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Medicine in our waters – so what?

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Abstract

Drugs that we take for common diseases might have more side effects than doctors realize. And not just for us – for the environment, too! Because the medicine we take is not completely used up in our bodies, it ultimately ends up in sewage systems. From there, it enters rivers and oceans, where it might impact fish and other living things. We set out to examine what happens when a certain type of fish (the Siamese fighting fish, also called the Betta fish) is exposed to a very common drug named metformin in its water. This drug is commonly given to people with *diabetes* and is also used for many other illnesses. And it did have an effect on our fish. We found that even low levels of the drug (as they are currently found in nature) change the behavior of the Betta fish: it makes males less aggressive, which can impact their chances of reproducing.

Introduction

Each medicine comes with a long description of side effects on its packet outlining what expected and unexpected reactions might occur in our body when we take it. What it does not warn us about is that these side effects can also occur outside our body – in nature! That's because our bodies do not use up medicines completely. Whatever is left over has to come out the other side, making its way into toilets, and from there, via the sewage systems, into ponds, rivers, lakes, and oceans.

You might think that a little bit of medicine exiting your body is not a big deal. But how about drugs that are *prescribed* by the millions? Could they have an impact on aquatic ecosystems? We wanted to find out what happens when fish are exposed to these commonly prescribed drugs in their water.

One commonly prescribed drug is metformin, which doctors all over the world give to people with a type of diabetes, amongst many other health conditions. Studies have shown that this drug can be found at concentrations of 1-47 µg (*micrograms*) per liter of water coming out of water treatment plants. But nobody has yet studied what effect this has on aquatic creatures.

So we set out to be the first to address this question by studying what happens when certain fish, the Siamese fighting fish *(Betta splendens)*, are exposed to this drug in their water.

Figure 1: The Siamese fighting fish (*Betta splendens*, also called "Betta fish"), comes in many bright colors. Males defend territories where they build nests and attract mates.
Source: Funfood, Wikipedia

More about Betta fish:
You might have seen these colorful fish in pet stores or people's fish tanks. With their big fins and bright colors (they can be yellow-red, blue, green or even purple), they are hard to overlook. Male fighting fish live up to their name by commonly attacking other (male) fish of their kind that cross their paths. This is not because they are bullies, but because their aggressive behavior helps them to defend the territory that they need for building a nest and to attract mates. A friendly Betta fish would be unlikely to produce any offspring! Betta fish are useful as *model organisms* for studying the impact of chemicals in water on fish – so they were perfect for our study.

Methods

Our goal was to expose male Betta fish we bought from a store to the concentration of the metformin drug that is commonly found in wastewater (40 µg/L), as well as to twice that much (80 µg/L) for a time period of five months, and then look for changes in their behavior. We randomly selected 17-18 fish to either be in one of two experimental *treatment groups* (low or high dose of drug), or in a *control group* without the drug.

But before we could start our experiment, we first had to see what level of aggression each fish showed **before** we added the drug to the water, to have a baseline we could measure changes against. To do this, we built a fish dummy that looked pretty much like a real male Betta fish. It was even motorized so that it could move around in a controlled way! We then showed it to individual Betta fish that were housed in small tanks by themselves and recorded their behavior. (We chose a dummy and not a real fish to better control what the "aggressor fish" would do).

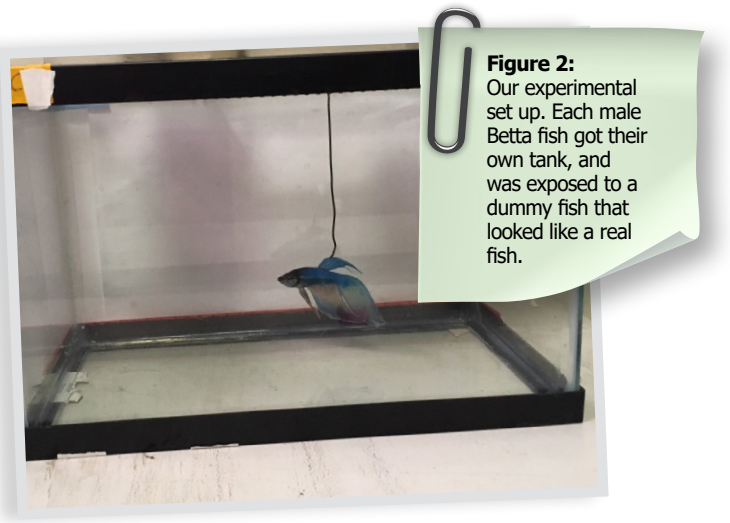


Figure 2: Our experimental set up. Each male Betta fish got their own tank, and was exposed to a dummy fish that looked like a real fish.

After these initial "baseline tests", we exposed each fish in one experimental group to low levels, and the fish in the other group to high doses of the drug. We checked how each fish reacted to the dummy after four weeks of continuous exposure to the drug in their water and again after another 16 weeks (20 weeks in total).

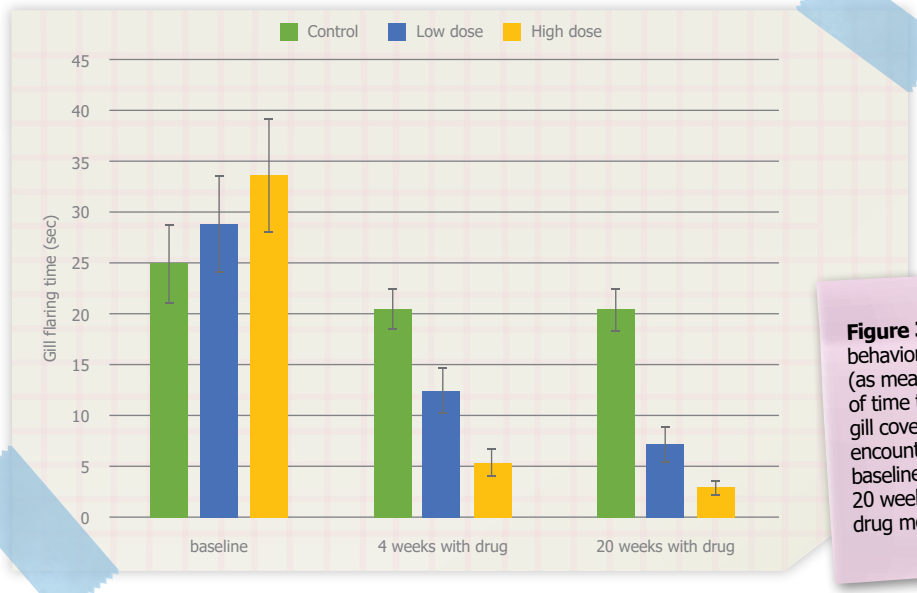
Results

Each Betta fish showed its typical aggressive behavior towards the dummy fish in three ways:

- Gill flaring (fish faces opponent and flares up his gill covers, fins and tail)
- Fin spreading (fish faces opponent sideways and spreads fins and tail)
- Tail beats (fish swims close to opponent and flicks his tails quickly)

We found that fish react less aggressively with metformin in their water (in concentrations that we find in wastewater in nature) compared to their baseline levels and compared to fish from the control group without the drug. This effect continued throughout the 20 weeks of our experiments.

Male fish that were exposed to twice the amount of the medicine currently found in nature (80 µg/L) showed even bigger changes in their behavior, i.e. they were even less aggressive.



Which group of fish showed the biggest change in their behavior after being exposed to the drug? What about the fish without any of the drug in their water?

Figure 3: Aggressive behavior of male Betta fish (as measured by the amount of time they flared their gill covers and fins) when encountering a dummy, in the baseline test and after 4 and 20 weeks of exposure to the drug metformin.

Discussion

We clearly showed that metformin drug in their water made male Betta fish less aggressive. We don't quite know how the drug does that, (and our study did not address this question) but we know from other studies that chemicals change the amount of *hormones* that aquatic animals produce. This in turn can change their behavior.

So is less aggression a big deal for male Betta fish? Do they turn into a "nicer version" of themselves? Well, less aggressive Bettas are worse off because they need their aggressive behavior to defend their territory, make nests, and find mates.

Our study only measured a tiny part (two concentrations of one drug) of potential effects of drugs on the environment. However, there are many other drugs out there that we discard or excrete into waterways daily, and the amount is likely to only increase in the future. We need more studies like ours to show what's happening when animals in nature are exposed to all these drugs.

Conclusion

What can you do to keep the environmental side effects of drugs as small as possible?

One big step is to never flush unused or expired medicine down the toilet. Instead, you should take it to a pharmacy which can safely get rid of it.

Secondly, don't take more drugs than you need. Your body will thank you, and so will the environment. Finally, educate yourself about possible environmental side effects of drugs. Hopefully we can find ways to minimize their effect on fish and other aquatic creatures in the near future.

Glossary of Key Terms

Control group - one of the tested groups in a scientific experiment which does not receive the primary "treatment" being tested. They may receive something else (perhaps an alternative treatment) or nothing (often called a "pure" control group). In this case, one group of Betta fish did not have medicine added to its water so that the scientists could compare them with the groups of fish that did have medicine added to their water.

Diabetes - a group of diseases that affect how our body deals with blood sugar. Diabetes can lead to excess sugar in your blood, which in turn can cause serious health problems. Metformin is a drug commonly prescribed for Type II diabetes and helps regulate the blood sugar of affected patients.

Hormone - a chemical substance produced in the body that controls and regulates the activity of certain cells or organs. Hormones can influence how humans and animals grow and how they behave, for example.

Microgram - a microgram is equivalent to one millionth of a gram and is represented with the symbol µg. It may not sound like much, but as our study shows, it can have an impact!

Model organism - is a species that has been widely studied, usually because it is easy to maintain and breed in a laboratory. Scientific discoveries in model organisms can often tell us a lot about the workings of many other organisms, too. Some common model organisms besides the Betta fish are fruit flies, mice, zebrafish, and the bacterium Escherichia coli.

(To be) prescribed - This is when a doctor or health professional recommends and authorizes a certain kind of treatment or medicine.

Territory - an area of land defended by an animal, or group of animals, from others of the same sex or species.

Treatment group - The group or groups of things/people/animals that will receive the study's intervention. In this case, two groups of Betta fish had different amounts of the medicine added to their water.

REFERENCES

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The Guardian: Drugs flushed into the environment could be the cause of wildlife decline
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Earth Friends: The amazing Betta fish
https://www.earthsfriends.com/siamese-fighting-fish/

Check your understanding

1. Why did we select the Betta fish for our study?

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2. Why did we measure the behavior of each fish **before** we exposed them to the drug?

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3. Why do we need a control group in our experiment?

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4. How does the diabetes drug metformin impact the behavior of the Betta fish?

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5. Why could this be a problem for the fish?

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6. What can you do to keep fish and other aquatic organisms safe from drugs in the water?
