Ionic Analysis of Common Beverages Spilled on Electronics

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Abstract
Electronics, especially mobile electronic items, are subjected to unintentional abuse by having various beverages spilled onto or into them. Ion Chromatography and emission spectroscopy were used to identify the common inorganic ions in various carbonated drinks, coffee, tea, milk, juices, beer, wine, hot chocolate and a well-known sports drink. Except for the carbonated drinks, the others were then intentionally spilled onto clean circuit boards, dried, extracted and re-analyzed. The results show that there is generally little change from the virgin materials using the IPC extraction method and thus a library of "usual suspects" can be accumulated for comparison purposes for electronic products that come back from the field.

Introduction
Any electronics manufacturer that does any warranty work is familiar with units coming back from the field that have had various encounters with commonly ingested liquids. The first two questions that need to be answered are:

1) Is the rework/repair covered by warrant?
2) What is the liquid in question?

Unfortunately when some customers know the answer to question number one is "no", they still try to sneak their electronic possession in "under the radar" and get it rejuvenated at the expense of the manufacturer. Over time this can be a very expensive proposition for the repair/rework depot. There is also the potential for bad publicity if the manufacturer cannot show that a defective product is not the cause of some inherent fault in the design or manufacture of the product. Knowing the identity of the root cause material in such instances is very important.

Question number two is just as critical. Is the material a corrosive acid or base, sea salt, a silicone, oil, beverage, or even a body fluid? Identification will allow the repair team to determine a disposition for the electronic article in question – scrap it or clean it and repair it. The present work deals with beverages but the method would be applicable to any ionic-containing fluid, like salt water, acids, bases or body fluids. Note that most labs in our industry will not deal with body fluids because of the lack of proper protocols to deal with the potential health issues relating to working with such materials.

There are many types of circuit board failures that are either initiated or exacerbated by the presence of an ionic contamination. The mechanisms of these failures always require three conditions: ions, water, and a voltage bias[1]. The ions can be deposited during the many production steps from board manufacture to assembly. In the latter case this can happen by finger prints, dirty/improper gloves, airborne particles, etc.[2] or, as in the case of this study, by a field contamination. Water can penetrate to the printed circuit board assemblies (PCBAs) in many ways, a liquid spilled on a device may leak through the casing joints or through the human interface openings (keypads) and onto the board or moisture from the air may condense onto the board in a high humidity environment or sea salt environment. It is usually impractical to make electronic devices that are completely waterproof, thus there will almost always be a path to carry water and contamination onto a circuit board assembly. The third condition, a voltage bias, is available virtually anywhere across an assembly. The bias between any two adjacent components is enough to initiate electrochemical interactions in the right conditions. The main types of contamination-provoked failures germane to the present discussion (there are others) are leakage/shorting, corrosion and electrochemical migration (ECM).

Current leakage and shorting are fairly simple failure mechanisms. When a liquid is spilled onto a board two things can happen. The solution may immediately cause a short by providing a highly conductive path across an insulated area. This will lead to an instant or 'catastrophic' failure. Current leakage occurs when a conductive solution draws small amounts of current from a component, affecting its functionality.

Corrosion is a problem typical to virtually all areas of engineering and technology. In the electronics industry in particular, corrosion is largely viewed as being completely unacceptable. This being said, oxidation and corrosion of most metal surfaces in all but completely clean and dry environments are unavoidable. Coatings and other such methods discourage these problems from developing to levels affecting conductivity and pre-assembly solderability, but there will always be

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some level of oxidation occurring across a PCB assembly. The type of corrosion that is of consequence in the context of this study is electrochemical corrosion. The presence of an electrical current will rapidly accelerate corrosion processes. Halides

such as fluoride, chloride, bromide and iodide are highly corrosive. Acids, of course, are also very corrosive and can be introduced to PCBs in many of the same ways as other ionic contaminants. It is important to remember that although this study covers only the usual ionic contaminants, weak organic acids such as malate are present in many of the drinks being studied. These acids, in large enough amounts, can lead to failures in much the same ways as ionic constituents. They are not covered in this study. Corrosion is a failure issue in-and-of itself; however, the same chemistry is an important first step in ECM failure mechanisms.

Electrochemical migration (ECM) is a category that includes a few related failure mechanisms. Dendritic growth and conductive anodic filament (CAF) formation are consequences of ECM. CAF will not be discussed in this paper. Dendrites form, for example, when copper is dissolved into solution and re-deposited as tree-like structures that can extend far enough across a surface to arc a current and cause a short.

Halides are the main concern for most contamination related failure mechanisms. There are a number of standard limits available for these ions and for total allowable ionic contamination of bare boards and assemblies; however, there is little known about the specific risks of other anions and ions in general. The industry accepted maximum level of ionic contamination is 1.56µg/cm^2 of NaCl or equivalent[3]. There are many other suggested limits from a number of sources. **Table 1** is a reproduction of a table compiled by C. Hillman[1] outlining some of the suggested maximum levels of chloride and bromide contamination.

Table 1 Maximum chloride and bromide contamination levels

Ion	Bumiller[8]	Pauls[9]	GE[10]	NDCEE[11]	IPC[12]	DoD[13]
Chloride (µg/cm^2)*	0.31	0.31	0.54	0.70	0.95	0.95
Bromide (µg/cm^2)*	1.6	3.1	1.6	2.3	1.2	1.2

*converted from µg/in^2

Experimental

Sixteen beverages were chosen for this study to reflect likely sources of contamination in the field. All of the samples chosen are common drinks that may be spilled on an electronic device. The brand of drinks used were selected because of their market prevalence or because they are a good representative of the drink subgroup. The following samples (See **Figure 1**.) were analyzed in this study:

Coca-Cola™
Pepsi Cola™
Dr. Pepper™
Sprite™
Barq's Root Beer™
Canada Dry Ginger Ale™
Starbuck's™ Coffee
Red Rose™ Tea
Minute Maid™ Apple Juice
Tropicana™ Orange Juice
Heinz™ Tomato Juice
Wolf Blass™ Wine
Alexander Keith's India Pale Ale™
Nestle Carnation™ Instant Hot Chocolate
Gatorade™ Sports Drink
Milk (2%)

Figure 1 Some of the materials analyzed in the present study for ionic content

This study is limited to the common inorganic ions. Because of this and in order to prevent damaging the IC column and other equipment, all samples had to be cleaned of any sugars and other organics. Organics were removed by solvent

extraction using dichloromethane (DCM). Most of the above listed samples were centrifuged and filtered before extraction to remove any suspended solids which might cause the formation of a large stable emulsion or third phase. Following filtration through 0.2 micron syringe filters, 50mL of each sample was put into a clean separatory funnel, about 60mL of DCM was added, the mixture shaken, the organic and aqueous layers were allowed to separate and then the bottom (organic) layer was discarded. The top (aqueous) layer, containing the inorganic ionic material of interest, was again shook with ca. 60mL of DCM. This procedure was repeated once more with ca. 40mL of DCM or until the organic layer showed no further sign of extractant.

All of the samples were then analyzed by IC and ICP-OES to elicit their ionic compositions. Anions were analyzed using IC and included fluoride, chloride, bromide, nitrite, nitrate, sulfate and phosphate. Cations were analyzed using ICP-OES and included sodium, potassium, magnesium, calcium and iron. Calibration standards were prepared from individual ion standard solutions and purified 18.2MΩcm Mill-Q water. Reference standards were prepared from separately sourced standard solutions. Every extraction was carried out in parallel to a Milli-Q water blank. All blanks were prepared as samples and analyzed to assess method contamination.

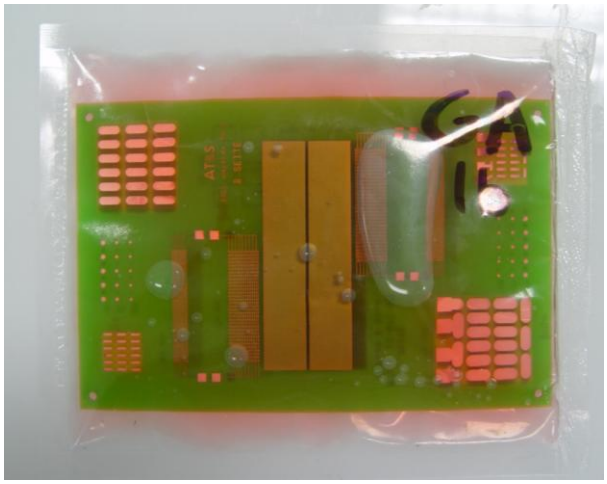
The IC system used consisted of a Dionex GP40 gradient pump coupled with a CD20 conductivity detector. A Dionex ASRS-ULTRA II 4mm suppressor was used to produce a more stable baseline. The stationary phase was an IonPac AS14A 4X250mm Dionex column equipped with an AG14A guard. An aqueous 8mM Na_2CO_3/1mM $NaHCO_3$ mobile phase was prepared by weight from EM Science dry chemicals. A three point linear calibration was used to calibrate the system with 1, 5, and 10ppm standard solutions. A volume of 34.5µL of each sample was injected and run isocratically through the chromatagraph for up to twelve minutes. Each sample batch was run between sets of three reference standards at 1, 5 and 10 ppm concentration. Samples were first analyzed at 100X dilutions and were further concentrated as necessary to resolve those analytes present in lower concentrations.

Cation detection and quantitation was achieved using a Perkin Elmer Optima 3000DV ICP with optical emissions detection. Samples were prepared in a 2% nitric acid aqueous medium at 10, 100 and 1000X dilutions. Calibration standards were run along with samples. A two point calibration was done with these standards at 1ppm and 10ppm. For Ca, Mg, Na, K and Fe two calibration standards were prepared. One contained 1 ppm of each element listed above, except 0.1 ppm of iron, while the other standard had ten times as much of each. A single verification standard was also run along with the samples at the middle point of 0.5ppm for Fe and 5ppm for the other cations.

The final portion of the study was to investigate what ions could be found from the residues of the above materials (excluding the carbonated drinks) spilled and dried onto circuit boards. The boards used were single-sided 11x17 cm FR4 PCBs. Five milliliters of each sample was spilled on individual PCBs using a volumetric pipettor to evenly distribute the contaminant across their surface. Each board was then baked at 50°C for twelve hours to dry the contaminants. After drying, the contamination was extracted using the IPC standard test method for ionic analysis of circuit boards[4]. Each board was placed in a heat sealable 500 series KAPAK® bag (claimed to have less than 250 ppb extractable materials on the packaging). Before sealing, 100mL of 60/40 IPA/H_2O extraction solution was added to each bag. The sealed bags were then immersed in an 75°C water bath for one hour to extract all surface contamination into solution. See **Figures 2 & 3**.

Following this extraction, 10mL of solution from each bag was decanted into 15mL tubes. Most of the IPA was evaporated from the solutions. This was achieved using a VWR standard heating block with clean, dry air blown across samples. Each 10mL sample was taken down to 1mL and then diluted back to 10mL with Milli-Q water. Drying was repeated to 1mL after which the solutions were again brought to 10mL with Milli-Q water. IPA removal is necessary to correct the baseline well as to ensure that samples are in the same solvent mix as reference and calibration standards. All of these extracted samples were then analyzed in the same way as the blank samples using IC and IPC-OES. Samples were run along with method blanks acquired from the extraction of clean PCBs.

In order to assess the cleanliness and repeatability of the experimental methods used in the course of this study, certain quality control measures were implemented. For every procedure, blanks were run to determine if the samples were being contaminated during any of the method steps. For the first part of the study, the analysis of the original materials, six blanks were prepared from the DCM extraction step through to analysis. None of the blanks run through the IC showed any traces of the seven analyte anions. One blank however exhibited a very small peak at a retention time of 4.8min. The blank was analyzed again and the unknown peak persisted. A similar peak was observed in some of the samples; however, it was decided that this contamination was of little consequence as it is present in very small concentrations and does not coincide with any analyte peaks.



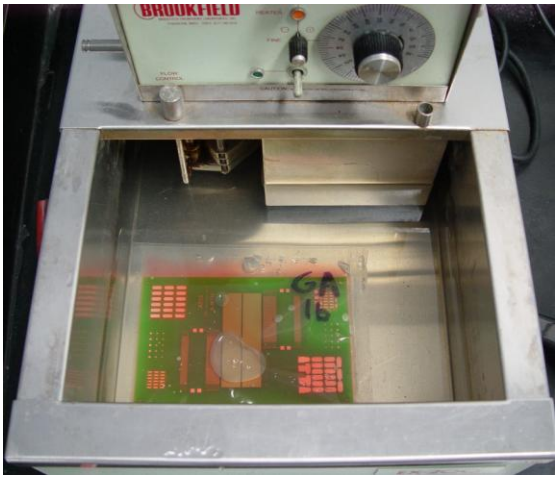


Figure 2 Contaminated board in extraction solution **Figure 3 Extraction process in 80°C water bath**

Also, it is possible for organic ions which have made their way into the column to present themselves intermittently during sample analysis as they have very long relative retention times which may span several of the 12 min method runs. This was a problem during the second part of the study, board extract analysis. These samples were a little dirtier than the first samples run because they didn't undergo a DCM extraction. Any of these samples which presented a large unknown peak on their chromatagrams were rerun to push the organics through. A second run always presented a proper chromatogram. No degradation or plugging of the columns was found from analyzing the board extracts.

The same six blanks from part one were also analyzed with the ICP for cation contamination. This time it was clear that the samples had been contaminated somehow. All six blanks consistently showed potassium and sodium concentrations of 1-5ppm. The source is, as yet, unknown. The contaminant concentration seemed to gradually diminish over successive blanks; this would suggest that the contamination is slowly being washed away. See **Figure 4**. The blank Na^+ and K^+ concentrations were averaged and subtracted from sample concentrations (1.33ppm for K^+ and 3.12ppm for Na^+). For the most part this adjustment had little significance considering that the majority of samples had K^+ and Na^+ concentrations which were at least two orders of magnitude larger than the contamination. The only two samples, in fact, which were significantly affected, were coffee and tea. Both of these samples presented Na^+ concentrations which were very near to the averaged contamination factor. It was assumed that the Na^+ component of these samples was nothing more than an artifact of contamination and the Na^+ concentrations were considered to be zero.

The blanks from part two of the study showed insignificant amounts of cation contamination. However, a small amount of analyte anions were detected in the blanks from the IC run. These samples presented discernable levels of chloride, bromide and nitrate. The contamination was very close to detection limits and had little impact on results. The chloride and bromide ions were most likely dissociated from the board laminate epoxy material. The epoxy is composed in large part of fire retardant bromine compounds. Chloride can be present in small amounts in the glass fibers used to reinforce the epoxy matrix of the PCB[1], but a more likely source is the dichloromethane. It has also found that Kapak bags may leach chloride and nitrate into solution during extraction[5].

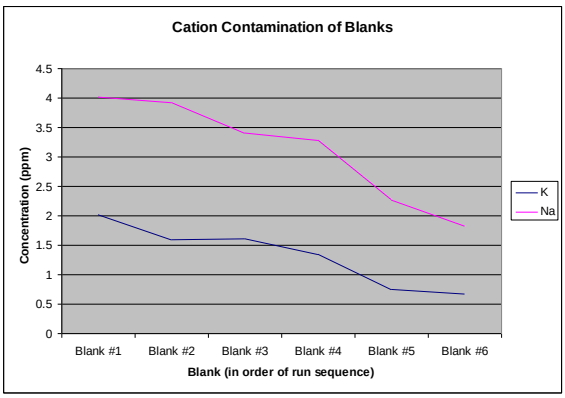


Figure 4 Cation contamination of part one blanks

Reference standards were run alongside samples to ensure that the instruments had been calibrated correctly and that the equipment did not drift over time. Four sets of 1, 5 and 10 ppm reference standards were run for IC anion analysis. The average results over each set of these four reference standards are plotted against the expected values for each ion in **Figure 5**. The reference standards show a slightly higher concentration than expected. Despite this, the standards show little variation, making the calibration acceptable for comparison of results. The highest standard deviation over any standard level for any ion was 9% from the sample mean. The ICP was externally calibrated with calibration standards analyzed during runs. Only one verification standard was needed to confirm a good calibration. The results from two of these standards, one from each run, are plotted against their expected value in **Figure 6**.

Duplicate samples were used to investigate the repeatability of experimental methods. Duplicates of the apple juice and tomato juice samples were prepared for part one of the experimental. The results, outlined in **Table 2**, illustrate an acceptable level of variation between samples. Only tomato juice was selected to run as a duplicate in the second part of the study because it contains the largest number of ions of any sample. These duplicates also exhibited an excellent level of correlation. It can be concluded that the experimental methods used are also sufficiently repeatable.

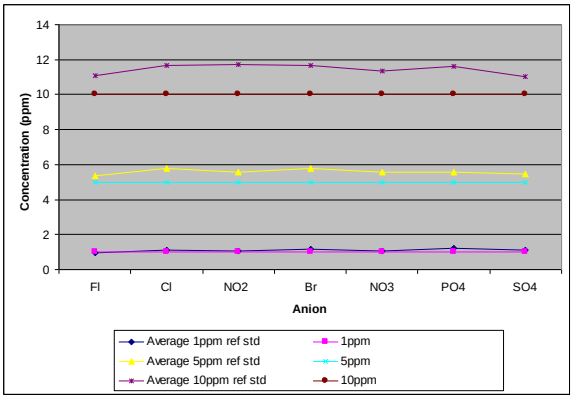


Figure 6 Results from ICP reference standards

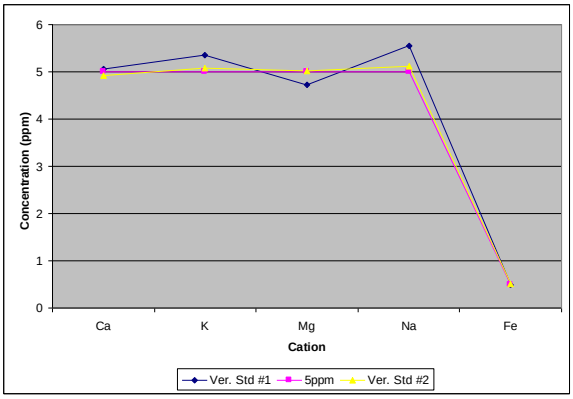


Figure 5 Results from IC reference standards

Table 2 Ion Concentrations collected from duplicate samples

	F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{-3}	SO_4^{-2}	Ca^{+2}	K^+	Mg^{+2}	Na^+	Fe^{+x}
Apple juice 1	165	81.5	0	0	0	3410	3.08	66.4	1080	45.6	4980	0.888
Apple juice 2	151	55.5	0	0	0	3350	3.01	66.0	1070	45.3	4840	0.867
Tomato juice 1	37.0	6920	0	45.0	0	446	151	45.8	1920	79.0	2740	15.8
Tomato juice 2	45.0	7260	0	46.0	0	542	166	49.3	2000	84.9	2880	17.2

Results and Discussion

In Part One the concentrations of all twelve analyte ions in each of the sixteen beverages were obtained. These ion concentrations are listed in **Table 3**. The concentrations found for the same ions in the extraction solutions obtained in Part Two are presented in **Table 4**. These concentrations have been adjusted for their effective dilution factor in extraction solutions (multiplied by 20) to better reflect correlations to the part one results.

It is an interesting aside to look at some of the data with regards to possible nutritional value. Apple juice and wine have the highest concentrations of fluoride. It is no surprise that milk has the most calcium – by a factor of ten. Tomato juice has the most iron and tomato juice and milk have the most potassium. Another surprise, but no if one really thinks about it, is that the highest level of sodium chloride is in the tomato juice.

In a few cases, the ionic content for the original materials from their containers and the ionic content of the corresponding sample extracts agree fairly well. This can be seen in the chromatograms in **Figure 7** for tomato juice and in the relative concentration charts for tomato juice and wine in **Figure 8**. Similar graphs could be constructed for the anions in milk, hot chocolate and beer. The same can be said for cations in coffee, Gatorade, milk and wine. For the ions the best agreement was for nitrate, nitrite, bromide and iron.

As expected, most of the differences between the original material and the extracts were caused by ions being apparently leached from the circuit boards. Only differences of greater than 30% are highlighted by color in **Table 5** below. If one also

ignores differences less than 1 ppm absolute, then the percentages for iron can also be ignored. The other three triple digit percentage values and the one highlighted decrease in percentage will be discussed here. For coffee the phosphate concentration goes from 147 ppm in the virgin material to 326 ppm in the extract, while equivalent concentrations of sodium in apple juice (AJ) and orange juice (OJ) jump from 50 to 113 ppm (AJ) and 21 to 69 ppm (OJ).

No definitive explanation for these anomalous increases can be given at this time. It could be surmised that in the case of the orange juice that a large portion of the ions of the virgin material was captured in solid materials that did not precipitate out in the centrifuging, but were removed in the dichloromethane extractions. There were of course no similar extractions of the

Table 3 Results from part one, analysis of virgin samples. (concentrations in ppm)

	F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{-3}	SO_4^{-2}	Ca^{+2}	Fe^{+2}	K^+	Mg^{+2}	Na^+
Canada Dry	0.65	39.49	na	na	na	0	36.92	na	na	2.49	5.00	56.2
Sprite	0.45	38.16	na	na	na	0.46	26.45	na	na	2.30	6.00	166
Barqs	3.48	37.65	na	na	na	0	13.64	na	na	2.45	5.10	143
Pepsi	2.58	40.00	na	na	na	774	82.2	na	na	32.90	2.41	23.7
Coca-Cola	3.15	37.00	na	na	na	977	47.2	na	na	1.78	5.14	25.0
Dr Pepper	2.91	5.43	na	na	na	619	15.6	na	na	11.30	0.27	67.4
Apple J	158	68.5	0	0	18.3	3380	152	66.2	0.878	1080	45.5	49.8
Beer	0	442	0	0	0	349	103	60.3	0	370	70.6	38.3
Coffee	81	13.4	0	9.8	9	147	25	16	0	897	47.8	0
Gatorade	12.5	539	0	0	0	305	11.6	6.45	0	151	0	504
Hot choc.	0	1860	0	0	0	817	52.5	29.4	0	1140	36.1	1450
Milk	0	2980	0	182	0	3310	296	587	0.115	1790	103	573
Orange J	62.5	99	10.5	16	24	2080	115	99.7	0.744	1760	107	21.1
Tea	16.1	6.75	0	0	0	28.3	11.3	2.86	0	107	8.09	0
Tomato J	41	7090	0	45.5	0	494	159	47.6	16.5	1960	82	2810
Wine	122	187	0	0	0	771	298	68.1	0.396	1120	127	79.5

Table 4 Results from part two, analysis of board extracts. (concentration in ppm; multiplied by 20)

	F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{-3}	SO_4^{-2}	Ca^{+2}	Fe^{+2}	K^+	Mg^{+2}	Na^+
Apple J	209	75.5	0	0	17.5	3080	144	113	1.05	2070	83.4	113
Beer	0	480	0	0	0	318	114	63.7	0	443	88.2	55.4
Coffee	115	16.2	0	11.0	7.60	326	18.2	16.2	0	971	50.6	0
Gatorade	11.8	525	0	8.80	8.00	418	9.80	5.00	0	142	0	456
Hot choc.	0	1460	0	0	0	789	39.0	31.5	0	1740	47.9	1750
Milk	0	2780	0	171	0	3360	276	490	0.365	1670	133	461
Orange J	101	148	0	0	0	2720	135	175	1.33	3440	189	69.3
Tea	19.4	13.2	0	4.80	9.60	41.0	16.8	4.88	0	172	11.5	0
Tomato J	35.0	7210	0	45.0	0	517	159	21.8	17.5	3280	67.4	4750
Wine	135	211	0	0	0	914	321	54.6	0.283	891	105	67.6

Table 5 ([Extract]*20- Virgin Material])/[Virgin material] in %

	F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{-3}	SO_4^{-2}	Ca^{+2}	Fe^{+2}	K^+	Mg^{+2}	Na^+
Apple J	32%	10%	0%	0%	-4%	-9%	-5%	71%	20%	92%	83%	127%
Beer	0%	9%	0%	0%	0%	-9%	11%	6%	0%	20%	25%	45%
Coffee	42%	21%	0%	12%	-16%	122%	-27%	1%	0%	8%	6%	0%
Gatorade	-6%	-3%	0%	0 to 9 ppm	0 to 8 ppm	37%	-16%	-22%	0%	-6%	0%	-10%
Hot choc.	0%	-22%	0%	0%	0%	-3%	-26%	7%	0%	53%	33%	21%
Milk	0%	-7%	0%	-6%	0%	2%	-7%	-17%	217%	-7%	29%	-20%
Orange J	62%	49%	11 to 0 ppm	16 to 0 ppm	24 to 0 ppm	31%	17%	76%	79%	95%	77%	228%
Tea	20%	96%	0%	0 to 5 ppm	0 to 10 ppm	45%	49%	71%	0%	61%	42%	0%
Tomato J	-15%	2%	0%	-1%	0%	5%	0%	-54%	6%	67%	-18%	69%
Wine	11%	13%	0%	0%	0%	19%	8%	-20%	-29%	-20%	-17%	-15%

material taken from the dried circuit boards. It could also be that the low pH of the orange juice was responsible for the extraction of especially the cations. Orange juice is the only beverage in table 5 that showed increases of more than 50% for all cations. Also not explainable is the large decrease in calcium concentration for tomato juice (48 to 22 ppm).

Variations in extract ion concentrations may compromise the ability of the data to differentiate between samples based on nominal concentrations alone. Relative ion concentrations however should remain the same regardless of a change in total concentration, unless large leaching/adsorption/absorption processes come into play. In fact, when examining a residue contamination on a board, it will never be possible to reference the original concentration of a solution that has deposited the contaminant. In failure analysis it will only ever be practical to assess the relative proportions of ions extracted from a board when trying to characterize a contamination.

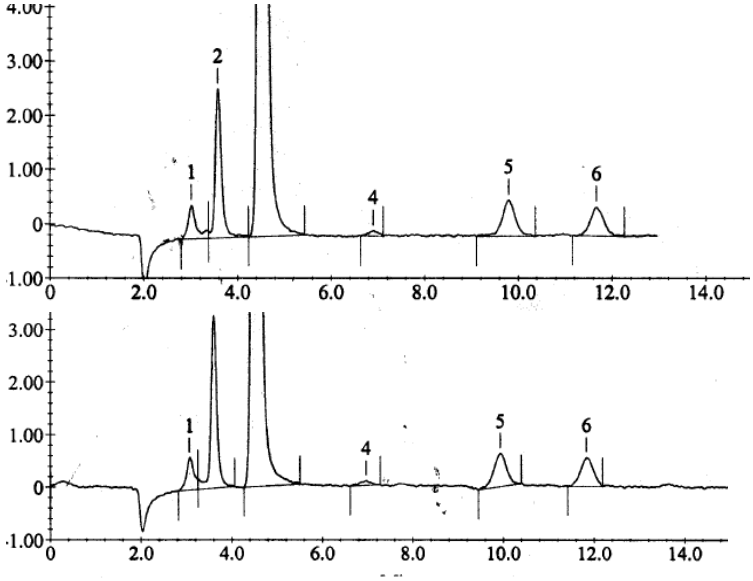


Figure 7 Top: The ion chromatogram (Conc. as a function of elution time) generated by the analysis of the straight tomato juice sample from part one. Fluoride (1), chloride (3), bromide (4), phosphate (5) and sulfate (6) are present in this sample as well as an unknown ion (2). Bottom: The ion chromatogram of the extracted tomato juice sample matches the above chromatogram almost perfectly.

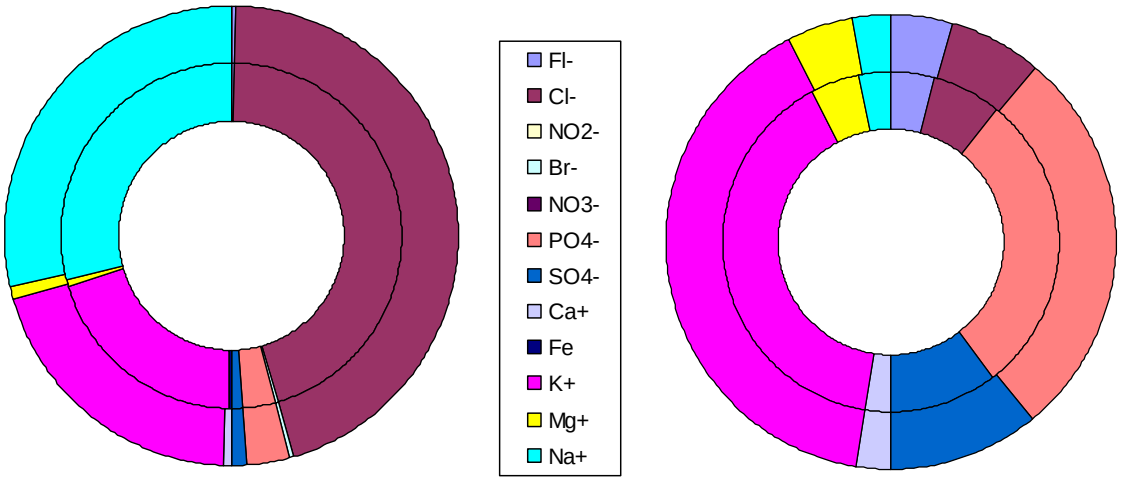


Fig 8 Charts of relative ion concentrations calculated for tomato juice (left) and wine (right) from Part One results (outside) and Part Two results (inside).

Examination of the data shows that the relative ordering of the concentrations of anions for the different materials does not change for: beer, coffee, hot chocolate, milk or wine. For Gatorade, tea and tomato juice the ordering only changes for the ions of least concentration. Only for orange juice does the ordering of chloride and sulfate change. The original difference is less than 20 ppm in about a 100 ppm. When the results are stated in terms of relative concentrations it becomes much easier to identify correlations between the two sets of data. The larger ion concentrations of a particular sample provide a better indicator for identification because the ions of lower concentrations have a greater tendency for variation.

A better strategy to quickly distinguish between multiple possible contaminants may be to compare ion ratios. For example, **Table 6** shows some ion ratios for the most commonly occurring ions in both sample sets. With as little as three independent ratios for comparison, the non-carbonated beverages can be conclusively distinguished. A flow chart based on this is shown in **Figure 9**. Many similar charts have been generated for all liquids, but are not reproduced here.

Table 6 Ratios of selected ions in part one and part two samples.

		apple	beer	coffee	Gator-ade	hot choc.	milk	orange	tea	tomato	wine
SO_4^{2-}/PO_4^{3-}	part 1	0.045	0.295	0.170	0.038	0.064	0.089	0.055	0.399	0.322	0.387
	part 2	0.047	0.358	0.056	0.023	0.049	0.082	0.050	0.410	0.308	0.351
F^-/Cl^-	part 1	2.309	0.000	6.043	0.023	0.000	0.000	0.633	2.385	0.006	0.652
	part 2	2.771	0.000	7.098	0.022	0.000	0.000	0.681	1.469	0.005	0.640
Na^+/K^+	part 1	0.046	0.103	0.000	3.338	1.272	0.320	0.012	0.000	1.434	0.071
	part 2	0.055	0.125	0.000	3.211	1.006	0.276	0.020	0.000	1.448	0.076

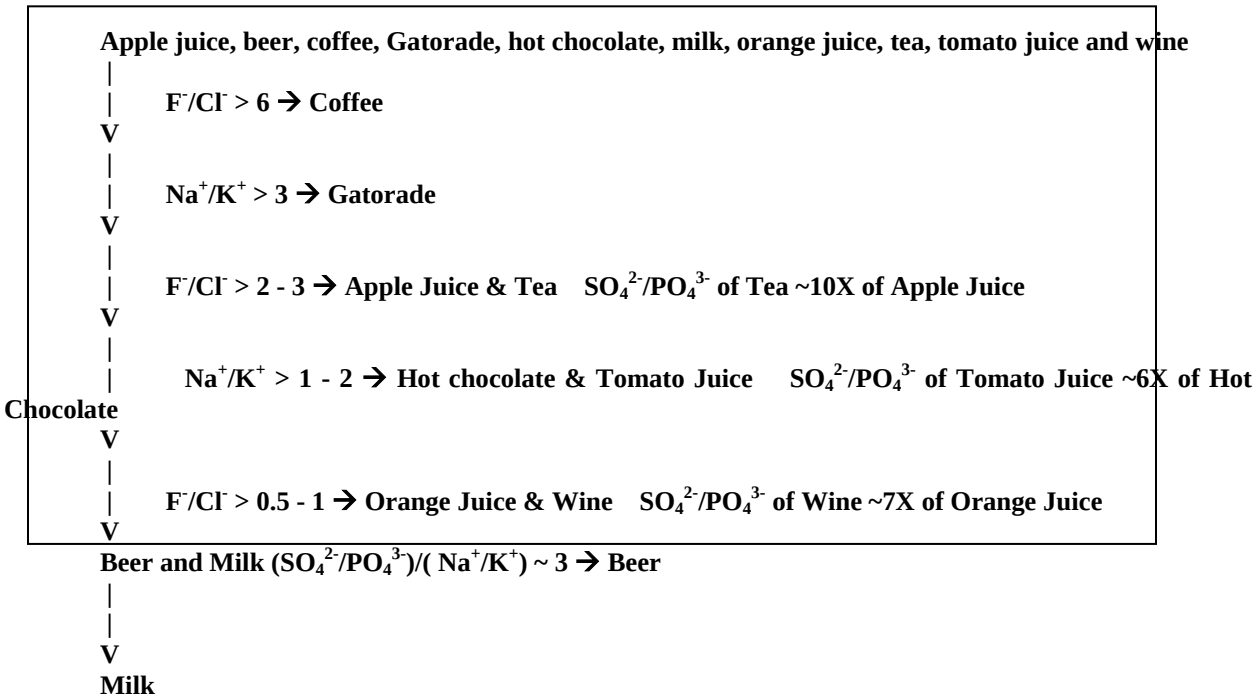


Figure 9 Flow Chart for identifying materials based only on three ion ratios

Conclusions

The work performed shows that ion chromatography and ICP-OES are good techniques for determining the ionic content in common beverages spilled onto and into electronics. A method of separating ionic compounds from covalent compounds was described in some detail.

Looking at the chromatograms, ionic concentrations and/or ionic concentration ratios allows one to determine which material one is analyzing. The exposure of the ionic-containing materials to printed circuit boards (at least ours) does not change them enough that they cannot be identified when they are dissolved back into solution for the circuit boards. It has also been determined that the dried beverages do not destroy the IC column when the dried residue on the circuit board is taken back up into solution to be separated ionically on the IC column.

Further work will be done to determine to corrosive effect of these materials on printed circuit boards and printed circuit packs.

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