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Report on the composition of prevalent salt varieties

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Summary

More and more specialty salts are available in the Swiss market and presumably also in other European countries. They are often marketed as being more natural and having special compositional, nutritional and health properties compared to normal table salt. However, not much is known about the composition of such salts other than their sodium chloride content. Consequently, the Swiss Federal Food Safety and Veterinary Office has analysed a wide variety of salts available in Switzerland, many of which are marketed to be particularly healthy.

In total, 25 different salts have been analysed. The mineral and trace element content of the salts was measured by three different spectroscopic methods. In addition, chlorine was measured by argentometric titration. To judge the nutritional and health relevance of the salts, the measured amounts have been compared with the recommended, respectively tolerable, intake levels of an average adult person of 60 kg body weight.

In general, standard salts, including rock and sea salt varieties, are of purer composition than specialty salts. Their average sodium chloride content ranges around 99%. Specialty salts on the other hand contain higher amounts of other elements which leads to a mean sodium chloride contents of 94%.

Many nutrients could not be detected at all, also in specialty salts, which means they are not present or only at levels below the detection limits of the chosen analytical methods. The ones that could be detected, are mostly present in levels which do not have any nutritional relevance. With a few exemptions they add less than 2% to the recommended daily intake levels. The three main exemptions are iron in Himalaya, Kala Namak and Bamboo salts, potassium in Persian salts and iodine in fortified salts.

As well as nutrients, many contaminants are either not present or only below detection levels. Most contaminants do not even reach 1% of tolerable intake levels. This is true particularly for standard rock and sea salts. Specialty salts generally contain higher amounts of contaminants.

All analysed salts are first and foremost salts and consist of between 83% to 99% sodium chloride. The additional elements – nutrients and contaminants – are present in trace levels which in the case of nutrients have no nutritional relevance or in the case of contaminants do not pose a health risk. Even more so, as salt is consumed in much smaller quantities compared to other foods.

This report clearly shows that specialty salts do not possess any advantages over standard salts. On the contrary, due to their low to inexistent iodine levels they cannot and should not routinely replace iodised table salts. Health professionals, food manufacturers and the general public should be or become aware about these facts.

In summary, even though specialty salts represent no appreciable risk from a toxicological viewpoint, they do not possess relevant beneficial nutritional properties to be recommended as a standard choice of salt.

Zusammenfassung

Auf dem Schweizer Markt und auch in anderen europäischen Ländern werden immer mehr Spezialitätensalze angeboten. Diese Salze werden oftmals als natürlicher als gewöhnliches Tafelsalz angepriesen. Zudem werden ihnen aufgrund ihrer Zusammensetzung spezielle gesundheitliche und ernährungsphysiologische Wirkungen nachgesagt. Allerdings ist wenig über die Zusammensetzung dieser Salze bekannt, mit Ausnahme ihres Gehalts an Natriumchlorid. Aus diesem Grund hat das Bundesamt für Lebensmittelsicherheit und Veterinärwesen diverse in der Schweiz erhältliche Salze analysiert, speziell solche, die als besonders gesund angepriesen werden.

Insgesamt wurden 25 verschiedene Salze analysiert. Deren Mineralstoff- und Spurenelementgehalte wurden mit drei verschiedenen spektroskopischen Methoden gemessen. Zusätzlich wurde Chlor durch argentometrische Titration bestimmt. Um abzuschätzen, welche Bedeutung die Salze für Ernährung und Gesundheit besitzen, wurden die gemessenen Mengen mit den empfohlenen bzw. tolerierbaren Aufnahmemengen einer erwachsenen Person von 60 kg Körpergewicht verglichen.

Gewöhnliche Stein- und Meersalze haben eine reinere Zusammensetzung als Spezialitätensalze. Ihr durchschnittlicher Gehalt an Natriumchlorid beträgt rund 99%. Spezialitätensalze hingegen enthalten höhere Mengen anderer Elemente und daher durchschnittlich nur rund 94% Natriumchlorid.

Viele Nährstoffe konnten in keinem der Salze nachgewiesen werden, was bedeutet, dass sie nicht in den Salzen enthalten sind oder nur in Mengen unterhalb der Nachweisgrenze der verwendeten Analysemethode. Jene, welche bestimmt werden konnten, sind meist in Mengen enthalten, die keine ernährungsphysiologische Bedeutung besitzen. Mit wenigen Ausnahmen tragen sie weniger als 2% zu den empfohlenen Tagesmengen bei. Die drei wichtigsten Ausnahmen sind Eisen in Himalaya, Kala Namak und Bambus Salzen, Kalium in Persischen Salzen sowie Jod in angereicherten Salzen.

Bei den Kontaminanten zeigt sich dasselbe Bild, sie sind entweder nicht vorhanden oder nur in Mengen unterhalb der Nachweisgrenze. Die meisten gemessenen Kontaminanten erreichen nicht einmal 1% der tolerierbaren Aufnahmemengen. Dies ist vor allem bei gewöhnlichen Stein- und Meersalzen der Fall. Spezialitätensalze hingegen enthalten höhere Mengen an Kontaminanten.

Alle analysierten Salze bestehen vor allem aus Salz und enthalten zwischen 83% und 99% Natriumchlorid. Alle weiteren Elemente – Nährstoffe wie auch Kontaminanten – sind nur in Spuren zu finden und besitzen weder ernährungsphysiologische Bedeutung noch stellen sie ein Gesundheitsrisiko dar. Insbesondere, da Salze in viel kleineren Mengen als andere Lebensmittel konsumiert werden.

Dieser Bericht zeigt eindeutig, dass Spezialitätensalze keine Vorteile gegenüber gewöhnlichen Salzen aufweisen. Im Gegenteil, wegen ihres geringen bis inexistenten Jodgehaltes sollten sie gewöhnliches jodiertes Salz nur ausnahmsweise ersetzen. Gesundheitsfachleute, Lebensmittelproduzenten und die allgemeine Bevölkerung sollten sich dessen bewusst sein bzw. darüber aufgeklärt werden.

Zusammenfassend kann gesagt werden, dass Spezialitätensalze aus toxikologischer Sicht kein Gesundheitsrisiko darstellen und keine nennenswerten ernährungsphysiologischen Eigenschaften besitzen. Daher können sie nicht für die alltägliche Verwendung beim Kochen und Würzen empfohlen werden.

Synthèse

Toujours plus de sels spéciaux sont proposés sur le marché suisse et probablement dans d'autres pays européens. Ces sels sont souvent présentés comme plus naturels que le sel de table traditionnel. On leur prête aussi des propriétés spéciales concernant leur composition ou leurs aspects sanitaires et nutritionnels. On ne sait presque rien sur leur composition excepté leur teneur en chlorure de sodium. Raison pour laquelle, l'Office fédéral de la sécurité alimentaire et des affaires vétérinaires (OSAV) a analysé différents sels en vente en Suisse et en particulier ceux qui sont décrits comme étant particulièrement bons pour la santé.

L'OSAV a analysé 25 sels. Il a mesuré leur teneur en sels minéraux et en éléments traces à l'aide de trois méthodes spectroscopiques. Il a déterminé, en outre, leur concentration en chlore par titration argentimétrique. Pour estimer les valeurs nutritionnelle et sanitaire de ces sels, l'OSAV a comparé les concentrations mesurées et les doses journalières recommandée ou tolérée pour un adulte de 60 kg.

La composition des sels gemmes et des sels marins habituels est plus pure que celle des sels spéciaux : leur teneur moyenne en chlorure de sodium est d'environ 99%. Les sels spéciaux, en revanche, présentent des concentrations plus élevées en d'autres éléments et seulement quelque 94% de chlorure de sodium en moyenne.

De nombreux nutriments recherchés n'ont été décelés dans aucun de ces sels. Cela signifie que ces nutriments sont soit absents soit présents en quantités si faibles qu'elles ne sont pas détectables par la méthode d'analyse utilisée. Les nutriments décelés étaient généralement présents en quantités si faibles qu'elles n'ont pas de signification nutritionnelle. À quelques exceptions près, les nutriments décelés représentaient moins de 2% de la quantité journalière recommandée. Les trois principales exceptions sont le fer, présent dans les sels Himalaya, Kala Namak et Bambus, le potassium présent dans les sels de Perse ainsi que l'iode présent dans les sels enrichis.

On observe le même tableau pour les contaminants: ils sont soit absents, soit présents en quantités inférieures à la limite de détection. La plupart des contaminants mesurés étaient présents en quantités qui n'atteignaient pas 1% de la dose journalière tolérable. C'était le cas notamment des sels gemmes et marins habituels. Les sels spéciaux, en revanche, contenaient des quantités de contaminants plus élevées.

Tous les sels analysés se composent principalement de sel: ils contiennent entre 83% et 99% de chlorure de sodium. Tous les autres éléments – nutriments et contaminants – sont présents sous forme de traces; ils n'ont pas de signification nutritionnelle et ne présentent pas de danger pour la santé, d'autant moins que les sels sont consommés en quantité bien plus faible que d'autres denrées alimentaires.

Ce rapport montre clairement que les sels spéciaux ne présentent aucun avantage par rapport aux sels traditionnels. Au contraire, en raison de leur teneur en iode, faible ou inexistante, ils ne devraient remplacer le sel iodé traditionnel qu'à titre exceptionnel. Il faudrait que les spécialistes de la santé, les producteurs d'aliments et la population le sachent ou en soient informés.

En résumé, on peut dire que d'un point toxicologique les sels spéciaux ne présentent pas de risque pour la santé, mais ils n'ont aucune propriété nutritionnelle notable et ne devraient, par conséquent, pas être recommandés pour un usage quotidien pour la cuisson ou l'assaisonnement.

Sintesi

In Svizzera e probabilmente anche in altri Paesi europei sul mercato è disponibile un numero sempre maggiore di sali speciali, generalmente pubblicizzati come più naturali rispetto al sale da tavola convenzionale. Inoltre, spesso si attribuiscono loro una particolare composizione e proprietà benefiche e fisiologico-nutrizionali. In realtà, oltre al tenore di cloruro di sodio, non si conosce molto della composizione di questi tipi di sale: per tale motivo l'Ufficio federale della sicurezza alimentare e di veterinaria ne ha analizzati diversi disponibili in Svizzera, molti dei quali pubblicizzati come particolarmente sani.

In totale sono state analizzate 25 varietà diverse di sale, misurandone il tenore di minerali e microelementi con tre metodi spettroscopici differenti e rilevandone la quantità di cloro tramite titolazione argentometrica. Al fine di determinare l'importanza di queste varietà di sale per l'alimentazione e la salute, è stato effettuato un confronto tra le quantità misurate e i livelli raccomandati o tollerabili per un adulto di 60 kg di peso.

In generale il sale convenzionale, tra cui il salgemma e il sale marino, presenta una composizione più pura rispetto ai sali speciali. Il loro tenore medio di cloruro di sodio è pari al 99 % circa, mentre nei sali speciali, a causa della presenza più elevata di altri elementi, è del 94 % circa.

Molte sostanze nutritive non sono state rilevate in nessuna varietà di sale, e ciò indica che esse non sono presenti oppure sono presenti a livelli inferiori alla soglia di rilevamento del metodo analitico applicato. Le sostanze nutritive individuate sono perlopiù presenti in quantità irrilevanti dal punto di vista fisiologico-nutrizionale e, con poche eccezioni, contribuiscono alla dose giornaliera raccomandata per meno del 2 %. Le tre eccezioni più importanti sono il ferro nel sale dell'Himalaya, nel Kala Namak e nel sale di bambù, il potassio nel sale blue di Persia e lo iodio nei sali arricchiti.

La situazione è analoga per i contaminanti, assenti o presenti a livelli inferiori alle soglie di rilevamento. In particolare nel salgemma e nel sale marino convenzionale, la maggior parte dei contaminanti non raggiunge l'1 % della quantità di assorbimento tollerata, mentre tale percentuale è superiore nei sali speciali.

Tutti i prodotti analizzati sono composti prevalentemente di sale e contengono tra l'83 % e il 99 % di cloruro di sodio. Gli altri elementi quali sostanze nutritive e contaminanti sono presenti solo in tracce e non hanno rilevanza dal punto di vista fisiologico-nutrizionale né rappresentano un pericolo per la salute, tanto più che il sale viene consumato in quantità notevolmente inferiori rispetto agli altri alimenti.

Il presente rapporto mostra chiaramente che i sali speciali non presentano alcun valore aggiunto rispetto al sale convenzionale. È importante che i professionisti del settore sanitario, le aziende alimentari e la popolazione siano a conoscenza o vengano informati del fatto che, al contrario, a causa del tenore di iodio basso o addirittura inesistente, solo eccezionalmente questi tipi di sale dovrebbero sostituire il sale iodato.

In conclusione si può affermare che dal punto di vista tossicologico i sali speciali non rappresentano alcun pericolo per salute, tuttavia essi non possiedono caratteristiche fisiologico-nutritive rilevanti e non sono dunque consigliabili per il consumo quotidiano.

1 Introduction

During the last ESAN meeting in Athens in 2015, the relevance of different types of salts was risen. Not much is known about the composition of salts other than their sodium chloride content. Consequently, the Swiss Federal Food Safety and Veterinary Office has analysed a wide variety of salts available in Switzerland, many of which are marketed to be particularly healthy.

This report presents and discusses the results of these analyses. Its aim is to give a scientifically sound background to judge the relevance of specialty salts[1] in comparison to standard iodised table salt.

It will be distributed to all ESAN members and will be presented during the upcoming ESAN meeting in Lisbon.

2 Starting point

For several years now, more and more specialty salts are available in the Swiss market and presumably also in other European countries. They are often marketed as being more natural and having special compositional, nutritional and health properties compared to normal table salt. Appendix 1 lists a selection of marketing statements used for selling specialty salts.

Specialty salts are not iodised in general. Therefore an increased intake of such salts instead of standard iodised table salt will have an impact on the iodine status of the Swiss population.

In Switzerland, about 54% of the iodine intake originates from iodised salt, the rest from iodine naturally present in foods [1]. Currently, the average salt intake ranges between 7.8 g for women and 10.6 g for men [2]. But only approximately half of the consumed salt is iodised [1], even though about 80% of the Swiss households use iodised salts [3, 4]. The main reason for this low proportion is that manufacturers and caterers are not legally required to use iodised salt in food production [4]. In some cases, the use of iodised salt prevents foods from being exported to other countries or has labelling consequences [5]. Additionally, from our collaboration with bakers we learned that some manufacturers believe sea salt to be a naturally good source for iodine and prefer to use the “natural” sea salt over the “artificially” iodised table salt.

Taking into account changing manufacturing processes (overall reduction of salt levels in processed foods, decreased use of iodised salt, increasing use of specialty salts), the iodine fortification of table salt in Switzerland has been increased from 20 mg/kg to 25 mg/kg in 2014 to ensure iodine sufficiency in the Swiss population [6].

However, if still more manufacturers do not use iodised salt and people start to use more and more specialty salts instead of iodised table salt, iodine status is likely to become critical.

To better assess the relevance and possible impact of specialty salts, a selection of salts has been purchased and analysed by the laboratory of the Swiss Federal Food Safety and Veterinary Office. This report presents the results and discusses the relevance of specialty salts and standard iodised salt in relation to nutrient and contaminant intake.

[1] In this report the term „specialty salts“ is used for salts that are sold as specialty products, generally much higher priced than normal table salts and often in combination with (not approved) health claims. Common specialty salts are Himalaya salt, Hawaii salt or Fleur de Sel.

3 Methods

Based on store checks and an internet research, a list of salts was selected for analysis. The salts were then purchased at local retailers or over the internet.

The mineral and trace element content of the salts was measured by three different spectroscopic methods. In addition, chlorine was measured by argentometric titration, which is based on the use of silver as a precipitating agent. In all methods, the samples were dissolved in diluted nitric acid, except for iodine measurements an alkaline solution was prepared.

Total reflection X-ray fluorescence analysis (TXRF) was used as an initial screening method for a subset of samples. The subset consisted of the first batch of available salts after purchase. TXRF is based on the irradiation of a sample by X-ray, whereby secondary X-rays are emitted that are characteristic of the respective elements present and their concentration. The results conveyed a first impression of the mineral composition (without sodium) of the salts and were regarded as qualitative data only, except iron (Fe) that was quantified with sufficient accuracy. The TXRF data was used to decide which elements would need to be further investigated by inductively coupled plasma mass spectrometry (ICP-MS).

Sodium (Na) and potassium (K) were measured by inductively coupled plasma optical emission spectroscopy (ICP-OES). The plasma is partly ionized argon at high temperatures that is heated by electromagnetic induction. Dissolved samples introduced into the plasma emit specific light in the visible and ultraviolet wavelength region according to their elemental composition. The instrument was calibrated using external Na and K-standards.

The trace element content was measured by ICP-MS. This method makes use of an argon plasma as ion-source, from which ions are extracted into mass spectrometers, i.e., sector-field mass analyser was used for iodine and a quadrupole for the remaining trace elements. Ions are separated by their mass-to-charge ratio and give signals proportional to the respective element concentration. Initial scans over the entire mass range from lithium to uranium were made to identify elements contained in the salt samples. Of all the trace elements present in salt samples only iodine, (I), aluminium (Al), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd), lead (Pb) and uranium (U) could be selectively detected and measured with sufficient accuracy. Iodine concentration was determined with iodine-129 as tracer and for all other elements a standard addition procedure was applied.

The limits of detection (LOD) of the ICP-methods were studied under experimental conditions, i.e., LODs were derived from calibration curves. For trace elements, individual LODs were calculated for each salt separately and thus varied considerably owing to different analytical sensitivities. In cases where no concentration equivalent was found, a corresponding LOD could not be calculated (marked as <LOD).

The data were further evaluated with Linear Discriminant Analysis (LDA), which is a statistical technique to classify objects into mutually exclusive groups based on a set of measurable object's features. The purpose of LDA in this study was to see whether the measured set of mineral and trace element compounds could determine group membership of the two objects rock and sea salt.

To judge the nutritional and health relevance of the salts, the measured amounts have been compared with the recommended, respectively tolerable, intake levels of an average adult person of 60 kg body weight (see appendices 3 and 4). For nutrients with a recommended intake range or a difference between males and females, the lower limits have been taken for all calculations. Two scenarios have been calculated, one with the recommended salt consumption of 5 g per day [7], a second with the current consumption level in Switzerland of 9 g salt per day [2]. In reality, salt intake is the sum of different types of salts consumed through different types of food. As the above described calculation approach assumes that the total intake comes from one and the same salt, it can be considered a best-case-scenario for nutrients and a worst-case-scenario for contaminants.

4 Results

In total, 25 different salts (1 standard rock and 9 specialty rock salts, 7 standard sea and 8 specialty sea salts) have been analysed. Tables 1 to 2 give an overview of the nutrient composition and table 3 of the contaminant content of the analysed salts. Calcium, phosphorus and strontium have also been analysed. These values however are only indicative. Therefore, they have not been included into the tables in this section but can be found in the characteristics of each salt in appendix 2. Light elements such as magnesium and boron were possibly present in some salts, however, could not be quantified.

The general impression was that most of the investigated salts were not homogeneous. This was visible to the eye by irregular colouring and graining. With respect to mineral and trace elements, this observation could be confirmed (except for sodium and chlorine) by repeated ICP-MS measurements.

For many trace elements the measurements showed a high degree of heterogeneity (expressed by a relative standard deviation >50%). Rock salt heterogeneity is attributed to differences in mineral composition of rocks and its deposition in salt layers [8]. In contrast, sea salt includes impurities that consist of variable amounts of trace elements, which are a result of the crystallisation process [9, 10].

Salt has proven to be a very difficult matrix for ICP-MS trace element determinations. Therefore, precision and accuracy of the values are inferior to “normal” food analysis.

In general, standard salts, including rock and sea salt varieties, are of purer composition than specialty salts. Their average (mean and median) sodium chloride (NaCl) content ranges around 99%, derived from sodium content[2]. Specialty salts on the other hand contain higher amounts of other elements which leads to sodium chloride contents of between 83% and 99%, with a mean of 94% and a median of 95%. This is for most specialty salts a characteristic of their inherent composition, for some also a consequence of various additions such as salsola stocksii to Kala Namak salt, dioscorea batata to one of the rock salts or active coal and taro to Black Hawaii salt. Persian salts are unique in that they contain a significantly lower sodium content than all other salts. In return, they contain more potassium.

[2] Calculated as salt equivalent with the equation “sodium x 2.5” according to Swiss labelling legislation.

Table 1: Nutrient composition of analysed salts - Minerals

	Na[1] Sodium	**Cl**[2] Chlorine	**NaCl**[3] Sodium chloride	**NaCl**[4] Sodium chloride	**K**[2] Potassium
	%	%	%	%	g/kg
Standard rock salts					
Table salt with iodine	n.a.	n.a.	-	-	n.a.
Standard sea salts					
Sea salt A	39.5	59.2	98.8	98.9	<0.05
Sea salt B	39.7	57.5	99.3	96	<0.05
Sea salt C	40.7	57.2	101.8	95.5	<0.05
Sea salt D	40.2	57.8	100.5	96.5	<0.05
Sea salt E	38.9	58.5	97.3	97.7	<0.05
Sea salt F	39.3	58.1	98.3	97	1.2
Sea salt G	39.9	57.0	99.8	95.2	<0.05
Specialty rock salts					
Blue Persian salt A	33.1	59.2	82.8	98.9	95.3
Blue Persian salt B	34.8	57.0	87	95.2	65.7
Himalaya salt A	38.0	58.4	95	97.5	<0.05
Himalaya salt B	37.9	58.5	94.8	97.7	<0.05
Himalaya salt C	38.2	58.5	95.5	97.7	<0.05
Himalaya salt D	37.7	57.7	94.3	96.4	<0.05
Kalahari salt	38.4	57.5	96	96	<0.05
Kala Namak salt	38.7	57.9	96.8	96.7	1.3
Rock salt with dioscorea batata	39.2	57.4	98	95.9	<0.05
Specialty sea salts					
Bamboo salt	36.8	57.2	92	95.5	1.3
Black Hawaii salt	36.7	57.8	91.8	96.5	<0.05
Fleur de Sel A	37.3	57.4	93.3	95.9	2.2
Fleur de Sel B	38.8	58.1	97	97	<0.05
Fleur de Sel C	38.5	57.7	96.3	96.4	1.1
Fleur de Sel D	36.9	58.4	92.3	97.5	2.1
Sea salt with algae	39.5	57.9	98.8	96.7	<0.05
White pyramid salt	37.7	58.5	94.3	97.7	<0.05

n.a. = not analysed

[1] *measured by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES)*

[2] *measured by Argentometry*

[3] *calculated from Na (x 2.5), assuming that sodium contributes 40% to sodium chloride*

[4] *calculated from Cl (x 1.67), assuming that chlorine contributes 60% to sodium chloride*

Table 2: Nutrient composition of analysed salts – Trace elements

	Cu[5] Copper	**Zn**[5] Zinc	**I**[5] Iodine	**Fe**[6] Iron
	µg/kg	µg/kg	µg/kg	g/kg
Standard rock salts				
Table salt with iodine	<LOD	LOD	n.a.	n.a.
Standard sea salts				
Sea salt A	<LOD	<4	<20	<LOD
Sea salt B	<LOD	485[a]	28	n.a.
Sea salt C	127	<28	<20	n.a.
Sea salt D	11.9[a]	<LOD	<20	n.a.
Sea salt E	<LOD	<6	54	n.a.
Sea salt F	<LOD	<LOD	44	n.a.
Sea salt G	<LOD	<LOD	<LOD	n.a.
Specialty rock salts				
Blue Persian salt A	<2	163[a]	<20	n.a.
Blue Persian salt B	<6	196	<20	<LOD
Himalaya salt A	<LOD	<37	<20	0.09
Himalaya salt B	135[a]	110[a]	<20	0.24
Himalaya salt C	<3	<166	<20	0.37
Himalaya salt D	<LOD	179[a]	<20	0.26
Kalahari salt	<LOD	<3	<20	<LOD
Kala Namak salt	1049	12566	22	0.36
Rock salt with dioscorea batata	50.2[a]	240[a]	<20	<LOD
Specialty sea salts				
Bamboo salt	822	983	<20	0.21
Black Hawaii salt	48.0[a]	56.6[a]	34	<LOD
Fleur de Sel A	<LOD	348[a]	36	n.a.
Fleur de Sel B	129[a]	<83	32	<LOD
Fleur de Sel C	<LOD	<LOD	21	n.a.
Fleur de Sel D	18.1[a]	133[a]	61.7	n.a.
Sea salt with algae	<LOD	<LOD	n.a.	n.a.
White pyramid salt	<19	<133	<20	n.a.

LOD = Limit of Detection / n.a. = not analysed

[a] Relative Standard Deviation >50%

[5] measured by Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

[6] measured by Total Reflection X-ray Fluorescence (TXRF)

Table 3: Contaminant contents of analysed salts

	Al[5] Aluminium	**Ni**[5] Nickel	**As**[5] Arsenic	**Cd**[5] Cadmium	**Pb**[5] Lead	**U**[5] Uranium
	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
Standard rock salts						
Table salt with iodine	811[a]	<100	<7	0.421[a]	<7	3.47
Standard sea salts						
Sea salt A	<291	<45	<LOD	<1	45.1	0.104[a]
Sea salt B	<393	<LOD	<LOD	<2	37.5[a]	0.035[a]
Sea salt C	<216	<34	2.78[a]	<3	59.8[a]	0.130[a]
Sea salt D	<641	<19	10.8[a]	<1	45.7[a]	0.950[a]
Sea salt E	742	<100	<6	<1	155	1.30
Sea salt F	<2014	41.5[a]	<LOD	<2	77.7[a]	2.37
Sea salt G	<858	<8	<LOD	<LOD	36.7[a]	0.104[a]
Specialty rock salts						
Blue Persian salt A	<239	<27	2.51[a]	<2	33.9[a]	0.173[a]
Blue Persian salt B	<628	32.1	3.11[a]	2.19[a]	20.6	0.642
Himalaya salt A	21864	100	<15	<1	38.4[a]	1.58[a]
Himalaya salt B	34246	53.2[a]	20.7	1.72[a]	52.0	3.93
Himalaya salt C	44654	<6	<7	5.44	72.7	4.14
Himalaya salt D	37556[a]	32.3	<19	3.3	84.4	3.42[a]
Kalahari salt	<1190	137[a]	53.7	<3	164	33.3
Kala Namak salt	47210	970	106	57.1[a]	178	2.33
Rock salt with dioscorea batata	<220	<38	<7	<1	<7	1.80
Specialty sea salts						
Bamboo salt	124084[a]	5941	33.1[a]	<9	120	18.4
Black Hawaii salt	4294	208	<8	<LOD	15.2	3.12
Fleur de Sel A	<1166	<131	0.232[a]	<1	<7	4.82
Fleur de Sel B	<823	90.3[a]	9.52[a]	<1	21.2[a]	1.34
Fleur de Sel C	<485	42.5[a]	<LOD	<LOD	15.0[a]	1.21
Fleur de Sel D	<882	<8	<4	1.71[a]	350[a]	6.87
Sea salt with algae	4004	<40	291	<2	<8	1.34
White pyramid salt	14915	<24	2.48[a]	2.58[a]	158[a]	0.812

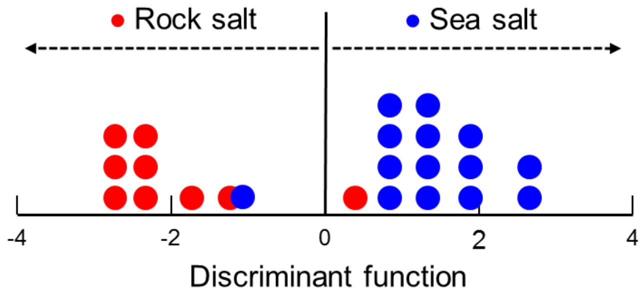
LOD = Limit of Detection

[a] *Relative Standard Deviation >50%*

[5] *measured by Inductively Coupled Plasma Mass Spectrometry (ICP-MS)*

Sea and rock salts can clearly be distinguished by their inherent mineral and trace element composition (see figure 1). Using linear discriminant analysis (LDA) with the measured Na, Al, Ni, Cu, Zn, As, Cd, Pb, U and I concentrations, the salts could be classified as either rock or sea salt. Only one case was misclassified in each salt group (Rock salt with dioscorea batata – LDA score 0.402 and White pyramid sea salt – LDA score -1.096). The rock salt might have been misclassified because of a likely change in the mineral and trace element spectrum due the addition of 4% dioscorea batata, a variety of yams. The LDA results lead to the assumption that the origin of the salts plays a more important role for defining composition than later contamination, for example during production, i.e. mining or desalination of sea water.

Figure 1: Relationship between mineral composition and origin (rock or sea salt) as shown by linear discriminant analysis



5 Discussion

Discussion of nutrient content

Many nutrients could not be detected at all, also in specialty salts, which means they are not present or only at levels below the detection limits of the chosen analytical methods. The ones that could be detected, are mostly present in levels which do not have any nutritional relevance. With a few exemptions they add less than 2% to the recommended daily intake levels.

One exemption is the iron content in some specialty salts (Himalaya salt, Kala Namak salt, Bamboo salt). 9 g of those salts provide up to 33% of the recommended daily iron intake, 5 g provide up to 19%. The iron content in Himalaya and Kala Namak salts – responsible for the typical colour of these salts - stems from naturally present impurities in the rocks where the salt is extracted from and differs substantially from one salt to another (between 0.09 and 0.37 g/kg). The iron in bamboo salt (0.21 g/kg) presumably is a result of its production process (roasted in young bamboo sealed with red clay [11]).

The iron in these salts is mainly present as insoluble iron oxide [12]. The same compound which is also permitted to be used as a colouring agent in food production [13, 14]. It has a low bioavailability as all non-heme irons and its absorption depends on the presence of inhibitors (e.g. phytate, polyphenols or calcium) and enhancers (e.g. vitamin c or meat and fish) [15]. Consequently, salts cannot be regarded as good nutritional iron sources despite their relatively high iron content.

The second exemption is the potassium content of Persian salts. 9 g of Persian salt contain up to 43% and 5g up to 24% of the recommended daily potassium intake.

The third exemption, not surprisingly, are salts fortified with iodine. Iodine requirements can be fully covered with current consumption levels of salt (taking into account that iodised salt only adds to about half of the total iodine intake [1]), however not with the recommended consumption level of 5 g per day. Thus, Swiss fortification levels might have to be adapted when salt consumption decreases over time.

On the other hand, non-fortified salts (including sea salts) do not contain significant levels of iodine although sea salts are thought to be good sources. In sea water, iodine is found in higher quantities than in any other environmental compartment. Sea water contains about 57 µ/L total iodine [16]. Iodine in seawater exists mainly as iodate and iodide. The total dissolved iodine concentration is almost constant regardless of the ocean; however, the distribution of iodate and iodide varies with depth and location [17].

On average, seawater in the world's oceans has a salinity of about 3.5 % (35 g/L) [18] which results in a theoretically achievable maximum iodine concentration of 1.6 µg/g salt. However, iodine contents in sea salt, if detected, were measured on low µ/kg levels only (details see tables 1 to 3). Consequently, the trace element iodine gets lost during the sea salt production and purification processes. In sea salt production, water evaporates from pools, leaving the salt behind. In evaporatively prepared salt, the iodine concentration is much lower than in sea water because of iodine loss. The selective crystallization process of sodium chloride partitions iodine and other trace impurities in the brine ("mother liquor"), whereby they are removed from the residual salt [9].

Sodium chloride, the main component of all salts, is composed of 40% sodium and 60% chlorine. Table 1 shows nicely that it makes sense to calculate sodium chloride content derived from sodium and not from chlorine, as some salts (e.g. Blue Persian salts) contain significant levels of potassium chloride. Thus, calculations derived from chlorine would overestimate sodium chloride content.

Discussion of contaminant content

As well as nutrients, many contaminants are either not present or only below detection levels. Most contaminants do not even reach 1% of tolerable intake levels (for details see appendix 4). This is true particularly for standard rock and sea salts. Specialty salts generally contain higher amounts of contaminants.

For cadmium, uranium and strontium low levels have been found for all salts including specialty salts. Higher levels were found for nickel, lead, arsenic and aluminium with highest levels (up to 32% of tolerable intake levels) in Himalaya, Kala Namak and bamboo salts.

Mostly, the values found in salts correspond to the prevalence of these elements in the earth's crust (see table 4).

Table 4: Concentration (in mg/kg) of elements in the earth's crust [19]

Element	Concentration
Aluminium	83000
Nickel	99
Uranium	66
Lead	13
Arsenic	1.8
Cadmium	0.16

The generally high contaminant levels in bamboo salt are probably a consequence of its production process (see end of second paragraph in discussion of nutrient content). The high levels in Himalaya and Kala Namak salt on the other hand are likely to be natural contamination.

A sea salt with algae (for "natural" iodine fortification) showed the highest arsenic content. As no other sea salt showed similar levels, this arsenic presumably stems from the algae, which contain up to about 100 mg/kg in dry matter [20]. Currently, there does not exist a tolerable intake level, neither from the European Food Safety Authority EFSA nor from the Joint FAO/WHO Expert Committee on Food

Additives JECFA. The content was therefore compared with the Benchmark dose lower confidence level limit ($BMDL_{01}$) published by EFSA [21]. 9 g of this salt lead to 15% of the BMDL.

Kala Namak showed the second highest concentration of arsenic. This volcanic rock salt is used in Indian cuisine [22]. Its characteristic sulfuric taste is a result of a high hydrogen sulfide content (approx. 200 mg/kg) which was assessed as safe for human consumption by the German "Bundesinstitut für Risikobewertung" [23].

Lead contents could also not be fully evaluated as the previously valid tolerable intake level has been withdrawn in 2011 and neither JECFA nor EFSA have published a new one [24, 25]. However, EFSA reported a $BMDL_{01}$ of 0.5 to 1.5 µ per kg body weight per day and 9 g salt contain up to 10.5% of the lower BMDL threshold.

6 Conclusion

All salts are first and foremost salts and consist of between 83% to 99% sodium chloride. The additional elements – nutrients and contaminants – are present in trace levels which in the case of nutrients have no nutritional relevance or in the case of contaminants do not pose a health risk. Even more so, as salt is consumed in much smaller quantities compared to other foods. For this reason, nutrient levels in salts should not be compared with other foods on a per 100 g basis. If levels are compared, it needs to be done on a portion basis.

Surprising exceptions are the iron content in some of the Himalaya salts and the potassium content in Persian salts. Theoretically, they could be considered recommendable sources for iron and potassium. However, as long as these salts are not fortified with iodine, they are not a suitable alternative for normal fortified salts unless iodine intake is guaranteed through other sources.

Iodised salt is an essential iodine source for people in Switzerland and many other countries. Natural fortification – as in the case of the sea salt with algae – does not present advantages over standard fortification. It might even to some extent be disadvantageous, as the iodine levels might vary and not be as standardised as with standard fortification. The addition of algae can also introduce new contaminants such as arsenic into the salt.

This report clearly shows that specialty salts do not possess any advantages over standard salts. On the contrary, due to their low to inexistent iodine levels they cannot and should not routinely replace iodised table salts. Health professionals, food manufacturers and the general public should be or become aware about these facts.

In summary, even though specialty salts represent no appreciable risk from a toxicological viewpoint, they do not possess relevant beneficial nutritional properties to be recommended as a standard choice of salt.

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Appendix 1: List of marketing statements for different "specialty" salts (non-exhaustive)

Product	Original statement	English translation	Source
Himalaya Salt	zur Schlafregulierung (ein Glas Wasser trinken, ein paar Körner Himalayasalz auf der Zunge zergehen lassen und Sie schlafen wunderbar)	For sleep regulation (drink a glass of water, have some Himalaya salt grains melt on your tongue and you will sleep like a baby)	www.salz-grotte.ch
Himalaya Salt	bei Wanderungen, Bergtouren oder beim Sport (am Himalayasalz Stein lecken, gibt Energie und alkalisiert die Körpersäfte)	During walks and hikes or sport (licking a rock of Himalaya salt will give you energy and will alkalise your body fluids)	www.salz-grotte.ch
Himalaya Salt	Stärkung des Immunsystems	Strengthens the immune system	www.salz-grotte.ch
Himalaya Salt	Entschlackung des Körpers	Purification of the body	www.salz-grotte.ch
Bamboo Salt	Als Magnesiumlieferant hat das Bambussalz auch andere gesunde Vorteile. So kann es z.B. bei nächtlichen Muskelkrämpfen, Menstruationsbeschwerden oder Allergien helfen. Auch können Nierensteine vermieden oder aufgelöst werden und bei Diabetes helfen. Inzwischen schwören viele auch bei einer Verstopfung oder Kreislaufbeschwerden auf die heilende Wirkung des Salzes.	Being a source of magnesium, bamboo salt also has further health advantages. It can help against muscle cramps at night-time, menstruation discomfort or allergies. Further, it can prevent or dissolve kidney stones and help with diabetes. Meanwhile many people also confirm its healing effects against constipation or circulatory problems.	www.jamina-shop.ch
Hawaii Salt	Schwarzes Palm Island Pacific Salz entsteht durch den Zusatz von hochreiner Aktivkohle. Aktivkohle ist als Nahrungsergänzung mit antitoxischer und verdauungsfördernder Wirkung bekannt.	Black Palm Island Pacific salt is produced by the addition of highly purified active coal. Active coal is a dietetic supplement known for its anti-toxic and digestive effects.	www.gewuerzprofi.ch

Appendix 2: Characteristics of analysed salts

The following pages contain the characteristics of the salts listed below.

Rock salts

Standard rock salt
Table salt with iodine

Specialty rock salts "Blue Persian"
Blue Persian salt A
Blue Persian salt B

Specialty rock salts "Himalaya"
Himalaya salt A
Himalaya salt B
Himalaya salt C
Himalaya salt D

Other specialty rock salts
Kalahari salt
Kala Namak salt
Rock salt with dioscorea batata

Sea salts

Standard sea salts
Sea salt A
Sea salt B
Sea salt C
Sea salt D
Sea salt E
Sea salt F
Sea salt G

Specialty sea salts "Fleur de Sel"
Fleur de Sel A
Fleur de Sel B
Fleur de Sel C
Fleur de Sel D

Other specialty sea salts
Bamboo salt
Black Hawaii salt
Sea salt with algae
White pyramid salt

Abbreviations

n.a.	not analysed
LOD	Limit of Detection
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
TXRF	Total Reflection X-ray Fluorescence[3]

[3] All values measured by TXRF (except iron) are indicative values only.

Table salt with iodine

Origin Switzerland

Type Rock salt

Composition **Ingredients:** Salt, 0.0025% iodide, anti-caking aging E341.

Nutrients					**Analysis**
Sodium	Na	n.a.			ICP-OES
Chlorine	Cl	n.a.			Argentometry
Potassium	K	n.a.			ICP-OES
Calcium	Ca	n.a.			TXRF
Iron	Fe	n.a.			TXRF
Zinc	Zn	<LOD			ICP-MS
		n.a.			TXRF
Phosphorus	P	n.a.			TXRF
Iodine	I	25*	mg	per kg	--
Copper	Cu	<LOD			ICP-MS

Contaminants					
Aluminium	Al	811	µg	per kg	ICP-MS
Nickel	Ni	<LOD			ICP-MS
Arsenic	As	<LOD			ICP-MS
Cadmium	Cd	0.421	µg	per kg	ICP-MS
Lead	Pb	<LOD			ICP-MS
Uranium	U	3.47	µg	per kg	ICP-MS
Strontium	Sr	n.a.			TXRF

* Fortification

Blue Persian salt A

Origin Iran

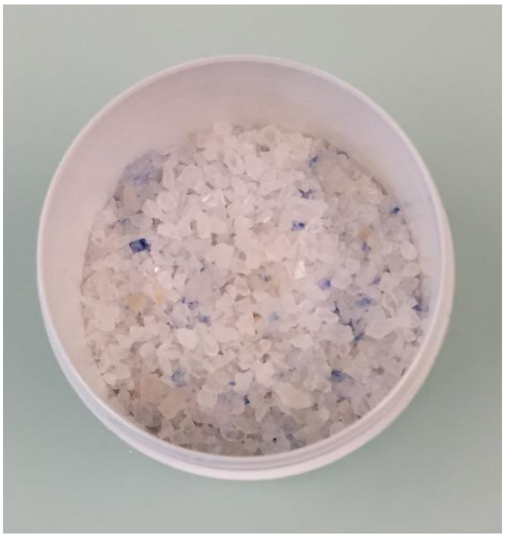
Type Rock salt

Composition **Ingredients:** 100% salt.

Nutrients					**Analysis**
Sodium	Na	33.1	%		ICP-OES
Chlorine	Cl	59.2	%		Argentometry
Potassium	K	95.3	g	per kg	ICP-OES
Calcium	Ca	n.a.			TXRF
Iron	Fe	n.a.			TXRF
Zinc	Zn	163	µg	per kg	ICP-MS
		n.a.			TXRF
Phosphorus	P	n.a.			TXRF
Iodine	I	<LOD			ICP-MS
Copper	Cu	<LOD			ICP-MS

Contaminants					
Aluminium	Al	<LOD			ICP-MS
Nickel	Ni	<LOD			ICP-MS
Arsenic	As	2.51	µg	per kg	ICP-MS
Cadmium	Cd	<LOD	µg	per kg	ICP-MS
Lead	Pb	33.9	µg	per kg	ICP-MS
Uranium	U	0.173	µg	per kg	ICP-MS
Strontium	Sr	n.a.			TXRF

Appearance



Blue Persian salt B

Origin not declared (packed in South Africa)

Type Rock salt

Composition **Ingredients:** 100% salt.

Nutrients				Analysis
Sodium	Na	34.8	%	ICP-OES
Chlorine	Cl	57.0	%	Argentometry
Potassium	K	65.7	g per kg	ICP-OES
Calcium	Ca	0.7	g per kg	TXRF
Iron	Fe	<LOD		TXRF
Zinc	Zn	196	µg per kg	ICP-MS
		0.004	g per kg	TXRF
Phosphorus	P	<LOD		TXRF
Iodine	I	<LOD		ICP-MS
Copper	Cu	<LOD		ICP-MS

Contaminants				
Aluminium	Al	<LOD		ICP-MS
Nickel	Ni	32.1	µg per kg	ICP-MS
Arsenic	As	3.11	µg per kg	ICP-MS
Cadmium	Cd	2.19	µg per kg	ICP-MS
Lead	Pb	20.6	µg per kg	ICP-MS
Uranium	U	0.642	µg per kg	ICP-MS
Strontium	Sr	0.027	g per kg	TXRF

Appearance

Himalaya table salt A

Origin Punjab, Pakistan

Type Rock salt

Composition **Ingredients:** 100% salt.

Nutrients

Nutrients				Analysis
Sodium	Na	38.0	%	ICP-OES
Chlorine	Cl	58.4	%	Argentometry
Potassium	K	<LOD		ICP-OES
Calcium	Ca	1.0	g per kg	TXRF
Iron	Fe	0.09	g per kg	TXRF
Zinc	Zn	<LOD		ICP-MS
		<LOD		TXRF
Phosphorus	P	<LOD		TXRF
Iodine	I	<LOD		ICP-MS
Copper	Cu	<LOD		ICP-MS

Contaminants

Aluminium	Al	21'864	µg per kg	ICP-MS
Nickel	Ni	100	µg per kg	ICP-MS
Arsenic	As	<LOD		ICP-MS
Cadmium	Cd	<LOD		ICP-MS
Lead	Pb	38.4	µg per kg	ICP-MS
Uranium	U	1.58	µg per kg	ICP-MS
Strontium	Sr	0.028	g per kg	TXRF

Appearance

Himalaya salt B

Origin Pakistan

Type Rock salt

Composition **Ingredients:** 100% salt.

Nutrients					**Analysis**
Sodium	Na	37.9	%		ICP-OES
Chlorine	Cl	58.5	%		Argentometry
Potassium	K	<LOD			ICP-OES
Calcium	Ca	1.2	g	per kg	TXRF
Iron	Fe	0.24	g	per kg	TXRF
Zinc	Zn	110	µg	per kg	ICP-MS
		0.003	g	per kg	TXRF
Phosphorus	P	<LOD			TXRF
Iodine	I	<LOD			ICP-MS
Copper	Cu	135	µg	per kg	ICP-MS

Contaminants					
Aluminium	Al	34’246	µg	per kg	ICP-MS
Nickel	Ni	53.2	µg	per kg	ICP-MS
Arsenic	As	20.7	µg	per kg	ICP-MS
Cadmium	Cd	1.72	µg	per kg	ICP-MS
Lead	Pb	52.0	µg	per kg	ICP-MS
Uranium	U	3.93	µg	per kg	ICP-MS
Strontium	Sr	0.041	g	per kg	TXRF

Appearance

Himalaya salt C

Origin Punjab, Pakistan

Type Rock salt

Composition **Ingredients:** 100% salt.

Nutrients | | | | | **Analysis**

Sodium	Na	38.2	%		ICP-OES
Chlorine	Cl	58.5	%		Argentometry
Potassium	K	<LOD			ICP-OES
Calcium	Ca	1.7	g	per kg	TXRF
Iron	Fe	0.37	g	per kg	TXRF
Zinc	Zn	<LOD			ICP-MS
		0.003	g	per kg	TXRF
Phosphorus	P	<LOD			TXRF
Iodine	I	<LOD			ICP-MS
Copper	Cu	<LOD			ICP-MS

Contaminants

Aluminium	Al	44’654	µg	per kg	ICP-MS
Nickel	Ni	<LOD			ICP-MS
Arsenic	As	<LOD			ICP-MS
Cadmium	Cd	5.44	µg	per kg	ICP-MS
Lead	Pb	72.7	µg	per kg	ICP-MS
Uranium	U	4.14	µg	per kg	ICP-MS
Strontium	Sr	0.050	g	per kg	TXRF

Appearance

Himalaya salt D

Origin South Africa (not clear if country of origin or country of packaging)

Type Rock salt

Composition **Ingredients:** 100% salt.

Nutrients				**Analysis**
Sodium	Na	37.7	%	ICP-OES
Chlorine	Cl	57.7	%	Argentometry
Potassium	K	<LOD		ICP-OES
Calcium	Ca	1.8	g per kg	TXRF
Iron	Fe	0.26	g per kg	TXRF
Zinc	Zn	179	µg per kg	ICP-MS
		0.002	g per kg	TXRF
Phosphorus	P	<LOD		TXRF
Iodine	I	<LOD		ICP-MS
Copper	Cu	<LOD		ICP-MS

Contaminants				
Aluminium	Al	37’556	µg per kg	ICP-MS
Nickel	Ni	32.3	µg per kg	ICP-MS
Arsenic	As	<LOD		ICP-MS
Cadmium	Cd	3.3	µg per kg	ICP-MS
Lead	Pb	84.4	µg per kg	ICP-MS
Uranium	U	3.42	µg per kg	ICP-MS
Strontium	Sr	0.045	g per kg	TXRF

Appearance

Kalahari Salt

Origin Kalahari, South Africa

Type Rock salt

Composition **Ingredients:** 100% salt.

Nutrients				**Analysis**
Sodium	Na	38.4	%	ICP-OES
Chlorine	Cl	57.5	%	Argentometry
Potassium	K	<LOD		ICP-OES
Calcium	Ca	<LOD		TXRF
Iron	Fe	<LOD		TXRF
Zinc	Zn	<LOD		ICP-MS
		<LOD		TXRF
Phosphorus	P	<LOD		TXRF
Iodine	I	<LOD		ICP-MS
Copper	Cu	<LOD		ICP-MS

Contaminants				
Aluminium	Al	<LOD		ICP-MS
Nickel	Ni	137	µg per kg	ICP-MS
Arsen	As	53.7	µg per kg	ICP-MS
Cadmium	Cd	<LOD		ICP-MS
Lead	Pb	164	µg per kg	ICP-MS
Uranium	U	33.3	µg per kg	ICP-MS
Strontium	Sr	<LOD		TXRF

Appearance

Kala Namak salt

Origin Pakistan

Type Rock salt

Composition **Ingredients:** 95% salt, 5% salsola stocksii.

Nutrients				**Analysis**
Sodium	Na	38.7	%	ICP-OES
Chlorine	Cl	57.9	%	Argentometry
Potassium	K	1.3	g per kg	ICP-OES
Calcium	Ca	0.3	g per kg	TXRF
Iron	Fe	0.36	g per kg	TXRF
Zinc	Zn	12’566	µg per kg	ICP-MS
		0.015	g per kg	TXRF
Phosphorus	P	<LOD		TXRF
Iodine	I	22	µg per kg	ICP-MS
Copper	Cu	1049	µg per kg	ICP-MS

Contaminants				
Aluminium	Al	47’210	µg per kg	ICP-MS
Nickel	Ni	970	µg per kg	ICP-MS
Arsenic	As	106	µg per kg	ICP-MS
Cadmium	Cd	57.1	µg per kg	ICP-MS
Lead	Pb	178	µg per kg	ICP-MS
Uranium	U	2.33	µg per kg	ICP-MS
Strontium	Sr	0.023	g per kg	TXRF

Appearance

Rock salt with dioscorea batata

Origin not declared

Type Rock salt

Composition **Ingredients:** Salt, 4% dioscorea batata, halite crystal salt.

Nutrients:

					Analysis
Sodium	Na	39.2	%		ICP-OES
Chlorine	Cl	57.4	%		Argentometry
Potassium	K	<LOD			ICP-OES
Calcium	Ca	1.0	g	per kg	TXRF
Iron	Fe	<LOD			TXRF
Zinc	Zn	240	µg	per kg	ICP-MS
		0.02	g	per kg	TXRF
Phosphorus	P	<LOD			TXRF
Iodine	I	<LOD			ICP-MS
Copper	Cu	50.2	µg	per kg	ICP-MS

Contaminants:

Aluminium	Al	<LOD			ICP-MS
Nickel	Ni	<LOD			ICP-MS
Arsenic	As	<LOD			ICP-MS
Cadmium	Cd	<LOD			ICP-MS
Lead	Pb	<LOD			ICP-MS
Uranium	U	1.8	µg	per kg	ICP-MS
Strontium	Sr	0.039	g	per kg	TXRF

Appearance

Sea salt A

Origin Montpellier, France

Type Sea salt

Composition **Ingredients:** 100% salt.

Nutrients				Analysis
Sodium	Na	39.5	%	ICP-OES
Chlorine	Cl	59.2	%	Argentometry
Potassium	K	<LOD		ICP-OES
Calcium	Ca	0.3	g per kg	TXRF
Iron	Fe	<LOD		TXRF
Zinc	Zn	<LOD		ICP-MS
		0.001	g per kg	TXRF
Phosphorus	P	<LOD		TXRF
Iodine	I	<LOD		ICP-MS
Copper	Cu	<LOD		ICP-MS

Contaminants				
Aluminium	Al	<LOD		ICP-MS
Nickel	Ni	<LOD		ICP-MS
Arsenic	As	<LOD		ICP-MS
Cadmium	Cd	<LOD		ICP-MS
Lead	Pb	45.1	µg per kg	ICP-MS
Uranium	U	0.104	µg per kg	ICP-MS
Strontium	Sr	0.021	g per kg	TXRF

Appearance

Sea salt B

Origin France

Type Sea salt

Composition **Ingredients:** 100% salt.

Nutrients				**Analysis**
Sodium	Na	39.7	%	ICP-OES
Chlorine	Cl	57.5	%	Argentometry
Potassium	K	<LOD		ICP-OES
Calcium	Ca	n.a.		TXRF
Iron	Fe	n.a.		TXRF
Zinc	Zn	485	µg per kg	ICP-MS
		n.a.		TXRF
Phosphorus	P	n.a.		TXRF
Iodine	I	28	µg per kg	ICP-MS
Copper	Cu	<LOD		ICP-MS

Contaminants				
Aluminium	Al	<LOD		ICP-MS
Nickel	Ni	<LOD		ICP-MS
Arsenic	As	<LOD		ICP-MS
Cadmium	Cd	<LOD		ICP-MS
Lead	Pb	37.5	µg per kg	ICP-MS
Uranium	U	0.035	µg per kg	ICP-MS
Strontium	Sr	n.a.		TXRF

Appearance

Sea salt C

Origin Mediterranean Sea

Type Sea salt

Composition **Ingredients:** Salt, anti-caking agent E535.

Nutrients				Analysis
Sodium	Na	40.7	%	ICP-OES
Chlorine	Cl	57.2	%	Argentometry
Potassium	K	<LOD		ICP-OES
Calcium	Ca	n.a.		TXRF
Iron	Fe	n.a.		TXRF
Zinc	Zn	<LOD		ICP-OES
		n.a.		TXRF
Phosphorus	P	n.a.		TXRF
Iodine	I	<LOD		ICP-OES
Copper	Cu	127	µg per kg	ICP-MS

Contaminants				
Aluminium	Al	<LOD		ICP-OES
Nickel	Ni	<LOD		ICP-OES
Arsenic	As	2.78	µg per kg	ICP-MS
Cadmium	Cd	<LOD		ICP-OES
Lead	Pb	59.8	µg per kg	ICP-MS
Uranium	U	0.130	µg per kg	ICP-MS
Strontium	Sr	n.a.		TXRF

Appearance

Sea salt D

Company	Migros www.migros.ch
Origin	Mediterranean Sea
Type	Sea salt
Composition	**Ingredients:** Salt, anti-caking agent E535.

Nutrients / **Analysis**

Sodium	Na	40.2	%	ICP-OES
Chlorine	Cl	57.8	%	Argentometry
Potassium	K	<LOD		ICP-OES
Calcium	Ca	n.a.		TXRF
Iron	Fe	n.a.		TXRF
Zinc	Zn	<LOD		ICP-MS
		n.a.		TXRF
Phosphorus	P	n.a.		TXRF
Iodine	I	<LOD		ICP-MS
Copper	Cu	11.9	µg per kg	ICP-MS

Contaminants

Aluminium	Al	<LOD		ICP-MS
Nickel	Ni	<LOD		ICP-MS
Arsenic	As	10.8	µg per kg	ICP-MS
Cadmium	Cd	<LOD		ICP-MS
Lead	Pb	45.7	µg per kg	ICP-MS
Uranium	U	0.950	µg per kg	ICP-MS
Strontium	Sr	n.a.		TXRF

Appearance

Sea salt E

Origin France

Type Sea salt

Composition **Ingredients:** 100% salt.

Nutrients				**Analysis**
Sodium	Na	38.9	%	ICP-OES
Chlorine	Cl	58.5	%	Argentometry
Potassium	K	<LOD		ICP-OES
Calcium	Ca	n.a.		TXRF
Iron	Fe	n.a.		TXRF
Zinc	Zn	<LOD		ICP-MS
		n.a.		TXRF
Phosphorus	P	n.a.		TXRF
Iodine	I	54	µg per kg	ICP-MS
Copper	Cu	<LOD		ICP-MS

Contaminants				
Aluminium	Al	742	µg per kg	ICP-MS
Nickel	Ni	<LOD		ICP-MS
Arsenic	As	<LOD		ICP-MS
Cadmium	Cd	<LOD		ICP-MS
Lead	Pb	155	µg per kg	ICP-MS
Uranium	U	1.30	µg per kg	ICP-MS
Strontium	Sr	n.a.		TXRF

Appearance

Sea salt F

Origin Algarve, Portugal

Type Sea salt

Composition **Ingredients:** 100% salt.

Nutrients				**Analysis**
Sodium	Na	39.3	%	ICP-OES
Chlorine	Cl	58.1	%	Argentometry
Potassium	K	1.2	g per kg	ICP-OES
Calcium	Ca	n.a.		TXRF
Iron	Fe	n.a.		TXRF
Zinc	Zn	<LOD		ICP-MS
		n.a.		TXRF
Phosphorus	P	n.a.		TXRF
Iodine	I	44	µg per kg	ICP-MS
Copper	Cu	<LOD		ICP-MS

Contaminants

Aluminium	Al	<LOD		ICP-MS
Nickel	Ni	41.5	µg per kg	ICP-MS
Arsenic	As	<LOD		ICP-MS
Cadmium	Cd	<LOD		ICP-MS
Lead	Pb	77.7	µg per kg	ICP-MS
Uranium	U	2.37	µg per kg	ICP-MS
Strontium	Sr	n.a.		TXRF

Appearance

Sea salt G

Origin France, Italy

Type Sea salt

Composition **Ingredients:** Salt, anti-caking agent E535.

Nutrients				**Analysis**
Sodium	Na	39.9	%	ICP-OES
Chlorine	Cl	57.0	%	Argentometry
Potassium	K	<LOD		ICP-OES
Calcium	Ca	n.a.		TXRF
Iron	Fe	n.a.		TXRF
Zinc	Zn	<LOD		ICP-MS
		n.a.		TXRF
Phosphorus	P	n.a.		TXRF
Iodine	I	<LOD		ICP-MS
Copper	Cu	<LOD		ICP-MS

Contaminants

Aluminium	Al	<LOD		ICP-MS
Nickel	Ni	<LOD		ICP-MS
Arsenic	As	<LOD		ICP-MS
Cadmium	Cd	<LOD		ICP-MS
Lead	Pb	36.7	µg per kg	ICP-MS
Uranium	U	0.104	µg per kg	ICP-MS
Strontium	Sr	n.a.		TXRF

Appearance

Bamboo salt

Origin South Korea

Type Sea salt

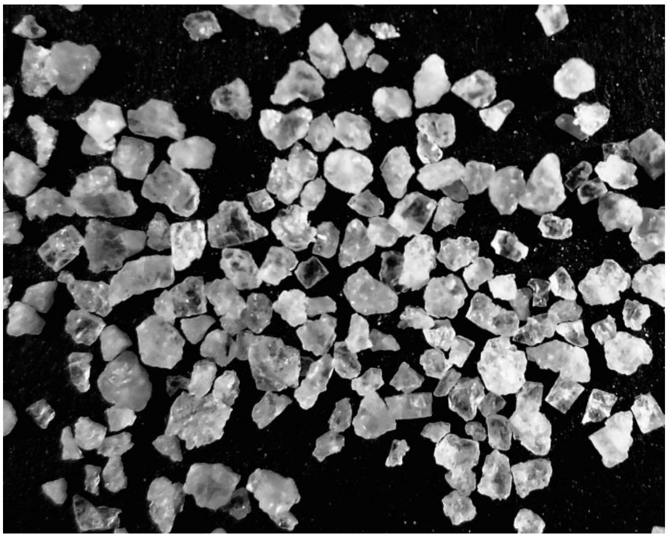
Composition **Ingredients:** 100% salt (roasted twice in bamboo).

Nutrients					**Analysis**
Sodium	Na	36.8	%		ICP-OES
Chlorine	Cl	57.2	%		Argentometry
Potassium	K	1.3	g	per kg	ICP-OES
Calcium	Ca	0.8	g	per kg	TXRF
Iron	Fe	0.21	g	per kg	TXRF
Zinc	Zn	983	µg	per kg	ICP-MS
		0.007	g	per kg	TXRF
Phosphorus	P	<LOD			TXRF
Iodine	I	<LOD			ICP-MS
Copper	Cu	822	µg	per kg	ICP-MS

Contaminants

Aluminium	Al	124'084	µg	per kg	ICP-MS
Nickel	Ni	5941	µg	per kg	ICP-MS
Arsenic	As	33.1	µg	per kg	ICP-MS
Cadmium	Cd	<LOD			ICP-MS
Lead	Pb	120	µg	per kg	ICP-MS
Uranium	U	18.4	µg	per kg	ICP-MS
Strontium	Sr	0.076	g	per kg	TXRF

Appearance



Black Hawaii salt

Origin Hawaii, USA

Type Sea salt

Composition **Ingredients:** Salt, active coal, taro.

Nutrients					**Analysis**
Sodium	Na	36.7	%		ICP-OES
Chlorid	Cl	57.8	%		Argentometry
Potassium	K	<LOD	g	per kg	ICP-OES
Calcium	Ca	<LOD			TXRF
Iron	Fe	<LOD			TXRF
Zinc	Zn	56.6	µg	per kg	ICP-MS
		<LOD			TXRF
Phosphorus	P	<LOD			TXRF
Iodine	I	34	µg	per kg	ICP-MS
Copper	Cu	48	µg	per kg	ICP-MS

Contaminants					
Aluminium	Al	4294	µg	per kg	ICP-MS
Nickel	Ni	208	µg	per kg	ICP-MS
Arsenic	As	<LOD			ICP-MS
Cadmium	Cd	<LOD			ICP-MS
Lead	Pb	15.2	µg	per kg	ICP-MS
Uranium	U	3.12	µg	per kg	ICP-MS
Strontium	Sr	<LOD			TXRF

Appearance

Fleur de Sel A

Origin Camargue, France

Type Sea salt

Composition **Ingredients:** 100% salt.

Nutrients					**Analysis**
Sodium	Na	37.3	%		ICP-OES
Chlorine	Cl	57.4	%		Argentometry
Potassium	K	2.2	g	per kg	ICP-OES
Calcium	Ca	n.a.			TXRF
Iron	Fe	n.a.			TXRF
Zinc	Zn	348	µg	per kg	ICP-MS
		n.a.			TXRF
Phosphorus	P	n.a.			TXRF
Iodine	I	36	µg	per kg	ICP-MS
Copper	Cu	<LOD			ICP-MS

Contaminants					
Aluminium	Al	<LOD			ICP-MS
Nickel	Ni	<LOD			ICP-MS
Arsenic	As	0.232	µg	per kg	ICP-MS
Cadmium	Cd	<LOD			ICP-MS
Lead	Pb	<LOD			ICP-MS
Uranium	U	4.82	µg	per kg	ICP-MS
Strontium	Sr	n.a.			TXRF

Appearance

Fleur de Sel B

Origin Aigues-Mortes, Camargue, France

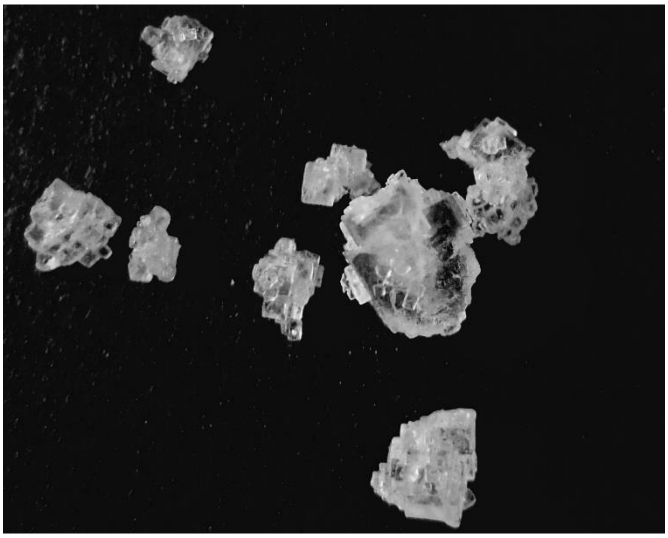
Type Sea salt

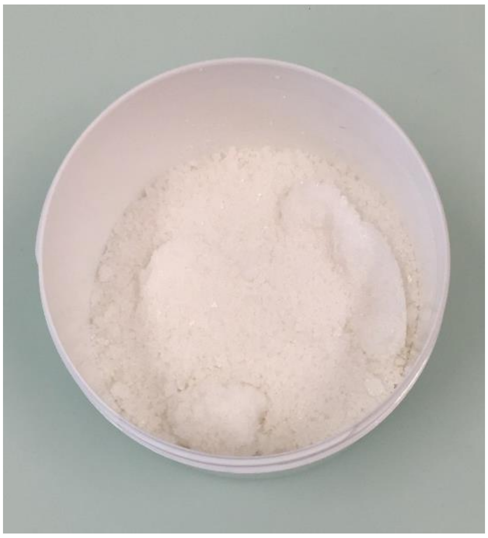
Composition **Ingredients:** 100% salt.

Nutrients					**Analysis**
Sodium	Na	38.8	%		ICP-OES
Chlorine	Cl	58.1	%		Argentometry
Potassium	K	<LOD			ICP-OES
Calcium	Ca	1.1	g	per kg	TXRF
Iron	Fe	<LOD			TXRF
Zinc	Zn	<LOD			ICP-MS
		0.003	g	per kg	TXRF
Phosphorus	P	<LOD			TXRF
Iodine	I	32	µg	per kg	ICP-MS
Copper	Cu	129	µg	per kg	ICP-MS

Contaminants					
Aluminium	Al	<LOD			ICP-MS
Nickel	Ni	90.3	µg	per kg	ICP-MS
Arsenic	As	9.52	µg	per kg	ICP-MS
Cadmium	Cd	<LOD			ICP-MS
Lead	Pb	21.2	µg	per kg	ICP-MS
Uranium	U	1.34	µg	per kg	ICP-MS
Strontium	Sr	0.064	g	per kg	TXRF

Appearance





Fleur de Sel C

Origin Greece (not clear if country of origin or country of packaging)

Type Sea salt

Composition **Ingredients:** 100% salt.

Nutrients				**Analysis**
Sodium	Na	38.5	%	ICP-OES
Chlorine	Cl	57.7	%	Argentometry
Potassium	K	1.1	g per kg	ICP-OES
Calcium	Ca	n.a.		TXRF
Iron	Fe	n.a.		TXRF
Zinc	Zn	<LOD		ICP-MS
		n.a.		TXRF
Phosphorus	P	n.a.		TXRF
Iodine	I	21	µg per kg	ICP-MS
Copper	Cu	<LOD		ICP-MS

Contaminants				
Aluminium	Al	<LOD		ICP-MS
Nickel	Ni	42.5	µg per kg	ICP-MS
Arsenic	As	<LOD		ICP-MS
Cadmium	Cd	<LOD		ICP-MS
Lead	Pb	15.0	µg per kg	ICP-MS
Uranium	U	1.21	µg per kg	ICP-MS
Strontium	Sr	n.a.		TXRF

Appearance


Fleur de Sel D

Origin not declared

Type Sea salt

Composition **Ingredients:** 100% salt.

Nutrients					**Analysis**
Sodium	Na	36.9	%		ICP-OES
Chlorine	Cl	58.4	%		Argentometry
Potassium	K	2.1	g	per kg	ICP-OES
Calcium	Ca	n.a.			TXRF
Iron	Fe	n.a.			TXRF
Zinc	Zn	133	µg	per kg	ICP-MS
		n.a.			TXRF
Phosphorus	P	n.a.			TXRF
Iodine	I	61.7	µg	per kg	ICP-MS
Copper	Cu	18.1	µg	per kg	ICP-MS

Contaminants

Aluminium	Al	<LOD			ICP-MS
Nickel	Ni	<LOD			ICP-MS
Arsenic	As	<LOD			ICP-MS
Cadmium	Cd	1.71	µg	per kg	ICP-MS
Lead	Pb	350	µg	per kg	ICP-MS
Uranium	U	6.87	µg	per kg	ICP-MS
Strontium	Sr	n.a.			TXRF

Appearance

Sea salt with algae

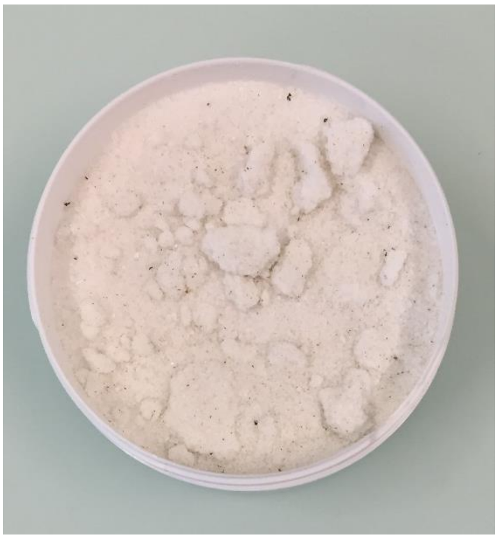
Origin not declared

Type Sea salt

Composition **Ingredients:** Salt, 0.4% algae from Iceland (leading to 2000 µg iodine per 100 g according to packaging information).

Nutrients				**Analysis**
Sodium	Na	39.5	%	ICP-OES
Chlorine	Cl	57.9	%	Argentometry
Potassium	K	<LOD		ICP-OES
Calcium	Ca	n.a.		TXRF
Iron	Fe	n.a.		TXRF
Zinc	Zn	<LOD		ICP-MS
		n.a.		TXRF
Phosphorus	P	n.a.		TXRF
Iodine	I	n.a.		ICP-MS
Copper	Cu	<LOD		ICP-MS
Contaminants				
Aluminium	Al	4004	µg per kg	ICP-MS
Nickel	Ni	<LOD		ICP-MS
Arsenic	As	291	µg per kg	ICP-MS
Cadmium	Cd	<LOD		ICP-MS
Lead	Pb	<LOD		ICP-MS
Uranium	U	1.34	µg per kg	ICP-MS
Strontium	Sr	n.a.		TXRF

Appearance



White pyramid salt

Origin not declared

Type Sea salt

Composition **Ingredients:** 100% salt.

Nutrients					**Analysis**
Sodium	Na	37.7	%		ICP-OES
Chlorine	Cl	58.5	%		Argentometry
Potassium	K	<LOD			ICP-OES
Calcium	Ca	n.a.			TXRF
Iron	Fe	n.a.			TXRF
Zinc	Zn	<LOD			ICP-MS
		n.a.			TXRF
Phosphorus	P	n.a.			TXRF
Iodine	I	<LOD			ICP-MS
Copper	Cu	<LOD			ICP-MS

Contaminants					
Aluminium	Al	14'915	µg	per kg	ICP-MS
Nickel	Ni	<LOD			ICP-MS
Arsenic	As	2.48	µg	per kg	ICP-MS
Cadmium	Cd	2.58	µg	per kg	ICP-MS
Lead	Pb	158	µg	per kg	ICP-MS
Uranium	U	0.812	µg	per kg	ICP-MS
Strontium	Sr	n.a.			TXRF

Appearance

Appendix 3: Recommended respectively tolerable intake levels

	DACH 2015 [26] (for 19-65 years old people)	**EFSA [21, 25, 27-32]**	**Other [33]**
	Recommended intake levels for nutrients		
Na	Estimated minimum intake recommendation: **550 mg/day**	--	--
Cl	Estimated minimum intake recommendation: **830 mg/day**	--	--
K	Estimated minimum intake recommendation: **2000 mg/day**	--	--
Cu	Estimated adequate intake recommendation: **1-1.5 mg/day**	--	--
Zn	Recommended dietary intake: **M 10 mg/day; F 7 mg/day**	--	--
I	Recommended dietary intake: **150 µg/day**	--	--
Ca	Recommended dietary intake: **1000 mg/day**	--	--
Fe	Recommended dietary intake: **M 10 mg/day; F 10-15 mg/day**	--	--
P	Recommended dietary intake: **700 mg/day**	--	--
	Tolerable intake levels for contaminants		
Al	--	Tolerable weekly intake **1 mg/kg body weight/week**	--
Ni	--	Tolerable daily intake **2.8 µg/kg bw/d**	--
As	--	Benchmark dose lower confidence level limit $BMDL_{01}$ **0.3-8 µg/kg body weight/day**	--
Cd	--	Tolerable weekly intake **2.5 µg/kg body weight/week**	--
Pb	--	Benchmark dose lower confidence level limit $BMDL_{01}$ **0.5-1.5 µg/kg body weight/day**	--
U	--	Tolerable daily intake **0.6 µg/kg body weight/day**	--
Sr	--	--	Minimal risk level **2 mg/kg body weight/day**

Appendix 4: Mineral and contaminant content in comparison with recommended respectively tolerable daily intake levels

The following figures show the percentage of recommended respectively tolerable intake level with an intake of 5 g salt vs. 9 g salt. For recommended respectively tolerable intake levels with a range or a difference between male and female, the lower values have been used. All tolerable intake recommendations have been converted to "per day" of a standard adult person of 60 kg of body weight for better comparison with 5g and 9g salt per day, respectively. When there is no bar, then either these elements have not been analysed or are present below levels of detection. For sodium and chlorine have been produced as the values. For details and absolute figures for all elements see tables 1 to 3 in the report.

3a) Nutrients

Figure 1: Calcium content in comparison with recommended intake levels

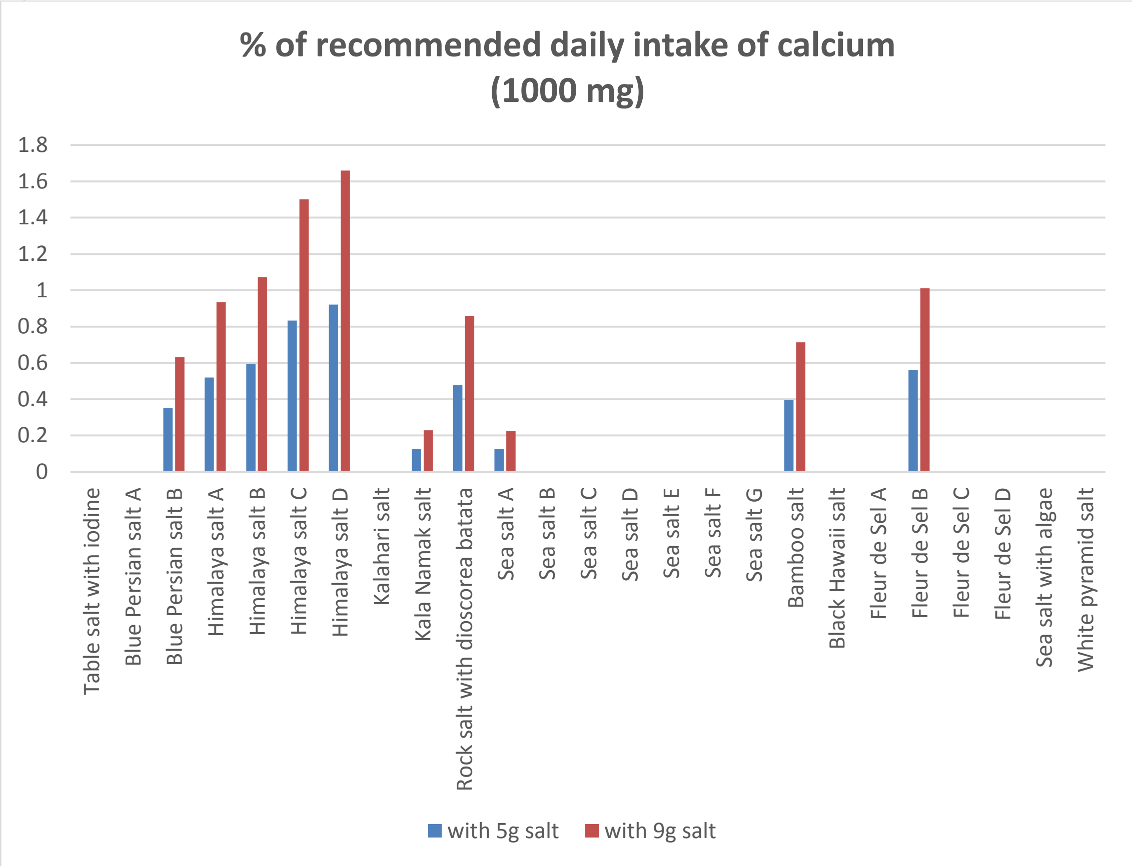


Figure 2: Potassium content in comparison with recommended intake levels

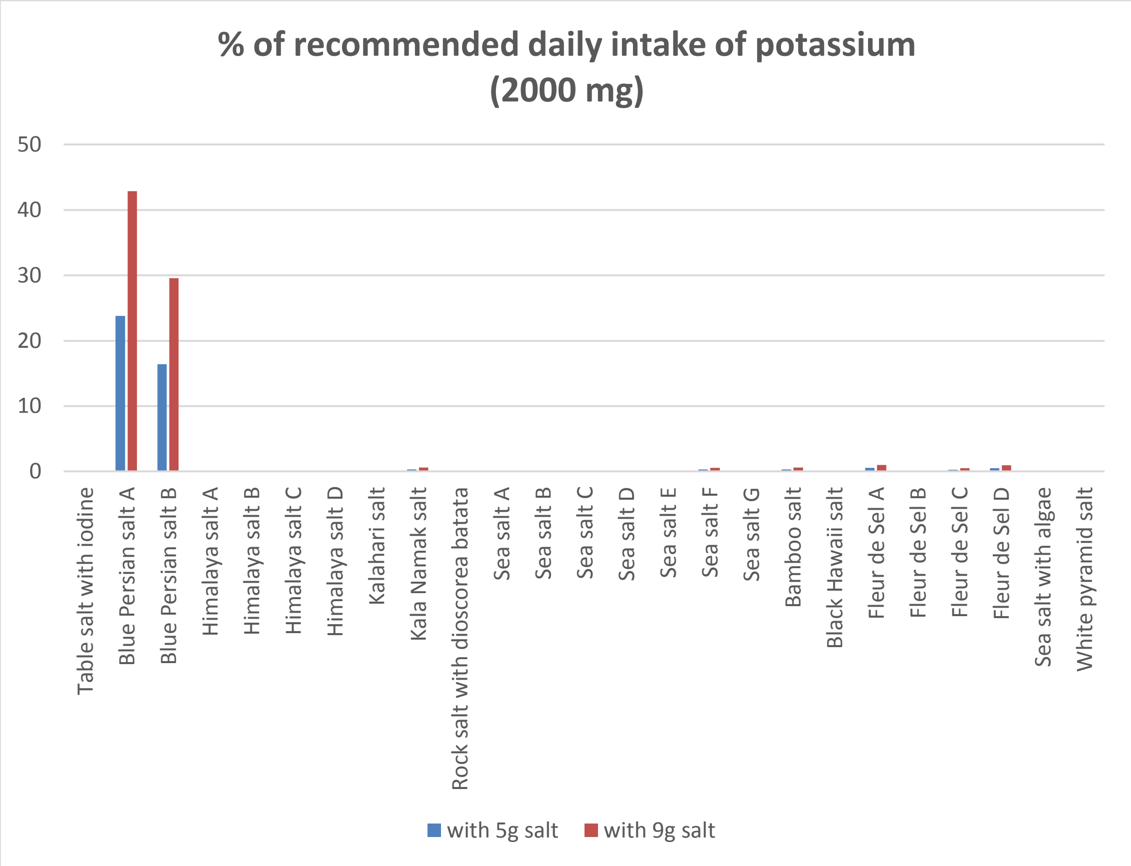


Figure 3: Copper content in comparison with recommended intake levels

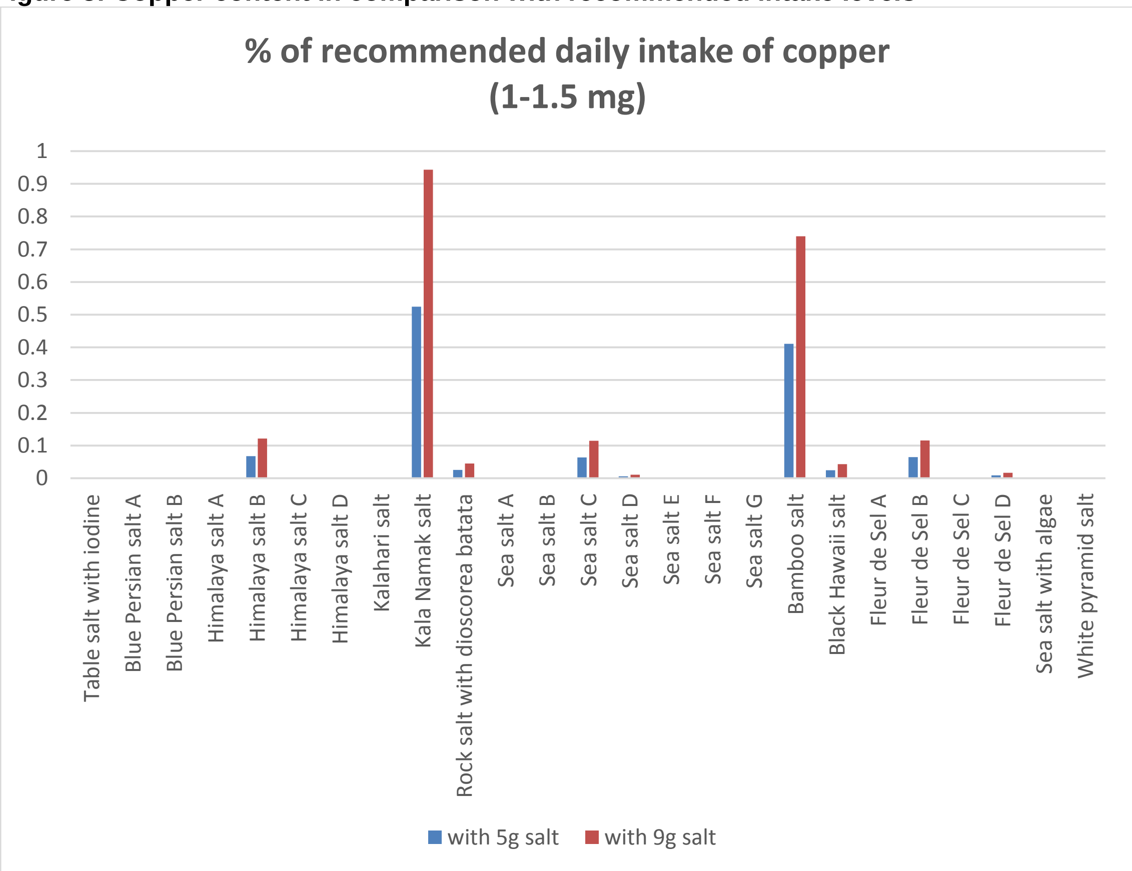


Figure 4: Zinc content in comparison with recommended intake levels

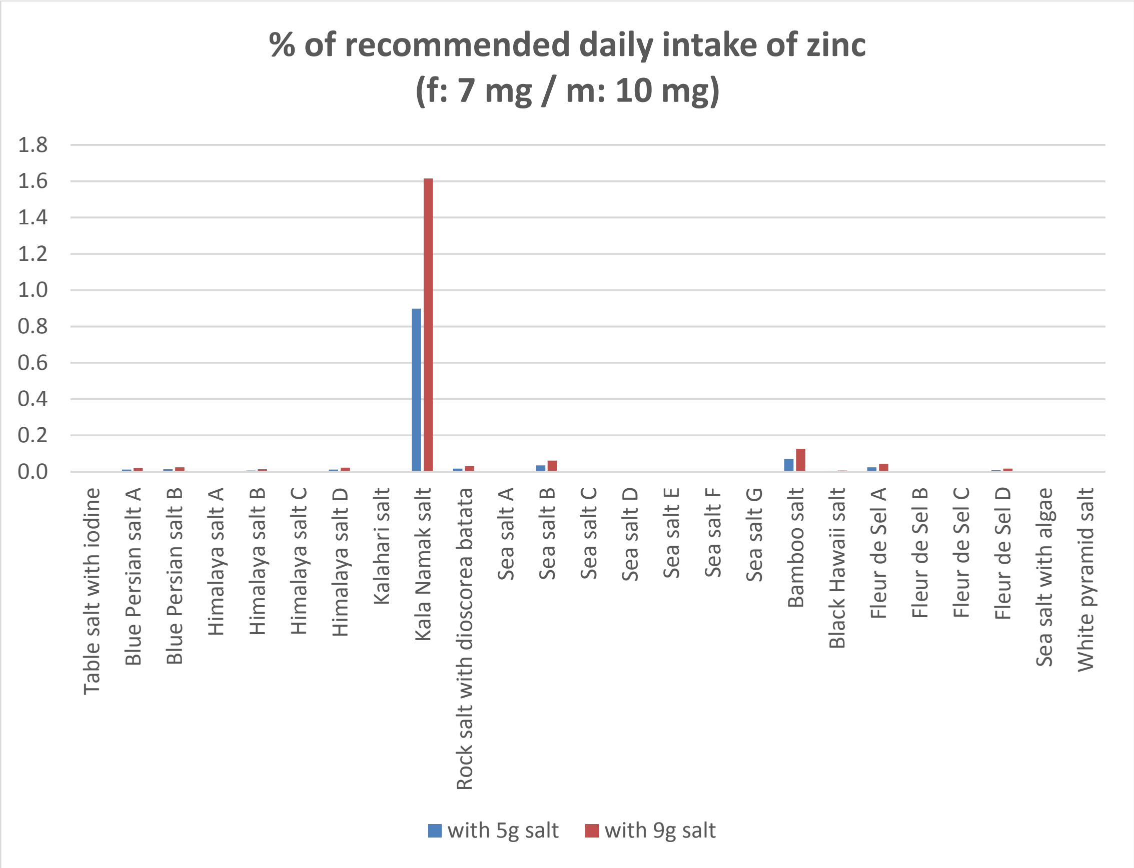


Figure 5: Iodine content in comparison with recommended intake levels

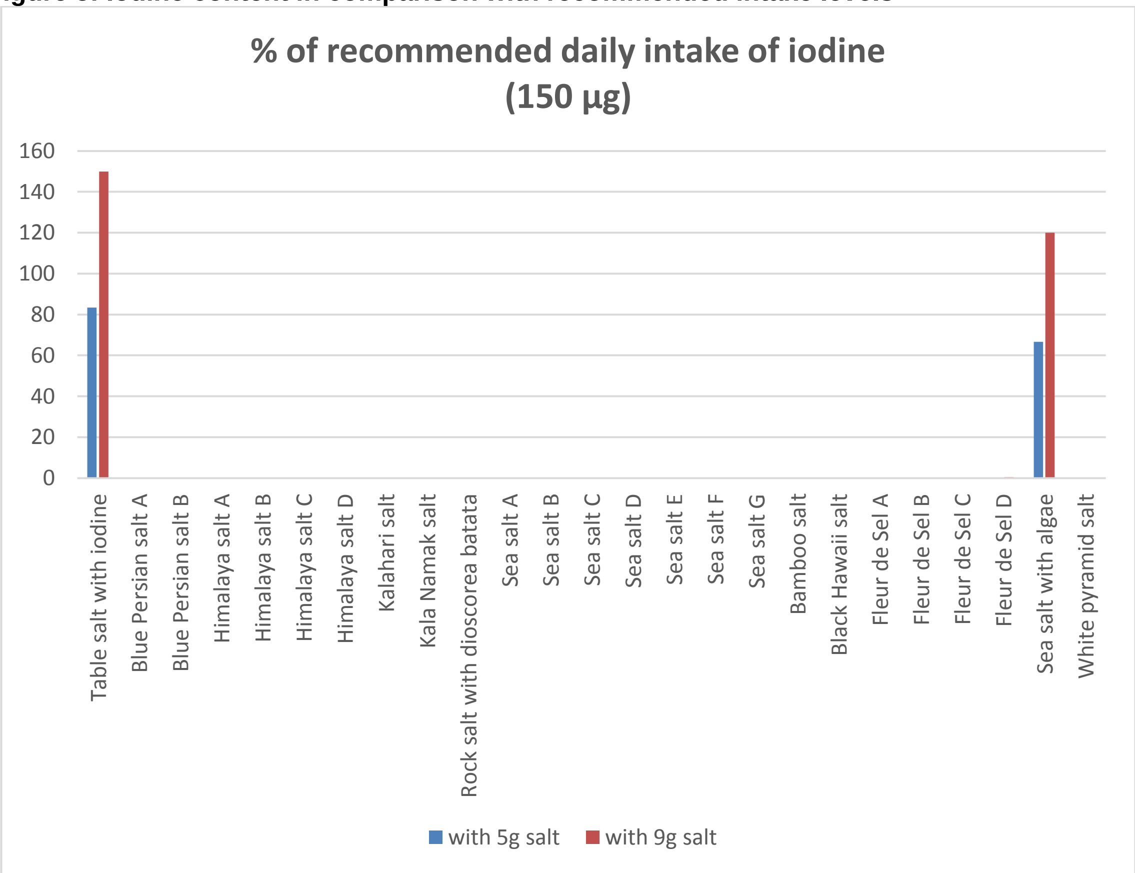
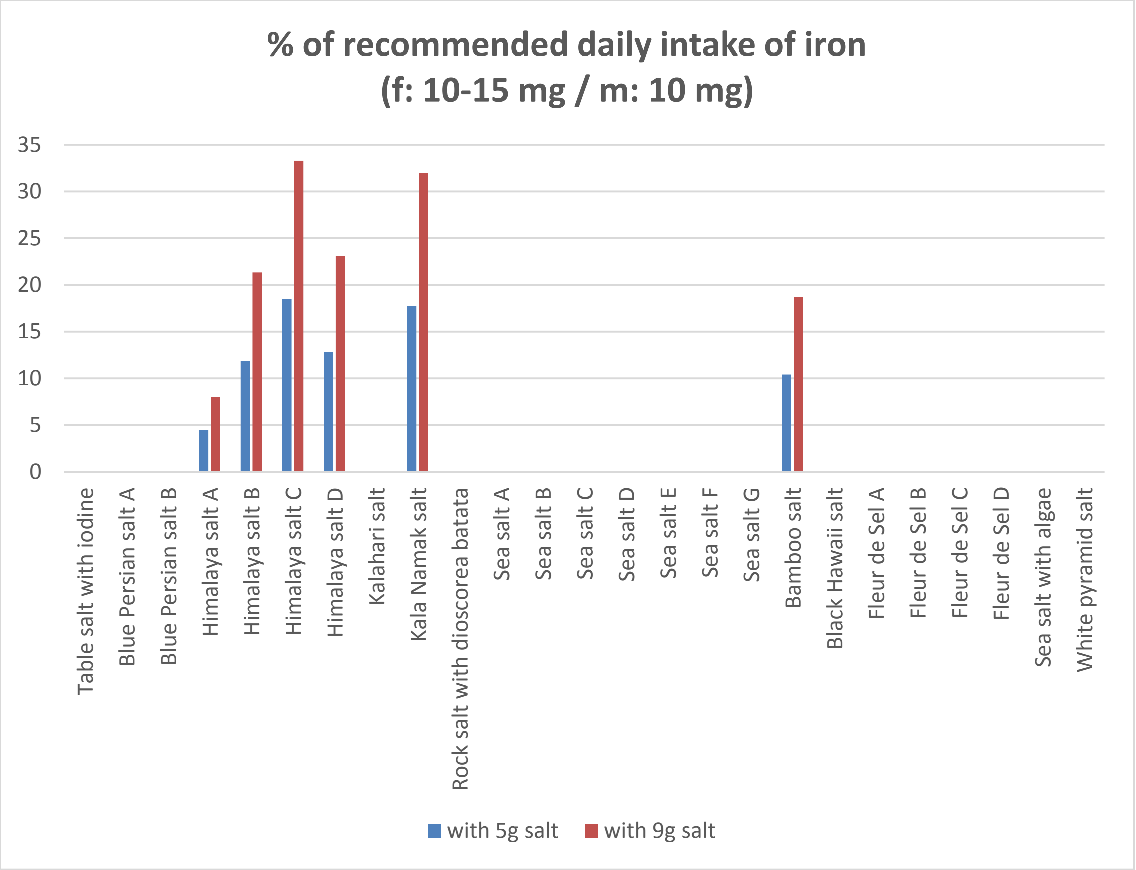


Figure 6: Iron content in comparison with recommended intake levels



3b) Contaminants

Figure 7: Aluminium content in comparison with tolerable intake levels

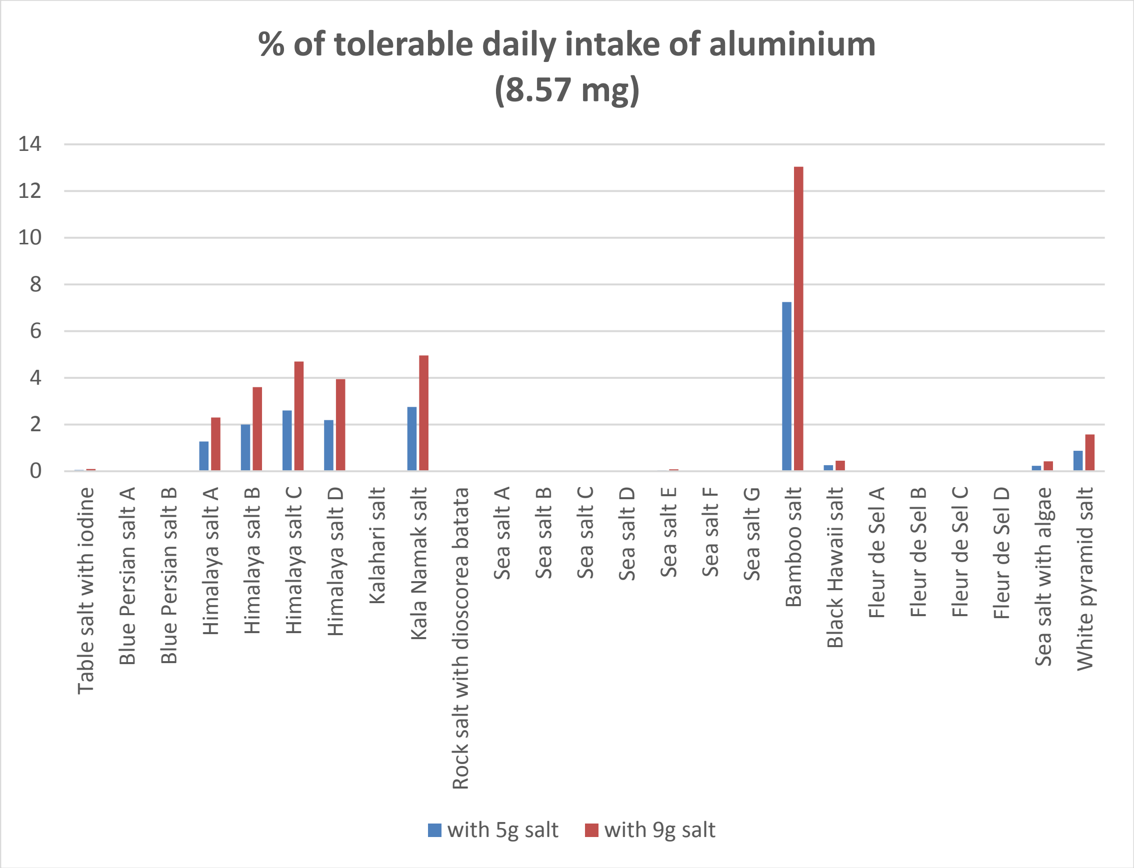


Figure 8: Nickel content in comparison with tolerable intake levels

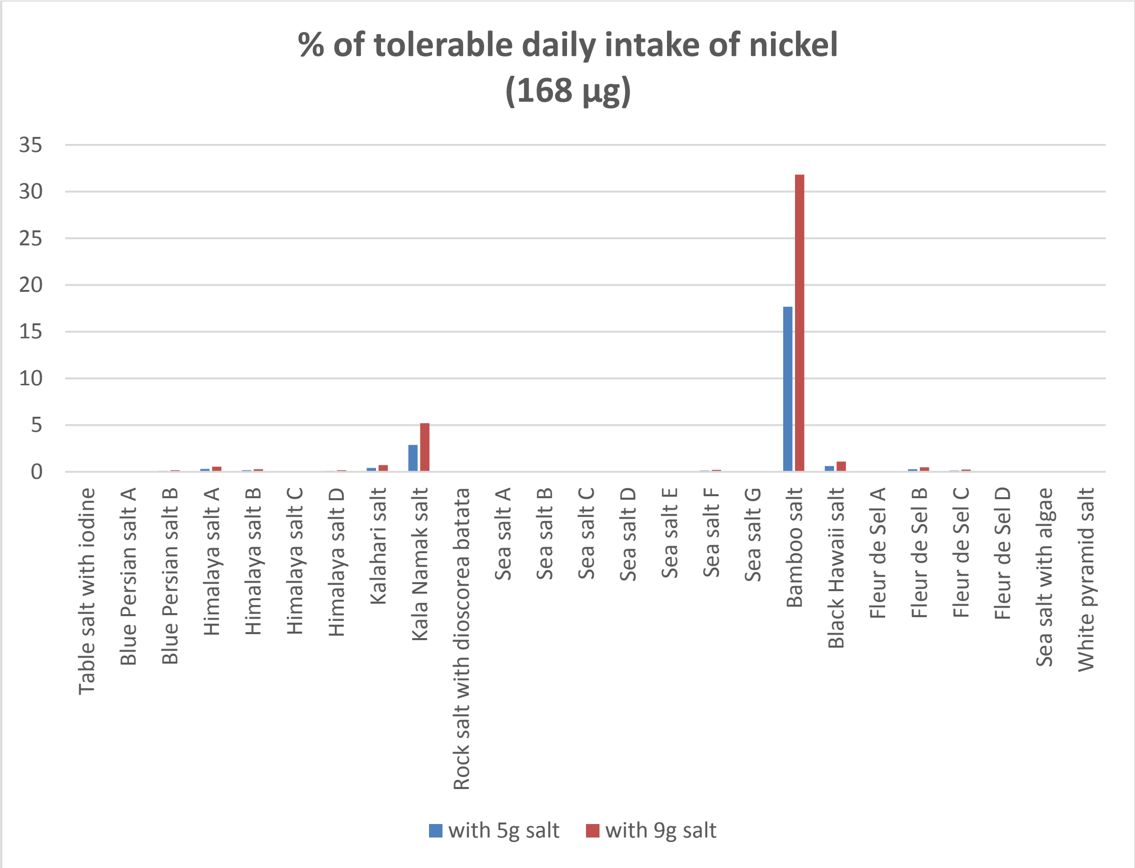


Figure 9: Arsenic content in comparison with tolerable intake levels

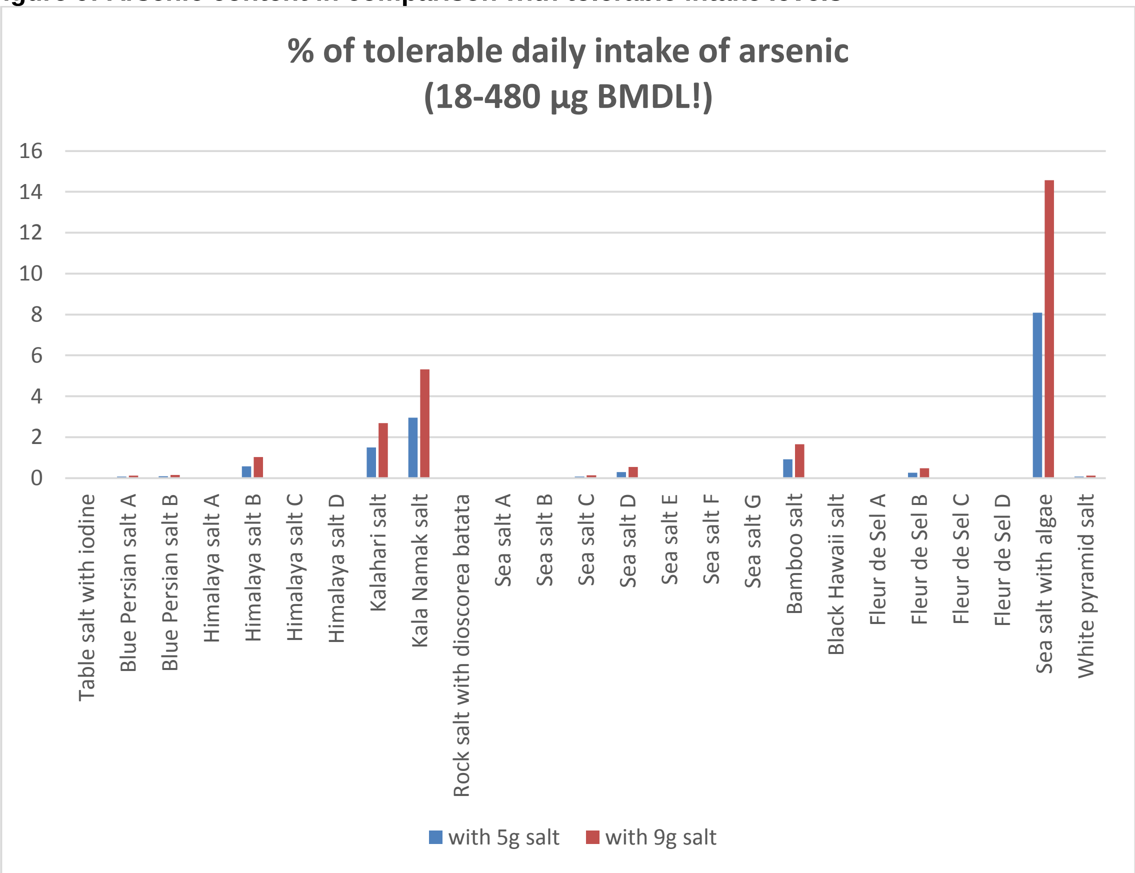


Figure 10: Cadmium content in comparison with tolerable intake levels

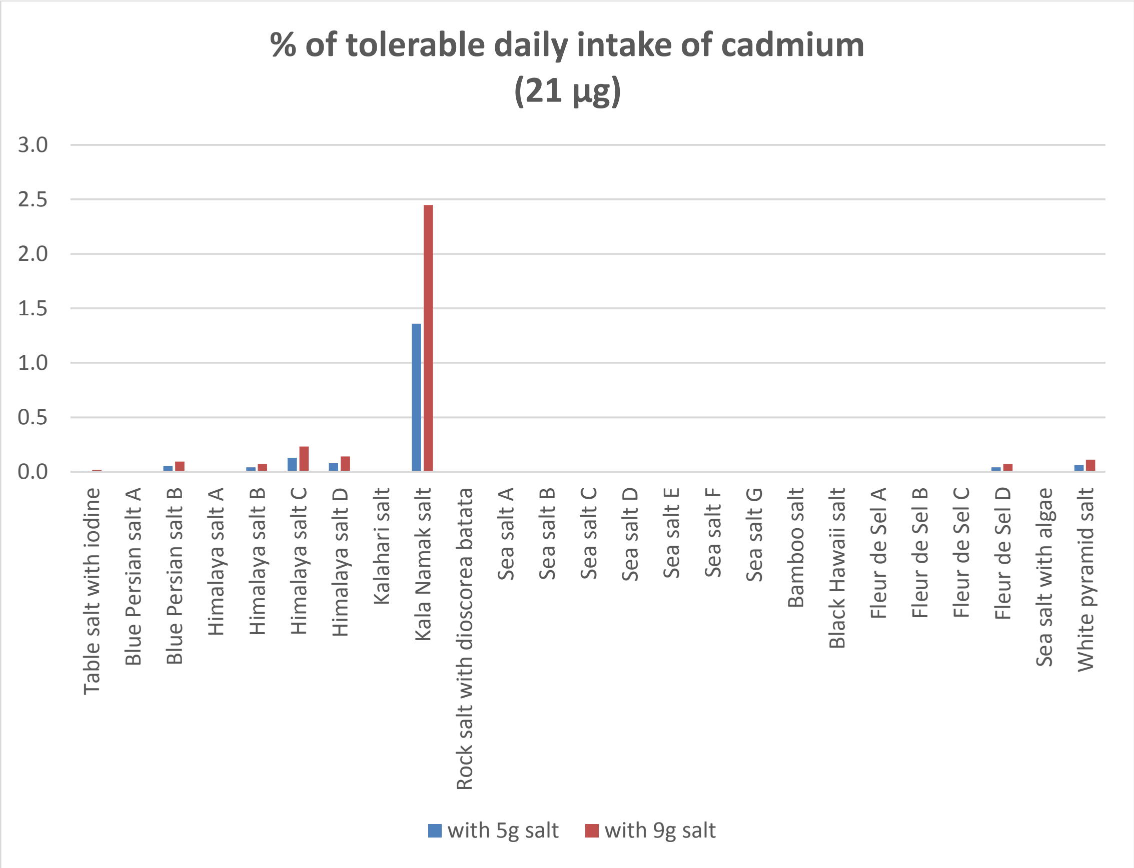


Figure 11: Lead content in comparison with tolerable intake levels

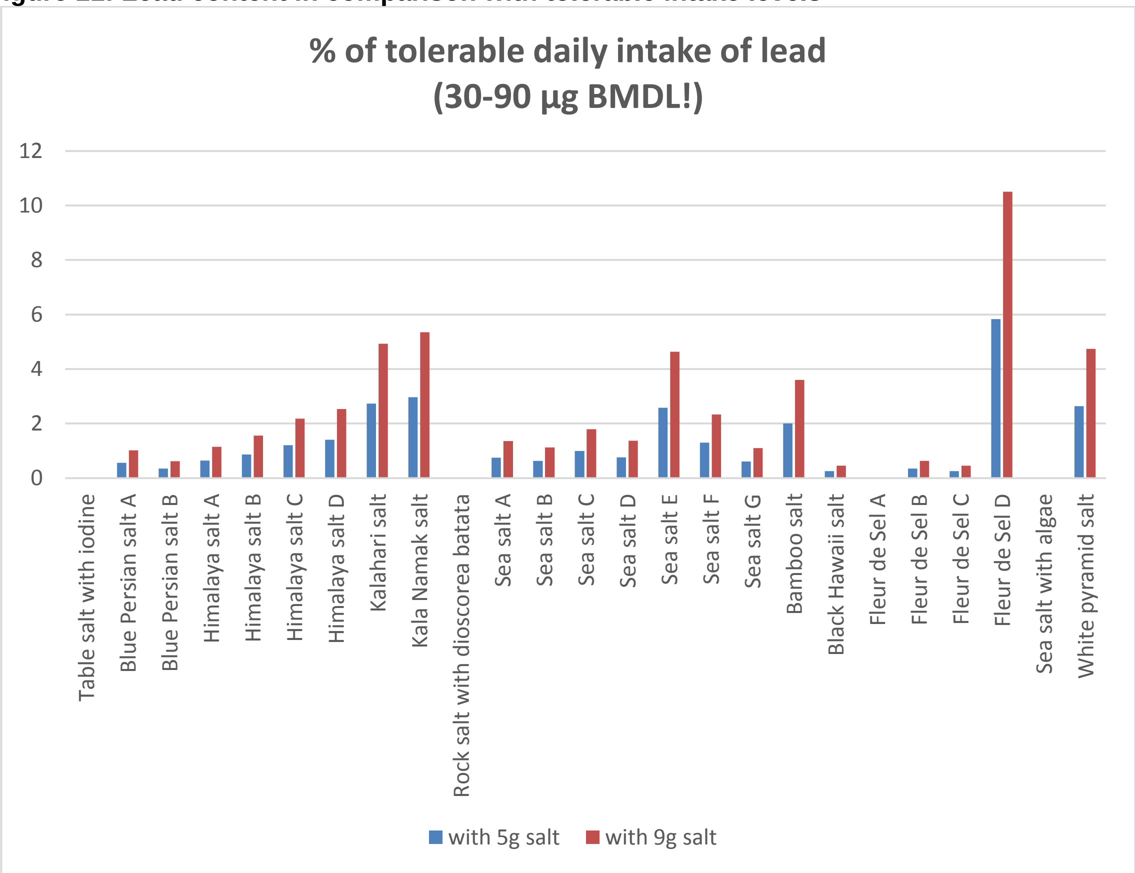


Figure 12: Uranium content in comparison with tolerable intake levels

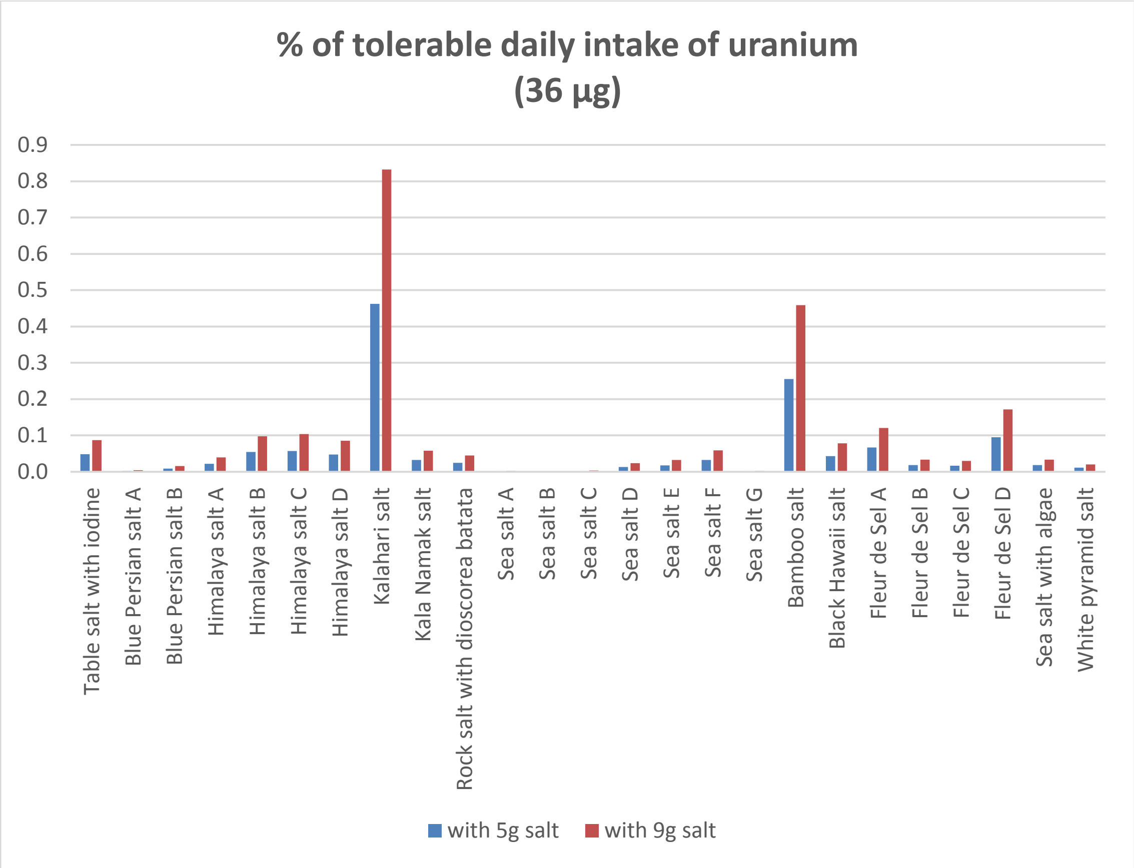


Figure 13: Strontium content in comparison with tolerable intake levels