

1

2

## A Home Aquarium

3

4

*Daddy, I love aquariums in animated movie Nemo. Why don't  
we keep fish in our home?*

5

6



7

8

Image from [www.weer.com](http://www.weer.com)

9

10

Jianjun Wang<sup>1</sup>, Beryl Ochieng<sup>1</sup>

11

Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences

12

13 **Microbes and Global Change**

14

15

**Aquariums**

16

17

**Storyline**

18

19

20

21

22

23

24

25

26

27

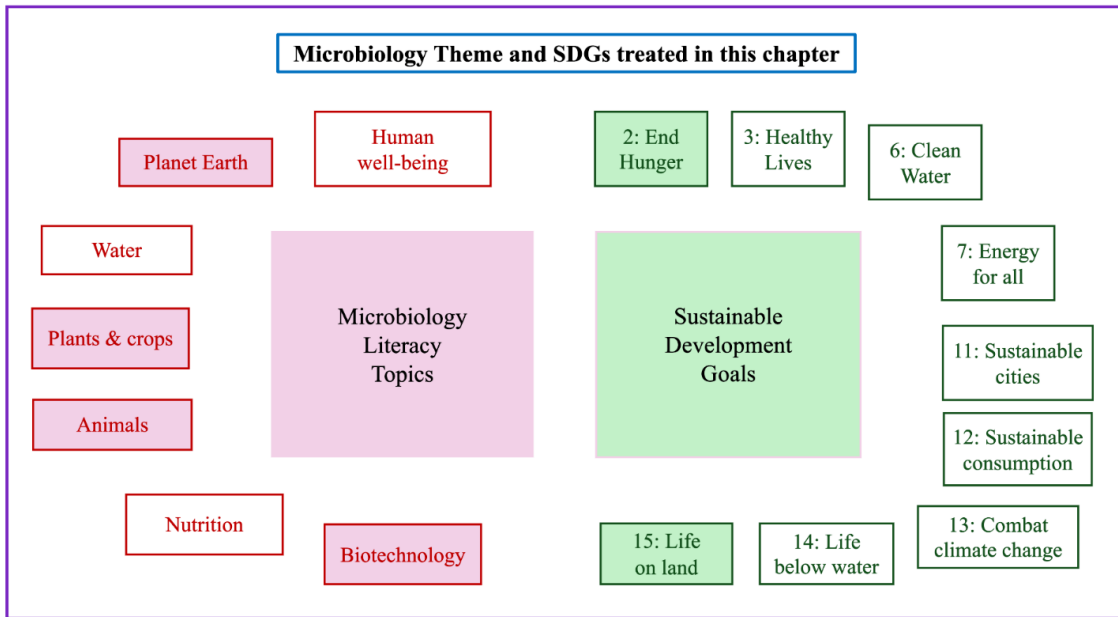
28

29

30

Aquariums can serve as a valuable tool to enlighten and educate children in areas such as microbiology, zoology, chemistry, environmental science, and global change. Fish are currently the third most popular pets worldwide, after dogs and cats, and at least 12% of the population owns or more pet fish. This highlights their significant economic and social value. Ownership a home aquarium can have both positive and negative impacts on children’s lives. Benefits include strengthened immunity, enhanced learning, and reduced stress and anxiety. However, there can also be hidden downsides related to environment and social factors. For instance, setting up and maintaining an aquarium requires considerable time and financial resources. Poorly maintained aquariums may also become a source of microbes that can cause infections and zoonotic diseases. In addition, the energy used to run the aquariums contribute to carbon emissions. Therefore, home aquariums are relevant to the 2030 United Nations Sustainable Development Goals (SDGs), and can provide an inclusive way for children to take part in SDGs implementation while helping to minimize future crises like Covid-19 and other diseases associated with animal-human interactions.

# A child-centric microbiology education framework



31

32

## A child-centric microbiology education framework

33 The microbiology and societal context. *The microbiology*: Microbes involved in carbon and nutrient  
 34 cycling; agriculture and biotechnology; strengthening children’s immune systems; fish infections and  
 35 zoonoses; fish invasion and habitat degradation; water abstractions and toxic algal blooms; greenhouse gas  
 36 emissions; alternatives to fish meal and fish oil. *To summarize the storyline*, microbes are linked with broader  
 37 biosphere processes, including adaptation to global warming; environmental sustainability; sustainable use  
 38 of aquatic resources; economic growth; poverty alleviation; sustainable livelihood, and food and nutrition  
 39 security.

40

41

**Table 1.** Microbiology theme and SDGs in this topic framework

<i>Microbiology Literacy Topics</i>	<i>Deliverables</i>	<i>Sustainable Development Goal</i>	
Human well being	Healthy people	1. No poverty	9. Industry innovations
Planet earth and biochemistry	Healthy animals	<b>2. Zero hunger</b>	<b>11. Sustainable cities</b>
Water	Climate change mitigation	<b>3. Good health</b>	<b>12. Responsible consumption</b>
Plant and food crop farming	Sustainable bio-economy	<b>6. Clean water</b>	<b>13. Climate actions</b>
Animals	Food security and safety	<b>7. Clean energy</b>	<b>14. Life below water</b>
Nutrition		8. Economic growth	15. Life on land
Biotechnology			

42

43 <sup>1</sup>The SDGs with bold fonts are the most crucial to this topic framework, even though the others are also  
 44 important and are interconnected.

Introduction of Microbes in Aquarium

Aquarium microbes are understudied, yet they have significant impacts on the pet fish industry and public health. Understanding these microbes and their habitats helps maintain the balance between “good” and “bad” microbes, leading to a more advanced health index and improved well-being. These microbes mainly live in aquarium water and on plastic and solid surfaces, such as plants, decorations, filter media, bio-wheels, pumps, rocks, gravel, sediment, and even glass.

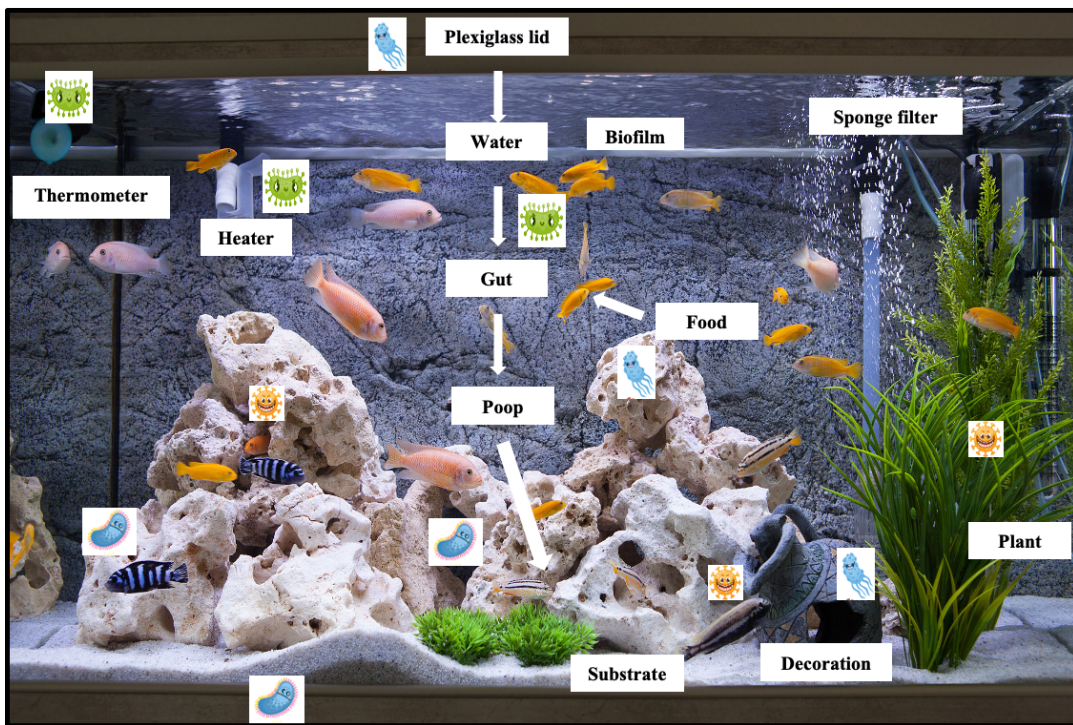


Figure 1. Microbes habitats in aquarium

55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
66  
67  
68  
69  
70

**Aquarium: the Microbiology**

***1. Mental, emotional, behavioral and health benefits of owning aquariums for children***

Watching an aquarium can reduce anxiety, depression and hostility in children. It also helps suppress the effects of attention deficit hyperactivity disorder (ADHD) and promotes relaxation, making it ideal for sleep. Some aquarium fish, such as *mandarin fish*, *clownfish*, *triggerfish* and *angelfish* are especially popular and visual appealing.

Aquarium fish and water contain some useful microbes that can help boost immunity in infants with developing immune systems. Humans are exposed to trillions of microbes from birth. Daily exposure for children to aquarium microbes may help diversify body microbes, hence leading to stronger immune system that can resist infections and diseases. Comprehensively, this may reduce healthcare costs if a child remain healthy. Health professionals also use aquariums to reduce pain during treatment. Some research suggest that watching an aquarium can act as a form of therapy.

71 **2. Spread of infections and diseases from fish to humans**

72 Like other pets, fish can carry microbes may cause infections and diseases in humans, although  
73 illnesses due to keeping fish is relatively rare. Diseases that are transmitted from pets to humans are known  
74 as zoonoses. The zoonotic diseases associated with pet fish are usually asymptomatic in fish but may produce  
75 symptoms in humans. One commonly reported fish-related zoonosis is *Mycobacterium marinum* infection,  
76 which mostly affects the skin.

77 Children, whose immune systems are still developing, are more vulnerable to bacterial and pathogens  
78 infections. The spread of zoonotic diseases from pet fish to children mainly occur by direct contacts with  
79 aquarium surfaces contaminated with fish waste, especially when children place their hands in their mouths  
80 or fail to wash their hands properly. Indirect contacts with microbes in contaminated aquarium water and  
81 objects may also contribute to infection. Other ways include inhalation of aerosolized materials or accidental  
82 ingestions from uncovered aquariums These routes are collectively referred to as transmission pathway of  
83 microbes. However, proper fish vaccination and routine aquarium maintenance have proven effective  
84 towards reducing the risks of these infections and diseases.

85

86 **3. Economic cost of setting up and maintaining home aquarium**

87 Aquarium ownership can become an expensive hobby Resources needed for maintaining an  
88 aquarium include ( I ) electricity to power air pumps, filters, heaters, and gravel vacuum used for cleaning  
89 the bottom of the aquarium. ( II ) nets for catching fish and ( III ) water conditioner for water treatments. In  
90 addition, ( IV ) fish food and ( V ) fish vaccines are also among the basic necessities. These facilities can increase  
91 costs, which maybe not suitable for individuals with a small budget. After al many products and materials  
92 used to set up and decorate aquariums such as glass and plastic components, are non-biodegradable and may  
93 have negative environmental impacts.

94

95

96

97 **4. Grief associated with loss of pet fish**

98           Comparatively to humans, pets can create emotional attachments, and grow and become part of the  
99 owner's family. For children especially, a pet pet could mean the world. When a child discovers that his/her  
100 favorite pet fish has died , the experience can result in psychological distress, sadness and loneliness. Coping  
101 with such a loss can be difficult and saying goodbye might not be emotionally challenging for people of all  
102 ages. In such instances, parental guidance in an open and honest way may be helpful in dealing with grief.

103

104 **5. Total solids (total suspended and total dissolved solids) in the aquarium**

105           Total solids basically refer to both total suspended solids and total dissolved solids, which may be  
106 either organic or inorganic. In aquariums, total suspended solid wastes originate from uneaten or excessive  
107 fish feed, fish feces, and decaying plant matter. Total dissolved solids wastes may be produced through  
108 metabolic processes of fish and from water treatment products such as water softeners. Generally, total solids  
109 have direct impacts on fish health and indirect impacts on the surrounding environments.

110           Total suspended solids wastes may weaken fish immunity and suppress their growth. High  
111 concentrations of total dissolved solids can increase temperature and negatively affect fish adapted to lower  
112 temperatures.. Fluctuations in temperature may also further affect microbial functions and slow down plant  
113 growth. Both total suspended solids and total dissolved solids reduce the water transparency resulting in  
114 hypoxic conditions. Hypoxia is a major contributor to fish mortality in aquariums. Another key  
115 environmental challenge associated with aquarium total solid wastes is the improper discharge of used  
116 aquarium water. Aquarium water should not to be discharged into sink drains because it may end up in  
117 natural water ecosystems, increasing nutrient levels, microbial contamination and toxins contents. Proper  
118 wastewater treatments should be carried out before disposal to help ensure the sustainability of the entire  
119 environmental ecosystems.

120

121

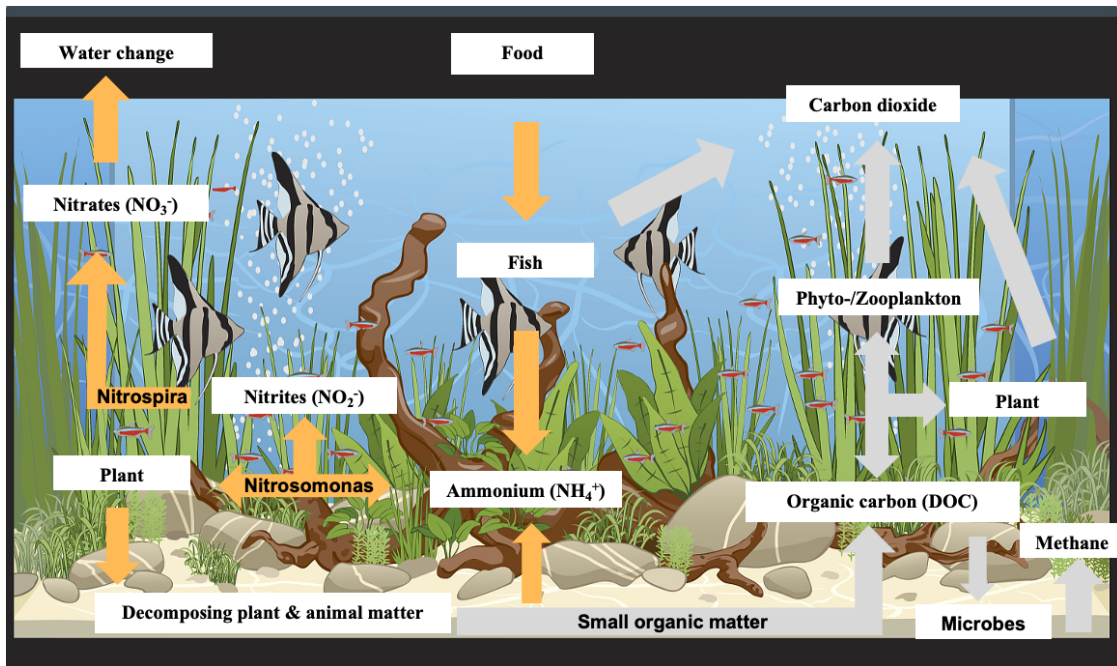
122

123 **6. Carbon footprint (greenhouse gasses) emitted during fish feed production process**

124 Carbon footprint refers to the total greenhouse gases emitted, including carbon dioxide, nitrous  
 125 oxides and methane. Despite the fish feed industry significantly contributes to the global economy, it also  
 126 contributes to the increase of atmospheric greenhouse gases that result in global warming. Fish feed is  
 127 composed of fishmeal and fish oil, usually manufactured of granules or pellets. Other ingredients  
 128 include vegetable proteins, cereal grains, vitamins and minerals which originate from crop production. These  
 129 fish diets vary depending on species; carnivores, herbivores and omnivores, and occasionally according to  
 130 feeding mechanisms such as benthic feeder, mid-water feeders and pelagic feeders.

131 The production of crop-based feed materials may be the largest contributor to greenhouse gas  
 132 emissions in aquaculture, followed by feed transportation and the energy used to operate aquarium systems.  
 133 It should be noted that, according to the Food and Agricultural Organization (FAO) 2010 report, the  
 134 emission level from fish feed production is still lower than that of livestock production. Spraying of crops  
 135 also introduces toxic aerosols and water vapor in air, that traps sunlight, thereby accelerating global warming.

136



137

138 **Figure 2. Carbon and nitrogen cycle in aquarium**

139

140 *7. Fish feed production process releases nutrients to the environment that facilitates water*  
141 *eutrophication*

142 The crop production provides raw materials used in industries for fish feed formulation, including  
143 fish meal and fish oil) The farming process is often associated with the use of pesticides, fertilizers and other  
144 toxic farm chemicals. Farm wastes can last for decades in the environment, causing significant environmental  
145 damage in the form of global warming, water eutrophication, soil pollution and biodiversity loss, therefore  
146 posing a substantial barrier to achieving numerous SDGs.

147 Among the environmental extremes caused by toxic farm wastes, water bodies are significantly  
148 affected by nutrient influx. High levels of inorganic wastes such as nitrates, phosphates, silicates and carbon  
149 are washed into open water ecosystems such as lakes, rivers, oceans, streams and reservoirs, which can cause  
150 microbial and algal blooms. A report by the United States Environmental Protection Agency (USEPA) reveals  
151 the negative impacts of excess nitrogen and phosphorus in water bodies. Excessive nutrients and other  
152 chemicals drained from farm fields through runoff and snow melts enter aquatic ecosystems, causing  
153 eutrophication. Eutrophicated water deprives aquatic life of oxygen, thereby affecting the entire aquatic  
154 ecosystem and rendering the water unsuitable for human use.

155

156 *8. Aquarium discharges nutrients and antibiotics affecting aquatic trophic ecosystem*

157 Aquarium water changes are important for fish health, aquarium plants, and maintaining the balance  
158 of microbial communities. The replacement of eutrophicated water with “clean water” is an important  
159 process, as it minimizes the accumulation of nitrites and toxins.

160 Through water changes, nutrients, antibiotics and other aquarium wastes are discharged into the  
161 environment. The presence of these nutrients and antibiotics triggers the enrichment of plankton  
162 populations. These plankton form an important part of the aquatic food chain, which are consumed by larger  
163 organisms. When excessive nutrients and antibiotics move up the food chain, they end up being consumed  
164 by higher trophic level consumers, zooplankton and fish. Moreover, excessive nutrients can cause increases  
165 in temperature, hypoxia and rapid pH fluctuations. These drastic changes in water quality parameters could

166 be attributed to the alarming cases of eutrophicated waters in recent times. The negative alteration of water  
167 quality parameters results in unsafe drinking and recreation waters, and in severe cases, may lead to death of  
168 native plant and animal species. Unutilized nutrients can also sink to the bottom of open water bodies and  
169 remain stored for centuries.

170

### 171 *9. Pet fish invasion and ecological impacts*

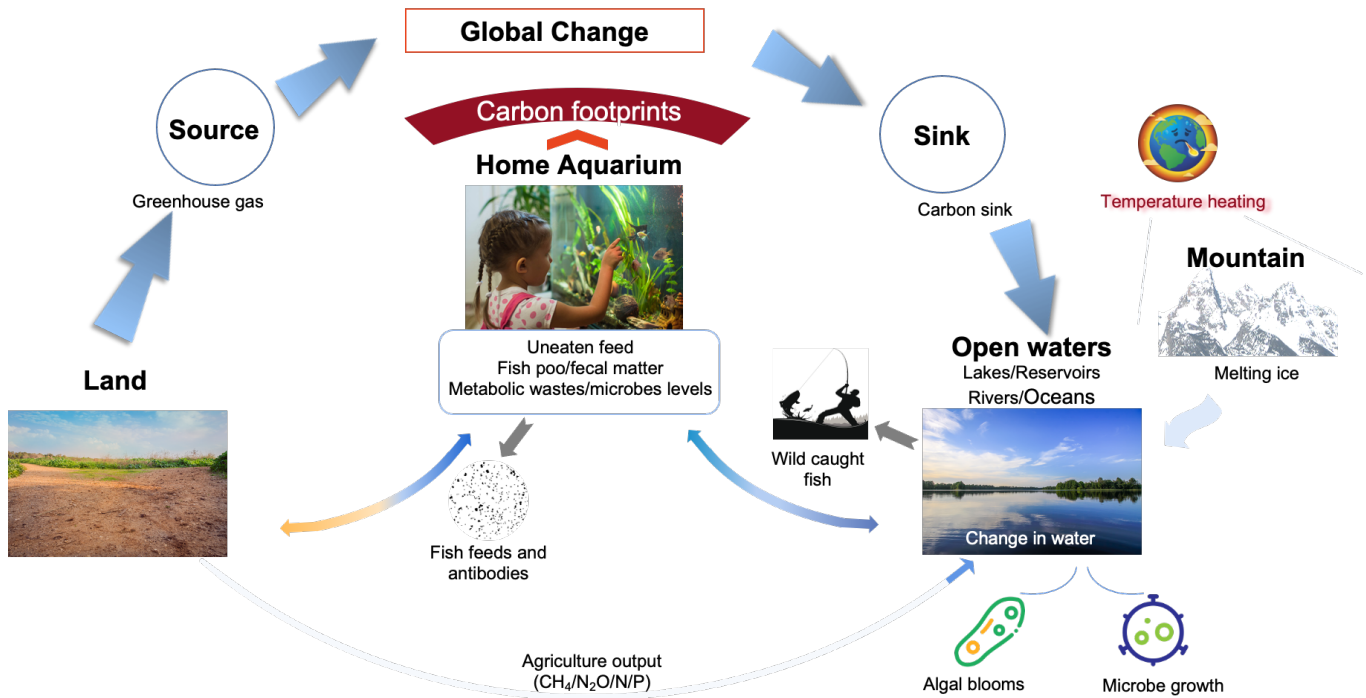
172 Studying the biology of pet fish invasion is important for environmental mitigation. Once the  
173 aquarium owner is no longer interested in pet fish, they release them into the natural environments, thereby  
174 becoming invasive species. A commonly known pet fish invasive species is the gold ish. The invaders  
175 accelerate biodiversity loss and alter the composition of natural ecological structures and eventually build up  
176 the ecological pressure. They also have an overall impact on nutrient dynamics, a parameter that regulates  
177 the food chain by promoting the growth of microbes and algal blooms, as well as impacting on other natural  
178 ecosystems organisms. One recent study in the USA pinpoints that globally, aquariums are speeding up the  
179 climate crisis by tampering with important plant and animal species from carrying out their natural ecosystem  
180 functioning.

181

### 182 *10. Implications of Global Change*

183 Endlessly, aquariums, microbes and the entire biosphere are interlinked, with no specific starting or  
184 ending point. Global warming drives the changes in microbial communities while microbes are essential in  
185 curbing global warming. The fish feed produced via crop cultivation and industrial manufacturing are fed to  
186 pet fish. The feed production process is a source of greenhouse gasses. In an aquarium, nutrients are released  
187 in water through fecal wastes and uneaten feed. The nutrients stimulate the growth of both “beneficial” and  
188 “harmful” microbes and aquarium plants. The unutilized aquarium nutrients and other chemicals are then  
189 released to the environment via water exchange. Some of the nutrients leach into the soil while others drain  
190 into water bodies. Excessive nutrients like nitrogen and phosphorus are the main limiting nutrients in waters,  
191 and could accelerate the microbes and algal blooms causing eutrophication, rendering the water unsuitable  
192 for domestic purposes. The toxicants also find their way into the aquatic food chain and are consumed by

193 fish. Some of the fish are harvested as wild-species, ending up in homes as pet fish, accompanied by harmful  
 194 microbes from natural ecosystems.



195

196

Figure 3. Aquarium impacts to the global change

197

198

199

### Relevance for Sustainable Development Goals and Grand Challenges

200

201 The microbes have a wide influence on aquarium ownership and our daily living. The microbial study  
 202 may have the potential to contribute to achieving various SDGs such as food security, good health, clean  
 203 energy, environmental degradation and global change as discussed below.

- 204 • **SDG 1- No poverty, end poverty in all its forms everywhere** (*eradicating extreme poverty for all people*  
 205 *everywhere by 2030*)

206 Globally, the number of people living in extreme poverty in the pre-covid pandemic was estimated to  
 207 be 581 million, while currently the number has risen to approximately 676 million. The sustainable target is  
 208 to get 1.7 million people out of extreme poverty by 2030. Microbes play two key roles in promoting this SDG.

## A child-centric microbiology education framework

209 First, exposure to “good” microbes helps build a stronger immunity hence a healthier population. When  
210 fewer resources are directed towards disease treatment, the economic status of most households is leveraged.  
211 Secondly, microbes have been applied in biotechnological processes to produce food, a way of reducing  
212 hunger. It should be noted that there are risk factors associated with “bad” aquarium microbes. An example  
213 is zoonoses that add an economic burden to homesteads through increased medical expenditures. There may  
214 be complicated associations between poverty and pet fish diseases caused by microbes. The risk is doubled in  
215 pet fish owners with the lowest socio-economic position. Microbiologists are committed to research new and  
216 sustainable fish zoonosis vaccines that will ensure that aquarium ownership does not contribute to the global  
217 poverty index.

218

- 219 ● **SDG 2- Zero hunger, achieve food security and improved nutrition and promote sustainable**  
220 **agriculture** (*end hunger and malnutrition, increase agricultural productivity*).

221 The world population has surpassed 8 billion, meaning more global challenges ahead. Food production  
222 for pet fish consumption could be an important cause of environmental damage and increased hunger in the  
223 world. Changes in dietary patterns across the pet fish industry from meat-based diets to affordable,  
224 nutritionally adequate, and environmentally friendly ones can be a proper way in achieving the SDG2. A  
225 plant-based diet can be a better alternative to meat-based diet but it still has some negative environmental  
226 impacts. This will ensure that more agricultural resources are directed towards human consumption and at  
227 the same time maintain good animal welfare and human well-being.

228

- 229 ● **SDG 3- Ensure healthy lives and promote well-being for all at all ages** (*improve health, reduce preventable*  
230 *disease and premature deaths*)

231 Mental wellbeing is paramount to SDG3, and pet fish can accelerate efforts to achieve the goal.  
232 Aquarium water sounds promotes good sleep and reduces anxiety and stress. Aquariums are also a source of  
233 diverse microbes that support healthy immune-system development in children, who are prone to allergic  
234 reactions. Additionally, the pet fish microbial products such as probiotics play a key role in good health. For  
235 instance, bacteria-mediated therapies have been effective in cancer and tumor therapy. In addition to the

## A child-centric microbiology education framework

236 positive health impacts, aquariums are also sources of disease-causing microbes. Recent studies suggest that  
237 some communicable and non-communicable diseases such as allergies and asthma are caused by harmful  
238 microbes. The health effects are related to SDG 1, SDG 2, SDG 6 and SDG 8, therefore there is a need to  
239 consider SDG 12 and SDG 17 to achieve good health and well-being for all.

240

- 241 ● **SDG 6- Improve water quality, wastewater treatment and reuse** (*assure safe drinking water, improve water*  
242 *quality, reduce pollution, protect water-related ecosystems, improve water and sanitation management*)

243 Aquariums can be used to support SDG 6. Through the water exchange from aquariums into the  
244 environment, waste from pet fish feed and feces finds their way into water ecosystems, leading to poor water  
245 quality. Moreover, the discharged water has nutrients and harmful microbes that cause microbial and algal  
246 blooms rendering the water unsuitable for domestic purposes. The chemicals and pesticides used in fish food  
247 production are contaminants of surface and groundwaters. However, upon good management of wastewater,  
248 aquarium water can be useful in home gardens to grow vegetables as it has been tested in aquaponic setups  
249 hereby reducing water wastage.

250

- 251 ● **SDG 7- Ensure access to affordable, reliable, sustainable and modern energy for all** (*ensure access to*  
252 *clean, renewable and sustainable energy, and increase energy use efficiency*).

253

254 Energy plays a major role in global warming, therefore there is a need to shift from unsustainable to  
255 sustainable energy sources in order to meet the United Nations Agenda by the year 2030. Aquariums need  
256 electricity to operate all its devices, but renewable energy sources such as solar and geothermal power can be  
257 more sustainable alternatives, as they are able to maintain a sustainable environment.

258

- 259 ● **SDG 8 and 9- decent work and economic growth, and industry, innovation and infrastructure**  
260 (*promote economic growth, productivity and innovation, enterprise and employment creation*).

## A child-centric microbiology education framework

261 Aquarium industry is a good business. It has direct economic impacts through the resources spent on  
262 purchasing goods needed for maintenance. It also helps provide economic opportunities and support gender  
263 equality through the creation of jobs in fish food production, fish rearing and biotechnology. Moreover, the  
264 aquarium microbes contribute to the biotechnology economy. The microbes can be used in innovation and  
265 industrial growth. All these bio-technological processes need workforce and hence generate more job  
266 opportunities.

267

- 268 ● **SDG 12- Responsible consumption and production patterns** (*achieve sustainable production and*  
269 *use/consumption practices, reduce waste production/pollutant release into the environment, attain zero waste*  
270 *life cycles, inform people about sustainable development practices*).

271 Fish feed intake and feeding behavior should consider the reduction in food loss and waste. This can  
272 save resources used for feed purchase in households and redirected toward purchasing food for human  
273 consumption, hence feeding more population. Reduction in food waste can also minimize the pressure  
274 enforced on climate, water, and land resources. The production processes of fish feed should be considered  
275 in a modernized and innovative way that reduces energy, food wastes and water use in aquariums, for instance  
276 the currently envisioned circular-economy.

277

- 278 ● **SDG 13- Take urgent action to combat climate change and its impacts** (*reduce greenhouse gas emissions,*  
279 *mitigate consequences of global warming, develop early warning systems for global warming consequences, improve*  
280 *education about greenhouse gas production and global warming*).

281 Microbes play a central role in climate change response, and the impacts of climate change heavily rely  
282 on microbial responses. Aquariums contain microbes both in water and fish gut. The microbes release carbon  
283 into the atmosphere, in addition to the carbon produced by aquarium plants. The process of transportation  
284 of aquariums from the market to homesteads also involves CO<sub>2</sub> emission which is detrimental to the  
285 environment. Additionally, the process of fish food/feed production releases greenhouse gases (GHG) to the  
286 atmosphere.

287

- 288       • **SDG 14- Conserve and sustainably use the oceans, seas and marine resources for sustainable**  
289       **development** (*reduce pollution of marine systems by toxic chemicals/agricultural nutrients/wastes like plastics,*  
290       *develop mitigation measures for acidification, enhance sustainable use of oceans and their resources*).

291       Overapplication of chemicals and pesticides in fish feed production and associated runoff drive the  
292       eutrophication of aquatic ecosystems, slowing the process of achieving SDG 14. Releasing untreated  
293       aquarium water into the environment is also a contributor to the eutrophication of water bodies.

294

295 **Potential implications for decision-making**

296 **1. Individual**

- 297 a) Freshwater vs saltwater fish species. Do conscientious purchasing decisions within the aquarium  
298 industry help reduce mortality rates and promote harvesting methods, regulation, and ecosystem  
299 conservation?
- 300 b) How are fish species supplied, - captive-bred vs wild-caught?
- 301 c) What measures ensure the survival of pet fish after introduction into the tank, such as appropriate  
302 water parameters and environmental conditions tailored to specific fish species to minimize  
303 mortalities.
- 304 d) Large or small aquariums: Do you have the expertise to properly house the fish, considering that  
305 some species require substantial space for thriving?
- 306 e) Choice of fish feed, including its carbon and environmental footprint, and feed sustainability.
- 307 f) Human gain vs environmental implications.

308

309 **2. Community policies**

- 310 a) Promote the highest standards for fish harvesting and management.
- 311 b) Consider the impacts of aquarium industry on the livelihood of indigenous peoples and local  
312 communities.
- 313 c) Address health and ecological concerns, such as fish diseases, excessive water use in the aquarium  
314 industry, and eutrophication on community water sources.
- 315 d) Support environmental conservation initiatives.

316

317 **3. National policies relating to pet fish ownership**

- 318 a) Establish and reinforce permits, regulations and importation procedures for the legal collection, trade  
319 and ownership of pet fish.
- 320 b) Promote humane handling, transportation and acclimatization processes to ensure fish welfare.
- 321 c) Require aquarium owners and industry personnel trained in state-of-the-art fish-handling, husbandry  
322 and storage facilities.
- 323 d) Support environmental conservation initiatives and sustainable aquatic resource management.
- 324 e) Implement measures to protect freshwater and marine ecosystems from degradation.

## A child-centric microbiology education framework

- 325 f) Prevent and mitigate eutrophication, harmful algal blooms and toxic algal outbreaks that affect water  
326 resources, fisheries and tourism.
- 327 g) Address greenhouse gas emissions and global warming that threaten aquatic habitats and  
328 biodiversity.
- 329
- 330 **4. International/Global policies relating to pet fish ownership**
- 331 a) Regulate and protect aquarium fish species according involved in international trade in accordance  
332 with the Convention on International Trade in Endangered Species of Wild Fauna and Flora  
333 (CITES).
- 334 b) Enforce international regulations and restrictions governing the aquarium and ornamental fish trade.
- 335 c) Promote global cooperation in environmental conservation and the sustainable management of  
336 aquatic ecosystems.
- 337

338

### **Pupil Participation**

339 1. Class discussion on issues associated with pet fish ownership.

340 2. Stakeholder awareness among pupils.

341

342

### **Questions and Exercises**

343 1. Discuss the positive and negative impacts of having home aquariums.

344 2. Explain the major environmental effects that may result from interactions of humans with pet fish.

345 3. Identify the fish welfare factors that must be considered when planning to own an aquarium.

346

347 **Teaching structure and Layout**

348 **Styles of teaching to be adopted by teachers**

349 Theoretical Approach: The lesson is based on the **Visual, Auditory, and Kinesthetic (VAK) learning**  
350 **model**, which emphasizes three major learning styles commonly used in educational curricula worldwide.  
351 **Visual learners** learn best through the use of pictures, diagrams, videos, and other visual aids. **Auditory**  
352 **learners** benefit from listening, discussions, and verbal explanations. **Kinesthetic learners** learn most  
353 effectively through hands-on activities, practical experiences, and active participation. Therefore, the topic  
354 should incorporate all three teaching approaches to ensure that the learning needs of different types of  
355 learners are effectively addressed and accommodated.

356

357

358

359

360

361

362

## Glossary

363 **antibiotics:** medicine used for the treatment of infection and diseases in humans and animals. In fish it  
364 aids in prevention of infections.

365 **aquarium:** a designed device that acts as a habitat for fish and other aquatic plants.

366 **bacteria:** tiny single cell organisms that almost exist everywhere in the universe. They are types of microbes  
367 besides viruses, fungi, protozoa

368 **benthic feeders:** organisms that thrives at the bottom of the water, they feed and stay at the bottom of the  
369 tank (aquarium)

370 **bio-based economy:** utilization of renewable biological resources such as fish, crops and microbes to  
371 produce other products.

372 **bio-wheel:** a device used for air/oxygen circulation in the aquarium in order to remove toxic substances  
373 such as ammonia build up.

374 **biodiversity loss:** the decline of living organisms from their natural habitats, mostly contributed by external  
375 factors (to a larger extent attributed to human activities)

376 **biotechnology:** use of biological mechanisms in industries for the production of substances, majorly the  
377 use of microbes in production of antibiotics etc.

378 **blooms:** a rapid growth of microscopic algae or cyanobacteria in water, often resulting in a colored scum on  
379 the surface.

380 **captive-breed:** rearing of fish in a controlled environment to build a healthy population.

381 **carnivores:** an animal that feeds on meat or eats another animal.

382 **circular economy:** a sustainable system of economy designed to tackle issues that affect the earth's  
383 ecosystems like global warming, biodiversity loss and eutrophication. The economy is based on the  
384 principle of reduce, reuse and recycle.

## A child-centric microbiology education framework

385 **attention deficit hyperactivity disorders (ADHD):** a chronic brain disease that affects millions of children  
386 and may continue to adulthood. The symptoms include restlessness and forgetfulness.

387 **ecological pressures:** pressures resulting from human activities which bring about changes in the state of  
388 the environment. Examples are global change, urban development and agriculture.

389 **environmental mitigation:** an action of addressing the negative effects to the environment caused by  
390 anthropogenic activities.

391 **eutrophication:** a natural gradual increase in minerals and nutrients concentration (mostly nitrogen and  
392 phosphorus) into the water ecosystems leading to excessive growth of aquatic life.

393 **filter media:** a type of filter used to clean water by removing waste products and toxic elements and allows  
394 beneficial microbes to thrive in your aquarium.

395 **fish meal:** a commercial nutrient-rich fish food/feed ingredient made from whole wild-caught fish, bycatch  
396 and fish by-products e.g., farmed fish.

397 **fish oil:** fat or oil extracted from the fish tissues with rich omega-3 fatty acids and can be used to formulate  
398 fish food/feed.

399 **footprint:** the amount of gas such as carbon dioxide emitted from the consumption of fossil fuels and  
400 accelerated by human actions. Furthermore, the gasses trap and release heat to the atmosphere.

401 **food chain:** a hierarchical transfer of matter, nutrients and energy by organisms in the form of food. The  
402 process begins with producers such as plants and ends with the consumers.

403 **greenhouse gas:** atmospheric gas that absorbs and emits sunlight resulting in global warming.

404 **habitat degradation:** a condition in which natural ecosystems declines due to factors such as pollution,  
405 invasive species, and over-exploitation, hence becoming unsuitable for native species.

406 **hypoxic:** a condition in which the organisms/ fish body have less oxygen to maintain normal functioning.

407 **health index:** a mathematical tool which measures the state of health outcomes and risk factors over time,  
408 of a well-defined population.

## A child-centric microbiology education framework

- 409 **invasion:** occasion whereby an organism is introduced from their native habitats into another, therefore  
410 establishing a sustainable population.
- 411 **microbes balance:** a mixture of prebiotic and probiotics that supports a healthy immune system and helps  
412 fight opportunistic and pathogenic bacteria from childhood.
- 413 **microbiome:** a community of microbes such as bacteria, viruses, protozoa, fungi found living together in a  
414 specific environment and interact with other organisms.
- 415 ***Mycobacterium marinum* infection:** skin infection in humans caused by direct contact of injured skin  
416 with fish or contaminated aquarium water. Also referred to as aquarium granuloma.
- 417 **nutrients cycling:** a process that involves recycling and reusing nutrients from the physical environment to  
418 the living organisms.
- 419 **nutrients dynamics:** transfer and retention of nutrients, over time and distance in the environment.
- 420 **nondegradable:** a substance not capable of breaking down and being absorbed in the environment over  
421 millions of years.
- 422 **omnivore:** an organism that feeds in both plants and animal matter.
- 423 **pathogen:** a microbe causing disease to its host.
- 424 **pelagic feeder:** organisms that feed on water surface or open waters.
- 425 **pellets:** small rounded fish feed/food that can either float or sink in water.
- 426 **poverty index:** percentage of households in a specific geographical area whose net income falls below  
427 threshold.
- 428 **Sustainable Development Goals (SDGs):** blue prints developed and adopted by all United Nation Member  
429 States in 2015 to achieve a better and more sustainable future for all by 2030.
- 430 **total solids:** a measure of suspended solids that either floats or settles in water.
- 431 **transmission pathway:** ways in which microbes spread from one infected host to another.
- 432 **water abstraction:** the process of taking water from natural ecosystems (lakes, streams, rivers etc)

## A child-centric microbiology education framework

433 **wastewater treatment:** a process by which water that has been contaminated by humans or nature is  
434 returned to good quality.

435 **wild-caught:** fish caught from the natural habitats.

436 **zoonosis:** disease caused by microbes and can be transmitted from animals to humans.

437 **zooplankton:** tiny microorganisms that freely float on the water surface.

438

439

The Evidence Base, Further Reading and Teaching Aids

440

441 *Positive Impacts of keeping pet fish*

442 <https://www.theguardian.com/environment/blog/2010/mar/17/ask-leo-fish>

443 <https://www.theguardian.com/environment/2009/jan/18/lucy-siegle-fish-keeping-eco-impact>

444 <https://www.gfk.com/insights/mans-best-friend-global-pet-ownership-and-feeding>

445 [trends#:~:text=On%20average%2C%20one%20third%20\(33,pet%20with%20ownership%20at%2012%2](https://www.gfk.com/insights/mans-best-friend-global-pet-ownership-and-feeding-trends#:~:text=On%20average%2C%20one%20third%20(33,pet%20with%20ownership%20at%2012%2)

446 [5.](#)

447 Chur-Hansen, A., & Winefield, H. (2013). Companion animals and physical health: The role of health  
448 psychology. Wiley. <https://hdl.handle.net/2440/84112>

449 Clements, H., Valentin, S., Jenkins, N., Rankin, J., Baker, J. S., Gee, N., ... & Sloman, K. (2019). The effects  
450 of interacting with fish in aquariums on human health and well-being: A systematic review. *PLoS one*, 14(7),  
451 e0220524. [10.1371/journal.pone.0220524](https://doi.org/10.1371/journal.pone.0220524)

452 *Reasons for not owning an Aquarium/pet fish*

453 <https://pethelpful.com/fish-aquariums/Reasons-Not-to-Have-Pet-Fish>

454 <https://earth.org/the-destructive-truth-behind-aquariums/>

455 *Aquarium contribution to carbon emission*

456 <https://www.theguardian.com/environment/2009/nov/13/ethical-living-carbon-emissions>

457 *Aquarium microbes*

458 <https://www.youtube.com/watch?v=Xw6lDWom7cw>

459 Smith, K. F., Schmidt, V., Rosen, G. E., & Amaral-Zettler, L. (2012). Microbial diversity and potential  
460 pathogens in ornamental fish aquarium water.

461 *Pet fish diseases*

462 [https://www.castledawnaquatics.com/blogs/question-of-the-day/can-aquarium-fish-disease-be-passed-on-to-](https://www.castledawnaquatics.com/blogs/question-of-the-day/can-aquarium-fish-disease-be-passed-on-to-humans)  
463 [humans](#)

## A child-centric microbiology education framework

- 464 Sanchez, M., Delpont, M., Bachy, M., Kabbaj, R., Annequin, D., & Vialle, R. (2015). How can surgeonfish  
465 help pediatric surgeons? A pilot study investigating the antinociceptive effect of fish aquariums in adult  
466 volunteers. *Pain Research and Management*, 20(1), e28-e32. <https://doi.org/10.1155/2015/419412>  
467 [https://asm.org/Articles/2022/March/Fish-Tank-Granuloma-and-Other-Waterborne-](https://asm.org/Articles/2022/March/Fish-Tank-Granuloma-and-Other-Waterborne-Diseases#:~:text=Aquarium%20filters%2C%20filter%20floss%2C%20biofilm,exceptionally%20high%20concentrations%20of%20bacteria.)  
468 [Diseases#:~:text=Aquarium%20filters%2C%20filter%20floss%2C%20biofilm,exceptionally%20high%20c](https://asm.org/Articles/2022/March/Fish-Tank-Granuloma-and-Other-Waterborne-Diseases#:~:text=Aquarium%20filters%2C%20filter%20floss%2C%20biofilm,exceptionally%20high%20concentrations%20of%20bacteria.)  
469 [oncentrations%20of%20bacteria.](https://asm.org/Articles/2022/March/Fish-Tank-Granuloma-and-Other-Waterborne-Diseases#:~:text=Aquarium%20filters%2C%20filter%20floss%2C%20biofilm,exceptionally%20high%20concentrations%20of%20bacteria.)  
470 <https://iacuc.wsu.edu/zoonoses-associated-with-fish/>  
471 *Ecological impacts of pet fish feeds*  
472 White, P. (2013). Environmental consequences of poor feed quality and feed management. *FAO Fisheries and*  
473 *Aquaculture Technical Paper*, 583, 553-564.  
474 *Pet fish loss*  
475 <https://www.hepper.com/coping-with-pet-fish-loss/>  
476 <https://petsdeath.com/fish/>  
477 *The role of microbiology in sustainable development*  
478 <https://asm.org/Articles/2021/October/The-Role-of-Microbiology-in-Sustainable-Development>  
479 *Pet fish invasion and ecological impacts*  
480 Nemo movie  
481 [https://news.mongabay.com/2013/10/pet-fish-invade-ecosystem-upending-nutrients-and-impooverishing-](https://news.mongabay.com/2013/10/pet-fish-invade-ecosystem-upending-nutrients-and-impooverishing-fishers/)  
482 [fishers/](https://news.mongabay.com/2013/10/pet-fish-invade-ecosystem-upending-nutrients-and-impooverishing-fishers/)  
483 <https://www.invasivespeciescentre.ca/take-action/dont-let-it-loose/>  
484 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3768308/>  
485 *Total solids in Aquarium*

486 [https://plecoplanet.com/forum/threads/the-importance-of-total-dissolved-solids-in-the-freshwater-](https://plecoplanet.com/forum/threads/the-importance-of-total-dissolved-solids-in-the-freshwater-aquarium.3480/)  
487 [aquarium.3480/](https://plecoplanet.com/forum/threads/the-importance-of-total-dissolved-solids-in-the-freshwater-aquarium.3480/)

488

489 *Aquarium Ownership Ethics*

490 <https://www.liveaquaria.com/article/124/?aid=124>

491

492