Exploring coral reef conservation in *Minecraft*

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Abstract

Laura, Sophie, Jackie and **Carly,** Science Hunters from Lancaster University, and **Tom** of Colville Primary School, London, explore the use of virtual worlds to understand real-world processes.

Keywords: Technology; Ecosystems; Constructivism

Minecraft is a computer game that allows players to move around in a virtual world, building almost limitless creations with a vast array of cubic blocks with varying textures and properties. Its representative settings and processes link to the real world, making the game a valuable tool for both presenting scientific concepts to children and allowing them to explore these ideas (Hobbs *et al*, 2019a). Used in a range of educational contexts around the world (e.g. Nebel, Schneider & Rey, 2016), it appeals to children as a medium for undertaking educational activities (Hobbs *et al*, 2019b, 2020).

The Science Hunters project combines *Minecraft* with a constructivist pedagogy utilising constructionism and anchored instruction, by first briefly introducing a scientific topic via hands-on activities and discussion, and then encouraging and supporting children to explore the content through inquiry-based learning. They follow their own ideas to experiment and build within *Minecraft*, guided by suggested tasks/challenges and support from project staff, within the framework of the topic

Figure 1 (a,b), Examples of resources used as visual aids, **(c)** models of living coral and **(d)** real samples of bleached coral, used in 'coral reef' sessions (photographs in the visual aids are courtesy of Professor Nick Graham, Lancaster University).

presented. In this way, they can explore the topic according to their own interests, while consolidating their learning.

Scaffolding, collaborative learning and discussion enable the children to construct meaning from their play. Topics cover a wide range of scientific fields, with a strong focus on environmental sciences, in line with the research backgrounds of the core project team. One of these topics is 'coral reefs', which links to research at Lancaster University where the project is based.

Coral reef ecosystems

Coral reefs are large underwater structures made of the skeletons of marine invertebrates (corals). Hard (scleractinian) corals are the foundation species of tropical reef ecosystems. They grow by extracting calcium carbonate from seawater and creating a durable exoskeleton that protects their soft bodies. A healthy reef ecosystem relies on corals continuing to build carbonate skeletons.

The bigger and more complex the coral cover, the more biodiverse the community composition of the ecosystem; reef fish are more abundant and there is greater biomass, species richness and trophic structure (food webs and chains). Coral reefs provide habitats for many species of aquatic animals and plants and act as natural barriers, protecting settlements from hurricanes, typhoons and tsunamis. Fishing is an important activity at coral reefs. If reefs are damaged, they are less productive in terms of fishing and many people suffer; they are an essential system for food security (Nash & Graham 2016). Coral reef ecosystems support the livelihoods of more than 500 million people globally and are worth an estimated US$375 billion per year (Coral Reef Alliance, 2019a).

A range of threats pose a risk to coral reefs around the world, even in protected areas such as the Chagos Archipelago in the Indian Ocean, the largest 'no-take' marine protected area in the world. These include ocean warming, ocean acidification, sea-level rise, crown-of-thorns starfish that consume hard coral, and unsustainable fishing practices (Coral Reef Alliance, 2019b).

Using *Minecraft* to explore threats to corals

During 'coral reefs' sessions, children are introduced to corals and threats posed to coral reefs. They handle samples of real bleached coral and representative models of living (i.e. non-bleached) coral, as well as visual aids demonstrating core concepts (Figure 1). Key threats are introduced (See Box 1 p26).

It is important to monitor coral reef health in order to manage them effectively. Children are invited to explore ecosystem-based management by considering which factors could be observed, for example:

- range of fish species present;
- size and amount of fish present;
- extent of dead corals; and
- extent of live coral cover.

They are then able to either explore a coral reef and representations of these threats in *Minecraft*, in a bespoke construction that guides them around a specially built coral reef, or to construct their own coral reef. In both scenarios, a specific task is set to build a glass-bottomed research ship for conducting observations of coral reefs.

Evaluation in primary schools

An evaluation of the efficacy of the 'coral reefs' session for increasing children's knowledge of the topic was undertaken in primary schools in England. Changes to understanding through participating were assessed by comparing observational data collected during the topic

Box 1. Key threats to coral reefs.

Unsustainable fishing practices – which take place even in the protected Chagos area where over 50% of coral reefs are thought to be fished unsustainably (Nash & Graham, 2016):

- **Fish aggregating devices (FADs)** – buoys that float through an area to attract large fish. Fishing boats sail FADs through Chagos, harvesting the catch when it is out of the no-take zone.
- **Illegal, unreported and unregulated fishing boats** – these are often small and therefore hard to detect, taking valuable species such as sharks, tuna and grouper.
- **Nets** – found caught in coral or along the seabed, from either illegal fishing or left over from before areas received protected status.

Crown-of-thorns starfish eat living coral:

- One starfish can consume up to 6 m^2 of living coral reef per year.
- Because of overfishing of their natural predators, these starfish can cause extensive damage.
- Manual extractions are relatively successful in reducing the population.

Climate change:

- Ocean warming causes coral bleaching (corals lose their algae, which give them their colour). Bleached coral is an indicator of poor reef health.
- Ocean acidification inhibits growth of coral skeletons.
- Rising sea levels lead to deeper waters, exposing corals to less sunlight and thereby slowing their growth.

introduction, when children were verbally invited to share what they currently knew and understood about the subject, and in a summarising phase at the end of the session in which children discussed what they had learned.

Evidence of other impacts, such as enjoyment and positive associations with science, were also recorded:

'I learnt that there is coral on Minecraft. Also, I learnt that algae dyes coral and algae can be blue and red.'

'I learnt how to play Minecraft and I know that corals are dying because of global warming.'

'It was fun because I learnt new things.'

'This session has been really helpful to understand things about oceanographers; it was amazing.'

'This session was really good and fun. I've learnt something about the coral reefs. It was fantastic.'

'I really loved learning about coral and coral bleaching.'

In addition, 68 Year 5 pupils (ages 9-10, 38 female, 30 male and including 11 with additional needs and 28 with English as an additional language) answered three multiple-choice questions on paper before their workshop began, with the answers being embedded within the session. At its end, children were asked to answer the same three questions again. These questions are shown in Figure 2, with correct answers highlighted.

Figure 2. Key threats to coral reefs.

1. Is coral...?

- ❍ a plant
- ✓ an animal
- ❍ both
- ❍ neither

2. What gives coral reefs their colour, and is lost during coral bleaching?

- ❍ coral skeleton
- ✓ algae
- ❍ sea water
- ❍ dye

3. Which one of these is a threat to coral?

- ❍ sea birds
- ❍ people eating fast food
- ✓ crown-of-thorns starfish
- ❍ conservationists

Before the session, the mean score on these questions was 32% ± 2.9%. After it, the mean score was 79% ± 3.0%, an increase of 47% ± 4.2%. The modal score before the session was 1 out of 3, while afterwards it was 3 out of 3; 55 students improved their scores, with none decreasing. The scores and improvement for each question are shown in Table 1. Statistical analysis determined that this outcome is statistically significant ($p < 0.001$); that is, these are real results and have not occurred by chance. There were no significant differences between scores for girls and boys.

Case study: Colville Primary School

The coral reef ecology session was delivered at Colville Primary School in London in July 2019. The school has introduced *Minecraft* to support different areas of the curriculum, including science, and is therefore well placed to provide insightful feedback into the impact of the session in facilitating meaningful scientific understanding through using the game.

The Science Hunters coral reef session was very impactful, in that the children could connect real-world understanding of coral reefs, and the dangers they face, with the virtual simulated reef environment. It was amazing to see how they treated the virtual reef and marine life with the same kind of care that they would have in the real world. It was very satisfying watching some of the children discover bleached coral in the game (which appears grey due to the absence of the algae), demonstrating their understanding of how coral functions. It was fantastic that the children also handled real coral, further solidifying the link between virtual and real.

The session itself was an excellent way to engage pupils with learning about coral reefs, as it allowed

Table 1. Breakdown of mean scores before and after the session.

Question	Mean pre-session score (%)	Mean post-session score (%)	Change in score (%)
1 (What is coral?)	5.9	69	63
2 (What gives coral colour?)	54	78	24
3 (Threats to coral)	35	91	56

them to take the initial scientific concepts and explore them further in a 3D world. The whole approach of Science Hunters is a very effective way to get children into science, as it allows them to go on virtual field trips and discover things themselves, just as scientists do in real life. It was clear to see that they are much more likely to be curious about (and therefore retain information about) scientific concepts by being able to learn in such an open-ended and involved way. In a parallel project, children also built and ran their own marine conservation centre in *Minecraft,* growing and transplanting coral, as well as protecting endangered marine species.

Summary

The successful Science Hunters' approach of using hands-on topic introductions and the computer game *Minecraft* to engage children with science has been applied to learning about coral reef ecology. Evaluation of the topic delivery in primary schools has shown it to be effective, with a significant increase in knowledge about the subject evident in children participating in the session and clear benefits seen by schools.

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Applied science in the kitchen

■ Geoff Auty

Abstract

Scientific thinking can be applied to things we do at home. Effective results can be achieved in cooking or cleaning while also focusing on doing so with minimal waste of resources. This can also mean better economy. Choosing appropriate designs of equipment can make certain jobs easier. Three different topics are described to demonstrate these principles

Cooking the vegetables – a consideration of economy

In my young days, houses had coal fires, and the cooking was done on the kitchen fire with its open hearth and its attached coal oven. A pan to boil potatoes was put on the edge of the fire and, provided that they didn't boil dry, the potatoes were cooked after 20 minutes of boiling (from when the water had reached boiling point). Nobody knew or cared whether the heat used was excessive. It was just a part of the whole heating of the house, and a considerable part of the thermal energy went up the chimney in the output gases (carried by convection) and into the atmosphere. Now we have gas or electric cookers, which are easier to control, and we are told to be aware of the excess use of energy (and costing more than needed).

However, at one house I used to visit years later, by which time coal fires were a thing of history, if it was approaching lunchtime the kitchen door would be slightly open, even in the coldest weather, because the potatoes were on the boil and water was running down the windows. The gas on the cooker was turned to maximum because it was deemed essential to keep the potatoes boiling – the presumed logic being that that was the way it appeared when we had had coal fires. In former times, houses were not so well insulated and did not have sealed doors and windows as they have today. That would have been a separate problem because the smoke had to go up the chimney, and fresh air had to come in from outside.

Raw potatoes are solid and hard, and they 'cook' because chemical changes occur slowly when they are kept at 100°C, and they are usually soft enough to eat after 20 minutes. But how long would it take if they were kept at 99°C or 95°C? The answers might be 'not much longer'. But how much?

I have not done a careful scientific test with measurements and timings, but I have tried a simple technique at home using a gas cooker. When the water starts to boil, I turn the gas off. After about 10 minutes I turn it on and let the water 'come to the boil'. That takes only about a minute and I turn the gas off again. After a further 10 minutes, as far as I can tell, the potatoes are cooked as effectively as if I had kept the gas on, with the water boiling throughout. I do not have a thermometer at home to measure how far the temperature has fallen during 10 minutes but, if the lid stays on the pan, the reduction can't be much because the water returns to boiling very quickly when the gas is turned on again. An advantage for me in being able to carry out this investigation is that the pan used has a heat-resistant ('Pyrex') glass lid. This will provide better insulation than an aluminium lid. Also it is possible to see whether the water is boiling, and how rapidly, without removing the lid. With the gas left on at minimum, very gentle boiling continues. But I have not found a significant difference between the cooking times for this 'gentle continuous boil' method and the '10 minutes off' method I have described. A further variable that we cannot control easily is that not all potatoes are identical, and the 20 minutes of boiling is a general target time (guaranteed softening by then but, for some potatoes, 15 minutes or less could be adequate).

I am sure teachers of science subjects will know that having the gas on high does not make the water hotter (the temperature stays at boiling point).

But a greater rate of heating simply creates more evaporation. I suspect many people think (as explained above) that vigorous boiling (bouncing the potatoes around in the water) makes them cook faster, but I doubt whether that is true.

I wonder how much energy would be saved if the whole country adopted my method.

I doubt whether this will be on an exam paper any time soon, and some would argue that therefore it should not be pursued in lesson time. Yet it is just as valid as any other method of teaching ideas about boiling point and heat transfer. I also believe that education is for life, not just for exams, and this is a useful way to manage teaching the topic of variation of boiling point with pressure without reaching for the contents of the chemistry lab store. A possible method is to set different targets to different groups of students – 10 minutes boiling, 15 minutes boiling, 18 minutes boiling, 20 minutes boiling, 25 minutes boiling. If suitable equipment is available, testing with and without a cover (acting like the pan lid) could be another set of options using various times.

Each group can then share results with the whole class and contribute to a group discussion to provide a summary of what has been found out.

Another factor is the potato size. Cutting them into small pieces will enable a shorter cooking time than leaving them whole because the temperature throughout each piece will reach that of the water more quickly.

A word of warning

On one occasion, I tried this investigation with a class. I bought a bag of Maris Piper potatoes, thinking that, being a named variety, they would be of high quality. After the chosen boiling time they were no longer the soft solid potatoes we expected, but they had collapsed into a soggy mess in the water. Choose the variety carefully if trying this investigation! Over 50 years ago, food shopping tended to be done at suburban or village shops, and varieties of vegetables were limited to what was available locally. Vegetables were usually weighed as required and they did not often have a label to show the variety.

Vegetables are now available from supermarkets already weighed and packed in bags labelled with the variety, and imports make different varieties available for longer 'seasons' than in the past.

Lesson management

Students simply watching and waiting is not a good use of class time. Although 20 minutes is the longest waiting time implied by the above explanations, a quicker option could be to use small pieces of potato (such as 3 cm cubes) and examine how far the cooking has progressed after 10 minutes by cutting a potato and measuring the depth of softening. Ideally, a kitchen fork would be used for this test but they are not normally available in a school lab. Also 'softness' is a somewhat subjective test.

To provide a more scientific test, a method such as that shown in Figure 1 could be considered. To provide a simple apparatus, a nail is pushed through a strip of wood near one end after drilling a suitable hole to create a tight fit. Leaving the point on the nail is perhaps better for simulating the action of the prong of a fork but, if there is a safety concern, the point could be filed off. Three or four nails would be an even better simulation of the action of a fork. Possibly only six or eight sets of these test rigs would be needed, for a class of 30. They could be shared as needed and students would be interested in watching each other's tests.

Other root vegetables such as carrots, turnips and swedes could be tested in the same way.

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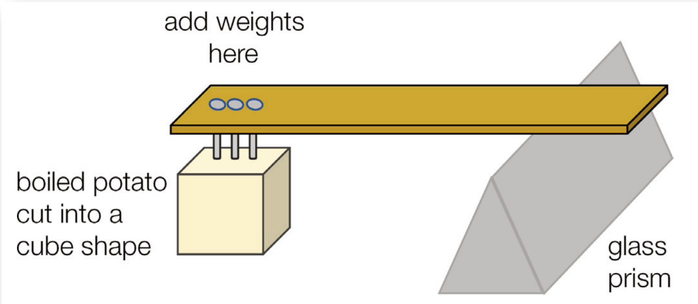
Figure 1. An apparatus designed to test the softness of boiled potatoes.



Pour experiences

During cooking or dining, there will be a need to pour liquids, for example draining the potatoes before mashing or adding milk to tea.

If you fill a simple cylindrical mug (such as shown in Figure 2) with water to the brim and try to pour the water into a similar container, it is likely that you will spill some.

Figure 2. A simple design for a coffee mug.

This leads to some questions.

- Can you pour without spilling if it is, say, half full?
- Can you identify a level at which pouring will always be successful?
- Does it make a difference if you pour carefully or it is better to pour quickly?
- How would you measure 'carefully'?

Some other mugs have the same basic cylindrical shape, but the rim has a gradual outward turn as shown in Figure 3.

Figure 3. A mug with a 'turned-out' rim.

I have heard it suggested that the shape of Figure 3 is more comfortable for drinking, but it does not seem significantly better to me.

The pan on the left in Figure 4 has vertical walls and the rim is turned outwards along the whole circumference until horizontal. The pan on the right has walls sloping outwards. The rim has no curved edge, but at a position 90° from the handle, a lip (V-shape section) is pressed outwards. On this pan, although not on all models of the same kind, there is a similar lip on the opposite side. This is helpful to left-handed people. It is not so obvious in the photograph, but close inspection shows deviation in the curve of the rim next to the handle of the other pan.

Figure 4. Two small pans from the kitchen.

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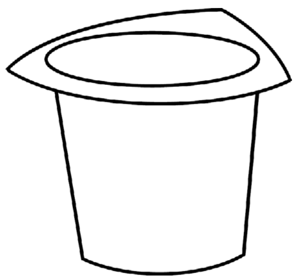
Inspect some of the beakers or other containers used in a school laboratory. Popular glass beakers have both a turned-out rim (as on the pan on the left in Figure 4) and a V-shaped lip (even more sharply angled than the pan on the right).

One design of plastic beaker used in school laboratories has a three-pointed brim as shown in Figure 5, but it is unlikely that any container at home will be similar.

Figure 5. A plastic beaker found in a school laboratory.



Practical challenge

What makes the design of a container successful for pouring? I have set students the following challenge:

- Suppose you are employed as a designer for a company that wants to make a new range of pans and advertise with the slogan 'pours without spilling'. What would you advise?
- Will you be able to explain your findings?

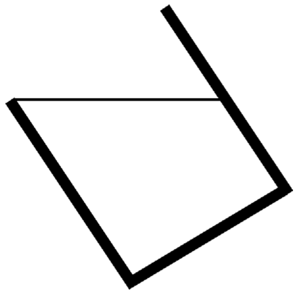
Teacher notes

This is an interesting investigation using simple equipment. Yet it is unlikely that it could be used for an assessed investigation because we cannot identify all the variables clearly. We cannot quantify 'pour carefully'. Containers can have a wide variety of shapes.

The qualities of liquids (surface tension and viscosity) play a role – a jug might successfully pour custard but not water.

The angle and precise shape of a lip or rim are important. Containers with a small all-around rim are often better than those with a lip.

Figure 6. A cylindrical container tipped and about to pour liquid.



When a drop of water is about to run over the edge, what will happen to it?

If the movement is slow, the drop could fall vertically (success), but it is more likely that it will cling to the outer wall and dribble down it (failure!).

If pouring quickly, there is a chance (not a guarantee) that the water will break away from the surface at the rim and fall in a curve (parabola), not vertically. That is why you might be more successful pouring confidently rather than carefully.

The design of a rim or a lip is important. Figure 7 shows a number of V-shaped lips used on pans or jugs with variable amounts of 'turning'. Shape (a) is very little better than a straight-edged container. Liquid is likely to cling to the outer wall unless there is only a small amount in the container to begin with. Shapes (b), (c) and (d) should be successful because, when the container is tipped, the liquid would have to run upwards in order to cling to the lip and run onto the outside of the vessel.

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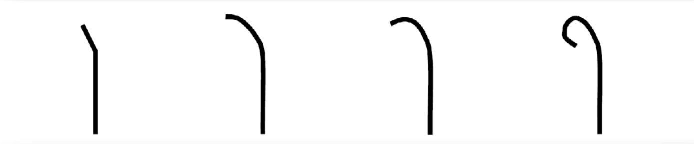
Figure 7. Cross-section showing the amount of 'turning' of the edge of a V-shaped lip of some containers.



(a) simple lip	(b) edge of lip turned to horizontal	(c) edge of lip turned further	(d) edge of lip turned even further

With an all-around rim (Figure 8), the same principle applies. Shape (a) is very unlikely to pour effectively if the container is full, and not much better than having vertical sides. As with the turned lips of Figure 7, shapes (b), (c) and (d) will be successful when the container is tipped, because liquid can drip rather than clinging to the outside 'wall'.

Figure 8. Cross-section shapes at the all-around rim of some containers.

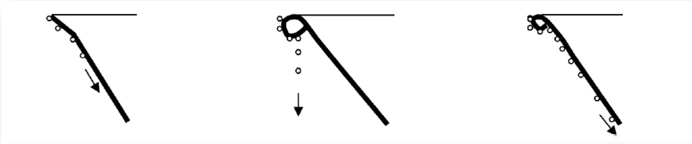
(a) splayed edge	(b) edge of rim turned to horizontal	(c) edge of rim turned to vertical	(d) edge of rim rolled and fully sealed

The fully rolled rim is popular on enamelled pans. Sealing the rolled edge keeps it clean.

Consider in Figure 9 the comparison between three designs, a lip in (a) and rolled rims of two sizes in (b) and (c), ready to pour. What happens to the first droplet?

If the rolled rim is very small, surface tension will keep the liquid clinging to the surface and enable sufficient upward movement to occur for the liquid to run to the side as with other designs.

Figure 9. Three containers starting to pour liquid; for ease of illustration, the liquid is shown as droplets but in fact they will merge into continuous streams.



(a) liquid can cling to the outside of the vessel while running downwards	(b) with a large rolled rim, liquid will initially cling to the rim but then falls off because it cannot run a significant distance upwards to the side of the pan	(c) with a small rolled rim, liquid clings sufficiently to run slightly upwards under the rim to the side

Another factor is that, if you pour quickly, small droplets do not get a chance to form and the surface tension of the body of liquid keeps it together rather than allowing any to break away from the main flow and cling to the outside of the vessel.

Disposable vending cups or picnic cups (or party cups) are available in all these shapes and can be used to test the principles. The above investigation has many factors not easy to quantify precisely, but there is plenty of fun in trying.

Clean-up time

After cooking and dining, there is the question of washing up. In my childhood, the same soap powder seemed to be used for washing clothes and washing up after meals – I never heard the word 'detergent'. But then 'washing-up liquid' came on the scene.

Some considerable time later, I was surprised to see someone who was intending to wash nothing more than half a dozen coffee cups squirt liquid into a bowl to cover the whole bottom surface (about 25 cm across) before adding hot water. Apparently that was what he thought was needed.

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In fact, very little washing-up liquid is needed, but it does depend on how much washing-up there is and on how dirty or sticky the various items are. It also depends on whether the 'stickiness' is caused mainly by fat, oil, starch or sugar.

It is difficult to carry out real tests that are precise, but I can give my experience. If no cooking is involved (e.g. a breakfast of cereals, toast and coffee), a squirt of liquid that would just about spread to the size of a 1 pence coin, put into the wash bowl before adding water, is plenty.

After a cooked dinner, all the tableware and cooking utensils have to be washed. The same amount of liquid and hot water as used for breakfast seems to cope with the cups, plates and cutlery. However, the white froth on the surface of the water gradually becomes less, and the cleaning feels more difficult to achieve as time passes. The cleaning fluid is gradually being used in reacting with sticky and dirty substances and the water is becoming cooler. Yet the dirtiest dishes and cooking utensils are still to be washed. Adding more hot water and more washing-up liquid is needed; or a fresh start.

Testing

As a test for these effects, students could mix various quantities of cooking oil with hot water and small quantities of washing-up liquid. Without access to laboratory facilities, I do not have quantities to recommend. However, the target is to have clean surfaces and very little froth left over. I think it can be left to students to plan such an investigation; and remember that temperature plays a part.

Environmental considerations

In the UK, we have an excellent sewage system for disposing of our dirty water. It is so good that it is possible to pour liquid waste down the sink and forget about it. The sewage treatment works can take out the waste material, and the water is returned in a nearly clean state to the rivers.

However, fats can come out of the water before reaching the sewage works and coat the insides of the pipes. The reason is that the fat would be dissolved in hot water, but some of it comes out of solution and becomes 'semi-solid' as it cools when travelling through the pipes. There were pictures in the news on television a few months ago showing that a city sewer about 1.5 metres wide had become blocked with fat, which could only be removed by digging.

The obvious reaction would be to suggest that people should use more detergent to ensure that all fat is dissolved, but it is not so simple. Too much detergent is also a problem. Detergent that has not reacted remains in the water that is returned to the rivers – not good for the fish (in the rivers or eventually in the sea). In addition, froth will form if the river is stirred up by running over rocks. Furthermore, many rivers have weirs – these were originally built to raise the level of water to provide the pressure to drive waterwheels, and later to provide sufficient depths of water for large cargo boats (barges) to transport more goods than the roads in former centuries could handle. The turbulence created in water with excess detergent spilling over a large weir can create large amounts of froth. In a town some 12 miles downstream from where I live, it is quite common (not daily, but perhaps once or twice a year depending on the weather) for froth accumulating at the bottom of the weir to be blown around the streets. Relatively harmless, but certainly messy!

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