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# Toxicity of traditional and soluble film automatic dishwashing tablets

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## Abstract

**Introduction:** Detergents used in automatic dishwashing machines are of two main types: traditional tablets that require removal from an external wrapper and newer soluble film tablets.

**Objective:** To determine the toxicity of automatic dishwashing tablets.

**Methods:** Telephone enquiries to the UK National Poisons Information Service were analysed for the period January 2008 to June 2019.

**Results:** *Ingestion*: Ingestion was involved in 798 traditional tablet exposures and 725 soluble film exposures. Clinical features (Poisoning Severity Score $\geq$ 1) developed in 22.2% of patients ingesting traditional tablets and in 28.8% ingesting soluble film tablets; moderate or severe toxicity was rare (<0.5% for both traditional and soluble film tablets). Children ($\leq$5 years) significantly ($p < 0.0001$) more often developed features following ingestion of soluble film ($n = 193$, 28.2%) than traditional tablets ($n = 134$, 19.1%). In contrast, adults more often developed features following ingestion of traditional than soluble film tablets, although this difference was not statistically significant. *Eye exposure*: The eye was involved in only 26 of 1539 exposures; 17 of 26 exposures resulted in ocular features. The most commonly reported features were conjunctivitis, eye pain and blurred vision, although one patient sustained a corneal abrasion and developed loss of vision. *Skin exposure*: Thirty-four of 1539 exposures involved the skin but only 3 developed dermal features which were minor.

**Conclusions:** Children ($\leq$5 years) significantly more often developed features following ingestion of soluble film than traditional tablets, although the likelihood of a child developing features was relatively low (<30%) and features that did develop were almost always mild. In contrast, adults more often developed features following the ingestion of traditional than soluble film tablets. Overall, the eye was involved in only 1.7% of exposures and only one patient sustained a corneal abrasion.

## Keywords

Automatic dishwashing tablet, dishwashing tablet, household product, soluble film tablet, traditional tablet

## Introduction

A recent survey has indicated that half of UK households have an automatic dishwashing machine.[1] Proprietary detergents used in these machines are of two main types: traditional tablets which consist of a compressed powder contained within an external wrapper that requires removal prior to loading the tablet into the machine and soluble film tablets which are enclosed by a dissolvable polyvinyl alcohol film (Figure 1).

Soluble film tablets can be placed directly into the dispenser of a dishwashing machine which could

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**Figure 1.** Examples of traditional (top) and soluble film (bottom) automatic dishwashing tablets.

improve safety as direct contact with the chemical constituents is avoided. However, the integrity of the soluble film can be compromised and the contents of the tablet can be released prematurely when in contact with moist hands or saliva. Pressure alone is very unlikely to lead to a tablet bursting, although pressure applied to the liquid part(s) of an automatic dishwashing tablet will deform the compartment to accommodate the pressure.

The major constituents of both traditional and soluble film tablets are a source of hydrogen peroxide ($\leq$20%) and non-ionic surfactants ($\leq$5%) and both types of tablet are alkaline (pH 9–11) in solution. Other constituents in some formulations include sodium carbonate $\leq$30%, sodium tripolyphosphate $\leq$50% and sodium silicate $\leq$10%, which reduce water hardness.[2]

The traditional (wrapper covered) type of tablet consists of a compressed powder, which is relatively hard to break when bitten. Some soluble film tablets also contain powder (which is less compacted than traditional tablets), although others contain liquid and/or gel components that are packaged into separate compartments of the soluble film casing. The liquids and gels used in this product type tend to be viscous, which may lead to a greater contact time, for example, if eye or skin is exposed. Furthermore, the presence of fluid components can potentially increase the chance of exposure when these products are squeezed, for example, by a child, and the liquid can spray unpredictably.

We have reported previously on the toxicity of automatic dishwashing tablets and have shown that the ingestion of both traditional and soluble film tablets only rarely produced clinically significant symptoms (Poisoning Severity Score (PSS) $\geq$ 2).[2,3] This is surprising given the ingredients, though could be explained by the fact that the majority of exposures occurred in children, so the amount of material actually ingested was very small or that most was spat out. Our previous studies unexpectedly also suggested that the ingestion of a soluble film automatic dishwashing tablets was more likely to result in clinically significant features. As no other studies have been published, we have extended the period of analysis by 3 years and 6 months to increase patient numbers and to ascertain whether the earlier preliminary observations remain accurate.

## Objective

To determine the toxicity of automatic dishwashing tablets and to ascertain if exposure to a soluble film automatic dishwashing tablet is more likely to result in features than exposure to a traditional dishwashing tablet.

## Methods

The UK National Poisons Information Service (NPIS; www.npis.org) provides information and evidence-based management advice about individual substances through its online database TOXBASE® and its 24-h telephone advice service, staffed by information scientists and supported by consultant clinical toxicologists. The service takes telephone enquiries regarding poisoning incidents from National Health Service healthcare professionals.

Enquiries involving automatic dishwashing tablets were analysed for the period 1 January 2008 to 30 June 2019. The United Kingdom Poisons Information Database central database was searched for enquiries involving all types of automatic dishwashing products and each exposure to a tablet was categorised as being of the traditional or soluble film type. Data (both from the text narrative as well as discrete data fields) extracted from the enquiries included age of patient, route(s) of exposure, source of enquiry, location where exposure occurred, circumstances of exposure, product information, and features and PSS.[4]

The data relating to the traditional and soluble film type of tablets were analysed and their toxicity was compared. Comparisons were also made between paediatric ($\leq$5 years) and adult exposures. A two-sample $\chi^2$ test was performed using GraphPad Prism Version 7.04 to determine whether there were significant differences between exposures to traditional and soluble film tablets and between children and adults. Enquiries received from outside the UK were excluded from this study.

This study did not require approval by a UK Research Ethics Committee as the UK Health Research Authority has declared that ethical approval is not needed for research studies that use information collected routinely in any UK administration (England, Wales, Scotland, Northern Ireland) as part of usual clinical care, provided this information is passed to the researchers in a fully anonymised format.

## Results

Traditional automatic dishwashing tablets accounted for 804 exposures and soluble film tablets for 744 exposures. There were also 356 exposures to automatic dishwashing tablets of an unknown type; these were not included in the comparison. Overall, paediatric (<18 years) exposures accounted for 95.2% of soluble film and 88.8% of reported traditional automatic dishwashing tablet exposures.

### *Ingestion*

Ingestion (which included either swallowing of some or all of a tablet or buccal contact with a tablet) was involved in 798 traditional tablet exposures and 725 soluble film exposures. A significantly ($p < 0.0001$) greater proportion of young children ($\leq$5 years) ingested soluble film tablets ($n = 684$, 94.3%) than traditional tablets ($n = 700$, 87.7%). Significantly ($p < 0.0001$) more adults ($\geq$18 years) ingested traditional tablets ($n = 82$, 10.3%) than soluble film tablets ($n = 25$, 3.4%); a considerable proportion of those ingesting traditional tablets were aged $\geq$60 years ($n = 45$), were suffering from dementia ($n = 18$), and lived in a nursing/care home ($n = 15$).

The majority of patients remained well (PSS 0) following the ingestion of a traditional (77.8%) or soluble film (71.2%) dishwashing tablet (Table 1). Overall, 22.2% of patients ingesting traditional tablets and 28.8% of patients ingesting soluble film tablets developed features (PSS $\geq$ 1, $p = 0.003$). Most reported features were minor in nature (PSS 1) although there were six patients in total (three for each tablet type) that developed moderate features (PSS 2). In four of these six moderate cases, patients had prolonged or multiple vomiting episodes, one patient foamed at the mouth subsequent to vomiting and another developed stridor following a single vomiting episode. There were no severe features reported following ingestion for either tablet type.

Vomiting was the most commonly reported feature in young children ($\leq$5 years) following the ingestion of a traditional tablet ($n = 104$, 14.9%) or a soluble film tablet ($n = 156$, 22.8%; Table 2).

Similarly, the most frequently reported feature among adults ($\geq$18 years) who ingested a traditional tablet was vomiting ($n = 19$, 23.2%). Mouth irritation ($n = 3$, 13.6%), vomiting ($n = 2$) and dyspepsia ($n = 2$) were most commonly reported following soluble film tablet ingestion, although only in a small number of patients.

Children ($\leq$5 years) significantly ($p < 0.0001$) more often developed features (PSS $\geq$ 1) following ingestion of soluble film tablets ($n = 193$, 28.2%) than

**Table 1.** PSS[4] following exposure to traditional tablets or soluble film automatic dishwashing tablets.

| | Traditional tablets[a] | | | | Soluble film tablets[a] | | | | PSS 0[b] |
|---|---|---|---|---|---|---|---|---|---|
| | PSS $n$ = (%) | | | | PSS $n$ = (%) | | | | $p$ |
| Exposure route | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | |
| Ingestion | 621 (77.8) | 174 (21.8) | 3 (0.4) | 0 | 516 (71.2) | 206 (28.4) | 3 (0.4) | 0 | 0.003 |
| Eye contact | 1 (20.0) | 4 (80.0) | 0 | 0 | 7 (35.0) | 12 (60.0) | 0 | 1 (5.0) | 0.520 |
| Dermal contact | 16 (84.2) | 3 (15.8) | 0 | 0 | 15 (100) | 0 | 0 | 0 | 0.107 |

PSS: Poisoning Severity Score.
[a]Excludes from the total, the five ingestion cases and one eye contact case (traditional tablet exposures) and six ingestion cases (soluble film tablet exposures) where PSS was not known.
[b]Traditional tablets versus soluble film tablets.

**Table 2.** Most commonly reported features in young children (≤5 years) following the ingestion of a traditional or soluble film automatic dishwashing tablet.

| | Traditional tablets | | Soluble film tablets[a] | | $p$[b] |
|---|---|---|---|---|---|
| Feature | $n$ | % | $n$ | % | |
| Vomiting | 104 | 14.9 | 156 | 22.8 | <0.0001 |
| Nausea | 7 | 1.0 | 5 | 0.7 | 0.595 |
| Coughing | 6 | 0.9 | 11 | 1.6 | 0.201 |
| Mouth irritation | 2 | 0.3 | 6 | 0.9 | 0.145 |

[a]Excludes from the total, the three ingestion cases (soluble film tablet exposures) where features were not known.
[b]Traditional versus soluble film tablets.

traditional tablets ($n$ = 134, 19.1%). In contrast, adults more often developed features (PSS ≥ 1) following the ingestion of traditional tablets ($n$ = 39, 47.6%) than soluble film tablets ($n$ = 8, 36.4%), although this difference was not statistically significant.

In children (≤5 years), vomiting occurred more frequently following soluble film tablet ingestion ($n$ = 156, 22.8% vs. $n$ = 104, 14.9%; $p < 0.0001$). Conversely, among adults vomiting was reported more frequently following the ingestion of a traditional tablet ($n$ = 19, 23.2%) than a soluble film tablet ($n$ = 2, 9.1%); however, this was not statistically significant. Furthermore, there were no statistically significant differences between any of the other features reported by children (≤5 years) or adults.

## *Eye exposure*

The eye was involved in only 26 of 1539 exposures: 20 involved soluble film tablets and 6 involved traditional tablets. Fifteen (57.7%) exposures involved adults ($n$ = 11 for soluble film tablets and $n$ = 4 for traditional tablets). The PSS and features were not known in 1 case leaving 25 for analysis; over two-thirds ($n$ = 17, 68%) of patients developed ocular features.

Patients were exposed most often ($n$ = 11, 42.3%) to the liquid portion of a soluble film tablet and most of these cases (9 of 11) developed ocular features. Exposure in this way occurred when the liquid component of the tablet squirted into the eye, either from squeezing the capsule or from prising apart two capsules that had adhered to each other. In seven (26.9%) cases, patients were exposed to the powder from a tablet: four were traditional tablets and three were soluble film tablets. In two cases, exposure occurred after unwrapping a tablet: in one, it is presumed that the patient rubbed their eyes with hands contaminated with dishwashing powder, while in the other, the powder had fallen into the eye of their child. In another case, the powder was released in the process of prising apart two capsules that had adhered to each other, but in the four other cases, the circumstances were not known. Overall, three patients exposed to the powder from a tablet developed features. In another case, a soluble film tablet had been dissolved in water and the water had been splashed into the eye, although the

patient remained well. The circumstances of exposure for the remaining seven cases were not known.

The most commonly reported feature in the 25 cases was conjunctivitis; 6 of the 7 reports followed exposure to a soluble film tablet and 4 involved children $\leq$5 years old. Eye pain was also reported in six cases, of which four followed soluble film tablet exposure. Blurred vision ($n = 2$) or eye irritation ($n = 1$) was occasionally reported. Given the small number of exposures, it is not surprising that there were no statistical differences in the frequency of reported features between the two tablet types.

All but 1 of the 17 symptomatic cases was graded as minor (PSS 1) toxicity. In the last case which involved exposure to the liquid portion of a soluble film tablet, an adult sustained a corneal abrasion and developed loss of vision; this case was graded severe (PSS 3).

### *Dermal exposure*

Thirty-four of 1539 exposures involved the skin: 19 were due to traditional tablets and 15 to soluble film tablets. All but one case involved children ($\leq$5 years). In 11 (32.4%) cases, exposure was to the powder component of a tablet, in 9 (26.5%) cases, there was exposure to tablet residue and in 2 (5.9%) cases, exposure to the liquid component of a tablet occurred. In the remaining 12 cases, the tablet constituent was not known. The areas most frequently exposed were the hands and/or fingers ($n = 14$) and face/mouth ($n = 13$), although no such information was available in eight cases.

Only 3 of 34 patients developed dermal features, all of which followed exposure to a traditional tablet. Two children developed a skin rash (one exposed to powder, the other unknown) and one adult exposed to tablet residue reported a tingling sensation at the contact site.

## Discussion

This study confirms that the ingestion of automatic dishwashing tablets, regardless of type, only rarely produces clinically significant (PSS $\geq$ 2) toxicity. This is surprising given that the major constituents of toxicological importance are sodium percarbonate (a source of hydrogen peroxide) and sodium carbonate.

Toxicity from hydrogen peroxide occurs as a result of its corrosive effects and release of oxygen causing embolism.[5] Ingestion of hydrogen peroxide may cause irritation of the gastrointestinal tract with nausea, vomiting, foaming at the mouth, multiple gastric ulcers and erosions in the duodenal bulb, haematemesis and gas embolism.[6–8] The foam may then obstruct the respiratory tract[9] or result in pulmonary aspiration. Ingestion of products with a concentration greater than 10% has been associated with a more severe outcome,[10] particularly in children.[7,8,11,12] Blistering of the mucosae and oropharyngeal burns are common following the ingestion of solutions of 30% or over, and laryngospasm[13] and haemorrhagic gastritis[14] have been reported. Sinus tachycardia, lethargy, confusion, coma, convulsions, stridor, subepiglottic narrowing, apnoea, cyanosis and cardiorespiratory arrest may ensue.[5] In fatal cases, this sequence may occur within minutes of ingestion. Immediate and permanent neurological impairment has been described following the ingestion of 35% hydrogen peroxide[15] and deaths have occurred in adults and children.[10,14–17]

The estimated maximal amount of hydrogen peroxide liberated from a typical traditional dishwashing tablet is approximately 1.3 g, assuming that all of the powder is swallowed, the powder completely dissolves and that full release of hydrogen occurs, which is unlikely to be the case. Hydrogen peroxide liberation from a soluble film automatic dishwashing tablet is likely to be similar, although in tablets containing gel or liquid surfactant compartments the amount may be lower as the amount of powder may be lower. Therefore, it is not likely that the more severe features reported after exposure to high strength hydrogen peroxide solutions would occur, unless several tablets were intentionally ingested. In our study nausea and vomiting, foaming at the mouth, oral irritation, stridor and dyspepsia could have been induced by hydrogen peroxide.

Sodium carbonate ingestion in humans has led to stridor, drooling, coughing and oedematous lips.[18] Experimental studies[19] have shown that following eye exposure, sodium carbonate causes conjunctivitis, corneal opacities and chronic superficial keratitis. Hence, coughing, stridor, eye pain and conjunctivitis reported in our study might have been caused in part by sodium carbonate, with a contribution from the presence of non-ionic surfactants. Although sodium silicate has also been shown to cause conjunctivitis, iritis and corneal opacity experimentally,[20] it is unlikely to do so at the concentration present in most tablets.

In our study,798 patients ingested traditional tablets and 725 ingested soluble film tablets, although

a greater proportion of young children (≤5 years) ingested the latter. The appearance of soluble film tablets may be a reason for this, as some types contain colourful liquids or gels which are visible through the transparent film covering. In contrast, traditional tablets consist only of a compressed powder, which is not visible until the external foil wrapper is removed. Adults more often ingested traditional than soluble film dishwashing tablets, probably reflecting their wider use by this age group.

Despite the potential for improved safety with the use of soluble film tablets, clinical features were reported significantly ($p < 0.0001$) more frequently following soluble film tablet ingestion than following the ingestion of traditional tablets, but only among children ≤5 years. Vomiting was reported significantly ($p < 0.0001$) more often in children following soluble film than traditional tablet ingestion.

What factors could explain these apparent differences? Firstly, traditional tablets are hard, compressed powders which are difficult to break, whereas soluble film tablets contain loose powder which is held firm by the soluble film covering until it disintegrates on contact with water. Secondly, some soluble film tablets contain liquids or gels which may be more easily ingested and may spray unpredictably, for example, into the face or eye, when squeezed.

Our results may be subject to bias as reports to the UK NPIS are voluntary and are more likely to occur if there is a clinical concern, for example, because clinical features are present. The total number of exposures among the UK population may be much higher and asymptomatic exposures are less likely to be reported. In addition selection, bias may occur towards more severe cases when hospitals seek advice from the NPIS only when cases are more serious. That said, any bias is likely to be similar for both traditional and soluble film tablets. Secondly, incomplete data reporting can be a problem, for example, an exact product name is not always known.

## Conclusions

Children (≤5 years) significantly ($p < 0.0001$) more often developed features (PSS ≥ 1) following the ingestion of soluble film ($n = 193$, 28.2%) than traditional tablets ($n = 134$, 19.1%), although the likelihood of a child developing features following ingestion was relatively low (<30%) and features that did develop were almost always mild, with fewer than 0.5% reporting moderate or severe (PSS ≥ 2) features. In contrast, adults more often developed features (PSS ≥ 1) following the ingestion of traditional ($n = 39$, 47.6%) than soluble film tablets ($n = 8$, 36.4%), although this difference was not statistically significant. The eye was involved in only 26 of 1539 exposures; 17 of these exposures resulted in ocular features. The most commonly reported features were conjunctivitis, eye pain and blurred vision. One patient sustained a corneal abrasion and developed a loss of vision. Only 3 of 34 patients dermally exposed developed features.

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