After Wildfire

Section 3

Water Quality Concerns After Wildfire

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Wildfires not only impact vegetation and land animals (including human beings and their property) they can also trigger flooding and harm aquatic habitat and water quality. The increased probability of catastrophic wildfires in the western United States and elsewhere in the world has increased the need to understand the effects fires may have on the physical and chemical properties of water. Surface water flowing from burned areas may carry greater levels of sediment, organic debris and chemicals that may significant degrade water quality and impair aquatic habitats.

Water quality, be it surface or subsurface water, is generally evaluated according to three major criteria: microbiological, physical and chemical properties. Within each, individual items relate to safety and aesthetics. Feeding poor quality water can have an effect on livestock. Often animals may not exhibit the effect even though productivity has been reduced.

Water quantity is also important. Providing unlimited high quality water is necessary for optimizing animal health and production. Water constitutes 60 to 70 percent of an animal's body. Consumption of water is more important than the consumption of food nutrients. Animals should be given all the water they can drink. Animals deprived of a sufficient water supply may become stressed and dehydrated. Water-related health problems in livestock may be caused by lack of an adequate supply and/or a supply of poor quality water. A general guide is that animals will drink 6 to 12 percent of their body weight in water per day. The lower levels in cooler climates and the higher level for hotter climates. Considering that a gallon of water weighs 8.3 pounds, a 1200 pound cow needs 8.7 gallons per day in January and during the hot season she needs 17.4 gallons per day.

Water consumption requirements vary depending on such things as kind and size of animal, physiological state of the animal (lactating, pregnant, growing, maintenance), activity level, type of diet, climatic conditions, and quality of the water. Lactating beef cows will consume up to 75 percent more water than dry cows. Calves require much more water after weaning than before. More active animals require more water. Activities such as grazing, and breeding may increase the evaporative heat loss of the animal, dramatically affecting water needs. Dry diets require more water consumption than moist diets such as silage or lush pasture. Hot summer days (90° F or 32° C) will result in 2.5 to 3 times the water consumption of fall, winter and spring days when temperatures are 32° F (0°C) and below. Humidity also affects the amount of water animals will consume by increasing their demand. Higher humidity limits the cooling ability of animals, through evaporespiration. Water with a higher salt content can actually increase the animal's water consumption.

General Impact of Wildfires:

Fires change rainfall interception, infiltration, evapotranspiration and snow accumulation through the loss of vegetation canopies, litter and soil organic matter. This greatly increases erosion from rainfall. Changes in these processes can result in a large net change in runoff and erosion on the watershed scale. For high severity wildfires, peak streamflow discharge can be up to 60 times higher than what would be expected under pre-fire conditions or from comparable unburned watersheds.[1]

During the fire itself, rapid and extreme increases in water temperatures, lower water levels, and soil and ash polluting the water may make it impossible for fish to breath. In addition, some fire suppressant compounds (i.e. red slurry) that are dropped onto wildfires can cause death in fish and amphibians and are a concern for drinking water sources. The effect of sunlight on the slurry intensifies the toxicity of at least one chemical, sodium ferrocyanide (see Chemical cyanide section). Even in slurry compounds without this chemical there are still toxic levels of ammonia. Such compounds react with other substances to produce chemicals that are toxic to fish and amphibians.[1]

The loss of vegetation and the increase in water flowing through the watershed also affect the movement of nutrients. Following wildfire, nutrient losses from a watershed usually increase. Nutrient concentrations including nitrate, organic nitrogen, potassium, calcium and magnesium commonly increase after fire. The type and amount of specific nutrients lost following fire vary from watershed to watershed, depending on burn intensity and erosion rates. Increased concentrations of nutrients

1. (Tiedemann et al., 1979)

into water bodies are short lived, generally being greatest during the first few storms or snow melts after the fire. Water quality typically returns to pre-burn levels within one or two years, as fresh water entering the streams from springs and the atmosphere over time helps clean and dilute most pollution.

Soil and water quality

Physical and chemical properties of forest soils, which determine site productivity and influence water infiltration and runoff rates can be significantly changed for a few years following wildfires. Changes in soil pore space and infiltration rates are small as long as the organic layer is not completely consumed. A properly applied prescribed fire will not burn all of the litter layer, nor will it kill the roots of understory plants whereas wildfires usually burn hot enough to completely consume all organic or litter layers and also kill roots of understory plants. Without litter and plants to protect the soil, runoff and erosion can create changes to water quality and quantity.

Physical water quality conditions

Many physical water quality conditions in streams can be affected by wildfires. Surface water temperature, turbidity, sediment, and algae will be discussed.

Temperature

Since more sunlight reaches streams and the soil along their banks, water temperatures may increase after a wildfire. Soil properties can be altered when the loss of litter and duff layers causes soil to be heated. This can form a water repellent layer of soil. The actual rise in temperature depends on both the length of stream exposed and the mitigating effects of increased streamflow.

Elevated stream temperatures may affect fish habitat. However, in normally cool streams the increase may not be enough to cause problems. For optimal livestock production water should be neither hot nor frozen. Steers gained .3 to .4 lbs. more per day when drinking water between 40 and 65 degrees F versus those drinking warmer water.[2]

Sediment and Turbidity

Wildfires remove plants whose roots hold the soil together, so after a fire even a mild rain can cause erosion. Eroded soil is carried into rivers and lakes. This sediment can take the form of suspended and/or bedload sediment. Suspended sediment is typically fine particles and organic material that stays mixed in the water. Bedload is material that is too heavy to stay suspended in the water and moves in contact with the streambed or as a result from storms or human-induced events.

Turbidity is cloudiness in water caused by suspended particles. High levels of turbidity can make treatment and filtering of water difficult. Turbidity may also affect the palatability of the water for livestock use, and the animals' acceptance of the water.

Algae

Algae is a term general term used to describe many forms of aquatic plant life, but not all aquatic plants are algae. Nearly all waters have some form of algae growing in them. Nutrients and sunlight are needed along with the water to create growth conditions for algae. Increased water temperature and nutrients following wildfires, especially where the canopy cover of a stream has been removed, will greatly increase algae growth in surface waters. Blue-Green Algae can be toxic to animals. However, only a couple toxic types have been found in Montana and they usually occur in still waters. No good method exists to predict whether or not the algaes will produce the toxins. If you suspect algae toxicity, look for any dead animals around the water source, as nearly all animals are affected. Blue Green Algae is also slimy and difficult to pick up in your hand. So if you can pick up the algae, it is probably not a toxic form.

Chemical water quality conditions

pH

The pH of water denotes either alkalinity or acidity. A pH of 7 is neutral; over 7 indicates alkalinity; below 7 indicates acidity. Forested lands are normally acidic (less than pH 7) while many of the grasslands are alkaline. Most cases of increased pH after wildfires are associated with forested land where soil pH is typically acidic and large amounts of organic matter burn. It is rarely a concern, as most water samples fall within the acceptable range of 6.5 to 8.5.

Alkalinity

Increased alkalinity is usually attributed to ash in a stream.

Bicarbonates and carbonates may contribute heavily to alkalinity (pH) levels. As the pH goes up, the waters become more alkaline, and at values of around 10, waters are very highly alkaline and contain carbonates. Excessive alkalinity (above 8.5) in water can cause physiological and digestive upset in livestock. However, most waters have alkalinities of less than 10 and are not harmful.

Salinity

Saline water is not the same as alkaline water. The expression "Total Dissolved Solids" (TDS) is often used to denote the level of water salinity. Salinity refers to salts dissolved in water. Salts commonly present in water include carbonate, bicarbonates, sulfates, calcium, magnesium, nitrates, chlorides, phosphates, and fluorides. Highly mineralized waters (high TDS) don't have much effect on health as long as there are no continuing laxative effects and normal amounts of water are consumed. One gram of sulfate per liter may cause scours. Salts such as sodium-chloride change the electrolyte balance and intracellular pressure in the body, producing a form of dehydration. Salts also place a strain on the kidneys. Excess fluoride causes degeneration of the teeth. Occasionally the levels of salts are high enough to cause harmful effects that result in poor performance,

2. (Boles, et al., 1988)

illness or even death in animals forced to drink them. Various salts have slightly different effects. These effects seem to be additive, which means that a mixture of them causes the same degree of harm as a single salt of the same total concentration.

Animals have the ability to adapt to saline water quite well, but abrupt changes from waters of low salts to waters of high salt concentrations may cause harm. Animals may refuse to drink high saline water for many days, followed by a period where they drink a large amount. They may then become sick or die. High salt concentrations that are less than toxic may actually cause an increase in water consumption. The tolerance of animals to salts in water depends on factors such as water requirements, species, age, physiological condition, season of the year and salt content of the total diet as well as the water.

Salinity is expressed as parts per million (ppm) or as milligrams per liter (mg/l). Electrical Conductivity (EC) is directly correlated to TDS and can also be used as a measure of salinity.

Table 1. A guide to the use of saline waters for livestock

Total Soluble Salts Content of Waters (mg/l)	Comments
Less than 1,000	These waters have a relatively low level of salinity and should present no serious effect.
1,000 to 2,999	Waters should be satisfactory. May cause temporary and mild diarrhea in livestock not accustomed to them, but should not affect their health or performance.
3,000 to 4,999	Should be satisfactory, although may cause temporary diarrhea or be refused at first by animals not accustomed.
5,000 to 6,999	Can be used with reasonable safety. Avoid using waters approaching the higher levels for pregnant or lactating animals.
7,000 to 10,000	Considerable risk may exist using these waters for pregnant or lactating animals, young animals or any animals subjected to heavy heat stress or water loss. In general, use should be avoided although mature animals may subsist for long periods of time under conditions of low stress.
More than 10,000	Not recommended for use under any conditions.

From: NAS, 1994. Nutrients and Toxic Substances in Water for Livestock and Poultry.

Nutrients:

Nitrate and phosphorus in surface waters, which contribute to increased aquatic plant and algae growth, increase following a wildfire

Nitrogen:

Nitrates, mainly nitrate-nitrogen, increase in the soil and are mobile in water. Therefore, they readily move into ground and surface water. The nitrates are not very toxic themselves, but in the rumen the bacteria reduce them to nitrites that then get into the blood stream. Nitrites convert the red pigment, hemoglobin (which is responsible for carrying oxygen from the lungs to the tissues) to a dark brown pigment, methemoglobin, which will not carry oxygen. When this conversion is about 50 percent complete the animal shows signs of distress suggesting a shortage of breath. At an 80 percent or more conversion, the animal usually dies from suffocation. Non-ruminants may convert small amounts of ingested nitrate to nitrite in their intestines, but the amount converted is not harmful.

Nitrates in the diet may interfere in the conversion of carotene to vitamin A under some circumstances, but experimental data shows this to be of no practical significance. Further, the experimental evidence suggests that chronic nitrate poisoning does not occur in livestock and that the young are no more susceptible to the acute type than are older animals. As a rule, nitrate poisoning results from ruminants eating forages of high nitrate content. Nitrates are occasionally found at toxic levels in water. Nitrites are also found in water on many occasions, but not at levels dangerous to livestock. As a rule, reports of water analyses include nitrites with the nitrates.

Phosphorus:

Phosphorus will usually increase the first year after the fire. Phosphorus readily binds to soil particles. Because of this adherence to sediments, initial storms following a fire wash increased levels of phosphorus into surface waters. An increased phosphorus level in water contributes to eutrophication, a process of nutrient enrichment that results in the body of water becoming filled with aquatic plants and low in oxygen content.

Dissolved Oxygen:

Some types of aquatic life can survive in streams with a Dissolved Oxygen (DO) level of 4-6 mg/l. However, to maintain cold water fisheries DO levels must be between 8 and 13 mg/l. Dissolved Oxygen levels are lowered when sediments and debris enter the water. The sediments absorb sunlight, increasing the temperature of the water. This lowers the water's oxygen holding capacity. Cold water will hold more oxygen than warm water. Soil temperatures that increase as a result of wildfires also increase the water temperature. The decomposition process of organic matter in the water lowers the DO content because decomposition uses oxygen.

Cyanide:

Cyanide can be of special concern after wildfires because it is a product of some types of the red fire retardant slurry. Even though some cyanide is produced naturally in wildfires,[3] it is most likely that increased levels of cyanide result from the use of fire retardant slurry. Free cyanide is acutely toxic to salmonids at concentrations ranging from 30 µg/L (ppb) to 160 µg/L, depending on species. Other species of freshwater fish are somewhat more tolerant.[4] In livestock, cyanide toxicity is more commonly a result of prussic acid poisoning. Prussic acid production is apparently more likely to occur in ruminants because both chewing by the animal and rumen bacteria release cyanide from the plant materials being consumed. Hydrochloric acid in the stomachs of horses and swine destroys plant enzymes that release the toxin. Sheep are slightly more resistant to cyanide than are cattle. Once cyanide is absorbed, it is readily transported throughout the body, and is very toxic to all animals. In cells, cyanide reacts with cytochrome oxidase (an enzyme involved in the electron transport system that enables cells to use oxygen) to form a stable, inactive complex. As a result, the cyanide ion inhibits the release of oxygen from the hemoglobin of blood to individual cells. Without oxygen, cellular respiration ceases and cells die rapidly due to hypoxia. This should rarely be a problem unless the livestock are in direct contact with the slurry or the slurry is in or washed into livestock drinking water supplies.[3,4]

Other Chemicals:

Many other chemicals may be found in water, some of which could be detrimental to livestock production, but are not considered to be of major concern after wildfire unless special situations existed in the area of the fire. Table 3 lists what are generally considered safe levels of some potentially toxic nutrients and contaminants in water for cattle.[5]

Table 2. Nitrate levels as ppm in water and percent in forages expressed in three different units:

Potassium Nitrate (KNO_3)	Nitrate Nitrogen (N)	Nitrate (NO_3)	INTERPRETATION
WATER			
0-720	0-100	0-440	Considered safe.
720-2100	100-300	440-1300	Exercise caution. Consider additive effect with nitrates in feed.
Over 2100	Over 300	Over 1300	Potentially toxic.
FORAGES			
0-1%	0-.15%	0-0.65%	Considered safe.
1-3%	0.15-0.45%	0.65-2%	Exercise caution. May need to dilute or limit feed forages.
Over 3%	Over .45%	Over 2%	Potentially toxic.

Correlation between units
1% KNO_3 = 0.14% N = 0.61% NO_3
1% N = 7.22% KNO3 = 4.43% NO_3
1% NO_3 = 0.23% N = 1.63% KNO_3

Table 3. Contaminant levels generally considered safe

Element	ppm
Aluminum	5.0
Arsenic	0.2
Boron	5.0
Cadmium	0.05
Chromium	1.0
Cobalt	1.0
Copper	0.5
Fluorine	2.0
Lead	0.1
Mercury	0.01
Nickel	1.0
Selenium	0.05
Sulfate	1000.0
Vanadium	0.1
Zinc	25.0

3 (Yokelson,R. J., et al., 1997)
4 (Moore, 1990)
5 (Boyles, 2000)

Summary

Wildfires can have an effect on water quality. Most effects come from added sediments and debris to the surface water. In some cases these physical effects can reroute streams where other chemical and biological conditions can be concerns for animals drinking water and aquatic life. If a water body is known to have nutrient levels that are high enough to be given consideration prior to the wildfire, special care should be taken to manage for any increases resulting from the fire.

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AFTER WILDFIRE — Information for landowners coping with the aftermath of wildfire

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This book provides information to help landowners cope with the aftermath of future wildfires in Montana and in other states. Each section can be copied and distributed as needed. To obtain a copy of this publication or any of the following sections, please contact your local Montana State University Extension agent or download a PDF file at www.montana.edu/publications.

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