Water Damage Prevention and Recovery

Techniques and materials for preventing damage to consumer electronics after water exposure

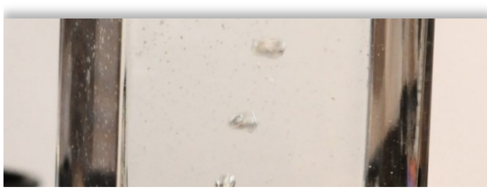
Water damage costs smartphone users millions of dollars each year in replacement and repair costs as well as lost device functionality and diminished resale value. Each year at Gazelle, we purchase many broken smartphones to be refurbished and reused or recycled. This process reduces the financial burden of water damage, helping smartphone owners recover some value from their damaged phones. However, in many cases it may be possible to avoid water damage altogether by following the correct steps to recover a phone after accidental water exposure.

To help our customers protect their investments, we have conducted a series of tests to determine the best way to prevent water damage in a phone that has recently been immersed in water.

Conventional wisdom suggests that a smartphone can be protected from damage after water exposure by placing it in a container of dry, uncooked white rice for at least 24 hours. Despite the popularity of this solution, we had seen little evidence that it works or that uncooked rice is the best drying agent available.

We sought to answer three questions:

1. **Does the popular practice of placing a phone in a container of white rice produce a meaningful chance of recovery?**
2. **Does dry uncooked rice perform better than other common household substances?**
3. **What other factors affect the probability of successful recovery of a phone that has been exposed to water?**



We ran two tests to answer the questions above. The first test examined the real-world effectiveness of common solutions for water damage. The first test consisted of placing nine smartphones in water and then attempting to recover them using common materials as drying agents.

The second test directly compared common household goods as drying agents. Sponges containing 5 ml of water were each placed into a container of drying agent. The volume of water lost by each sponge over 24 hours served as a measure of that drying agent's performance in absorbing water from the surrounding environment.

Test one demonstrated that it is possible to recover a waterlogged phone using this method, even after ten full seconds of water immersion. Six of nine devices turned back on and two were recovered enough to get some data off of them. Samsung devices proved dramatically more resilient than Apple devices in this test.

Each phone spent ten seconds underwater before being retrieved, manually dried and placed in a container of drying agent.

Test two revealed that uncooked white rice is actually an inferior drying agent, not only to silica gel, but to other common household materials such as instant oats, couscous and instant rice. The results also call into question the practice of sealing a device in a container of drying agent. In this test, which represents the typical application of the common recovery practice, open air exposure performed better than enclosed exposure to rice or any of the other drying agents that we tested.

The results suggest that the common advice and practice of sealing water-exposed devices in a container of dry uncooked white rice may actually **reduce the recovery rate** for the many thousands of water damaged phones each year, resulting in increased recovery costs, data loss and user inconvenience. It also suggests that the commonly available "rescue" kits consisting of a sealable bag and packet of silica gel are probably less effective revised to reflect this.

Test One Materials

- iPhone 4 (3)
- iPhone 3GS (1)
- Galaxy S III (5)
- Water-sensitive dots (100)
- Philips screwdriver
- Pentalobe screwdriver
- Drying agents
  - Silica gel (crystal style cat litter)
  - Uncooked white rice
  - Cat litter
  - Rolled Oats
  - Instant Oats
  - Instant Rice
  - Instant Couscous
  - Chia seeds

Test One: Immersion and Recovery

Nine phones were selected for the immersion and recovery test. Five of the phones were Samsung Galaxy S IIIs, three were Apple iPhone 4s and one was an Apple iPhone 3GS. Each phone was dropped into about 12 inches of water for ten seconds before being retrieved by hand, dried manually and placed in a container with one of the drying agents.

METHODS

Preparation

To determine the extent of water penetration, we opened up the phones before conducting the test and placed water contact indicators throughout the inside of each phone. These indicators turn from white to red upon contact with water, showing which areas of each phone were exposed. Phones with cracks in the screen or body were sealed with clear lacquer to prevent accelerated flooding. A photograph was taken with each phone's built-in cameras to verify functionality and to provide a file for data recovery attempts at the end of the test.

Immersion

The test container was a 4"x4"x18" glass container with about 12 inches of water. Each phone was turned on and dropped from the water's surface. The phones remained at the bottom of the container in a vertical position for roughly 10 seconds before being retrieved by hand.

Recovery

After retrieval, each phone was manually dried with paper towels, powered off, and stripped of its battery (if it had a removable battery). The SIM cards and/or removable SD cards were removed and the phone was vigorously shaken, tilted and manipulated to extract as much water as possible.

When no more water could be manually extracted, each phone was sealed into a zip-lock bag filled with one of the drying agents. The phones remained in the drying agents for 72 hours.

Drying Agent Assignments

iPhone 4 #1	Silica gel
iPhone 4 #2	Uncooked white rice
iPhone 4 #3	Instant rice
iPhone 3GS	Instant oatmeal
Galaxy S III #1	Silica gel
Galaxy S III #2	Cat litter
Galaxy S III #3	Rolled oats
Galaxy S III #4	Instant oatmeal
Galaxy S III #5	Chia seeds

Water contact indicators such as this were placed through each phone. Upon contact with water the indicators turn red.

Functional Testing

After 72 hours in their respective drying agents, the batteries were reinstalled and several attempts were made to power each phone on. Phones that did not respond were plugged in to charge before attempting again. After each phone's functionality was determined, they were disassembled for examination of the water contact indicators and evaluation of water damage.

OBSERVATIONS

Immediately after the phone enters the water

The Samsung Galaxy S IIIs failed quickly when exposed to water. Two of them stopped working within 1-2 seconds of water contact. The other three retrieved. The two that failed immediately were playing or recording video at the time of exposure, suggesting that use of the graphics chipset at the time of water exposure increases susceptibility to damage or functional disruption.

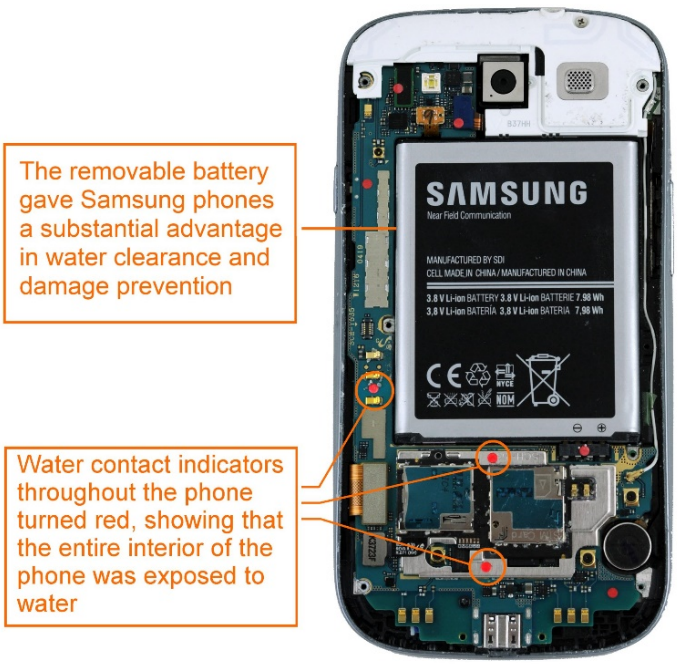
The iPhones initially appeared to tolerate water exposure much better, and all of them continued to function until they were turned off manually.

After the phone is retrieved from the water

Upon removal from the water, the phones drained water for several minutes in response to shaking and tilting. The Samsung Galaxy S IIIs contained a fair amount of water in the battery compartment, which was easily eliminated, once the battery had been removed. None of the phones appeared to have water inside of their displays.

After the phones were dried over 72 hours

After 72 hours of drying time, two of the iPhone 4s and the iPhone 3GS failed to power on. Despite their apparent failure during immersion, the Samsung Galaxy S IIIs were all functional, and none of them showed any sign of serious corrosion - yet.



The water contact indicators revealed the Samsung Galaxy S IIIs and iPhone 4s were completely flooded during the ten seconds in the water. In eight of the nine phones, every water sensor had been completely exposed. The iPhone 3GS appeared to have remained partially dry towards the top of the phone where the water contact indicators had not been triggered.

Incomplete drying

The Samsung Galaxy S IIIs appeared completely dry inside, however, two of the iPhone 4s contained visible water drops, despite 72 hours in drying agents. Water appeared to be trapped around and under the battery and under various pieces of electronic shielding. One of these iPhone 4s had been in uncooked white rice and the other in silica gel.

Damage assessment

Close inspection of the unresponsive iPhone 4s revealed corrosion around the battery connector and that the battery had swelled. Replacing the batteries in these phones restored some of the functionality.

The phone that had been stored in silica gel became completely functional after replacing the battery, suggesting that the battery and connector were the only components damaged.

The second non-functioning iPhone did not immediately respond to the replacement battery. After several minutes, it vibrated, but the display did not turn on. However, the phone did respond to data recovery attempts.

Upon connection with a laptop, the phone immediately appeared in iTunes and displayed its content before spontaneously disconnecting. We were unable to maintain a connection between the phone and the laptop, however the files were recovered one at a time by quickly clicking on them during the brief period of connectivity.

The iPhone 4s all showed signs of complete flooding. All 12 water contact indicators had turned red

Two of the iPhones had visible water trapped around the battery, even after 72 hours in a drying agent.

Ultimately the point of failure on these phones was the battery and battery connector.

A removable battery, as used in the Samsung phones, would likely have prevented the damage that these phones incurred.

CONCLUSIONS

Drying agents work, with some limitations

The popular approach of manual drying and storage in drying agent proved effective for six out of nine phones and partially effective for two more. The choice of drying agent did not have a clear relationship with the successful recovery of the phone. Indeed the two failed iPhone 4s were treated with the most and least absorbent drying agents yet both retained water and suffered similar failures.

Phone design significantly affects the chance of recovery

The presence of water in two of the iPhones suggests that the drying agents are not capable of quickly eliminating large quantities of residual moisture. It also suggests that the iPhone 4's design is more prone to water retention than that of the Samsung Galaxy S III.

The iPhone's components appear to be more tightly packaged, limiting air circulation inside-the phone. The non-removable battery contributed to the water retention, as water was clearly trapped between the battery and housing. Moreover, the iPhone's non-removable battery was the iPhones' primary failure point, due to the failure of the battery and connector.

The immediate failure and subsequent recovery of the Samsung Galaxy S IIIs suggested a catastrophic electronic failure such as a short circuit. However, it is possible that the shutdown we witnessed was some form of overload protection. It is likely that the removable battery contributed to the improved drying and higher survival rate, and it is also possible that the relatively open design of the phone's housing allowed water to escape and or evaporate more readily.

OUTCOMES

Phone	Drying agent	Outcome
iPhone 4 #1	Silica gel	Turned on w/ battery swap
iPhone 4 #2	Uncooked white rice	Partial Recovery w/battery swap
iPhone 4 #3	Instant rice	Turned on
iPhone 3GS	Instant oatmeal	Unrecoverable
Galaxy S III #1	Silica gel	Turned on
Galaxy S III #2	Cat litter	Turned on
Galaxy S III #3	Rolled oats	Turned on
Galaxy S III #4	Instant oatmeal	Turned on
Galaxy S III #5	Chia seeds	Turned on

Test Two: Drying agent Performance

Test Two Materials

- Sponges 1"x2"x.5" (9)
- Filtered tap water (450 ml)
- 20 oz. re-sealable plastic containers (9)
- ACP-200 digital pocket scale
- Waxed paper
- Drying agents
  - Silica gel (crystal style cat litter)
  - Uncooked white rice
  - Cat litter
  - Rolled Oats
  - Instant Oats
  - Instant Rice
  - Instant Couscous
  - Chia seeds

Our first test confirmed that the commonly prescribed treatment for wet phones can be successful. However, it called into question the effectiveness of drying agents in this process. To determine how effectively these materials promote evaporation, we tested the drying abilities of several common household substances in a controlled comparison.

MATERIALS

Each sponge was weighed before being wetted with 5 ml of water, then weighed a second time before being placed into the plastic containers. Seven containers each held 100 grams of a drying agent and the eighth container was empty except for the sponge.

The ninth sponge was placed in open air, next to the containers. Inside the containers each sponge sat on top of a piece of waxed paper, just large enough to prevent direct contact with the drying agent. This barrier reduced the wicking effect. Wicking action cannot easily play a role in the evaporation of water trapped within a phone, because there is normally no direct contact between the water and the drying agent.

After 24 hours, the sponges were removed from their containers, examined, and re-weighed to determine the total amount of water lost.

OBSERVATIONS

The sponge sealed in an empty container lost the least weight at just 0.7ml. The lost water was visibly condensed on the container's lid. Silica gel was the best-performing drying agent, losing 6.1 ml, followed by cat litter at 5.5 ml. Uncooked white rice was the worst, with just 4.0 ml of water loss in 24 hours. The instant rice, instant couscous and instant oatmeal all performed nearly identically, losing 5.0 ml.

The open-air sponge outperformed the others by a wide margin, losing 7.6 ml during the test. The ambient temperature during this test was 71 degrees with a relative humidity of 40%.

DISCUSSION

The drying agents each produced a clear benefit compared to an empty, sealed container. However, there is wide variability in drying agent performance, suggesting that the choice of drying agent may have a meaningful impact on the successful recovery of a phone. Despite its popularity, uncooked white rice proved to be an inferior drying agent compared to other common household materials.

All of the materials in this test were purchased at a grocery store and should be readily available to most smartphone owners.

The instant grain products all performed substantially better than conventional white rice and represent a viable option in the absence of silica gel (which is available in the form of crystal style cat litter).

Our team expected silica gel's high performance, however we did not anticipate that open air would out-perform it and this definitely warrants further investigation.

Why was open air better than silica gel?

In the containers full of drying agents, the air serves as an intermediate medium, absorbing the water from the sponge and depositing it into the drying agent. Ideally the drying agent should absorb moisture quickly enough to drive the moisture content of the air well below ambient humidity. This pocket of dry air would result in accelerated evaporation from the sponge. However, if the drying agent cannot absorb moisture quickly enough, the air in the container will become humid and evaporation will slow.

In the open air scenario, the water contained by the sponge is absorbed and carried away by the ambient air. Because the air supply is virtually limitless, the moisture from the sponge cannot drive up the ambient humidity as it does in the enclosed scenario. The rate of evaporation should, therefore, remain fairly constant.

In our tests, the drying agents were evidently unable to create a pocket of drier-than-ambient air. Consequently the open-air sponge lost more water weight than the sponges treated with drying agents. However, this does not prove that the drying agents are *incapable* of outperforming open air under the right circumstances. Our tests used just 100 grams of each substance and the containers could have held considerably more.

Increasing the amount of drying agent might accelerate the absorption of moisture. However, it would also reduce the total quantity of air, potentially increasing humidity. We do not have sufficient data to determine which of these effects would be greater if we increased the amount of drying agent. Subsequent tests should seek to determine the relationship between the drying agent/container volume ratio and absorption performance.

RECOMMENDATIONS

Remove as much water as possible before using a drying agent

Even the best performing drying agent was unable to eliminate the residual moisture in one of the phones. Therefore, it is advisable to maximize the initial water extraction rather than relying on rice or any other substance to dry the phone. Using a water-tolerant vacuum cleaner, or compressed air may improve initial water extraction. The use of mild heat may be helpful as well, although we didn't test this. However, Apple lists the iPhone's maximum tolerable temperature as 113 degrees Fahrenheit and the Samsung phones are likely similar. Therefore, extreme caution is advised when applying heat.

Open the phone to promote air circulation

In the case where device recovery is critical, the most effective solution is probably to open the phone's housing thereby maximizing air exposure. This can be done with a small Phillips screwdriver for a Galaxy, but the iPhone requires a specialized "pentalobe" screwdriver, which can be purchased on eBay or from iFixit.com. Opening the housing will typically void a smartphone's warranty, but this is not a concern since water damage will already void that contract.

Good drying agents are an option. Uncooked white rice is not.

After extracting as much water as possible from the device, using large quantities of a drying agent may help accelerate the drying process. If a drying agent is used, silica gel is the best of the options tested, followed by couscous and instant rice. Conventional cat litter, oats, and chia seeds are not recommended because of the dust and debris that they deposit inside of the phone. Water damage recovery kits that contain small quantities of silica gel are not recommended because they are unlikely to perform as well as open air. Uncooked white rice is not recommended due to its poor performance as a drying agent.