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TEST PROCEDURES FOR OBTAINING REPRESENTATIVE EXTRACTS SUITABLE FOR RELIABLE IN VITRO TOXICITY ASSESSMENT OF PAPER AND BOARD INTENDED FOR FOOD CONTACT

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Additives/Contaminants:	Food contact materials, Packaging paper and board
Food Types:	

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ABSTRACT

This paper describes the use of a suite of extraction procedures applicable to the assessment of the *in vitro* toxicity of paper/board samples intended for food contact applications. The sample is extracted with ethanol, water, or exposed to modified polyphenylene oxide (Tenax[®]) for fatty, non-fatty and dry food applications respectively. The water extracts are directly suitable for safety assessment using *in vitro* bioassays. The ethanol extracts of the paper/board and of the exposed Tenax, require pre-concentration to give acceptable sensitivity. This is because the *in vitro* bioassays can tolerate only a small percentage of added organic solvent before the solvent itself inhibits. The extraction procedures have been selected such that they mimic the foreseeable conditions of use with foods and that they are also fully compatible with the battery of *in vitro* biological assays for the safety assessment of the total migrate. The application of the extraction protocols is illustrated by the results for one of the many paper/board samples provided by the BIOSAFEPAPER project industrial platform members. The assessment indicated that this sample should not be considered as suitable for use with fatty foodstuffs but was suitable for dry and non-fatty foods. Information subsequently received from the manufacturer revealed that this was a non-food grade product included in the project to test the capabilities of the bioassay procedures. The selection criteria for the test conditions and the suite of methods developed has been prepared in CEN format and is currently being progressed by CEN/TC172 as a European Standard.

INTRODUCTION

Paper and board is not currently subject to any specific legislation at European Union (EU) level but like all food contact materials they should meet the general requirements laid down in Framework Regulation (EC) No. 1935/2004 (EC 2004). This states, in Article 3, that (to paraphrase) 'Materials and articles shall not, under normal or foreseeable conditions of use, transfer their constituents to food in quantities which could endanger human health'. A Resolution specific to paper and board has been issued by the Council of Europe (CoE) (Council of Europe 2002). This contains a listing of substances used along with certain purity requirements, extraction limits or migration limits. Possible contaminants are listed too. This CoE list contains a large number of substances (more than 200) for which toxicological assessments have been made but an even larger number of substances (more than 500) that have not yet been fully evaluated. Paper and board are natural products made up of a large number of organic molecules and again, the toxicity of all of these substances, individually and in combination, is not known. Therefore although migration tests and chemical analysis for known harmful substances can be carried out, they cannot be applied comprehensively to a product with an incompletely defined chemical composition, such as paper and board. In addition it is a virtually endless task to assess the safety of each substance in turn.

One complementary approach to safety assessment was investigated within the EU funded BIOSAFEPAPER project and this is to consider the toxicity of the overall migrate derived from paper and board. Traditional tests for acute and chronic toxicity are time-consuming, expensive, and have ethical concerns (animal experiments). Moreover, they are very difficult to apply to products like paper and board, and the mixtures that may migrate from them. Instead, the BIOSAFEPAPER project developed

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4 and intercalibrated a battery of short term toxicological tests that are applicable to
5 extracts of paper and board. The toxicological tests and some results have been
6 described by Severin et al. (2005) and Bradley et al. (2008). We describe here, the
7 development and application of a suite of extraction procedures applicable to the
8 assessment of the *in vitro* toxicity of paper/board samples intended for food contact
9 applications.
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22 **MATERIALS**

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26 *Extraction media.* Ethanol was obtained from Fisher (Loughborough, UK) and Tenax
27 TA 60-80 mesh from Chrompack. Water was taken from a normal laboratory deioniser.

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29 *Other chemicals.* Normal laboratory grade and as described by Bradley *et al.* (2008).
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35 *Paper and board samples.* A range of sample types was provided by the
36 BIOSAFEPAPER project industrial platform members for use in method development
37 and for the assessment of the bioassay procedures.
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45 **METHODS**

46 **Preparation of cold- and hot-water extracts**

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48 The sample was extracted with water as described in EN 645 (cold) (EN645 1994) or in
49 EN 647 (hot) (EN647 1994). The extract was sterile-filtered through a membrane filter
50 and stored in a sterilised glass bottle.
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Preparation of an ethanol extract

A specimen (200 g) of the paper/board sample was cut into strips and placed into a 2 L glass bottle. Aqueous ethanol (95% v/v, 2 L) was added to fully submerge the sample. The bottle was stoppered and stood at room temperature (~ 23°C) for 24 hours. The extraction solvent was recovered from the sample with minimal mechanical pressing and filtered through a Whatman no.1 filter paper that was pre-washed with ethanol. A portion (800 mL) of the extract was placed into a 1 L bottle and without heating it was evaporated just to dryness under a gentle stream of nitrogen. The residue was redissolved in 80 mL ethanol and stored in a 100 mL bottle.

Preparation of a Tenax extract

Preparation of cleaned Tenax. Tenax is conventionally activated by oven heating at ca. 300°C in air, but it breaks-down to give a constant background bleed (equivalent to ca. 0.5 mg/dm²) in subsequent ethanol extraction. Since this background bleed may interfere with the toxicity tests, an alternative method of activation was developed. The Tenax was soxhlet-extracted for 16 hours with ethanol. It was then transferred to a wide-necked conical flask, placed under a gentle stream of nitrogen, dried at room temperature and then activated by heating for 16 hours at 150°C.

Exposure to Tenax. Twelve 1.5 dm² circles of paper/board were prepared using a circular knife or using a scalpel with a circular template. A specimen was placed into a 14 mm internal diameter glass Petri dish and cleaned Tenax (3 g) was added. The Tenax was smoothed using a spatula to give an even bed covering all of the specimen. A further two specimens were placed on top of the Tenax with the food contact surface in contact, followed by a second portion (3 g) of Tenax. This process was repeated until the twelfth and final specimen rested on top. The result was a stack of the 12 specimens in the glass Petri dish, with the Tenax (6 beds of 3 g each) making single-

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4 sided contact with the food contact surface of the paper/board. The dish lid was fitted
5 and the assembly transferred to an oven for exposure according to the time and
6
7 temperature conditions selected for the intended food use (see later).
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13 *Preparation of an ethanol extract of the exposed Tenax.* The paper/ board specimens
14 were removed using tweezers, allowing the exposed Tenax powder to fall into the dish.
15 Minimal brushing-off was used if the Tenax adhered to the paper/board. The exposed
16 Tenax was placed into a conical flask and ethanol (100 mL) was added. The contents
17 were swirled for a few minutes to extract the Tenax and then the powder was allowed
18 to settle. The extract was decanted and filtered through Whatman no.1 filter paper that
19 has been pre-washed with ethanol. The extraction was repeated using a second and
20 then a third portion of ethanol (each 100 mL). The combined extracts were
21 concentrated to a volume of 80 mL using a gentle stream of nitrogen.
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34 **Preparation of blank control extracts**

35 For each of the extraction procedures, a method blank was prepared for submission to
36 the *in vitro* bioassay tests by using water, 95% ethanol or Tenax as appropriate but
37 with no paper/board sample used.
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45 **Storage of extracts**

46 The extracts were submitted to the *in vitro* bioassays as soon as possible after
47 preparation to prevent any chemical or microbiological deterioration. If there was
48 expected to be any delay (more than a few hours) the water extracts were stored
49 refrigerated and then brought to room temperature before the bioassay procedures
50 were conducted, to allow any precipitate (that may have formed on cooling) to
51 redissolve. The ethanol extracts (as such or as ethanol extracts of Tenax) were by
52 definition sterile and so were stored at room temperature in the dark.
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Characterisation of the test extracts

Detailed descriptions of the analytical procedures used are given by Bradley et al. in (Bradley et al. 2008). An appreciation of the procedures is useful in interpreting the results and so they are described in outline here.

GC-MS analysis of the water extracts

A portion of the water extract was fortified with internal standards, 14-methylpentadecanoic acid and cholestanol, evaporated to near dryness then derivatised using BSTFA (N,O-bis(trimethylsilyl)trifluoro-acetamide). The derivatised extract was dissolved in dichloromethane (1 mL) and analysed by GC-MS using a procedure described by Björklund-Jansson et al. in (2002). The GC-MS analysis was operated in full scan mode (m/z 50 to 600).

GC-MS analysis of the ethanol extracts

For analysis without derivatisation, the internal standards 1,9-dichlorononane and 1-fluorononane were added, the extract was diluted by a factor of 10, and then analysed by GC-MS. For analysis with derivatisation, the internal standard hexadecanoic acid was added, the sample was evaporated to dryness, derivatised with BSTFA and analysed by GC-MS as described above.

GC-MS analysis of the ethanol extracts of the exposed Tenax

The Tenax extracts in an ethanol vehicle were analysed by GC-MS with and without derivatisation as described above but without the dilution step.

Toxicological assessment of the test extracts

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4 A battery of short-term toxicological tests was applied to determine the cytotoxicity and
5 genotoxicity of the extract. The detailed descriptions of the tests and their outcomes
6 are described by Bradley et al. (2008). Additional testing was performed to illustrate
7 the effect of the extraction methods on the results obtained and this is described here.
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9 Cytotoxicity was assayed using the metabolically competent mouse hepatic cell line
10 Hepa-1 with total protein content (TPC) as toxicological endpoint. The Ames test was
11 used to measure mutagenicity, using the tester strain TA98 without metabolic
12 activation.
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26 DISCUSSION

27 28 29 30 Principles guiding the selection of the extraction media

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32 Three guiding principles were considered in developing the extraction protocols for
33 paper/board samples submitted to bioassay procedures. These were:
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37 *Identity:* The chemical content of the extract prepared should be related to the
38 chemical migration expected for that paper/board sample in contact with foodstuffs;

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41 *Compatibility:* The extract should be homogenous, stable, free from particulates and
42 suitable for use in the bioassay procedures.
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46 *Concentration:* The concentration submitted to bioassay should be no less than the
47 concentration of migrants in foodstuffs;
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54 The identity of substances migrating from paper/board samples will be dependent on
55 the type of foodstuff with which it comes into contact.
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Contact with moist, aqueous, acidic and alcoholic foods. The European Standard hot and cold water extraction procedures (EN645 1994, EN647 1994) were considered to be appropriate (Björklund-Jansson et al. 2002) for paper/board samples described as being intended for contact with moist, aqueous, acidic or alcoholic foods and so they were used.

Contact with fatty foods. There are no equivalent standard methods available for paper/board intended for contact with fatty foods. As recommended in the CoE guidelines, the test conditions established for plastics were considered. Directive 85/572/EEC (EU 1985) on plastics describes olive oil as a simulant of fatty foods but clearly olive oil is not suited for a highly absorbent material such as paper or board. Directive 82/711/EEC, as amended (EU 1982 and EU 1997), describes the use of alternative simulants for fatty foods. These methods have been standardised by CEN (EN1186 2002) and describe the use of 95% (v/v) aqueous ethanol and isooctane. Ethanol is the extraction solvent defined for polar plastics (EN1186 2002) and since paper and board are polar substrates then ethanol was expected to be the most suitable. To test this assumption, work was carried out within the BIOSAFEPAPER project, described in the final project report (European Union 2006) by testing nine paper and board samples using isooctane and 95% (v/v) aqueous ethanol. In every case, the ethanol solution extracted a higher mass of extractable substances than did isooctane (Table 1).

Place Table 1 about here

Considering extraction of specific substances, GC-MS analysis of the extractable substances was performed using methods described by Björklund-Jansson et al. (2002). The results for 5 of the nine samples are presented in Figure 1. This shows

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4 that the extracted substances were mainly wood extractives such as fatty acids, resin
5 acids, fatty alcohols, sugars and sterols, along with other chemicals such as phthalates
6 and hydrocarbon waxes. Figure 1 also illustrates that ethanol extracted a greater
7 quantity of total substances analysable by GC-MS and also extracted a better range of
8 both polar and non-polar substances compared to isooctane. As expected the
9 distribution of substances was skewed slightly towards polar substances using ethanol
10 (e.g. fatty acids) and was skewed slightly towards non-polar substances using
11 isooctane as the extraction solvent (e.g. wax alkanes). Overall, ethanol gave the best
12 balance and the greater total extractables in every case. Therefore, the conclusion
13 was that paper or board samples intended for contact with fatty foods, should be
14 subjected to extraction using 95% (v/v) aqueous ethanol.
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Place Figure 1 about here

Contact with dry foods

Technical Document No. 2 of the CoE Resolution on paper and board recommends that for dry foods that are listed in Directive 85/572/EEC with no simulant specified, then migration testing should use modified polyphenylene oxide (Tenax). Tenax has been used by others to test paper and board intended for dry foodstuffs (Bradley et al. 2002, Summerfield and Cooper 2001, Sturaro et al. 1994, Boccacci Mariani et al. 1999, Aurela et al. 1999) or intended for use at high temperature (Mountfort et al 1996). A test method for migration from paper and board using Tenax has been standardised (EN14338 2003).

Compatibility

The extracts must be presented in a test vehicle that is compatible with the biological assays used to assess the toxicity of the migrate. The assays that make up the short term test battery are listed in Table 2.

Aqueous foods. Hot and cold water extracts prepared according to EN645 and EN647 are, following sterile filtration, directly compatible with the *in vitro* assays and so could be used as such.

Fatty foods. The tolerance of the organisms used in the assays to some standard laboratory solvents was determined. The results obtained are given in Table 2 (European Union 2006). Of the solvents tested ethanol and acetone were considered to be the most suitable delivery vehicles for the extracts. Acetone can become contaminated because it extracts strongly some plastic-wares used commonly in *in vitro* assays (data not shown) so ethanol was both the most suitable extractant and the most suitable delivery vehicle for testing paper/board intended for fatty foods.

Dry foods. Tenax is a finely-powdered, insoluble polymer. It was necessary to take the exposed Tenax and extract the total migrate from it using a suitable solvent that could then serve to transfer the total migrate into the *in vitro* toxicity test systems. Ethanol is a suitable solvent for extraction of Tenax (e.g. used Tenax was regenerated using ethanol extraction) and ethanol is also a suitable vehicle for the toxicity assays (see above) and was therefore selected for use in this way.

Concentration

As mentioned above, the concentration in the extracts tested must be equal to or greater than the levels that would migrate into foods. In general any tests carried out

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4 by total immersion (i.e. the hot water, cold water and ethanol extracts) are more severe
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6 than normal or foreseeable conditions of use in contact with foodstuffs and would
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8 therefore overestimate any 'real' migration. The extent of the overestimation will
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10 depend on the exact food contact conditions including the time and temperature
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12 conditions of use, the nature of the food (i.e. total or point contact, intimate or indirect),
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14 the mass:area ratio of food:packaging, and the chemical composition and physical form
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16 of the food. In many cases the overestimation will be large. The rigorous extraction
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18 tests by total immersion will contain the same substances and at higher concentrations
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20 than any migration likely to occur into foods. The one significant exception to this is
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22 likely to be the extraction of certain heavy metals such as cadmium, chromium and
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24 lead, where use of an acidic simulant such as 3% (w/v) aqueous acetic acid gives
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26 higher extraction than using plain water (Björklund-Jansson et al. 2002). Since
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28 separate purity criteria exist for these undesirable heavy metals (Council of Europe
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30 2002), this is not a significant drawback of the choice of extraction test media selected
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39 Tenax is a powdered polymeric simulant and it makes intimate contact with the
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41 paper/board samples. Tenax has been shown to overestimate the migration from
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43 paper/board samples into foodstuffs (European Union 2003) and therefore Tenax is
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45 expected to provide higher migration levels than dry foods. To select the most suitable
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47 exposure conditions results obtained within another EU funded project
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49 (RECYCLABILITY) were considered. Here the kinetics of the migration of model
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51 substances from paper/board samples into Tenax were derived. Exposure times and
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53 temperatures were selected based on the time taken to reach a migration equilibrium
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55 between paper/board samples and Tenax.
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Place Table 2 about here

As the battery of test organisms can tolerate only up to 2% ethanol in their buffered aqueous culture media, a pre-concentration step is required in order to fulfil the criteria that the concentration of the substances in the bioassay should be no less than the migration concentration in foodstuffs. This was achieved through the use of a high mass of paper/board to volume of extraction solvent and a further concentration step. The effect of this higher paper/board to solvent ratio on the solubility of the extractable substances and the effect of the concentration step on precipitation problems or loss of volatile extractives were investigated and the optimum extraction conditions were derived (European Union 2006). The optimum ratio found to overcome the solubility limitations was 200 g of paper or board extracted with 2 L of 95% ethanol (i.e. a 1:10 w/w ratio). The grammage of the samples described as intended for contact with fatty foods ranged from 140 to 666 g/m² and therefore 200 g of paper/board in 2 L of extraction solvent is equivalent to a range of 0.015 to 0.071 dm² per mL of ethanol. A further 10-fold concentration step was achieved by evaporation to achieve a final concentration in the range 0.15 to 0.71 dm² per mL. In EN1186 Part 15, 1 dm² of sample is extracted with 50 mL of solvent giving 0.02 dm² per mL. Therefore the concentration of the extracts prepared was between 7.5 and 35 times greater than if they had been prepared according to EN1186 Part 15. For further comparison, the hot or cold water extraction procedures (EN645 1994, EN647 1994) use 10 g of paper/board and 200 mL of water (0.04 g/mL). The concentrated 95% ethanol extract is at a concentration ratio of 1 g paper/board per mL of solvent. This is 25-times more concentrated than the water extracts. Although the high ratio of paper/board to solvent and the evaporation step go some way towards concentrating the extracts they are not capable of fully accounting for the 50-fold dilution that would be necessary prior to their use in the bioassays at 2% addition. Further concentration was not possible without

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4 loss of migrants either due to solubility limitations or precipitation. As mentioned above
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6 the intimate double sided contact between the test sample and the extraction solvent
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8 provides an extract of much higher concentration than that of the migrate into foods
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10 and therefore the concentration factor achieved in this way was considered to be
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12 sufficient.
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17 For Tenax, a concentrated sample was achieved by the use of (i) a high ratio of
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19 paper/board to Tenax and (ii) subsequent concentration of the ethanol extract obtained.
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21 The standard method EN14338 (EN14388 2003) taken as the starting point specifies
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23 that 4 g of Tenax is exposed to 1 dm² of paper or board and then extracted with solvent
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25 to achieve a final volume of 50 mL – giving an extract equivalent to 0.02 dm² per mL.
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27 By increasing the ratio four-fold (18 dm² tested with 18 g of Tenax) and by
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29 concentrating the ethanol extract to a final volume of 80 mL (the minimum volume
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31 required for the suite of bioassays) gave an extract equivalent to 0.23 dm² per mL of
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33 extract - a 10-times increase in concentration relative to EN14338 (EN14388 2003).
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35 This concentration (on a dm² per mL basis) is within the same range as obtained by the
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37 preparation of the ethanol extracts of samples intended for contact with fatty foods
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39 (described above). Since Tenax overestimates the migration of paper and board
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41 samples into foods (European Union 2003) this concentration was considered to be
42
43 satisfactory to provide a suitable extract for application in the bioassays in terms of
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45 both the identities and concentrations of the migrating substances.
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52 Based on the principles for the selection of the extraction media along with the
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54 experimental results obtained, a protocol was derived for the selection of extraction
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56 media and extraction/migration conditions. These are summarised in Table 3.
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Place Table 3 about here

TEST RESULTS FOR SAMPLE NSP4 AS AN ILLUSTRATIVE EXAMPLE

Within the BIOSAFEPAPER project 20 different paper/board samples were tested (European Union 2006). Sample NSP4 was described as 100% recycled Board GD3 (WLC) and its grammage was 300 g/m³. Because its intended use was poorly defined it was tested using water, ethanol and Tenax. For this reason it is a good example of how the testing scheme elaborated here works in practice.

The concentrated ethanol extract of sample NSP4 showed positive results in genotoxicity assays. The extract induced mutations in the Ames tester strain TA98 without metabolic activation and it was clearly cytotoxic too (Bradley et al. 2008). The extract was analysed by GC-MS as such and also following derivatisation with BSTFA. Table 4 lists the substances detected along with their estimated concentrations. The most prominent substances were diisopropylnaphthalene isomers, C15-C29 alkanes and phthalates. Individually it is not expected that any of these substances would give the positive responses observed in the cytotoxicity or genotoxicity tests. This suggests either that other substances are present in the extract that are not detected by GC-MS and that it is these substances which elicit the positive response or that the response is due to the combined effect of one or more of these substances. Either way, the results emphasise the importance of testing the whole migrate for toxicity as well as considering the individual substances.

Place Table 4 about here

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4 Based on these results it was concluded that NSP4 could not be considered as suitable
5 for contact with a fatty foodstuff without further investigations of the cause of the
6 positive results. It later transpired that this sample was a non-food grade board and
7 therefore this positive response could be used to demonstrate that the battery of tests
8 is capable of detecting a sample that should not be used in contact with a fatty
9 foodstuff.
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20 A dilute 95% ethanol extract of NSP4 was prepared according to the EN1186 Part 15
21 giving an equivalent of 0.02 dm²/mL. This extract gave no genotoxic response (Table
22 5) nor any cytotoxic response (Figure 2). This demonstrates that without the
23 concentration step the ethanol extract applied to the battery of toxicological tests is not
24 sufficiently concentrated to assess the safety of the paper/board sample.
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41 This extract prepared without concentration was analysed by GC-MS and the results
42 are compared with those from the concentrated extract in Table 4. The agreement in
43 the results is excellent when expressed in units of mg substance per kg board, both for
44 the individual substances listed and for the total substances detectable by GC-MS, 653
45 versus 757 mg/kg.
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53 Further tests were carried out to determine whether or not NSP4 could be considered
54 suitable for contact with aqueous or dry foods. A cold water extract was prepared and
55 the sample was also tested with Tenax for 5 days at 50°C. The extracts were analysed
56 by GC-MS and were tested for cytotoxicity.
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7 The cold water extract of NSP4 contained a number of individual substances. The
8 substances detected (Table 6) were different to those found in the ethanol extracts.
9 This was as expected given the different properties of the two solvents. In addition to
10 the identified substances the GC-MS chromatogram contained many peaks that could
11 not be matched with any library spectra. The total quantity of the non-identifiable
12 peaks was estimated to correspond to approximately 690 $\mu\text{g}/\text{dm}^2$.
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22 Place Table 6 about here
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26 The range and concentrations of the individual substances migrating from the board
27 into Tenax were less than those extracted by 95% ethanol (Table 4). No cytotoxic
28 responses against the mouse Hep-A strain were observed with the water extract or the
29 Tenax extract (data not shown). Based on these results it can be considered that
30 sample NSP4 is suitable for contact with aqueous and dry foods but not with fatty
31 foods.
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43 CONCLUSIONS

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47 Methods of test for the preparation of extracts suitable for *in vitro* toxicological
48 assessment have been elaborated along with the rationale for their selection. The test
49 methods have been applied to twenty representative paper and board samples. The
50 results of the chemical characterisation and toxicological assessment of one of these
51 twenty samples is presented to illustrate the approach. This board sample was found
52 not to be suitable for contact with a fatty foodstuff. Individually it is not expected that
53 any of the substances identified in the ethanol extracts would result in the positive
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4 responses observed in the cytotoxicity or genotoxicity tests. This suggests either that
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6 other toxic substances are present in the extract that are not detected by GC-MS or
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8 that it is the combined effect of two or more of these substances that elicits the positive
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10 response. Either way the results emphasise the importance of testing the whole
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12 migrate for toxicity as well as considering the individual substances. The selection
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14 criteria for the test conditions and the suite of methods developed has been prepared in
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16 CEN format and is currently being progressed by CEN/TC172.
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34 findings and the conclusions in this paper are the responsibility of the authors alone
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36 and they should not be taken to represent the opinion of the European Commission or
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38 any paper and board making companies.
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Table 1. Total extractables (gravimetric, mg/dm²) from nine typical paper/board samples extracted with isooctane or 95% ethanol *

Sample code #	1	2	3	4	5	6	7	8	9
Isooctane	< 0.5	0.9	< 0.5	11.3	4.7	0.6	15	20	0.9
95% Ethanol	< 0.5	2.4	0.8	39	12	9.3	20	31	2.3

* Extracted for 24 hours at room temperature (~ 23°C).

Deleted: using the procedure described in EN1186-15 - total immersion test

Deleted: for 24 hours

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Table 2. The maximum solvent concentrations compatible with the battery of short term cytotoxicity tests [4,11]

Non-toxic concentration in different tests (% v/v)						
Solvent	Acute cytotoxicity tests			Sublethal cytotoxicity tests		Bioluminescence test (EC ₅₀)
	Mouse hepatoma cell line (Hepa-1)	Human larynx carcinoma cell line (Hep-2)	Boar spermatozoan motility inhibition test	RNA-synthesis inhibition test		
				HepG2 cells	Hela cells	
Ethanol	2	1	2	2	0.5	15
Methanol	1	1	2	> 2	> 0.5	12.5
DMSO	0.5	2	1	2	0.5	> 10
Acetone	> 2	> 2	1	> 2	> 0.5	7.5
Hexane	> 2	not tested	1	> 2	not tested	0.06

NB: The symbol > means that the system tolerated the solvent up to the maximum concentration tested.

Table 3. Extraction solvents and test conditions proposed to test paper and board food contact materials

Food contact conditions	Extraction solvent/food simulant	Test conditions
Contact with moist, aqueous, acidic or alcoholic foodstuffs at temperatures up to 20°C - all times	Cold water	24 hours at room temperature <u>(23°C)</u>
Contact with moist, aqueous, acidic or alcoholic foodstuffs at temperatures above 20°C - all times and temperatures	Hot water	2 hours at 80°C
Contact with fatty foodstuffs - all times and temperatures	95% (v/v) aqueous ethanol	24 hours at room temperature <u>(23°C)</u>
Contact with dry foodstuffs - long-term frozen storage	Tenax	10 days at 20°C
Contact with dry foodstuffs - short-term (≤ 1 week) contact at refrigerated temperature	Tenax	24 hours at 20°C
Contact with dry foodstuffs - short-term (≤ 1 day) contact at ambient temperature	Tenax	24 hours at 20°C
Contact with dry foodstuffs - all other contact conditions including high temperature applications but not cooking or baking, or if contact conditions are unknown	Tenax	5 days at 50°C

Table 4. Estimated concentrations (units of $\mu\text{g/mL}$ of extract and mg/kg paper) of the substances in the extracts of NSP4

	Ethanol extract $\mu\text{g/mL}$ / mg/kg board	Dilute ethanol extract $\mu\text{g/mL}$ / mg/kg board	Ethanol extract of Tenax $\mu\text{g/mL}$ / mg/kg board	Substance identification
Extract is cytotoxic ?	Yes	No	No	
Extract is genotoxic ?	Yes	No	not tested	
RT (min)				
18.16/18.7	218 / 218	15 / 256	44 / 66	diisopropylnaphthalene isomers
16-29.4	154 / 154	8.3 / 138	50 / 71	C15-29 n-alkanes
20.13	120 / 120	7.2 / 119	17 / 26	diisobutyl phthalate
25.48	38 / 38	< LOD	< LOD	dehydroabietic acid
21.1	37 / 37	1.7 / 28	1.5 / 2.3	dibutyl phthalate
26.15	29 / 29	1.9 / 32	2.0 / 2.9	bis(2-ethylhexyl) phthalate
19.02	27 / 27	1.8 / 31	4.0 / 5.9	tetramethyl biphenyl isomer
23.6	22 / 22	0.76 / 13	< LOD	bis(2-ethylhexyl) fumarate
22.81	21 / 21	< LOD	< LOD	9-octadecenoic acid
24.66	16 / 16	0.97 / 16	1.1 / 1.6	methyl dehydroabietate
22.48	16 / 16	1.2 / 20	< LOD	octadecenoic acid, methyl ester
23.18	16 / 16	< LOD	< LOD	bisphenol A

23.02	6.7 / 6.7	< LOD	< LOD	octadecanoic acid
16.25	5.6 / 5.6	< LOD	< LOD	2-phenylphenol
25.74	5.1 / 5.1	< LOD	< LOD	2-(methoxymethyl)-2-phenyl-1,3-dioxolane
23.14	4.6 / 4.6	< LOD	< LOD	2-(phenylmethoxy)naphthalene
17.11	3.1 / 3.1	< LOD	< LOD	diethyl phthalate
26.58	2.9 / 2.9	< LOD	< LOD	7-oxodehydroabiatic acid, methyl ester
23.79	2.6 / 2.6	< LOD	< LOD	4-benzyl biphenyl
14.72	2.4 / 2.4	< LOD	< LOD	vanillin
17.68	2.4 / 2.4	< LOD	< LOD	benzophenone
26.05	2.4 / 2.4	< LOD	< LOD	dicyclohexyl phthalate
16.09	1.9 / 1.9	< LOD	< LOD	no good library match
10.49	1.7 / 1.7	< LOD	< LOD	nonanal
6.06	0.6 / 0.6	< LOD	< LOD	hexanal
10.54	0.6 / 0.6	< LOD	< LOD	no good library match
9.29	0.5 / 0.5	< LOD	< LOD	2-ethyl-1-hexanol
	757 / 757	39 / 653	120 / 176	SUM
	0.5 / 0.5	0.5 / 8.4	0.5 / 0.7	LOD (limit of detection)

Table 5. The responses of the Ames tester strain TA98 to ethanol extracts of sample NSP4

Sample	Concentration (μ l per plate)	revertants per plate (\pm SD)	
		-S9	+S9
Concentrated ethanol extract ¹	0	26 \pm 8	32 \pm 6
	5	26 \pm 6	not tested
	10	33 \pm 2	not tested
	25	41 \pm 6	not tested
	50	70 \pm 17	40 \pm 9
	100	90 \pm 13	27 \pm 8
	200	114 \pm 6	43 \pm 6
Ethanol extract made according to CEN standard	0	28 \pm 1.7	not tested
	5	25 \pm 3.8	not tested
	10	35 \pm 6.1	not tested
	25	24 \pm 1.5	not tested
	50	28 \pm 7.8	not tested
	100	27 \pm 3.6	not tested
	200	33 \pm 2.6	not tested
Benzo(a)pyrene ²	2 μ g/plate	20 \pm 2	235 \pm 21
Nitroquinolineoxide ²	1 μ g/plate	589 \pm 23	not tested

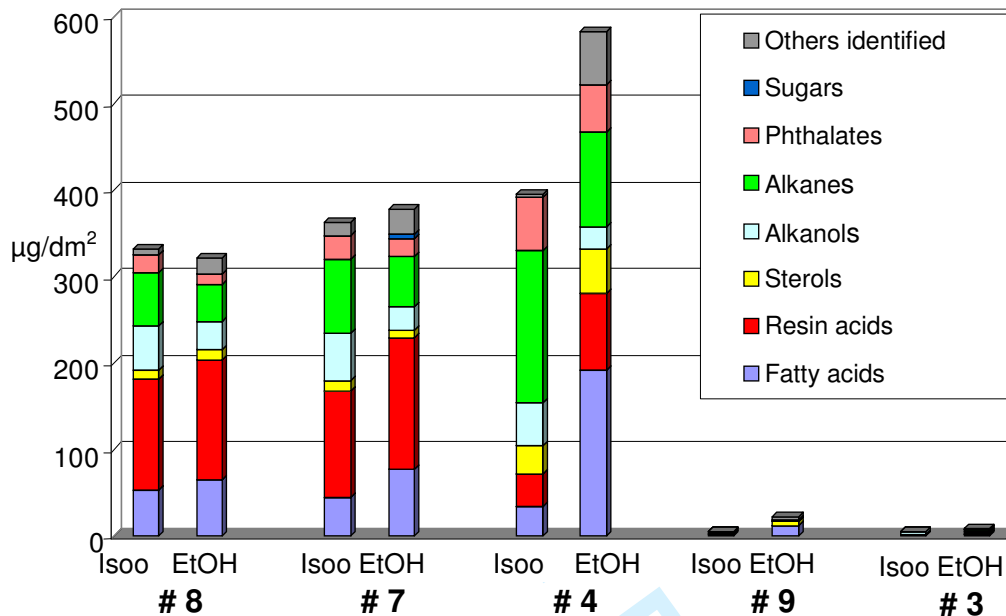
¹ The results of the concentrated extract have been reported separately [4].

² Positive controls

Table 6. Estimated concentrations (units of $\mu\text{g/mL}$ of extract and mg/kg paper) of the substances in the water extract of NSP4

	Water extract $\mu\text{g/mL}$ / mg/kg board	Substance identification
Extract is cytotoxic ?	No	
Extract is genotoxic ?	No	
Retention time		
8.01	0.3 / 7	C9:0 nonanoic acid
8.73	0.1 / 2	C10:0 decanoic acid
9.93	0.2 / 6	C12:0 lauric acid
15.95	0.1 / 2	resin acid (palustrinic acid)
16.34	0.1 / 2	resin acid (not specified)
16.80	0.1 / 1	resin acid (not specified)
17.43	0.1 / 1	resin acid (isopimaric acid)
17.85	0.2 / 4	resin acid (not specified)
18.50	2.2 / 54	dehydroabietic acid
19.12	0.2 / 6	resin acid (abietic acid)
6.59	0.5 / 12	3-hydroxypropanoic acid
8.49	0.3 / 7	3,4-di-hydroxybutanoic acid
8.86	0.2 / 6	mono-hydroxybutanedioic acid
9.80	0.1 / 3	4-hydroxybenzoic acid
10.61	0.2 / 5	vanillic acid
32.90	0.2 / 4	lignan (conidendrinic acid isomer)
33.13	0.4 / 11	lignan (conidendrinic acid isomer)
various	10 / 247	no good library match
	15.5 / 380	SUM
	< 0.1 / < 1	LOD (limit of detection)

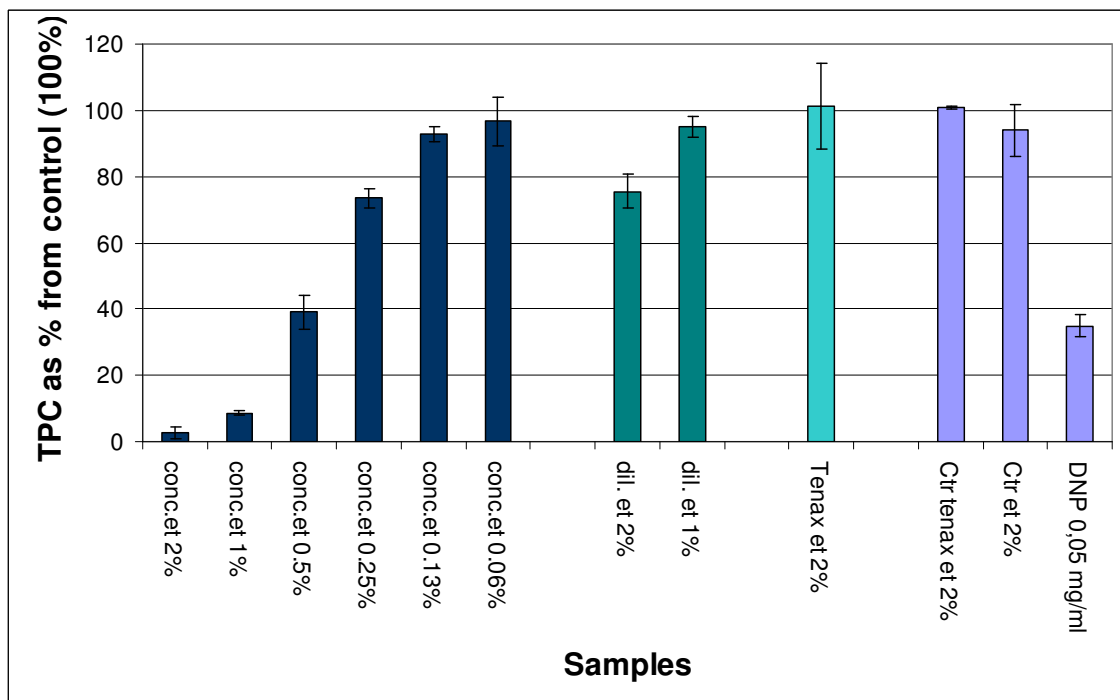
Figure 1. GC-MS comparison of the extractable substances obtained using isooctane and 95% ethanol on five paper / board samples *



* Extracted for 24 hours at room temperature (~ 23°C).

Deleted: Extracted using EN1186-15 - total immersion test at room temperature for 24 hours. GC-MS analysis as described [10]

Figure 2. The cytotoxicity of NSP4 against Hepa-1 cells using total protein content (TPC) as toxicological endpoint



Note: The lower the column, the more toxic is the sample tested.

conc.et = concentrated ethanol extract

dil.et = dilute ethanol extract

Tenax et = ethanol extract of exposed Tenax

Ctr tenax = ethanol extract of control Tenax

Ctr et = control ethanol

DNP = dinitrophenol, positive control for TPC