercial feed (370 ± 92 μg/kg) showed typical disease signs associated with elevated intestinal *Clostridium* levels (34). In addition, these signs were effectively suppressed by administering humic acids that bind to glyphosate molecules in the intestinal tract (35).

Research is also being done to evaluate the persistence of glyphosate in the soil after application. It has been shown that glyphosate applied on soil undergoes a decay in 2 phases. In the soil solute phase, the initial decay is quite fast—showing a half-life of several days. In this phase, aminomethylphosphonic acid (AMPA), the main metabolite, is formed. Glyphosate and AMPA are then both adsorbed to clay and organic matter particles. Once adsorbed, their degradation is very slow, and both compounds are characterized by the European Food Safety Authority (EFSA) as "persistent" in soils. The period required for 90% dissipation of glyphosate and AMPA (DT90) is estimated to be more than 1,000 days depending on the soil type, environmental conditions, and prior exposure of soil microorganisms to the herbicide (36). Thus, glyphosate may decay partially in a few months, but its degradation product, AMPA, can potentially persist for years in soils with high clay content (37).

Glyphosate Effects on Plant Nutrients

In addition to the impact that glyphosate has on human and animal health due to its effects on the soil microorganisms and gut microbiome, there are numerous other harmful effects as well. It is of significant concern that glyphosate is stripping plants of nutrition. As a nonselective herbicide, it is preventing most plants from making certain proteins necessary for plant growth. Specifically, GBHs inhibit the shikimate pathway, a metabolic pathway used by plants, fungi, and bacteria (38). Importantly, this pathway is required to create alkaloids, which provide the medicinal qualities of plants and important aromatic amino acids, such as tyrosine, tryptophan, and phenylalanine. These amino acids are the building blocks of critical neurotransmitters and hormones. Alkaloids are organic nitrogen compounds of plant origin that have diverse and important physiological effects on humans and animals. These components contribute to the medicinal properties in food. In fact, alkaloids possess a variety of pharmacological potentials, including effects that are analgesic, anticancer,

ISSN 2474-1906

antihyperglycemic, antiarrhythmic, antibacterial, and neuromodulatory (39). This ultimately means that glyphosate is blocking plants from producing bioactive molecules that contribute to animal and human health and is, thereby, preventing food from being medicine. Glyphosate is creating conditions wherein plants are becoming "empty" of important micronutrients animals and humans need.

Endocrine Disrupting Chemical

Glyphosate has many key characteristics that qualify this chemical as a major disruptor of hormones and endocrine systems in the body (40, 41). Companion dogs and cats commonly suffer from many endocrine diseases, including thyroid disease, adrenal gland disease, pituitary problems, and diabetes. There are numerous studies showing the impacts of glyphosates on hormones, reproduction, and birth defects (42, 43).

Toxic Effects

Glyphosate is readily absorbed through the GI tract as well as the sinuses and respiratory tract, with lesser amounts thought to be absorbed through dermal contact. Absorbed glyphosate is shown to be distributed to the kidneys, liver, and brain and circulates in the blood. However, it does not significantly accumulate in the body (44, 45).

The majority of absorbed glyphosate is excreted within approximately 7 days, primarily through urine and feces. Glyphosate is thought to not undergo significant metabolism in mammals and is often measured as direct glyphosate or its primary metabolite, AMPA (43, 46).

Testing for glyphosate levels in humans and animals is typically measured in urine samples, and these findings are discussed below. It is important to note that the kidneys appear particularly sensitive to the toxic effects of GBHs, and multiple studies have demonstrated the negative effects this chemical has on kidney tubules and kidney function (47–50). Numerous studies have also reported liver damage and liver disease associated with GBH exposure (49–51).

The carcinogenic properties of glyphosate have also been widely reported, and there are several known litigation cases (against Monsanto) that have awarded settlements to human cancer victims with high exposure levels to glyphosate (52). Several studies in humans have linked herbicide exposure to cancers of the colon, sinus, lung, prostate and ovary; lymphomas; and multiple myelomas (53, 54). In 2017, the International Agency for Research on Cancer (IARC) classified glyphosate as "probably carcinogenic" in humans. Increasing evidence shows that glyphosate and GBHs exhibit cytotoxic and genotoxic effects, cause inflammation and increase oxidative stress, disrupt the estrogen pathway, impair some cerebral functions, and allegedly correlate with some cancers. GBHs are also shown to affect lymphocyte functions and the interactions between microorganisms and the immune system (1).

Routes of exposure to glyphosate toxicity include ingestion, absorption into the skin or eyes, and inhalation. And although lesser volumes are thought to be absorbed by dermal contact, Monsanto's own study showed that farmers who mix and load glyphosate without wearing rubber gloves have almost 5 times the urinary concentration of glyphosate than that of farmers who wear rubber gloves (55).

For dogs and other animals, foods are likely the largest source of glyphosate exposure, but it appears that dogs may be getting significant environmental exposures as well. Indeed, most canine companions spend quite a bit of time outside in the grass, lawns, and other areas that may be sprayed with Roundup® or similar GBHs. This can add up to significant skin and contact exposure. Furthermore, dogs engage in substantial interaction with the environment through their olfactory senses, which means they generally spend a lot of time sniffing in areas of grasses, plants, and along the ground. This puts them at higher risk for sinus and inhalation exposure compared to their human companions. The Cummings School of Veterinary Medicine at Tufts University reported that exposure to lawn chemicals raises the risk of canine malignant lymphoma by more than 70%, and veterinary studies at Purdue University found links between glyphosate exposure and bladder cancer in dogs (56, 57).

Gut Toxicity and Leaky Gut Syndrome

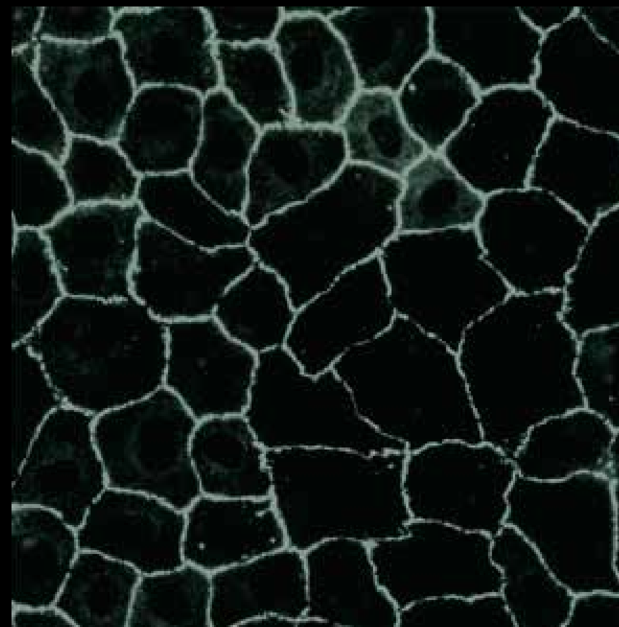
The toxic actions of glyphosate on mucous membranes lead to numerous health issues. In the intestines, glyphosate directly damages the epithelial tight junction tissue on contact, weakening the barriers that are designed to protect the body from toxins and harmful particles. Injury to the tight junctions between cells in the gut leads to intestinal permeability—that is, leaky gut syndrome. Leaky gut is known to be a root cause of disease, immune-mediated issues, and chronic inflammatory conditions (58). Once the gut barrier is penetrated, much of the immune system is exposed. In other words, just behind the thin protection layer of endothelial cells is the gut-associated lymphoid tissue (GALT). The GALT is a layer of immune cells that comprises 60% to 70% of the immune system, and more than 80% of the antibodies produced by the immune system originate in the GALT. The gut–brain axis is also affected by leaky gut and the resulting impact on the gut microbiome. In fact, studies have documented anxiety and depression-like behaviors in mice associated with GBH exposure effects on their gut microbiota (59).

Glyphosate acts through zonulin-mediated pathways to damage the tight junction system (**Figures 2 and 3**). Zonulin is a protein that increases intestinal permeability in the jejunum and ileum and is considered a biomarker for barrier permeability (60). Gliadin, the main protein component of gluten, acts in the same way to affect zonulin and damages the tight junction barrier. The zonulin production initiated by the glyphosate assault quickly becomes systemic. This injury to the tight junction membrane in the brain can result in a breakdown of the blood–brain barrier and a host of neurological symptoms that are typical with gluten sensitivity and celiac disease.

Several studies have shown similar damaging effects on the gut lining and resultant hyperpermeability caused individually by both glyphosate and gluten (61–63). Preliminary unpublished research is looking at the effects of the combination of glyphosate and gluten (or specifically gliadin, as the breakdown of gluten) potentially creating a toxic synergy together and thereby markedly increasing the hyperpermeability in the gut lining (in-person and email communication with Zach Bush, MD, Seraphic Group, Charlottesville, VA, March 2019).

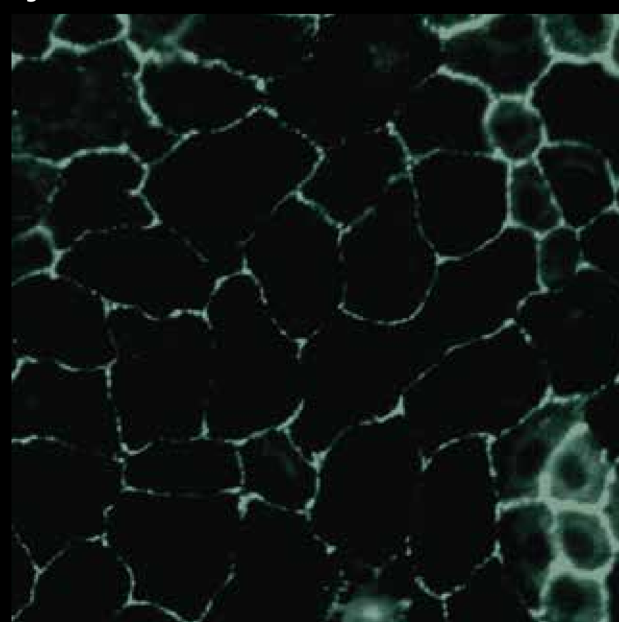
Hyperpermeability of the gut lining results in GI inflammation (inflammatory bowel disease [IBD]) as well as chronic systemic inflammation and reactive immune response. Understanding the similar effects caused by glyphosate and gluten with potential for greater combination effects could suggest a possible link to the significant rise in gluten sensitivity issues, affecting the health of both animals and people over the last few decades. Although glyphosate was brought to market in 1974, its widespread use became more common in the 1990s, which parallels the timing of growing recognition with health issues caused by gluten reactivity. Another notable point is that increased hyperpermeability in the gut allows for additional toxins (beyond glyphosate) to gain systemic access into the body as well. Furthermore, the destruction of the gut barrier leads to a significant disruption in the microbiome, which impacts the immune system, gut health, brain health, and overall body systems.

Figure 2



Intestinal epithelial cells (IEC-6 small bowel cells in cell culture) with healthy tight junctions. Image printed with permission of Intelligence of Nature™ (ION*).

Figure 3



Intestinal epithelial cells (IEC-6 small bowel cells in cell culture) damaged by glyphosate. Image printed with permission of Intelligence of Nature * (ION*).

A study published in 2014 searched US government databases for GE crop data, glyphosate application data, and disease epidemiological data. Correlation analyses were performed on a total of 22 diseases in time-series data sets. This paper, titled "Genetically Engineered

ISSN 2474-1906

Crops, Glyphosate, and the Deterioration of Health in the United States of America," concluded that the effects of glyphosate and GE crops on human health should be further investigated due to the significance and strength of the correlations (64).

Levels of Glyphosate Exposure

The majority of the American human population have detectable levels of glyphosate in their urine, with a notably significant increase in levels measured in the past few decades. Research from the University of California evaluated glyphosate levels in humans from 1993 to 2016. This study published in 2017 measured levels of glyphosate and its major metabolite, AMPA, in the urine of human adults in Southern California, demonstrating a 33-fold increase in AMPA levels during that period (65).

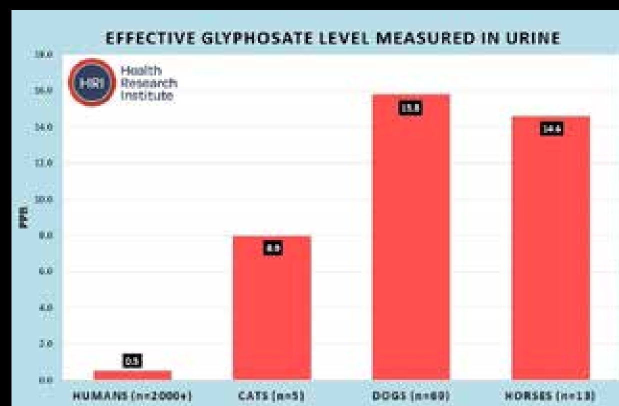
Additional studies have evaluated levels of glyphosate exposure in dogs, cats, horses, farm animals, and even wildlife. The Health Research Institute (HRI) (b) is an independent nonprofit laboratory and research organization that uses cutting-edge mass spectrometry-based methods to test food and feed for nutrients, micronutrients, and pesticides, including glyphosate. Findings from the HRI have established that dogs in the United States have an average of 32 times more glyphosate levels measured in their urine compared to humans. Horses are trailing just behind that at 29 times greater levels than humans and cats with levels at 16 times greater. The lower levels in cats can be explained by several factors, including fewer plant-based ingredients used within appropriate feline diet formulations, as well as reduced environmental exposure of most companion cats with typical indoor lifestyles. Horses consume a plant-based diet in addition to living outdoors, which increases their routes of exposure. Farm animals and wildlife have been tested, too, and it is noteworthy to mention that dogs have the highest levels of glyphosate in their urine than any animals tested (**Figure 4**).

Glyphosate Testing and Glyphosate Levels in Foods

The HRI also offers direct-to-consumer testing of people and animals via submission of urine and hair samples. HRI has tested glyphosate levels in numerous types of fresh foods and commercial pet foods, in addition to testing urine, feces, hair, and amniotic fluid samples from humans, dogs, cats, horses, farm animals, and wildlife.

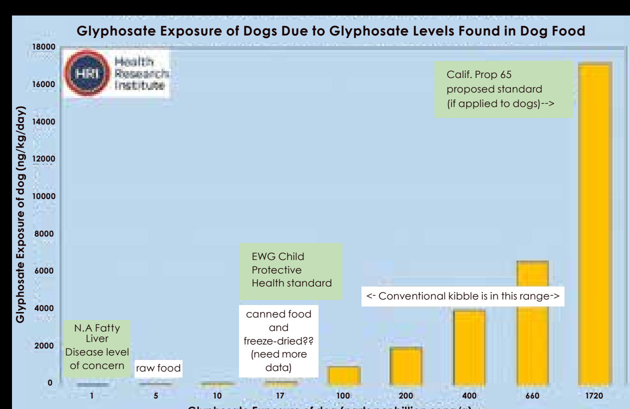
These types of studies have shown that most pet foods have significantly high levels of glyphosate. In unpublished trials performed by HRI, 1 bowl (8 oz) of typical dry kibble dog food could have 115 µg of glyphosate, compared to a similar volume of a raw/fresh/minimally processed meal, which typically contains less than 0.29 µg. In other words, an average quality kibble meal contains 400 times the glyphosate present in a fresh food minimally processed meat-based meal (**Figure 5**). Thus, there is a remarkable difference in the level of exposure to this toxin for pets eating a heavily processed diet compared with a species-appropriate fresh meat-based diet (email communication with John Fagan. PhD, Health Research Institute, 505 Dimick Drive, Fairfield, IA, March 2022).

Figure 4



Glyphosate levels measured in animals.
Image printed with permission of Health Research Institute (HRI).

Figure 5



Glyphosate levels measured in types of dog foods.
Image printed with permission of Health Research Institute (HRI).

Furthermore, because many non-GMO crops are known to contain higher levels of glyphosate than the GMO crops, this creates a significant concern regarding the levels of glyphosate in nonorganic foods, such as oats, lentils, chickpeas, beans, peas, and potatoes. Interestingly, these foods are typically included in even higher portions in the grain-free varieties of pet food. Understanding that glyphosate is a notable offender to gut health by causing gut permeability and microbiome disruption, questions arise regarding the influence that high levels of glyphosate in many dog foods may have on the absorption or utilization of certain nutrients and amino acids, in addition to many other issues.

HRI has tested organic foods and the urine of humans consuming organic foods versus nonorganic foods and reports that a substantial portion of foods labeled "organic" do not contain detectable levels of glyphosate. Because of the pervasive presence of glyphosate in the agroecosystem, it is unavoidable that traces of glyphosate or its metabolites are present in many organic products, but measurable levels of glyphosate are found in only a very small proportion of organic products. The uncommon presence of measurable levels of glyphosate in organic foods may occur as the result of various factors, including drift from nearby farms; comingling in transport, packaging, or processing; and perhaps some mislabeling or fraud.

Minimizing the Damaging Effects of Glyphosate

One important measure of protection from glyphosate and other toxins is to eat organic and clean foods as much as possible. For canine and feline diets, feeding a species-appropriate meat-based diet will significantly decrease the pet's exposure to glyphosate as well as other herbicide toxins.

There are also some natural supplement products that can significantly help combat the damage caused in the body by consistent exposure to glyphosate and other toxins in food and the environment. Humic substances are known to protect the gut and other mucosal surfaces from the damaging effects of glyphosate (35). A proprietary blend (c) that uses soil-based, humic substances and carbon-based redox molecules to support the communication between mitochondria, cells, and bacteria is available. This helps to strengthen epithelial barriers and tight junction integrity, restoring damage from glyphosate disruption in the gut, kidney tubules, and sinus tissues, which also supports a healthy microbiome shift. An in vitro study evaluating the efficacy of this product on small bowel and colon epithelial cells incubated with this extract and then treated with glyphosate showed

ISSN 2474-1906

enhanced membrane integrity compared to controls as measured by Transepithelial Electrical Resistance (TEER) (66).

Zeolites are a natural substance that can address toxin damage and support detoxification from glyphosates and other chemicals (67, 68). Specifically, clinoptilolite is the most widely used zeolite for therapeutic and detoxification purposes. Zeolites are microporous, aluminosilicate minerals found in volcanic rock. These minerals are commonly used as commercial adsorbents and catalysts because they possess specific affinity for adsorbing and removing toxins and heavy metals, as well as supporting gut health and providing anti-inflammatory benefits. Furthermore, zeolites are commonly added to large animal feed and poultry feed and can also be added into companion animal (dogs, cats, and horses) diets as a routine supplement.

Conclusion

Glyphosate is a chemical substance that is heavily infiltrating the ecosystem and contributing to a host of adverse environmental and health consequences. It has been demonstrated that exposure levels to animals and humans have increased at alarming rates over the last few decades. Although there is a growing push to limit the use of glyphosate due to the vast body of accumulating research about its negative impacts, GBH chemicals are still widely used in agriculture and commonly used for residential lawn and garden purposes in the United States. In the European Union, however, glyphosate is only approved for use through December 2022 and has already been completely banned in some countries in Europe. Furthermore, a recent forum was held with the Review Board of the US Environmental Protection Agency (EPA) regarding the EPA's review of glyphosate. Dr. Zach Bush was among the scientists who attended to provide new evidence to support the revocation of glyphosate's license in the United States (teleconference communication, May 2022).

Given the rising extent of information regarding the dangers and widespread effects of glyphosate, it is important for veterinarians to be informed about this issue and how it is affecting animal patients, as well as the collective of animals and humans within the global environment.

Acknowledgments

The author wishes to thank those who contributed to this paper with shared information, edits, and/or images:

John Fagan, PhD, CEO & Chief Scientist, Health Research Institute

Kim Stevens, Rebekah Graves, and Zach Bush, MD, Intelligence of Nature* (ION*)

The author did not receive funding from the ION* Company, and there are no conflicts of interest with any contributing parties or individuals.

Endnotes

a. Roundup®, Monsanto, Whippany, NJ 07981.

b. Health Research Institute, Fairfield, Iowa. www.hrilabs.org.

c. Intelligence of Nature (ION*), Charlottesville, VA. https://intelligenceofnature.com

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