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The Security of Urine Drug Testing

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ABSTRACT

We studied 23 different commercial products for collecting, storing, securing, and mailing urine samples analyzed for illicit drug use. Despite their tamper-indicating features, we found that all of these products can be quickly and easily tampered with, either before or after sample collection, while leaving little or (usually) no evidence likely to be detected. Either false positive or false negative drug test results could then occur. A brief review of other security practices and standards associated with urine drug testing suggests there may often be additional serious security problems. Given the importance of drug testing, and the fact that illicit drug tests have a huge impact on people's careers, livelihood, and reputations, improved security—especially better tamper detection features—would seem warranted.

INTRODUCTION

Urine is frequently analyzed for purposes of detecting illicit use of drugs and controlled substances (Kissack, et al., 2008). Applications include law enforcement and forensics; accident investigations; screening of employees and potential employees; fitness of duty checks for critical personnel such as those involved in the transportation or nuclear industries; tests of national, international, and scholastic athletes for cheating; and evaluations of whether an individual should receive (or continue to hold) a security clearance.

The results of drug tests based on urinalysis have very important implications for the individual in terms of his or her career, livelihood, and reputation (Tjarks, 2006; GAO, 2007; Jaffee, et al., 2007; Brunet, 2004; Hiltzik, 2006). Test results are equally critical for employers, government, schools, sports, and society. Fairness, justice, and national security may hinge on obtaining accurate results. Consequently, having good security for urine samples would seem essential.

The security of urine drug testing procedures have been considered and questioned (GAO, 2007; Schmidt, 2007; Jaffee, et al., 2007; Jaffee, et al., 2008; Doria, 2008; Dasgupta, 2008), as has testing's fairness, effectiveness, and transparency (Hiltzik, 2006; ACLU, 2008). Almost all of the previous security focus has been on potential attempts by the tested subject to hide his/her illicit drug use by providing a bogus urine sample or by adding an interfering chemical. We believe two security issues have not received sufficient attention: (1) the possibility of a malicious adversary deliberately trying to create a false positive test result for an innocent individual, and (2) the efficacy of the tamper detection measures used to protect the urine collection sample vial both before and after sample collection.

Potential motivations for producing false positive test results for somebody else include discrediting a disliked co-worker or employee; radical activists or hostile foreign nationals attempting to discredit or impede a government program, facility, or organization, and/or their key personnel; and transportation personnel or managers trying to falsely place blame on a scapegoat after an accident. Similarly, athletic competitors or gamblers may want to disqualify athletes, or even an entire team. All that is required to disqualify a national sports team from international competition is for 2 team members to fail a drug test (Doria, 2008; WADA, 2009b).

Tampering with the sample vial prior to its use would seem to be a particularly attractive attack since less attention is typically paid to the security of the sample vial prior to urine sample collection. Injection of just a tiny amount of liquid into the vial is all that is needed to produce a false positive (or potentially false negative) test result. This liquid can be very difficult to spot with the naked eye—especially if nobody is looking for it, or there is over confidence in the effectiveness of the tamper-indicating seals used with the sample vial. It is also possible that fine powders or liquid-encapsulated microparticles can

be inserted into a sample vial and dispersed on the interior surface before urine sample collection. These adulterants would be even more difficult to spot visually.

Figure 1 - 22 of the 23 commercial urine drug testing products that were studied. (Figure 3 shows the other product.) Most of the adhesive label seals shown attached to the sample collection vial are meant to be applied after sample collection, but some are meant to detect tampering with the unused sample collection vial.

As an example, consider the drug nandrolone. The threshold for a positive test result for male athletes is 2 ppb (Hiltzik, 2006; de Geus, et al., 2004). Inserting as little as 30 ng of nandrolone into an unused sample vial—about 1 millionth of the volume of a typical 0.07 ml water drop—could produce a false positive test result. Detecting this adulterant would require visually spotting an essentially transparent volume with a cross section of 0.03 mm—assuming the adulterant wasn't dispersed throughout the interior of the unused sample collection vial.

Some of the more complex sample vials, especially those that produce a drug test result immediately, have inner chambers that are difficult to inspect without disassembling the sample vial, which is not standard testing procedure. Attacking a vial prior to use can occur at the factory or vendor's warehouse, while the vials are in storage or sitting on a loading dock, or just prior to use.

In this study, we analyzed 23 commercial products widely used by government, private industry, and non-government organizations for collecting, storing, securing, and mailing urine samples. We paid particular attention to the tamper-indicating seals or other features each provided to protect the sample collection vial before and/or after urine sample collection. At the end of this paper, we consider other security issues associated with urine drug testing.

PRODUCTS

The 23 urinalysis products we studied (see figure 1) used several different tamper detection strategies. 7 came in a tamper-evident plastic bag and/or had an adhesive label tamper-indicating seal placed on the unused urine sample vial. These features were presumably intended to detect tampering with the vial prior to use, though this is not certain. 2 of the adhesive labels on the collection vials were marked

"sterile" so that the intent might rather have been just to guarantee sterility for the vials prior to collecting a urine sample.

16 of the products made no effort to detect tampering prior to collecting a urine sample. This is unfortunate for reasons discussed above.

All 23 products included some kind of attempt at tamper detection after urine sample collection. 2 had irreversible mechanical designs built into the sample vial. Once the lid was shut on the vial, these would (theoretically) become damaged should the lid be reopened. All 23 products included a supposedly tamper-indicating adhesive label seal that was to be placed over the sample vial lid once a urine sample was collected. One of the products included a tamper-indicating plastic bag used for shipping the urine sample vial.

In this paper, we avoid identifying the products, vendors, and manufacturers by name. (Persons, organizations, and companies with a legitimate need to know can, however, contact us for more details.) There are two reasons for doing this. Firstly, we do not want to make it even easier to tamper with urine samples by publicly discussing vulnerabilities, or providing information on which products may be most at risk. Secondly, we believe that the lack of effective security identified in this work for urine testing products is endemic to the industry. In our experience, singling out products, manufacturers, and vendors for criticism does not usually result in the security vulnerabilities getting fixed. Security improvements in commercial products usually come when customers demand better security from the industry as a whole, not when specific products are criticized.

METHODS

The only tools used to attack the 23 urine sampling products were the following: bare hands, gloves, pocket knife, parts of a ball point pen, syringe, syringe needle, small screwdriver, and a solvent readily available to consumers at most large grocery and hardware stores. These tools and the attack methods we used are readily available to almost anyone at modest cost. High-tech attacks also appear possible, but unnecessary and were not investigated in this study.

In all cases, the tamper-indicating seal or tamper-evident packaging was put back in a manner that showed either no evidence at all, or else subtle evidence unlikely to be spotted unless the medical personnel, drug testing officers, or lab technicians processing the urine samples knew what to look for, and spent significant time looking for specific attacks.

RESULTS

All of the tamper detection features on the 23 urine testing products we studied could be quickly and easily defeated. Attack times ranged from 3 seconds to 3 minutes, depending on the seal. With practice, these times could be considerably shortened. For some of the products, we demonstrated up to 7 completely different defeats. [In the context of a tamper-indicating seal, "defeating" means to remove the seal, then replace it with either the original seal, a duplicate, or a counterfeit, but without being detected (Johnston, 2006). An "attack" is an attempt at a defeat; a successful attack equals a defeat. Note that seal is not a lock; yanking a seal off a container does not defeat the seal because the fact that the seal is missing or damaged will be noted at the time of inspection (Johnston, 2006).]

None of the tamper-indicating adhesive label seals provided by the vendors or manufacturers—either for pre-collection or post-collection security—represented any significant challenge to defeat. These seals were meant to be applied to the lid and side of the collection vial. Adhesive label seals are not usually very effective for tamper detection in any security context (Johnston, 1997), but using them on urine collection vials typically made of slippery polyethylene or polypropylene plastic (as was the case for the products studied here) seems unwise. In fact, the labels for half a dozen of the products detached from the vial on their own within a few minutes to a few hours of being applied. (More would probably have done so if the temperature and/or humidity were allowed to oscillate.) When the labels didn't detach on their own, it was easy to carefully lift the label without damage, then reattach after tampering with the vial, leaving no visible evidence, and probably no evidence at all. The use of a solvent decreased the time and skill required for an attack. All adhesives used by the labels were soluble. After the solvent evaporated away 10-60 seconds later, the adhesive on each label seal could be reused to "reseal" the sample vial.

6 of the "tamper-indicating" adhesive label seals provided with the urine collection vials had no serial numbers printed on them. For these, an adversary would need merely to obtain some identical, unused seals, perhaps by ordering them from the Internet (no questions asked). He could then remove the original seal, and replace it with an identical copy after tampering with the sample vial. Even when the adhesive label seal has a serial number, most vendors and manufacturers allow the customer to specify the serial number range he wants printed on the seals. This makes replacing the original adhesive seal with another having the same serial number especially easy. Almost anyone moderately skilled in art or graphics arts, however, would have no difficult modifying the apparent serial number on any adhesive label seal, or forging a new number.

The 2 sample vials that had built-in irreversible mechanical assemblies could be easily opened, then reclosed in 3 seconds without leaving any evidence. This was done by manually manipulating the mechanisms with parts from a common ball point pen.

The pre-collection and post-collection tamper-indicating bags used to hold the sample vial could also be quickly defeated. In one case, the (presumably) tamper-indicating bag containing the unused sample vial had holes in the bag to prevent over-pressurization. We were able to lift the portion of adhesive label attached to the vial's lid by poking a syringe needle through the hole. See figure 2. No solvent was needed. We then unscrewed the vial lid from outside the bag to gain access. Placing a very small, nearly invisible drop of liquid in the vial (though a syringe needle passing through the bag's hole) would then have compromised the drug test. The adhesive label was then reattached to the sample vial lid after the lid had been screwed back on. Given that the plastic bag had no serial number or art work, it would have been only slightly more work to open the bag, attack the vial, and then heat-seal the vial inside another, identical looking plastic bag.

The plastic (post-sample) shipping bags provided with some sample vials were equally easy to defeat. In one case, 1 cm gaps were automatically left in the top edges of the bag after it was sealed (even following the vendor's directions), allowing easy access with a syringe needle to the sample vial. See figure 3. Either an attack of the sort described in the above paragraph could be done, or else foreign liquid could be inserted into the vial with a syringe needle through the ejector pin mark. See figure 4.

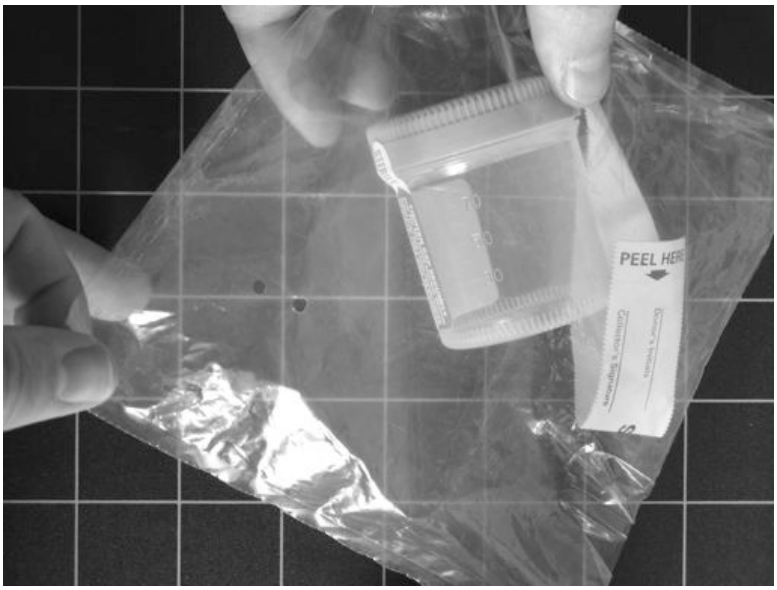

Figure 2 - This sample collection vial has an adhesive label seal on the lid prior to use, as well as an adhesive label seal (shown to the right of vial, inside the bag) for applying to the vial after a urine sample is taken. The pre-sample seal and the lid can be removed from outside the bag, then replaced without any evidence. Two holes in the plastic bag are shown. These can be exploited to insert a microscopic contaminant into the open vial.

Figure 3 - A tamper-indicating shipping bag for a urine sample collection vial. When assembled according to the manufacturer's instructions, a 1 cm wide slit is left on each side of the top fold. This allows easy access to the sample vial inside the bag. A syringe needle protective cap is shown entering through the left slit.

An injector pin mark (or "knockout mark") typically appears in plastic products made by the plastic extrusion process. This defect in the plastic can be easily exploited by an adversary for hiding a very small hole made by a syringe needle. If the hole is small enough, no liquid leaks out from the vial. Other defects that commonly occur in extruded plastics can also be exploited to hide a small syringe needle hole, including such defects as splay marks, bubbles, blisters, "fisheyes", and shock marks (Polydynamics, 2008). A small hole in the vial can also be easily repaired or plugged.

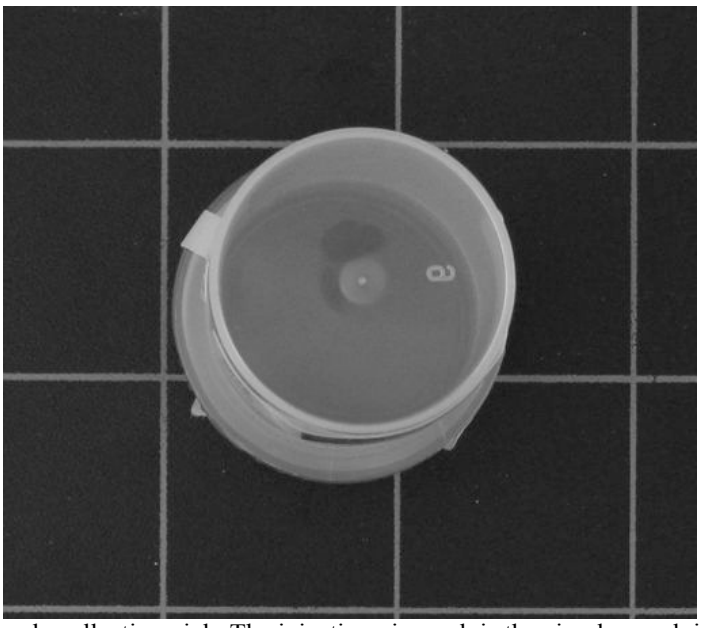

Figure 4 - The bottom of a sample collection vial. The injection pin mark is the circular mark in the center, surrounded by a larger concentric circle of translucent plastic. Using this ubiquitous defect, it is easy to hide a very small syringe needle hole.

Some of the sample vials have other, non-tamper-indicating adhesive labels on them to show the brand name, to serve as a label to write information about the sample on, or to serve as a liquid crystal thermometer strip for checking that the urine sample is at body temperature (and thus not some other liquid). All of these labels are very effective in hiding a small hole made by a syringe needle. The labels need only be peeled back slightly, the foreign liquid injected into the sample vial through a syringe needle, and then the label pressed back in place.

PROBLEMS WITH THIS STUDY

While this appears to be the first study of the efficacy of the tamper-indicating features found on urine testing products, it is a very limited, rudimentary analysis. We did not have substantial time or funding to study urine testing products in detail, nor did we look at all products that are commercially available. We also did not study any given drug testing security program in detail.

Our emphasis was on attacks that could not be detected visually. This is appropriate because—at most—only visual inspection of seals is typically employed (DOT, 2006; HHS, 2008; SAMHSA, 2008; WADA, 2009a; WADA, 2008; USADA, 2006; USADA, 2008). Other seal inspection techniques are possible (Johnston, 2006; Johnston, 1997), but these also would be unlikely to detect most of the attacks we demonstrated.

A serious limitation of this study is that we conducted no blind or double blind tests of our alleged defeats. The decision to declare an attack successful, i.e., a defeat, was based on our own judgment and many years of experience with studying vulnerabilities in tamper-indicating seals and tamper-evident packing. Based on our experience, we believe the attacks demonstrated in this study (even if not well practiced) would not be detected, in most cases, even if the people handling the sample vials were alerted to the possibility of an attack—something adversaries don't usually do. Nevertheless, a more

comprehensive study would include double blind or at least blind tests of whether the tampering is indeed undetectable.

Despite these limitations in the study, we believe our results clearly indicate that tamper detection for urine drug testing products is remarkably poor.

OTHER SECURITY ISSUES

There are no meaningful security standards for how to deal with urine samples for drug testing. Federal standards and guidance, such as those of DOT and HHS, provide little useful guidance on sample security or how to choose or use the tamper-indicating features of urine collection vials (DOT, 2006; HHS, 2008). HHS does admit that adhesive label seals don't stick very well to urine sample vials, but can only offer the suggestion to stick another seal perpendicularly over the first seal when this happens (HHS, 2008). HHS and SAMHSA require the urine sample to be sealed with a "tamper-resistant device" (HHS, 2008; SAMHSA, 2008), potentially indicating some confusion about what a seal is. A seal indicates tampering, but does not resist it or prevent it (Johnston, 2006), except perhaps in some vague psychological sense.

Both the U.S. Anti-Doping Agency (USADA) and the World Anti-Doping Agency (WADA) deal with testing national- and international-level athletes for illegal drug use. Their various handbooks, standards, and guidance for drug testing (WADA, 2009b; WADA, 2008; WADA, 2009a; USADA, 2006; USADA, 2008) do not exhibit much sophistication or useful suggestions about security issues, tamper detection in particular. They tend to focus mostly on issues of false negatives, and then not very thoroughly. For example, the "International Standards for Laboratories" used by WADA provide no indication of how testing labs are to spot tampering with the urine sample vial beyond checking if the seal is missing or not attached (WADA, 2009a). There is no guidance on spotting surreptitious attacks. Moreover, the WADA Laboratory Standard (WADA, 2009a) refers to a seal as a "tamper proof evident method (sic)" and a "tamper-resistant device", again indicating potential confusion about tamper detection.

Chain of custody for most drug testing programs is defined as paperwork designed to document the history of the sample and who handled it, with no apparent thought or guidance given to *securing* the chain of custody, or even guaranteeing the authenticity of the paperwork. (See, for example, SAMHSA, 2008; WADA, 2008.)

Both the USAD and WADA explain a complex urine sampling procedure (WADA, 2009b; USADA, 2006; USADA, 2008) that appears rife with potential security problems. Given the complexity, and the large number of personnel potentially involved—the Athlete, Athlete's Representative, Chaperone, Doping Control Officer, shipping personnel, laboratory technicians, and other individuals involved in the process—the potential for distraction, misdirection, "palming", and sleight-of-hand with a sample vial or seal seems significant. Both agencies make it clear it is up to the Athlete or his Representative to check the unused vial for tampering and foreign substances prior to urine sample collection, and to seal the vial after a sample is collected. Lacking instruction in tamper detection or seal use, being limited only to naked eye inspection when the adulterant may be extremely tiny, and having to deal with the intimidating stress of the situation, it is unlikely the Athlete or his Representative (typically a coach or agent) is in a position to do a good job with any of these security tasks.

None of the Federal or Anti-Doping Standards and Guidelines call for tamper detection training for drug testing personnel (or the subjects to be tested), even though training is known to be a critical factor for effective tamper detection (Johnston, 1997). They also do not call for vulnerability assessments,

reviews of security procedures by security experts, rigorous chain of custody procedures, nor do they offer suggestions for how to choose and evaluate urine sampling products or their tamper-indicating features. There is no significant discussion of the transport security for the samples. For many companies and organizations doing workplace testing, the urine samples are simply stuck in the mail, or sent via overnight carrier, with variable levels of security, and little more than the poor quality tamper detection provided by the urine collection products themselves.

Typically, the sample storage lock box (if there is one) used for temporary storage of urine drug testing samples on site also has disturbingly poor security. This box often has an easy-to-pick 3-pin lock. Moreover, in our experience, the box is rarely bolted down securely or stored in a well-controlled area, making it easy to enter from the bottom or sides to swap urine samples, or to replace the entire box with an identical one (readily available commercially) containing phony or adulterated urine samples.

We believe another security vulnerability with urine drug testing can potentially be easily exploited by a moderately sophisticated adversary. While we did not demonstrate it in this study, we believe it is possible to use a nebulizer to create a fine aerosol of drug metabolites. If this was generated a few rooms over from where the urine sample is collected or from the test laboratory, or if the aerosol was sent through the building's ventilation system, a false positive result could be made to occur. Unlike doping the victim's food or handing the victim contaminated food, this could be done remotely. This kind of attack would probably not be as feasible for drug metabolites that are large molecules, and for which the positive test thresholds are relatively high.

CONCLUSIONS

We found the tamper detection features of the 23 commercial products we studied to be remarkably poor by the standards of any tamper detection application. Indeed, we believe the liquor carts and the single-serve liquor bottles used by U.S. airlines to serve air passengers have both better security and better tamper detection features—yet drug testing is surely a more critical matter.

The use of adhesive label seals on (slippery) polyethylene or polypropylene vials and lids is a particularly poor choice for tamper detection. Glass would be a better choice of material for the vials for both reasons of better adhesion and because of the increased difficulty of penetrating the vial with a syringe needle.

The official national and international security standards for drug testing, as well as common practice, also appear severely lacking in effective security, or even careful thinking about security. Better tamper detection, security protocols, guidance, and standards are possible and, in our view, necessary given the importance of drug testing to both the individual and society.

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