Migration of N-nitrosamines from rubber gloves for handling food - Effect of extraction media

O Pinprayoon¹ and W Mae¹
¹ Rubber and Rubber Products Group, Department of Science Service, Bangkok, Thailand
E-mail: porawan@dss.go.th

Abstract. Rubber gloves are used daily in variety applications including for food handling purposes. In order to assess possible exposure of the wearers to N-nitrosamines as well as possible release of N-nitrosamines to foods being contacted to these gloves, effects of extraction media are investigated. Artificial sweats (both alkaline and acid solutions), artificial saliva, and some food simulants are used for the extractions and twelve N-nitrosamines including NDMA, NDEA, NDPA, NDiBA, NDBA, NPIP, NPYR, NMOR, NEPhA, NMPHA, NDiNA, and NDBzA are analysed using GC-TEA. By using different extraction media, the levels of the released N-nitrosamines and N-nitrosatable substances are different leading to the differences in the judgement for the EU Directive compliance. By comparing with data of daily intake of N-nitrosamines from foods, the intake of N-nitrosamines migrated from gloves used for food handling under the most unfavourable circumstances could lead to an exceeding of dietary intake. Therefore possible risks associated with the use of rubber gloves for food handling are considered high.

1. Introduction
Considerable interest has been shown in literatures concerning the release of nitrosamines and nitrosatable substances from rubber products [1-16, 19-20]. Elastomer teats and soothers were amongst the first rubber products of interest since they involved child use and care articles. Extensive studies as well as risk assessments had been conducted and limits of nitrosamines and nitrosatable substances released from teats and soothers were later imposed by authorities in order to minimize risk being associated with these products [17-18]. Balloon and condom were also the rubber products of which risk for human health relating N-nitrosamine has been concerned. However, there are number of studies supporting the conclusion that risk for an induction of tumors from nitrosamines in balloons and condoms was very low [8-10, 21-23]. For rubber gloves, there are several works investigating on the release of N-nitrosamines and N-nitrosatable substances form these products using artificial sweat as well as artificial saliva as the extraction media [11-14]. However, a literature focusing on the effects of extraction media is lacking. When rubber gloves are used, particularly in food handling applications, two possible exposures to N-nitrosamine have to be concerned. For glove users, the exposure may occur through the wearer skin whilst for food consumers, the possible exposure may occur through the release of N-nitrosamines to foods being contacted to the gloves.

In this study, an effect of extraction media used to extract nitrosamines from rubber gloves was investigated. Artificial saliva, artificial sweats, and some food simulants were used as the extraction media. This work is intended to gather information needed for an establishment of test method suitable for the determination of N-nitrosamines released from rubber gloves used for food handling purposes as well as for the assessment of possible risk associated with the use of these products.
2. Materials and methods

2.1 Nitrosamine standards
N-nitrosamine standards used in this study are N-nitrosodimethylamine (NDMA, CAS No. 62-75-9), N-Nitrosodiethylamine (NDEA, CAS No. 55-18-5), N-Nitrosodipropylamine (NDPA, CAS No. 621-64-7), N-Nitrosodiisobutylamine (NDiBA, CAS No. 997-95-5), N-Nitrosodibutylamine (NDBA, CAS No. 924-16-3), N-Nitrosopiperidine (NPIP, CAS No. 100-75-4), N-Nitrosopyrrolidine (NPYR, CAS No. 930-55-2), N-Nitrosomorpholine (NMOR, CAS No. 59-89-2), N-nitroso N-ethyl N-phenylamine (NEPhA, CAS No. 612-64-6), N-nitroso N-methyl N-phenylamine (NMPhA, CAS No. 614-00-6), N-nitoso-N,N-di(3,5,5-trimethylhexyl)amine (NDiNA, CAS No. 1207995-62-7), N-Nitrosodibenzylamine (NDBzA, CAS No. 533-53-8) and N-Nitrosodisopropylamine (NDiPA, CAS No. 601-77-4).

2.2 Extraction media
The artificial saliva was prepared in accordance with EN 12868:2017 [24] and used within five days. The artificial sweats were prepared as described in ISO 105-E04:2013 [25] and used within the day of preparation. 10% ethanol and 4% acetic acid solutions were used as aqueous food simulants.

2.3 Column for solid phase extraction
A pre-filled, single-use cartridge was used for solid phase extraction (SPE). The cartridges were HyperSep SLE pH 9 and HyperSep SLE pH 7 purchased from Thermo-Scientific.

2.4 Glove samples
Four glove samples comprised of two powder-free gloves made of natural latex and two powder-free gloves made of nitrile latex. Sample codes and average weights of the samples are given in Table 1.

Table 1. Sample codes and average weights glove samples

| No. | Sample code | Material       | Weight (g/glove) |
|-----|-------------|----------------|------------------|
| 1   | NR1         | Natural rubber | 5.1              |
| 2   | NR2         | Natural rubber | 36.4             |
| 3   | NT1         | Nitrile rubber | 4.8              |
| 4   | NT2         | Nitrile rubber | 2.8              |

2.5 Sample preparation and migration experiment
Rubber gloves were cut into pieces having sizes approximately 2 cm x 2 cm. Cut pieces of about five grams were extracted using different media (2.2). The migration experiment was carried out as prescribed in EN 12868 except for the boiling process and the migration time was shortened from 24 to 4 hours in order to mimic the real use of rubber glove in food industry. After migration process, the extract was purified through SPE cartridge, followed by concentrated to a volume of about 5 ml in water bath, rinsed with 1 ml of absolute ethanol and further concentrated to a volume of 1.0 ml by gently passing a flow of nitrogen over its surface. The concentrated extract was transferred to a GC vial for analysis.
2.6 Calibration solutions for GC-TEA
Calibration solutions were prepared from stock solutions of certified mixtures of twelve N-nitrosamines. At least five different calibration levels with concentration covering ranges from 2 ng/ml to 500 ng/ml for each N-nitrosamine standard were prepared by dilution with ethanol and addition of 100 ng/ml internal standard solution. A calibration blank solution as well as a sample blank solution also contains approximately 100 ng/ml of the internal standard.

2.7 Analysis of twelve target N-nitrosamines
The determination of N-nitrosamines and N-nitrosatable substances released from samples were done in duplicate and the average values of each nitrosamine per sample weight (μg/kg) were calculated. The releases of the twelve target N-nitrosamines were determined using GC-TEA system and the results confirmed by GC-MS/MS. The GC-TEA analysis was performed on Thermo-Scientific Trace 1300 Gas Chromatography connected with Ellutia 800 Series Thermal Energy Analyser (TEA). The GC column used was TR-FFAP (0.32 μm internal diameter, 30 m length, 0.25 μm film thickness). The GC-MS/MS analysis was performed on Thermo-Scientific Trace 1300 GC System connected with Thermo-Scientific TSQ 8000 Evo Triple Quadrupole Mass Spectrometer. The GC column used was TG-WAXMS (0.32 μm internal diameter, 30 m length, 0.5 μm film thickness).

3. Results and discussion

3.1 Released of N-nitrosamines and their precursors
N-nitrosamine migration from four samples after extraction at 40 °C for 4 hours using different extraction media were analysed by GC-TEA. The amount of N-nitrosamines and N-nitrosatable substances, determined as N-nitrosamines, expressed in μg/kg of rubber are shown in Table 2. In general, NDBA and its precursor were detected in all samples with different levels depending on the extraction media used. Other target N-nitrosamines were also detected, i.e. NDMA and NDEA in Sample NT1 and Sample NR1 extracted with artificial alkaline-sweat, and NMOR in Sample NT2 extracted with artificial saliva. For the rest of target N-nitrosamines i.e. NDPA, NDiBA, NPIP, NPYR, NEPhA, NMPhA, NDiNA and NDBzA, the compounds were not detected.

Considering the migration levels with no respect to the extraction media, the total N-nitrosamines varied from 2.3 to 325 μg/kg whilst the total N-nitrosatable amines varied from 0 to 3,697 μg/kg. Of these released compounds, NDMA were found in range from 0 to 9.3 μg/kg, NDEA from 5.1 to 314 μg/kg and NDBA from 2.3 to 41.0 μg/kg. In addition, the N-the nitrosatable NDMA and the N-nitrosatable NDEA were not detected while the nitrosatable-NDBA were found in range from 0 to 3697 μg/kg.

Comparing to work of Feng et al [11-12], the authors reported that the detection frequency of NDMA, NDEA and NDBA in all latex glove samples were 23%, 62% and 62%, respectively. The samples being investigated were 13 latex gloves including seven household gloves, three sterile gloves and three examination gloves using similar extraction media and conditions, i.e. extraction with artificial sweat (pH 5.5) at 37 °C for 4 hour. The migration level of NDMA ranged from 23.02 to 151.99 μg/kg, NDEA ranged from 10 to 301.95 μg/kg and NDBA ranged from 57.00 to 1,909.31 μg/kg. The total N-nitrosamines varied from 15.98 to 1,919.23 μg/kg of which the highest level had exceeded approximately 192 times of the recommended limit of the EU Directive 93/11/EEC.
Table 2. N-nitrosamines and the N-nitrosatable substances released from glove samples using different extraction media

| Sample | Compound | Extraction medium |
|--------|----------|-------------------|
|        |          | Saliva¹ | Alk-sweat² | Ac-sweat³ | 10% Ethanol | 3% Acetic acid |
| NT1    | Total N-nitrosamines | 2.3 | 11.2 | 325 | 2.8 | 3.8 |
|        | - NDBA   | 2.3 | 11.2 | 7.4 | 2.8 | 3.8 |
|        | - NDMA   | nd | nd | 4.0 | nd | nd |
|        | - NDEA   | nd | nd | 314 | nd | nd |
|        | Total N-nitrosatable substances | 13.6 | 1.0 | 12.6 | 3.4 | 0.4 |
|        | - NDBA   | 13.6 | 1.0 | 12.6 | 3.4 | 0.4 |
| NT2    | Total N-nitrosamines | 12.3 | 16.8 | 12.7 | 9.2 | 6.1 |
|        | - NDBA   | 5.1 | 16.8 | 12.7 | 9.2 | 6.1 |
|        | - NDMA   | 7.2 | nd | nd | nd | nd |
|        | Total N-nitrosatable substances | 59.0 | 1.6 | 77.4 | 2.4 | 0.3 |
|        | - NDBA   | 59.0 | 1.6 | 77.4 | 2.4 | 0.3 |
| NR1    | Total N-nitrosamines | 20.7 | 41.0 | 266 | 40.9 | 24.3 |
|        | - NDBA   | 20.7 | 41.0 | 30.1 | 40.9 | 24.3 |
|        | - NDMA   | nd | nd | 9.3 | nd | nd |
|        | - NDEA   | nd | nd | 227 | nd | nd |
|        | Total N-nitrosatable substances | 3697 | 52.2 | 164 | 55.9 | 0 |
|        | - NDBA   | 3697 | 52.2 | 164 | 55.9 | 0 |
| NR2    | Total N-nitrosamines | 11.2 | 21.6 | 25.3 | 40.8 | 11.3 |
|        | - NDBA   | 11.2 | 21.6 | 25.3 | 40.8 | 11.3 |
|        | Total N-nitrosatable substances | 25.0 | 0 | 5.7 | 0 | 2.6 |
|        | - NDBA   | 25.0 | nd | 5.7 | nd | 2.6 |

¹ Artificial saliva, ² artificial alkaline-sweat, ³ artificial acid-sweat, “nd” not detected.

Generally, nitrosamines are formed as a result of a reaction between nitrosating agents and secondary amines in rubber. Sources of secondary amines are from accelerators used in cure systems. The amines being breakdown products produced as a result of the chemical reactions tacking place during vulcanization. From this study which NDBA, NDEA, NDMA and NMOR were detected, it can be implied that some certain accelerators being employed could be one or more compounds given in Table 3.

Table 3. Nitrosamines derived from some commonly used accelerators

| Accelerator | Secondary amine | N-nitrosamine |
|-------------|----------------|---------------|
| TMTD, TMTM and ZDMC | Dimethylamine | NDMA |
| ZDEC and TETD | Diethylamine | NDEA |
| ZDBC | Dibutylamine | NDBA |
| MBS | Morpholine | NMOR |

3.2 A closer look on the effect of extraction media
The effect of extraction media on the migration of N-nitrosamine and N-nitrosatable substance was closer looked by focusing on the migration levels of NDBA and its precursor. At the controlled
migration condition i.e. temperature at 40 °C for 4 hours, the power of extraction media are illustrated in Figure 1.

It can be seen from Figure 1(A) that, for nitrile rubber gloves (Sample NT1 and NT2) the extractable NDBA were migrated to the extraction medium from the highest to the lowest levels by extraction with alkaline-sweat, acid-sweat, 10 % ethanol, 3 % acetic acid and artificial saliva, respectively.

Fig. 1. NDBA and its N-nitrosatable substance released from glove samples using different extraction media after extraction at 40 °C for 4 hours (A) NDBA from nitrile gloves (B) nitrosatable-NDBA from nitrile gloves (C) NDBA from natural rubber gloves (D) nitrosatable-NDBA from natural rubber gloves. Solid lines are drawn for eye-guide only.

Interestingly, the artificial saliva which was regarded as the EU reference test solution for determination of N-nitrosamines and N-nitrosatable substances in teats and soothers are the least powerful to leach out NDBA. For the N-nitrosatable substance, Figure 1(B) shows that the NDBA-precursor was able to migrate from the samples in higher levels using acid-sweat than those of artificial saliva, 10 % ethanol and artificial alkaline-sweat, respectively.

Considering gloves made of natural rubber (Sample NR1 and NR2), Figure 1(C), the released NDBA were detected with the highest to the lowest levels by extraction with 10 % ethanol, alkaline-sweat / acid-sweat, 3 % acetic acid and artificial saliva, respectively. Again, the artificial saliva was found to be the least powerful extraction medium for the NDBA. For the N-nitrosatable
substance, Figure 1(D) indicates almost the same trend as found for nitrile glove samples except the swap order between the acid-sweat and the artificial saliva.

Special attention had been paid on the effect of using acetic acid as the extraction medium. It was discovered that the amount of the NDBA detected in a test portion for the N-nitrosatable substance and N-nitrosamines (refer to EN 12868, Solution A and B, respectively) were very close and almost in the same level. For example, the NDBA detected in Solution A (Sample NT1) was found to be 4.2 μg/g whilst in Solution B the NDBA detected was found to be 3.8 μg/g. According to EN 12868, the nitrosatable-NDBA released from Sample NT1 was calculated to be 0.4 μg/g (see Table 2). In some particular occasions i.e. Sample NR1, the NDBA detected in Solution A was less than that of Solution B in a very close gap, leading to the result of a negative value of the nitrosatable-NDBA (in Table 2, shown as “not detected”). To elaborate this effect, it is essential to briefly explain the extraction procedure prescribed in EN 12868. In EN 12868, while Solution B is basic solution (pH 9), Solution A was made acidic by adding hydrochloric acid in order to enable nitrosation process. Consequently, the amount of nitrosamines detected in Solution A is expected to have higher value than that of Solution B (nitrosatable substances = nitrosamines detected in Solution A - nitrosamines detected in Solution B). In this work, the pH of the 3% acetic acid solution was approximately 2-3, therefore both solutions were already in acidic pH from the earlier state of the migration step. Consequently, the N-nitrosatable substances migrated from the sample during the migration period were probably began nitrosation process immediately after leaching out leading to the result in a similar amount of NDBA detected in Solution A and Solution B. This finding suggested that when the acetic acid is used as the extraction medium instead of artificial saliva, N-nitrosamines and N-nitrosatable substances may not be reported separately.

3.3 Compliance to the EU directive

Since there is no distinct standard test method and specific requirement for N-nitrosamines and N-nitrosatable substances in rubber products except for teats and soothers, it is often that the limits set in EU Directive 93/11/EEC is required and the EN 12868 is therefore being referred. If this also applied to rubber latex gloves and assuming that some modifications on the migration conditions are allowed, the total N-nitrosamines and N-nitrosatable amines released from the products shall not exceed the limits as the following values:

0.01 mg (10 μg) in total of N-nitrosamines /kg of rubber glove
0.1 mg (100 μg) in total of N-nitrosatable substances/kg of rubber glove

Using data in Table 2, judgement for compliance to EU Directive are listed in Table 4.

It can be seen from Table 4 that by using different extraction media, the levels of the released N-nitrosamines and N-nitrosatable substances would be different and the judgment for the EU Directive compliance would consequently be affected. For example, when using artificial saliva as the extraction medium, only Sample NT1 complied with the EU Directive. However when alkaline and acid sweats were used, none of samples complied with the Directive.
Table 4. Levels of N-nitrosamines released from samples and judgements for the EU Directive compliance

| Sample | Compound                                      | Amount released, µg/g | Extraction medium |
|--------|----------------------------------------------|-----------------------|-------------------|
| NT1    | Total N-nitrosamines                        |                       | Saliva            |
|        |                                              | 2.3                   | Alk- sweat        |
|        |                                              |                       | Ac-sweat          |
|        | Compliance to EU Directive                   | Yes                   | 325               |
|        | Total N-nitrosatable substances              |                       | 2.8               |
|        |                                              |                       | 3% Acetic acid    |
|        | Compliance to EU Directive                   | No                    | Yes               |
| NT2    | Total N-nitrosamines                        | 12.3                  | No                |
|        |                                              |                       | No                |
|        | Compliance to EU Directive                   | Yes                   | 12.7              |
|        | Total N-nitrosatable substances              |                       | 9.2               |
|        |                                              |                       | Yes               |
|        | Compliance to EU Directive                   | No                    | Yes               |
| NR1    | Total N-nitrosamines                        | 20.7                  | No                |
|        |                                              |                       | No                |
|        | Compliance to EU Directive                   | Yes                   | 266               |
|        | Total N-nitrosatable substances              |                       | 40.9              |
|        |                                              |                       | Yes               |
|        | Compliance to EU Directive                   | No                    | No                |
| NR2    | Total N-nitrosamines                        | 11.2                  | No                |
|        |                                              |                       | No                |
|        | Compliance to EU Directive                   | No                    | 25.3              |
|        | Total N-nitrosatable substances              |                       | 40.8              |
|        |                                              |                       | Yes               |
|        | Compliance to EU Directive                   | No                    | No                |

3.4 Possible risks associated with the use of rubber gloves for handling food

An attempt had been made to evaluate risk associated with the use of gloves for food handling purposes. Two possible risks were considered, the first being the risk of glove user to exposure nitrosamines through skin contact and the second being the risk of food consumer to exposure nitrosamines by consuming nitrosamine-contaminated foods.

In order to estimate the level of nitrosamines released per one glove, data in Table 1 were used and the level of total N-nitrosamines and N-nitrosatable substances in Table 2 were re-calculated and the results are shown in Table 5.

Table 5. Levels of N-nitrosamines released from samples expressed in µg/gloves

| Sample | Compound µg/glove | Extraction medium |
|--------|-------------------|-------------------|
| NT1    | Total N-nitrosamines | 11                |
|        | Total N-nitrosatable substances          | 65                |
| NT2    | Total N-nitrosamines             | 448               |
|        | Total N-nitrosatable substances       | 2148              |
| NR1    | Total N-nitrosamines             | 105               |
|        | Total N-nitrosatable substances       | 18766             |
| NR2    | Total N-nitrosamines             | 408               |
|        | Total N-nitrosatable substances       | 910               |

Using data in Table 5 and further assuming that one is wearing one pair of glove, for example, sample NT1, and work continuously in food production line for four hours. In worst case scenario, the entire N-nitrosamine contents were migrated from gloves in which half of them penetrated into the wearer skin and another half migrated into food they are being contacted. With these assumptions, the first possible exposure of glove user to nitrosamines through skin contact was estimated to be a maximum of 58 µg N-nitrosamines [one pair of glove contains (53+5) x 2 µg, so half of them equal to 58 µg] for worker whose sweat is alkaline, or a maximum of 1608 µg N-nitrosamines (1548+60) for worker whose sweat is acidic. For the possible exposure of food...
consumer to N-nitrosamines by consuming nitrosamine-contaminated foods, it was estimated to be a maximum of 29 μg N-nitrosamines (16+13) for alcoholic foods, or a maximum of 20 μg N-nitrosamines (18+12) for acidic foods. By using the same assumptions outlined above the possible exposures to N-nitrosamines for food handling purposes could also be estimated for Sample NT2, NR1 and NR2.

Comparing to the data of dietary intake of nitrosamines reported by the German Nutrition Society (the Nutrition Report 1988) that, for adults, the intake of N-nitrosamines from foods was between 0.2 (women) and 0.3 (men) μg N-nitrosamines per day [21]. This can be then implied that the use of rubber gloves, NT1, NT2, NR1 or NR2 for food handling purposes under the most unfavorable circumstances could lead to the exceeding of dietary intake so that risks associated with using gloves for food handling purposes are considered high.

4. Conclusion
The effects of extraction media used for extraction of N-nitrosamines from rubber gloves made of natural rubber and nitrile rubber lattices have been investigated. Artificial saliva, artificial sweats (both alkaline and acid solutions) and aqueous food simulants (10 % ethanol and 3 % acetic acid) were used as the extraction media at the control migration condition i.e. temperature at 40 °C for 4 hours. It was found that the NDBA and its N-nitrosatable amine were detected in all samples with different levels depending on the extraction media used. NDMA, NDEA, and NMOR were occasionally detected in some samples also depending on the extraction media. For the rest of N-nitrosamines being analysed i.e. NDPA, NDiBA, NPIP, NPYR, NEPhA, NMPHA, NDiNA and NDBzA, they were not detected. The effect of extraction media on the migration of NDBA and its N-nitrosatable amine was closer looked. At the control migration, the power of extraction media are different for gloves made of nitrile rubber from gloves made of natural rubbers. For nitrile rubber gloves, the extractable NDBA were migrated to the extraction medium from artificial alkaline-sweat > acid-sweat >10% ethanol > 3% acetic acid and > artificial saliva. For their N-nitrosatable NDBA, the substances were migrated to the extraction medium from artificial acid-sweat > artificial saliva > 10% ethanol and > artificial alkaline-sweat. For natural rubber gloves, the released NDBA were detected with the highest to the lowest levels by extraction with 10% ethanol, alkaline-sweat/acid-sweat, 3% acetic acid and artificial saliva, respectively. For their N-nitrosatable substances, similar trends to those of nitrile glove samples were found except the swap order between the artificial acid-sweat and the artificial saliva. This finding leads to the conclusion that by using different extraction media, the levels of the released N-nitrosamines and N-nitrosatable substances would be different and the judgment for the EU Directive compliance would be consequently affected. An attempt had been made to evaluate risks associated with the use of these rubber gloves for food handling purposes. By comparing with data of daily intake of N-nitrosamines from foods reported by the German Nutrition Society, it can be concluded that the intake of N-nitrosamines resulted from using gloves in this study for food handling purposes under the most unfavorable circumstances could lead to the exceeding of dietary intake. This means that the possible risks associated with the use of rubber gloves for food handling are considered high.

Acknowledgement
The authors gratefully acknowledge The Department of Science Service, Ministry of Science and Technology, Thailand, for supporting this research activity.
References

[1] Mutsuka M et al 2013 Analysis of N-nitrosamine migration from rubber teats and soothers Am. J. Anal. Chem. 4 277

[2] Vieira E R et al 2006 Determination of N-nitrosamines and N-nitrosatable substances in rubber teats and soothers by GC-TEA Braz. Arch. Biol. Technol. 49 73

[3] Voloshenko A et al 2011 GC determination of N-nitrosamines by supersonic molecular beam MS equipped with triple quadrupole analyzer, GC/SMB/QQQ/MS Anal. Chim. Acta. 685 162

[4] Havery D C and Fabio T 1982 Estimation of volatile N-nitrosamines in rubber nipples for babies’ bottles. Food Chem. Toxicol. 20(6) 939

[5] Sen N P et al 1984 Volatile N-nitrosamines in baby bottle rubber nipples and pacifiers: Analysis, occurrence and migration IARC Sci. Publ. 57 51

[6] Sen N P et al 1985 Nitrosamines in baby bottle nipples and pacifiers: Occurrence, migration, and effect of infant formulas and fruit juices on in‘Vitro formation of nitrosamines under simulated gastric conditions J. Agric. Food Chem. 33 420

[7] Park S J et al 2018 Release of N-nitrosamines and N-nitrosatable substances from baby bottle teats and rubber kitchen tools in Korea. Food Sci Biotechnol. 9(52) 1

[8] Altkofer W et al 2005 Migration of nitrosamines from rubber products – Are balloons and condoms harmful to the human health? Mol. Nutr. Food Res. 49 235

[9] Proksch E 2001 Review Toxicological evaluation of nitrosamines in condoms Int. J. Hyg. Environ. Health. 204 103

[10] Bliaudet H et al 1997 Migration of nitrosamines from condoms to physiological secretions Bull. Environ. Contam. Toxicol. 59 847

[11] Feng D et al 2009 Detection and toxicity assessment of nitrosamines migration from latex gloves in the Chinese market Int. J. Hyg. Environ. Health. 212 533

[12] Feng D et al 2012 Evaluation of simulant migration of volatile nitrosamines from latex gloves and balloons by HS-SPME–GC–MS J. Chromatogr. Sci. 50 733

[13] Eng A H 2001 Effects of chlorination on nitrosamines and nitrosatable substances in natural rubber gloves J. Rubb. Res. 4(1) 11

[14] Fiddler W et al 1985 Investigation of volatile nitrosamines in disposable protective gloves Am. Ind. Hyg. Assoc. J. 46(8) 463

[15] Fiddler W et al 1998 Nitrosamine formation in processed hams as related to reformulated elastic rubber netting J. Food Sci. 63(2) 276

[16] Fiddler W et al 1992 Nitrosamines in rubber bands used for orthodontic purposes Food Chem. Toxicol. 30(4) 325

[17] Commission Directive 93/11/EEC 1993 Concerning the release of the N-nitrosamines and N- nitrosatable substances from elastomer or rubber teats and soothers

[18] U.S. Food and Drug Administration 1984 CPG Sec. 500.450 Volatile N-nitrosamines in rubber baby bottle nipples

[19] Bouma K and Schothorst R C 2003 Identification of extractable substances from rubber netting used to package meat products Food Addit. Contam. 20(3) 300

[20] Pensahebe J W and Fiddler W 1994 Gas chromatographic/thermal energy analyzer method for N-nitrosodibenzylamine in hams processed in elastic rubber netting J. AOAC Int. 77(4) 981

[21] BgvV 2002 Risk assessment of N-nitrosamines in balloons http://www.bfr-bund.de

[22] VWA/KW Report nr. ND04o063/02 Migration of N-nitrosamines and N-nitrosatable substances from latex balloons, January 2005 http://www.nwa.nl

[23] SCCP Opinion on the presence and release of nitrosamine and nitrosatable compounds from rubber balloons, December 2007 https://ec.europa.eu/health/home_en

[24] EN 12868:2017, Child use and care articles-Methods for determining the release of N-nitrosamines and N- nitrosatable substances from elastomer or rubber teats and soothers, European Committee for Standardization

[25] ISO 105-E04:2013, Textiles - Tests for colour fastness - Part E04: Colour fastness to perspiration, International Organization for Standardization, Geneva, Switzerland, www.iso.org

[26] ISO 3696:1987, Water for analytical laboratory use - Specification and test methods, International Organization for Standardization, Geneva, Switzerland, www.iso.org