



Persistence of Touch DNA on Handled Fabrics Under Varying Humidity and Storage Conditions: A Review of the Evidence

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Article Info

Volume 1, Issue 1, 2026

doi: [10.62715/ijfs.2026.v1.i1.pp1-7](https://doi.org/10.62715/ijfs.2026.v1.i1.pp1-7)

Received: 27 September 2025

Accepted: 16 November 2025

Published: 18 January 2026

Abstract

Clothing, bedding and other textiles are among the items most often submitted to forensic laboratories for the recovery of DNA left by handling. Whether a profile is obtained depends on how much material was deposited and also on how much of it survives the interval between the contact and the laboratory bench. This narrative review brings together the published literature on the persistence of touch DNA on fabrics, with particular attention to humidity and to the conditions under which exhibits are packaged and stored. It first summarises what is known about the composition of a touch deposit and about the chemistry of DNA decay, then considers the properties of textile substrates, the effects of moisture, temperature, light and microbial growth, and the losses caused by packaging and transport. The literature agrees on direction more than on magnitude: dry, cool, dark storage in breathable packaging favours retention, damp storage favours loss, and results differ widely between donors, fabrics and laboratory methods. The review closes by considering what these findings mean for exhibit handling, for the evaluation of findings given activity level propositions, and for the design of future persistence studies.

Keywords: Touch DNA, Trace DNA, DNA persistence, Textile evidence, Exhibit storage, Activity level evaluation

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1. Introduction

The observation that a person can leave a typable quantity of DNA on an object simply by holding it was reported by van Oorschot and Jones (1997) and changed the range of exhibits that a forensic biology unit is asked to examine. Garments grabbed during a struggle, ligatures, gloves, bedding and bags are now routinely sampled in the hope of recovering DNA from the person who handled them. The deposits concerned are small. They sit at the lower limit of what short tandem repeat typing can resolve, where stochastic effects such as allele drop-out and heterozygote imbalance complicate interpretation (Gill et al., 2000).

Because the starting quantity is so low, any loss between deposition and analysis matters. A bloodstain

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that loses half of its DNA will usually still give a full profile; a touch deposit that loses half may give nothing usable. Fabrics add a further difficulty. They are porous, absorbent, flexible and frequently damp when seized, and they are folded, bagged, transported and stored, sometimes for years, before a cold case review reaches them. Trace DNA has been described as behaving like other trace evidence, with transfer, persistence and recovery each open to study (Wickenheiser, 2002; Raymond et al., 2009).

This article reviews what the published literature says about the second of those three terms, persistence, for touch DNA on handled fabrics, and about how humidity and storage conditions alter it. It reports no new experiments. Its purpose is to set out the points on which the literature is consistent, the points on which it is thin, and the practical consequences for those who collect, store and interpret textile exhibits.

2. Scope and Approach

The article is a narrative review of the published literature. It draws on the main review papers on trace DNA and DNA transfer (van Oorschot et al., 2010; Meakin and Jamieson, 2013; van Oorschot et al., 2019), on experimental papers that those reviews identify as informative about textiles, and on the general literature on DNA degradation. No claim of exhaustive coverage is made. Studies were read for what they show about three questions: what a touch deposit on fabric consists of, which environmental and storage variables change the amount of DNA recoverable over time, and how confidently the reported effects can be carried over to casework.

The term touch DNA is used here in its ordinary laboratory sense of DNA recovered from a surface that has been handled, with no identifiable body fluid present. The term says nothing about how the DNA arrived. Material recovered from a garment may come from the wearer, from a person who gripped it, or from someone whose DNA was carried there on another hand or object.

3. What a Touch Deposit on Fabric Contains

Early accounts assumed that handled items carry shed skin cells. The outer layer of the epidermis, however, is made up of cornified cells that have lost their nuclei, and later work has shown that the picture is more mixed. Quinones and Daniel (2012) found that a share of the DNA recovered from touched surfaces is cell-free, carried in sweat and other secretions, and the review by Burrill et al. (2019) describes a deposit made up of corneocytes with residual DNA, nucleated cells transferred to the hands from the face, mouth or eyes, and extracellular fragments. The proportions vary from person to person and from one contact to the next.

This matters for persistence because the fractions are not equally protected. DNA inside an intact cell is shielded from the surroundings to some extent, whereas free DNA in a film of sweat is exposed to water, to nucleases and to microorganisms from the moment it is laid down. On a fabric the liquid part of the deposit is drawn into the yarn by capillary action while cellular debris tends to stay nearer the surface. The two fractions may therefore be lost by different routes: the surface fraction by rubbing and shedding, the absorbed fraction by chemical and biological breakdown.

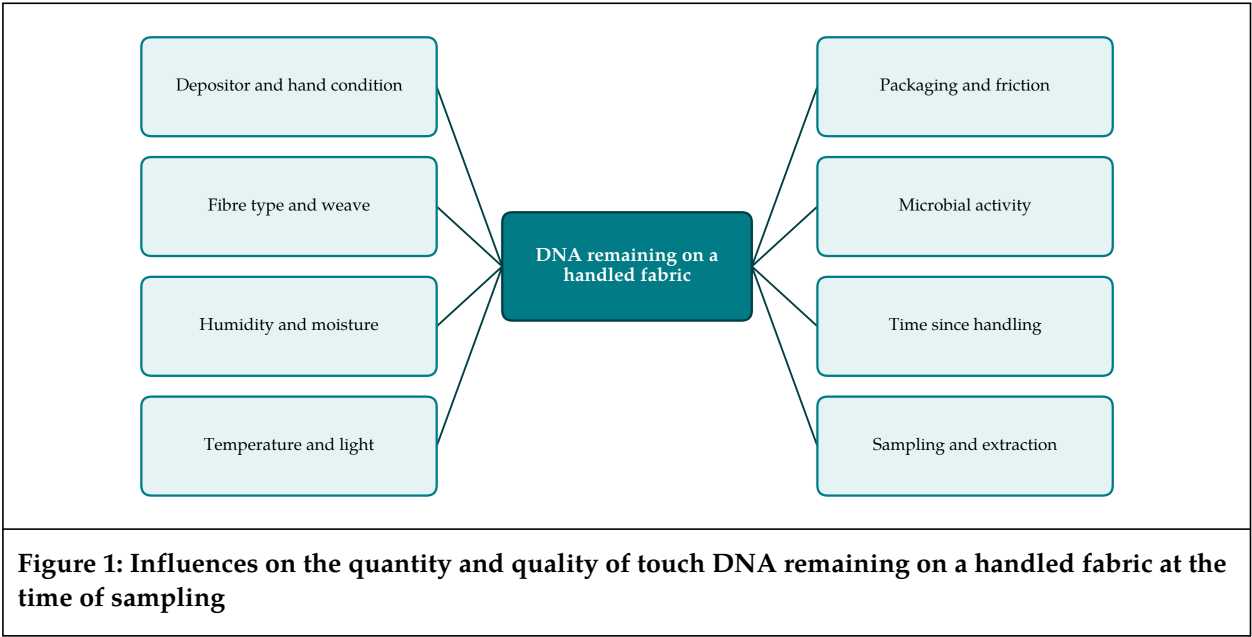
The amount deposited at the outset is itself highly variable. Individuals differ in their tendency to leave DNA, and the same individual differs with the time since hand washing and with recent activity (Lowe et al., 2002; Phipps and Petricevic, 2007). Comparative work on glass, fabric and wood found that the substrate influenced how much was transferred from the hand (Daly et al., 2012). Any study of persistence has to be read against this background of uncontrolled starting quantity, which is the main reason why results from different laboratories are so hard to compare.

4. How DNA Is Lost From a Textile

Loss takes two forms that are worth keeping apart. In the first, the DNA is physically removed from the fabric: rubbed off against packaging or an adjacent item, shaken out with loose fibres, or washed out. In the second, the DNA remains in place but is broken into fragments too short to be amplified. The chemistry of the second process was set out by Lindahl (1993). In the presence of water the molecule

undergoes hydrolytic loss of bases, followed by strand breakage at the damaged sites, and oxidative attack adds further lesions. Enzymes released by the donor's own cells and by bacteria and fungi cut the strands far faster than spontaneous chemistry does. A forensic review of degraded DNA describes the practical result: longer loci fail first, giving the sloping profile familiar to reporting scientists ([Alaeddini et al., 2010](#)).

Figure 1 groups the influences on what remains on a handled fabric at the time of sampling. Some act on the initial deposit, some on physical retention, some on molecular integrity, and the last belongs to the laboratory. The sections that follow take them in turn, and Table 1 summarises the direction of each effect as the literature reports it.



5. Fibre and Fabric Properties

Textiles differ in fibre chemistry, yarn structure, weave and finish, and each of these affects how a deposit is taken up and how easily it is given back. Cellulosic fibres such as cotton are hydrophilic and absorb the aqueous part of a deposit into the fibre and the spaces between fibres. Synthetic fibres such as polyester and nylon absorb little water, so material stays on or between the filaments. Experimental work on transfer has repeatedly found that porous, absorbent substrates take up biological material readily and release it poorly, while smooth non-porous ones do the reverse ([Goray et al., 2010a](#); [Goray et al., 2010b](#)).

For persistence the consequence is double-edged. Material drawn into a cotton yarn is less likely to be rubbed off in a bag, which favours retention, but it is also harder to recover by swabbing or tape lifting, so that a low yield may reflect poor recovery and not true loss. Studies of tape lifting from fabrics show that efficiency depends on the fabric and on the type of tape ([Verdon et al., 2014](#)). A report that DNA "persisted" on one fabric and not on another may therefore be describing the sampling method as much as the substrate. Rough or loosely woven fabrics that shed fibres can lose surface material with the fibres themselves, and dyes and finishes on some textiles are known sources of inhibition at the amplification stage.

6. Humidity and Moisture

Water is the common factor in every route of molecular degradation. Hydrolysis requires it, nucleases are active only in solution, and bacteria and moulds grow only above a certain moisture level. The general rule taught in every laboratory, that biological exhibits must be dried before packaging and kept dry afterwards, follows directly ([Butler, 2012](#)). For touch deposits on fabric the rule applies with more force than for body fluid stains, because there is so little template to lose and because much of it may be

extracellular.

Relative humidity of the surrounding air and the moisture content of the fabric are related but not the same. A hygroscopic fabric such as cotton or wool comes to equilibrium with humid air by taking up water, and that water is then available within the yarn where the absorbed fraction of the deposit sits. A polyester garment in the same air holds far less. A garment seized wet with rain, sweat or other liquids and sealed in plastic is in the worst position: liquid water is present, air exchange is nil, and mould can become visible within days. In outdoor and indoor exposure experiments on trace DNA, recoverable quantities fell faster on exposed outdoor items than on protected ones ([Raymond et al., 2009](#)), a result usually attributed to the combination of moisture, sunlight and temperature cycling.

Table 1: Influences on the persistence of touch DNA on fabrics and the direction of effect reported in the literature

Influence	Reported direction of effect	Main route of loss	Representative sources
Initial deposit	Varies widely between donors and between contacts by one donor	None; sets the starting quantity	Lowe et al., 2002 ; Phipps and Petricevic, 2007
Fibre and weave	Absorbent fabrics hold material but release less on sampling	Friction; poor recovery	Daly et al., 2012 ; Verdon et al., 2014
Moisture	Damp storage lowers quantity and profile quality	Hydrolysis, nucleases, microbes	Lindahl, 1993 ; Butler, 2012
Heat and sunlight	Warm or sunlit exposure speeds degradation	Chemical and photochemical damage	Raymond et al., 2009 ; Alaeddini et al., 2010
Packaging and handling	Contact with packaging removes and redistributes material	Physical transfer	Goray et al., 2010b ; van Oorschot et al., 2019
Time	Recovery falls with time; rate depends on the other influences	All of the above	Meakin and Jamieson, 2013

7. Temperature, Light and Microbial Growth

Temperature governs the rate of the chemical reactions described above and the growth of microorganisms. Low temperature slows both, which is why long-term storage of extracts and of some exhibits is done under refrigeration or freezing. For bulky textile exhibits freezing is often impractical, and room-temperature storage of thoroughly dried items in a climate-controlled store is the usual compromise. The literature supports the view that dryness matters more than cold: a dry item at room temperature is generally in a better state than a damp one in a refrigerator, where condensation can form on packaging each time the item is removed.

Ultraviolet light damages DNA directly by forming lesions between adjacent pyrimidine bases, and sunlight adds heat. Items left outdoors, on a vehicle seat behind glass or on a window ledge are exposed to both. Microbial growth is the remaining factor and the one most closely tied to humidity. Skin carries its own bacterial population, which is deposited with the donor's DNA, and textiles in use carry more. Given moisture, these organisms multiply and digest the available organic material, including DNA. The deposit and the means of its destruction therefore arrive on the fabric together.

8. Packaging, Transport and Storage

Advice on packaging has long favoured paper over plastic for biological exhibits, because paper lets residual moisture escape. For touch DNA a second consideration arises: the inner surface of any package is a surface to which DNA can transfer. The transfer literature shows that material moves from an exhibit to whatever it rubs against, and from one part of an exhibit to another when a garment is folded on itself ([Goray et al., 2010b](#); [van Oorschot et al., 2019](#)). The deposit of interest may thus be reduced at the place where it was laid down and reappear, diluted, somewhere else. This is persistence and transfer acting

together, and it bears on any argument that relies on where on a garment the DNA was found.

Repeated examination adds to the effect. Each time an item is unpacked, unfolded on a bench, viewed, photographed and repacked, surface material is disturbed. Cold case exhibits may have passed through several such cycles, some of them at a time when touch DNA was not contemplated and precautions against contamination were lighter. The reviews agree that the handling history of an exhibit should be recorded and considered when a result is interpreted (Meakin and Jamieson, 2013; van Oorschot *et al.*, 2010). Methods that show where cellular material lies on a surface before sampling, such as staining with a DNA-binding dye (Kanokwongnuwut *et al.*, 2018), may help to target what remains, although their performance on dark or patterned fabrics is limited.

9. Limits of the Evidence Base

Several features of the literature restrict how far its findings can be generalised. Gosch and Courts (2019) reviewed research on DNA transfer and concluded that studies are heterogeneous in design, often small, and reported in ways that prevent comparison. The same is true of persistence work on textiles. Donors are few, and the starting deposit is seldom quantified independently. Fabrics are described loosely, as "cotton" or "polyester", without weave, weight or finish. Humidity is frequently uncontrolled and reported only as ambient. Extraction, quantification and typing chemistries differ and have grown more sensitive over the years, so that an older finding that nothing was detected after a given period cannot be assumed to hold for a modern kit.

There is also an asymmetry in what is studied. Short intervals under benign indoor conditions are well represented, because they are easy to arrange. Long storage in realistic exhibit stores, with seasonal swings in humidity and repeated handling, is poorly represented, although that is the situation of most cold case material. Studies of persistence on worn clothing face the added problem that the wearer's DNA is replenished continuously and usually dominates, so that the persistence of a minor contributor's DNA is the quantity of forensic interest and the hardest to measure.

10. Implications for Casework and Evaluation

For exhibit handling the literature supports familiar advice with a few refinements. Textiles should be dried in a clean, protected space before packaging, packaged singly in breathable material, and stored dry, cool and dark. Areas likely to bear handler DNA should be protected from contact with the packaging where that is feasible, or sampled early. The record should state whether the item was wet when seized, how it was dried, and how often it has since been examined.

For interpretation the consequences are larger. Courts increasingly ask how and when DNA came to be on an item, and no longer only whose it is. That is a question at the activity level in the hierarchy of propositions described by Cook *et al.* (1998), and answering it requires probabilities for transfer, persistence and recovery under each side's account of events (Taylor *et al.*, 2018). The International Society for Forensic Genetics has issued guidance on such evaluations and stresses that the probabilities must rest on data relevant to the circumstances of the case (Gill *et al.*, 2020). Where an item has been stored damp, or for many years, or has been repeatedly handled, published persistence data from short, dry, controlled experiments may not be relevant, and the scientist should say so. The absence of a profile from such an item is weak support for the absence of contact.

Future studies would be most useful if they reported humidity and fabric moisture explicitly, described the textile in standard terms, quantified deposits at the outset on matched samples, distinguished loss by removal from loss by degradation, and followed items through realistic packaging and storage. Shared protocols of the kind that Gosch and Courts (2019) call for would allow results from different laboratories to be combined into the probability tables that activity level evaluation needs.

11. Conclusion

The literature on touch DNA is consistent about what harms a deposit on fabric and much less definite about how quickly the harm is done. Moisture is the dominant variable, acting through hydrolysis,

enzyme activity and microbial growth, and its effect depends on the fibre, on the packaging and on time. Physical loss to packaging and through repeated handling is a separate process that moves DNA as well as removing it. Both should be recorded in the history of an exhibit and weighed when a result, or the lack of one, is given evidential meaning. Better controlled and better reported studies on textiles, under storage conditions that resemble those of real exhibits, remain the clearest need.

Conflict of interest

To be declared by the author(s) before publication.

Funding

To be declared by the author(s) before publication.

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