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Endocrine Disruptors in Our Drinking Water: Should We Be Concerned?

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Background

Metropolitan Business Academy is an inter-district magnet high school that provides students with insights into the world of business. The business focus is on both entrepreneurship and college preparation. Ensuring the future availability of potable water for everyone could present business opportunities. Government regulation of water quality may impact the methods businesses use to produce their products. This unit will discuss some of the current issues facing our water supply. The lesson plans will be a collection of real life math problems which will use the challenges facing our water supply as a backdrop.

Our water systems may be contaminated by all of the medicines, antibiotics, birth control pills, vitamins, and menopausal drugs that we as a society take to feel healthier, and to get better faster. As we use these items, some of them will inevitably get into our water supply, potentially impacting our food sources and water sources. This, in turn, may be a factor in the health, growth, and evolution of humans and animals. How fast is this happening? Can it be quantified? Should we be concerned? Can this be modeled using mathematical tools, such as growth and decay models?

One of the New Haven Public Schools' Algebra I & II curricular power standards is "Collect real data and create meaningful graphical representations of the data". [1] The "Evolutionary Medicine" seminar has provided food for thought as to how humans and animals evolve as their environment changes. This unit will primarily look at problems based on our water systems and the students will be able to use their problem solving skills to analyze the problem and then communicate via algebraic and graphical models their conclusions.

The question is whether or not the pharmaceuticals intended to make our lives better, more productive, and less disease-filled, are in fact getting into our water systems and over time doing more harm than good.

Scientific studies of water sources, streams and rivers downstream of large urban areas and agricultural areas have shown that there is a measurable quantity of hormones and medicines in the water that should not naturally occur. One study has found an appreciable amount of pharmaceuticals in the San Francisco Bay. [2] This contamination was found in water that had already gone through the sewage treatment process.

Among the potential sources for these hormones are birth control pill and patch users. After having their particular intended effect, the body of the user disposes of these used hormones, and any excess through urine, which then enters the sanitary system. Depending on whether the users live in a rural setting or an urban setting, the hormones may flow into the water table via a septic system or into major waterways via sewage systems. It appears that neither type of system eliminates these hormones completely. While a sociological discussion of the impacts of hormonal birth control are beyond the scope of this document, the enhanced control and flexibility offered by their use is generally considered to make their introduction to society irreversible and to make them an option which will continue to be used for the foreseeable future.

In some cases, people who have leftover prescriptive and over-the-counter medicines dispose of them by flushing the remainder down the toilet. While it is understandable that most people might not understand the implications of such an action , the extent of the problem was illustrated recently, after Michael Jackson's death in 2009, when his doctor was interviewed by Diane Sawyer. While the doctor had presumably been educated in the proper cautions to take with prescription medicines, he stated that he had told Michael to flush his extra medicines down the toilet. [3]

Another source of hormonal contamination is thought to be the hormones that are used in livestock agriculture to increase meat production. [4] For our purposes, we are not considering the effect of eating the actual meat of an animal that has been given hormones, but looking at the impact of the hormones and hormone emulators that enter the ground and groundwater, and eventually our drinking water.

Another source is the pharmaceutical companies themselves. Over-production and out-of-date medicines (including hormonal) are dumped into our waste stream and eventually find their way into our groundwater, streams, and major waterways.

A last set of contaminants to consider are chemicals from our hair and bathing products which mimic estrogens when in the water system. Even the plastic bottles that are so commonly used for water, break down in the water and act like estrogen. The chemicals produced from hair and bathing products and the breakdown of plastic bottles are categorized as phthalates.

Concern over the impact of these products is not universal. There are those in the pharmaceutical industry who state that the amounts of these hormones that find their way into our drinking water are minuscule and have no measurable impact on us. [5] Some claim that there can be no harm to us because these medicines have gone through rigorous testing and are therefore safe even if they are in our drinking water. [6] Still others think that hormones have always been in our water system so there is no true reason for concern. As Dr. Robert Benson, as an independent researcher - in a role separate from his regular job at the Environmental Protection Agency(EPA) -- concluded from his study in rats that " it is unlikely that humans are suffering adverse effects from current environmental exposure to these phthalate esters" [7] American Chemistry Council Managing Director issues the following statement on July 9, 2009 that Dr. Benson's study confirmed his observation "that phthalates do not migrate out of products easily and they do not build up in the body; instead they begin to break down within minutes and are gone from the body in less than 24 hours" [8]

Early data indications are alarming; it has been demonstrated that wildlife in our major water ways have already shown biological responses that can be directly attributed to the increase of hormones or hormone emulators in the water. [9] For example, male fish are becoming feminized. While the infrastructure through which our drinking water passes may dilute the hormones that wildlife are exposed to before entry into our drinking water system, dilution does not constitute elimination. Once in our drinking water, it is possible that

one of the side effects of this increased hormone level is observed in the increasingly younger age at which girls are entering puberty. The impact on human males has yet be determined, but preliminary studies seem to indicate [10] that there are more boys born with defects. "For example, up to 7 percent of boys are now born with undescended testicles, although this often self-corrects over time. And up to 1 percent of boys in the United States are now born with hypospadias, in which the urethra exits the penis improperly, such as at the base rather than the tip", Kristoff reports based on information from The Journal of Pediatric Urology. [11] In addition there is an increasing amount of infertility among couples looking to have children that may be traceable to altered hormone levels. According to one report, infertility of married women between the ages of 20 and 24 has increased 177% from1965 to 1982. [12] Other longer term impacts to humans may not have yet even begun to appear. Correlation of the hormones found with problems found in the related population is a clearly identified problem to which mathematical tools can be applied.

If there is an impact to fish, one can only suppose that other creatures in our food chain are also being impacted by the chemicals in our water. While the amounts of these contaminants in our water system may seem to be very low, the impact on our world appears to have already started. The phenomenon of male fish taking on female characteristics has been observed both in the United States and in Great Britain. [13] This indicates a possible global issue rather than a national problem. Studying the potential impact on the reproduction of fish over successive generations, Jon Nash of Laboratory of Aquatic Ecology, University of Leuven, Belgium, stated "that exposure to environmentally relevant levels of [Endocrine Disrupting Compounds,] EDCs, cause very significant reductions in reproductive success. Lifetime exposure to 5ng/l of ethynylestradiol, for example, caused complete reproductive failure. Moreover, these reproductive failures were not generally caused by exposure proximate to the timing of spawning but by developmental disruption during embryonic and larval development". [14]

In the United States, The Food and Drug Administration has stringent testing requirements for drugs before allowing them to be placed on the market. It is reasonable to assume that the medicines are safe when used for the designated purpose and in the designated quantities. Birth control pills and hormone replacement drugs should be considered safe for the women for whom they have been prescribed. When these drugs find their way into our water supply, in small but measurable quantities, it is reasonable that there may be unforeseen consequences. There may be an impact of the small quantities of hormones on young girls and boys who would not usually be prescribed these drugs. The impact of being exposed to these hormones constantly in the water that we need for our very survival needs to be studied and quantified.

Even though hormones are naturally occurring and part of the normal growth and reproductive process, the amounts that are now occurring in our water systems are unprecedented. This issue merits greater study. Because there have been only a few generations of people since the prevalence of hormone usage by women and agriculture, the long term effects on people may not yet be evident.

From a math perspective the use of this relevant topic to discuss and use scientific notation with high school students presents itself well. There are measurable levels of these contaminants that have been determined and potential impacts of them have been identified. Further, a logical consideration is that the further hormones are from their sources the more their levels should be diluted in freshwater. This suggests a practical use of exponential decay models by the students.

Because this topic embraces current scientific studies and discusses changes in our environment that may be quantifiable and certainly of interest to high school students, it easily becomes the backdrop to several real life problems that the students would be engaged in solving. Because, there is still much that is unknown at

this time about the mechanisms that are intertwined, the students can be encouraged to postulate and conjecture what the future may bring based on facts given or add new measurement to their analysis. This would in fact be a great blending of science and math with a healthy dose of high level critical thinking and research, where there may not be a single correct answer. The students will be given the opportunity to defend their answers mathematically and with cogent arguments.

The following discusses or gives many facts about the topic and brings to light some of the current scientific studies occurring literally in our backyard. What we do as individuals does indeed impact what is in our water.

Is our Water Quality Being Monitored?

The United States passed a Safe Drinking Water Act in 1974 with amendments in 1986 and 1996. This act gives the EPA the authority to set standards for water quality and oversight over the states and water suppliers. The EPA sets the standards for the acceptable levels of the contaminants. The Act also established the process that the EPA must use to identify and list unregulated contaminants that might hold future risk to Americans. This is called the "Contaminant Candidate List". [15] There are primary drinking water regulations which contain enforceable standards to protect public health. Secondary regulations include non-enforceable regulations which contain guidelines. If the guidelines are exceeded it is not seen as a public health threat because the contaminants usually cause cosmetic or aesthetic issues. This would be something like skin or tooth discoloration or the smell or taste of the water.

In August 1996, Congress passed both the Food Quality Protection Act (FQPA) and amendments to the Safe Drinking Water Act (SDWA), both containing provisions calling for the screening and testing of chemicals and pesticides for possible endocrine disrupting effects. These laws require the EPA to develop a screening program that uses appropriate validated test systems and other scientifically relevant information to determine if the effect that certain substances have in humans is similar to the effect produced by a naturally occurring hormone. [16] Implementation of these sections of the law has yet to happen.

All public water systems must comply with the EPA regulations and keep the level of contaminants within the acceptable limits. There are a number of organizations involved in enforcing and monitoring the levels of contaminants. However, the Safe Drinking Water Act does not apply to bottled water. That is covered under the Food and Drug Administration (FDA). The Center for Disease Control and Prevention (CDC)is interested in any elevated amount of microbes that may cause a specific disease outbreak.

The World Health Organization(WHO) also monitors and establishes standards for the world's water supply. Their interest is primarily in undeveloped countries and establishing proper sewage treatment facilities.

Reports of local water testing are often mentioned in local newspapers and contain any unusual results if there is cause for public concern.

What is being monitored?

Water may be contaminated by many different substances. The main categories are microorganisms or microbes, organic chemicals, inorganic chemicals, disinfectants, disinfection byproducts and radionuclides. [17]

Microbes tested in drinking water include Cryptosporidium, Giardia lamblia, viruses from human and animal waste and legionella are found naturally in water, but multiply in heating systems. [18]

Organic Chemicals tested in drinking water include acryllamide, alachlor, atrazine, benzene, carbon tetrachloride, chlordane, dioxin, polychlorinated biphenyls(PCB), toluene, and vinyl chloride. These chemicals and others in this organic chemicals are generally from runoff from chemical, plastic, degreasing, and textile factories, and application of herbicides and insecticides. [19]

Disinfectants such as chlorine, chloramine and chlorine dioxide are also tested in drinking water and in some cases byproducts of the process used to control microbes. [20]

Disinfection byproducts tested in drinking water include bromate, chlorite, haloacetic acids, and total trihalomethanes which are byproducts of the use of disinfectants in the water to control microbes. [21]

Inorganic Chemicals tested for are antimony, arsenic, asbestos, barium, beryllyum, cadmium, chromium, copper, fluoride, lead, mercury, nitrate, nitrateselenium, and thallium. These inorganic chemicals get into the water supply by leaching from ore-producing sites, fertilizer, plastic and metal factories, runoff from croplands and landfills, and erosion of natural deposits. [22]

Radionuclides that are monitored include alpha and beta particle, radium 226 and 228 and uranium which come primarily from erosion of natural deposits. [23]

Some of the potentially harmful chemicals occur naturally in many areas and find their way into our water. At certain levels the elements are beneficial and necessary for healthy life, but at greater amounts can be harmful and cause illness. An example of this would be iron. Other chemicals are produced from the cleaning or sanitizing process where chlorine is used. Chlorine itself is dangerous to people, yet is used to kill germs or microbes. One of the outcomes is that chlorinated water is in most cases safer, because it contains fewer germs or microbes, but sometimes compounds created in the chlorination process are also harmful to humans. [24]

Chemicals like MTBE, which have been used in the United States as a gasoline additive to reduce automobile emissions from carbon monoxide do not yet have a standard maximum level, MTBE is being studied since there have been reports of it being detected in the surface water and ground water. [25]

Uranium has been found in the water at two Madison, Connecticut schools at 110 microgram per liter of water; well above the EPA thresholds of 30 microgram per liter for homes. There currently is no set standard for schools, but common sense dictates that there should not be allowed more uranium at schools than at homes. The uranium is in water from wells that were drilled several decades ago. [26]

Other than byproducts of the drug manufacturing process, there do not appear to be many pharmaceuticals currently on the monitoring list.

How is water being monitored?

It is becoming clear that it is important to monitor our water for possible contamination so that corrective measures may be taken if found necessary. Currently, water samples are taken and then tested to make sure that the levels of contaminants are within accepted regulated levels. The required number of samples taken on a daily and monthly basis is also regulated. In some cases, volunteers or seasonal workers are enlisted to collect samples and submit them for appropriate testing.

Bacteria and microorganisms are measured against the heterotrophic plate count or HPC, which indicates the level of bacteria that are naturally present in the environment. This allows for determining if there is an unusual amount of bacteria present. The lower the concentration of bacteria in a water system, the better maintained it is. The guideline is no more than 500 bacterial colonies per milliliter. Bacteria like cryptosporidium must not be in the water at all.

Turbidity or the cloudiness of water may be an indication of water quality and effective filtration. Higher turbidity would indicate that there may be high levels of disease causing microbes such as viruses, parasites and bacteria. But higher turbidity alone does not mean that microbes are present, or that the ones present are disease-causing microbes. Total coliforms must be measurably at zero. If a water system tests positive for coliform then it must be treated and retested.

There is not yet any defined hormone level guidance, nor any standard monitoring of what these levels are. However, since some of the endocrine disruptors are also pesticides and herbicides, there are guidelines for their maximum levels.

Endocrine Disruptor Screening Program

A growing body of scientific research indicates that many man-made industrial chemicals and pesticides may interfere with the normal functioning of human and wildlife endocrine systems. These endocrine, or hormone, disrupters may cause a variety of problems with development, behavior, and reproduction.

Disruption of the endrocrine system can occur in various ways. For example, some

chemicals may mimic a natural hormone, "fooling" the body into over-responding to the stimulus or responding at inappropriate times. Other chemicals may block the effects of a hormone in parts of the body normally sensitive to it. Still others may directly stimulate or inhibit the endocrine system, causing overproduction or underproduction of hormones. Certain drugs, such as birth control pills, are used to cause some of these effects intentionally.

While toxicological testing is done on many of the pesticides we use, as well as on some of the industrial chemicals, there is very little understanding of the effect these pesticides and chemicals have as endocrine disrupters after they have reached the water supply or even what the appropriate tests would be to determine the risks. Because it has become generally accepted that some testing is, indeed, appropriate, the Safe Drinking Water Act and the Food Quality Protection Act mandate that a program to test the water be

developed by the EPA under the authority they have been granted under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), and Toxic Substances Control Act (TSCA). [27]

EPA's Office of Prevention, Pesticides and Toxic Substances proposes to establish the Endocrine Disruptor Screening and Testing Advisory Committee (EDSTAC). The purpose of EDSTAC will be to provide advice and counsel to the Agency on a strategy to screen and test chemicals and pesticides that may be the cause of endocrine disruption in humans, fish, and wildlife. This strategy will be aimed at reducing or mitigating risk to human health and the environment. EDSTAC will use a consensus building approach to reach their findings and recommendations. [28]

Possible effects of endocrine disruptors have been observed on both animals and humans. The effects include behavioral, such as mating habits, physical, such as malformed genitalia and sterility. Lower sperm counts in humans over the last half century may also be attributed to endocrine disruptors, though there is still some question as to the specific cause. We still have a limited understanding about which specific chemicals interfere with the functions of the endocrine system. [29]

How An Endocrine Disruptor Works:

One of the ways that an endocrine disruptor works is that the chemical makes an organism produce more enzyme aromatase which then converts androgen hormones to estrogen hormones. Androgen hormones are those chemicals, like steroids that control the development and maintenance of masculine characteristics in vertebrates. This includes the activity of the male sex organs and development of male sex characteristics. Androgens are also the precursor of all estrogens, the female sex hormones. The primary and most well-known androgen is testosterone. Androgens play a major role in the development and maintenance of masculine secondary sexual characteristics.

In fish androgen hormones affect male aggression, [30] reproductive capability and defense of the young. [31] In frogs androgen hormones also impact reproductive capability. This includes the size of the voice box which in males must produce the desired mating call for reproduction to occur.

Once the frog or fish has more female hormones than male hormones, its characteristics start becoming female. This includes having the ability to have precursors to eggs and in some cases actual eggs. The voice of the male frog also changes and is not of the same quality as a normal male frog. The voice box, which is smaller than normal impacts the capability to produce a recognizable the mating call. [32]

The endocrine disruptors that are now found in our water have been implicated as the cause of the feminization of the frogs and fish. The changes that have effectively feminized the fish and frogs may impact these organisms' ability to reproduce.

What is happening to frogs?

Two prominent biologists/ herpetologists Tyrone Hayes of University of California, Berkeley, and David Skelly of Yale University have been involved in research on frogs. Their research is relevant because much of it has to do with determining the endocrine disruptors' impact on frogs. The research is telling us that even though frogs can evolve quickly to adapt to environmental change, there are concerns as to what is in the water system that is changing the frogs, making their survival less assured.

One contaminant to watch may be atrazine, an herbicide that has been pointed to as the endocrine disruptor that has been feminizing the frogs according to Tyrone Hayes. He suggests that this substance is much more dangerous in smaller amounts than the EPA currently tests for. In fact, he suggests that an amount 30 times less than what the EPA tests for can seriously damage the frogs. Paradoxically, higher levels seem to trigger a defense mechanism in the frogs and do not appear to harm the frogs as much. [33]

David Skelly isn't so sure that it is the atrazine that is the problem, but suggests that a trematode has a lot to do with frog deformities. Although he has been researching the feminization of male frogs, his primary focus has been the study of extra legs or missing legs. In another apparent paradox, the deformities also happen where the trematodes are not present. Biologist Skelly also observes that he had expected to find a lot of frogs effected around agricultural areas, but that he has found that this isn't so according to his research. It may be a matter of the thresholds of the chemical similar to that observed by Tyrone Hayes in his separate studies in that there may be so much atrazine in the water near farms that the natural defenses of the frogs come into play.

One postulation is that ponds have more fertilizer pollution. Therefore they have more algae, which typically means more snails to eat the algae. The trematodes are parasites of the snails. The trematodes leave the snails and burrow into the tadpoles at the area where their legs are formed. The legs do not form properly and the deformed frogs become easy prey for birds, which eat them and the trematodes. The trematodes lay eggs in the bird which are expelled near the water and the larva find snails to live in. David Skelly has done research in ponds literally in my backyard and has found a disturbing number of deformed frogs. [34]

Whatever the cause(s), there are issues with frogs throughout the world. This is cause for alarm, because frogs or amphibians have been adapting well to the environment around for 250 million years, yet within the past 30-40 years, it has become evident that they are struggling to survive. Frogs have deformities that have never been seen until recently: too many legs, not enough legs, male frogs having female characteristics, such as male genitalia that develop to become female-like with the possibility of laying eggs, and reduction of male voice boxes, so the call to mate is no longer understood by the female. Currently about 1 in 5-6 or about 18-20% of frogs appear to be feminized. [35]

Why do we care about the frogs?

Several reasons present themselves as to why we need to pay attention to what is happening with the frogs. First, whether humans eat them directly or not, they are a key part of the food chain. If something happens to materially change their numbers, there will be some other creatures above them on the food chain that will go hungry. Additionally, the organisms upon which frogs feed will have lost their natural predator, increase in number, and create an unbalance. Changes to each of these creatures, plants, or organisms will have similar cascading effects.

Second, frog endocrine systems are very similar to those of humans. If there is something substantial happening to the frogs' endocrine systems, there is justifiable concern that humans are also being affected in some way.

The third reason is that the frogs breathe through their skin, making them very susceptible to toxins in the water. The problems the frogs are having indicates that there are toxins in the water, the very water that humans also drink and need to survive.

Summary

Chemicals, whether natural or man made that are introduced into our environment affect all creatures, including humans. Depending on the chemical, animals and humans may evolve to coexist with the chemical. Since we all need water to survive, things that find their way into our water system have the possibility of harming or helping us. In some cases there may be no impact whatsoever.

People are being affected by what is in the water. How much and exactly how, no one is sure. One thing has been made clear though, is that there is a greater incidence of infertility and girls are entering puberty earlier. The incidence of boys born with defects in their genitalia has also increased. Is this a result of the increase of endocrine disruptors in our water supply? How this impacts our future is certainly a mystery for now.

Water is monitored, but it is questionable whether such monitoring accurately indicates safety for human consumption. This is clearly a health issue, and it is likely that the particular contamination that is worrisome has to do with endocrine disruptors coming from pharmaceutical, herbicides and beauty product contaminants. Judging from amphibian species declines, especially frogs, humans may be facing severe health issues in the future due to such contamination, and we may already be seeing these effects in terms of rising human infertility rates.

However, much research needs to be done because these issues are controversial, and scientists are not even in agreement regarding frog declines which are intensely studied. Below I present lesson plans relating to this exciting and important topic in biology, which can be used as a central focus in math.

Lesson Plans

Objective

The group of lessons are meant to be interdisciplinary lessons with a melding of science, math and writing. The following lessons provide thoughtful exercises that can be expanded on or taken in pieces for specific skills that may need to be addressed. When taken together the lessons will provide a real life scenario that will interest the students since the situations contain information about the world around them that is changing. Certainly, the topic of what is in our water, did we put it there, how long will it stay there, and is it safe to go swimming or to drink the water should be of interest to the students.

Lesson 1: Introductory lesson

As an introduction to this unit, the PBS special "Frogs the Green Line" which is about 30 minutes is viewed. This show is available on the Internet and is broken into pieces that may be viewed separately. Based on information from this introduction, the students will answer questions. CAPT (the standardized test that is currently given to sophomores in high school in Connecticut) type questions based on knowledge of percentage and proportions are included. This lesson is designed to introduce the topic of water and entice the students to think about it some more, instead of taking water for granted.

Questions that would be appropriate are:

1. Are frogs in trouble?
2. What is happening to the frogs? Name three things impacting the frogs.
3. Do you think what is happening to the frogs gives clues about what may be in your drinking water?
4. How many male frogs on average have female traits?
5. Based on your answer to number 4, how many male frogs would have female traits if there are 100 male frogs in the pond, 200 male frogs, 500 male frogs?
6. What if the percentage of male frogs having male traits, was 10%, how many male frogs would have female traits if there are 100 male frogs in the pond, 200 male frogs, 500 male frogs?

Lesson 2: Solutions

There are two basic ways that the level of a contaminant may be brought under the threshold stipulated by the EPA. One is to increase the amount of water, essentially diluting the solution. The other way is to eliminate the amount of the contaminant.

The following situation problems are about solutions. In order for students to be successful in solving these problems they need to be comfortable with scientific notation, since the amounts being discussed are very small and very large. The other skills that the students need to be proficient with are using percentages. To check these skills a few solution problems are presented to the students.

Solution Problems:

1. If you have one liter solution that is 20% saline and you want to have a solution that is 10% saline, how much water must you add?
2. If you have one liter of a solution that is 20% saline and one liter of another solution that is 10% saline and you mix them together, what is the percent of saline in the resulting solution?
3. If you have one liter of 20% saline solution, how much salt must be added to make the solution 30%?
4. If you have two liters of 15% saline solution and you wish to create a solution that is 25%, how much 40% solution do you need to add?

Real -Life Solution Problem:

Just as solutions are mixed together, in the real world contaminant levels may increase or decrease as clean or contaminated water is added to a pond from rain water or a flowing brook or river. During the summer, we have many "no swimming" alerts as certain contaminant levels rise above the maximum levels. This happens when there has been a heavy rain fall and sewage treatment area become overwhelmed and some untreated sewage ends up in the rivers and brooks. In addition heavy rains allow many items on the ground to be swept along and into the rivers and brooks as runoff. Many times, within a day or so, the swimming ban is lifted. This is due to the fact that the contamination levels have decreased because clean water has been introduced. Most times the water testers are not concerned about how long it will take for the water to be safe, but the beach goers and vacationers would like to know in order to make appropriate plans. You want to help the vacationers out and plan to use some of your knowledge of solutions to estimate how much clean water must get to the beach to make it safe.

For this lesson, you may wish to choose a local swimming area and have the students research how big the water area is and how deep, to estimate how much water is in it. If the area is being fed by a brook or river, an estimate can be made of how much additional water is entering this area. For the sake of the problem, this could be considered all clean water. Remember as clean water comes in, dirty water goes out.

Below is a table of estimated data that could be used before the research project. This information has to do with Lake Zoar in Monroe, Connecticut. This lake was created by a hydroelectric dam that was built on the Housatonic River. It is one area that bald eagles come to feed on fish during the winter. Beaches are

frequently shut down for bacteria counts after heavy rains. In addition, the river bed is contaminated with PCBs from a factory upriver in Massachusetts.

Lake Zoar, Monroe CT

Size	900 acres
Depth	20 feet
Contaminants	Bacteria count is 3 times acceptable level
Housatonic feeds	200 feet wide 15 feet deep flow rate5 feet per second
3 Brook feeds	5 feet wide, 2 feet deep, flow rate 5 feet per second

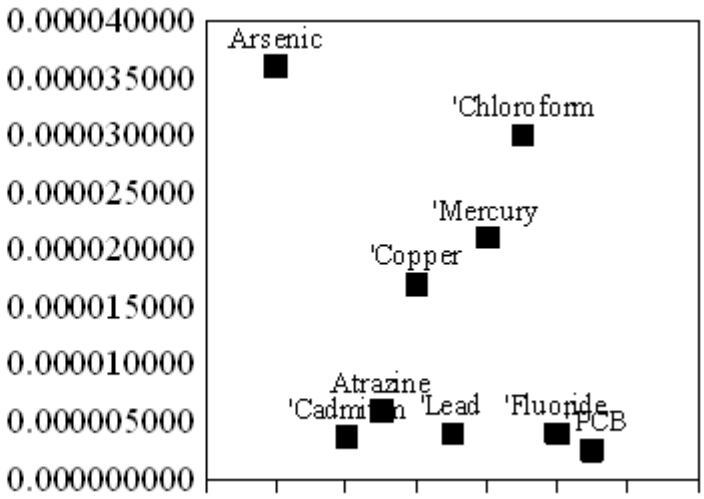
1. How much water must be replaced?
2. How much water is moving in replacing dirty water every second?
3. How much water is replacing dirty water every hour?
4. How long will it take before the level of bacteria is back to normal?

Express your water amounts in gallons and time in hours.. Remember that one cubic foot of water contains 7.48 gallons.

Lesson 3: Table and Graphs

The Third lesson reviews data on tables and graphs. A few of the chemicals in our water system currently being tested are shown on the tables and graphs. The numbers are represented in grams and liters. An interesting exercise could be made in translating the thresholds to ounces per quart. The maximum threshold,if sustained for more than one hour will potentially harm the wildlife in the water.

Chemical	Federal Maximum Concentration (gram per L)
Arsenic	3.60E-004
Cadmium	3.70E-006
Atrazine	3.00E-009
Copper	1.70E-005
Lead	6.50E-005
Mercury	2.10E-006
Chloroform	0
PCB	1.40E-008
Fluoride	4.00E-006



For Algebra I students, a review of scientific notation would be appropriate at this time in addition to ordering the chemicals by highest to lowest threshold levels.

Questions based on graph and table:

5. What chemical has the highest allowed maximum level?
6. What chemical has the lowest allowed maximum level?
7. Looking at the graph, what chemicals are above their maximum level?
8. Looking at the graph, what chemicals are below their maximum level?
9. If the Mercury level is doubled, how much is it over the allowed maximum?

A more complete table is available on the EPA government website. Students may be interested in other chemicals and what their thresholds are.

Lesson 4: Frog Populations

Before going into this activity, I would review percents and probabilities using a warm-up that gauges the students skill level.

Compare two ponds with the current number of frogs and the anticipated number of frogs after 2 years based on the following information.

The scouts are in the woods on their annual camping weekend. The scout leader has been taking an evolutionary biology class and has decided to put his knowledge to a test. He notices a pond that looks pristine. He decides to do a count of the number of frogs in the pond. Scout Chris finds 5 green frogs. Scout Kendra found 8 translucent frogs. Scout Harry found 15 yellow frogs.

1. Based on the amount of frogs they found and the fact they only canvassed 15% of the pond, how many frogs live in this pond?
2. Although the pond looked pristine, danger was lurking beneath the surface, runoff from a nearby chemical company has put the levels of atrazine in the water at a level that it has impacted the amount of frogs able to reproduce. 20% of the male frogs are unable to reproduce. If the frogs in the pond are ½ females and each female pairs up with only one male for life and produces 100 eggs each spring. How many eggs are produced in the pond this spring?
3. The probability that an egg becomes a tadpole, not having become a big blue fish's favorite lunch is 10%. How many tadpoles are there?
4. The probability that each tadpole or young frog not becoming bird food and becomes a grownup frog is 20%. No grown up frogs have perished this year. How many frogs are now in the pond?
5. Next year the same thing happens. How many frogs are in the pond?

The second pond looks about the same but is far enough away from the chemical factory so that there is no atrazine in the pond. If the number of frogs found are the same as for the first pond. How many frogs will be in this pond after 2 years? Explain what the difference is and why. Defend your answer.

Lesson 5: Frog Populations

This lesson uses frog populations to demonstrate exponential growth and decay. The lesson uses M&Ms or skittles (good to use if you have a student with a peanut allergy) as a tasty manipulative. Put the students into workable group sizes of 3 to 4 students. Both activities can be done in a block schedule day. This way you only need to get enough M&Ms for each class. You will need small cups, and plastic gloves, and plates for this activity. Since the students will be eating the candies afterwards, many do not want candies that have been handled by others. The M&Ms will represent the frogs in the pond. If you are not allowed to use candy in your classroom, pennies would also work.

Healthy pond

The students from New Haven have been monitoring a pond for the last several years. They have been testing the water and counting the frogs. The water appears to be clean, has been testing to be relatively free of chemicals, and the frogs appear to be healthy. They have discovered that each year the population of the frogs has increased by 25%. They decide to do a simulation of the growth of the frog population using m& ms. The students record their data in tables and graph the data.

This is what they did. (No M&Ms are to be eaten yet)

1. First they started with 10 M&Ms They put these in the cup. This is trial number zero.
2. Then they spilled the M&Ms onto a clean surface.

3. They counted the number of M&Ms that are facing up with the M&M showing. They add half as many M&Ms as they counted in step 3 to their current m& ms and put them all back into their cup. This is the next trial.
4. They record the current number of M&Ms in their table along with trial number.
5. They continue to repeat steps 2 through 4.for 5 more times
6. The information in the table is then graphed with trial number on the horizontal axis and total number of M&Ms on the vertical axis.
7. The students are asked to come up with the equation that models the simulation, predict how many M&M's after 10 trials.
8. Use the equation to determine if in year one there are 100 frogs, how many frogs would there be on year 10.
9. The students are to explain why the simulation depicts an increase of 25% each time.
10. The students then compare and contrast exponential growth to a linear function y=10+.25x

Unhealthy pond

The students from Waterbury have been monitoring a pond that is located near an old fertilizer factory. They have been noticing that the levels of chemicals in the water they are testing are noticeable. They have been catching frogs and have noticed that the frogs do not seem to be healthy. In fact one of the frogs was missing a leg. They have been keeping track of the number of frogs in the pond for several years and have noticed a decline in the number of frogs. They believe that the number of frogs seems to be decreasing by about 25% each year.

They decide to a simulation of what is happening in the pond and start by using the cup of M&Ms they have from the last activity.

1. They count the number of M&M's they currently have. This is trial zero.
2. Then they spilled the M&Ms onto a clean surface.
3. They counted the number of M&Ms that are facing up with the M&M showing.
4. They take half as many M&Ms they just counted and set aside. They they count their current m& ms and put them all back into their cup.
5. They record the number of the trial and the current number of M&Ms in their table.
6. They continue to repeat steps 2 through 5.for 5 more times
7. The information in the table is then graphed with trial number on the horizontal axis and total number of M&Ms on the vertical axis.
8. The students are asked to come up with the equation that models the simulation, predict how many M&M's after 10 trials.
9. Use the equation to determine if on year one there are 100 frogs, how many frogs would there be on year 10.
10. The students are to explain why the simulation depicts an decrease of 25% each time.
11. The students then compare and contrast exponential decay to a linear function y=100-.25x

The students then compare the two graphs and write a short description of how they are similar and different. Students are encouraged to share their findings and how their data may be somewhat different from other

groups. The students may now share the M&Ms within their groups.

Teachers can modify the percentages to others that seem reasonable and fit in with the number of M&Ms or pennies they have. Graphing calculators could be used to produce the graphs for special needs students.

Resources

Teachers:

Ralph M. Nesse, MD and George C. Williams PH.,Why We get sick: The new science of Darwinian Medicine. First Vintage Books ,January 1996 Information on Evolutionary Medicine and Biology

www.epa.gov

Environmental Protection Agency website contains current regulations and student activities and materials

Boston.com www.boston.com/news/nation/articles/2008/0312/water_hormones_everywhere

Pharmaceuticals & Hormones in drinking water

www.freedrinkingwater.com/water_quality/quality1/1-pharmaceuticals-hormones-in-your-water Pharmaceuticals & Hormones in drinking water Information on Hormones in drinimg water Water Studies

www.ewg.org/reports/downthedrain Sources of Hormone-Disrupting Chemicals in San Francisco Bay

Pharmaceuticals In our Water Supplies;//ag.arizona.edu/AZWATER/awr/july00/feature1.htm Water studies.

Hormonal Contraceptives Pollute Drinking Water- Environmentalists Turn a Blind Eye
www.lifesitesnews.com/ldn/2007/jul/07071105.html Water studies

Pharmaceuticals, Hormones, and Other Organic Waste Water Contaminants in US Stream http:/toxics.usgs.gov/pubs/FS-027-02/

Sedatives and Sex hormones in our water supply www.alternet.org/water/80505/

Sex Hormones, Mood Stabilizers Found in Drinking Water of 41M Americans

www.huffingtonpost.com/2008/03/10/sex-hormones-mood-stabil_n_90714.html

Hormone-mimics in Plastic Water Bottles Act as Functional Estrogens

This web site contains a lot of opinion and adult subject matter not for students, but current topics are discussed

www.sciencedaily.com/releases/2009/03/090326100714.html

Evidence for migration of steroidal estrogens through riverbed sediments

www.environmentalhealthnews.org/newscience/2007/2007-1008labadieetal.html

Felicity Barringer, -- Hermaphrodite Frogs Found in Suburban Ponds... more Hermaphrodite Frogs Found in Suburban Ponds, The New York Times, April 8, 2008

Nicholas Krsitoff ,New York Times

He frequently has interesting science articles on many current topics

Tefan Lovgren ,"Low Sperm Counts Blamed on Pesticides in U.S. Water" by,National Geographic News April 27, 2005 Information on fertility

http://www.nationalgeographic.com/

National geographic Magazine and website: science information and activities

www.yale.edu

Yale university site contains science experiment results of David Skelly and Peabody Museum

www.berkeley.edu

University of California's Berkely College's website contains information about Tyrone Hayes

Brynn Taylor, David Skelly, Livia K. Demarchis, Martin D. Slade, Deron Galusha, and Peter M. Rabinowitz,"Proximity to Pollution Sources and Risk of Amphibian Limb Malformation", Environmental Health Perspectives, Volume 113, Number 11, November 2005 Information about frof deformities

Students and Parents:

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www.berkeley.edu

Berkeley website contains information from Tyrone Hayes, frog researcher

www.epa.gov

environmental protection organization website contains current regulations and student activities

http://www.nationalgeographic.com/

National geographic Magazine and website Science information and activities

www.yale.edu and www.cbc.yale.edu/people/skelly

Yale university site contains science experiment results of David Skelly, frog researcher and Peabody Museum

Endnotes

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[3] Diane Sawyer, Good Morning America, ABC NEWS, July 9, 2009 (www.abcnews.com).

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