Food phosphates: Questions and answers

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Introduction: *What are food phosphates?*

Phosphates are inorganic compounds, based on the element phosphorus (P), combined with oxygen to form phosphates (PO_4), the form in which phosphorus is present in nature. Phosphorus is found widely in nature, in rocks, soil, and water, and in all living organisms, mostly in the form of phosphates. Phosphates are essential for plant growth, crops, and human health.

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However, phosphates are generally present in nature at low levels, because the only primary source is the slow erosion of rocks. Phosphorus is often thus " limiting " for plant growth. For this reason, human civilisations in the past had to make considerable efforts to ensure that phosphate supply to agriculture was maintained, by collecting and returning animal and human wastes to land. Today, man ensures phosphorus supply to crops by extracting phosphates from natural rock, to produce phosphate fertilisers.

Food phosphates are also made from phosphate rock, after intensive purification. Heat combination with different mineral salts (sodium, potassium, calcium, magnesium or iron) produces a wide range of specific compounds for different purposes. Nearly all phosphates extracted from rock are used in fertilisers, detergents or agricultural animal feed supplements, and only around 1% is used by the food phosphate industry.

Modern diets usually contain largely adequate levels of phosphate for human health, so food phosphates are not generally used as a dietary additive. They are used for a range of purposes including maintaining natural colours and flavours, acidity buffering, leavening, stabilisation of texture, shelf-life quality, and as a support for calcium, magnesium and iron mineral enrichments.

In the body, they are broken down to simple phosphate ions (PO_4), the basic building block of the many different biological molecules which include phosphorus. Excess phosphate is excreted by the kidneys when dietary intake exceeds the body's needs.

Food phosphates have been used safely for over 100 years. The European Union's Scientific Panel on Dietetic Products, Nutrition and Allergies assessed food phosphates in 2005 [i], within its ongoing studies of vitamins and minerals. The Committee concluded that there is no evidence of adverse effects.

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Why do our bodies need phosphates?

Phosphorus is the 6th most abundant element in our bodies [ii], present mostly as phosphates. Phosphates and their compounds are essential for the health of all living organisms: man, animals and plants. They are at the centre of all life, as key components of DNA (genes), cell structures, cellular energy cycles, bones and teeth, and in the capture of the sun's energy by plants (photosynthesis).

Because our bodies constantly excrete phosphates, through the kidneys, it is essential to have a regular adequate intake in our diets.

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Phosphates in the human body:

- our bones and teeth (dentin and enamel) are built of calcium phosphate based structures (hydroxyapatite): this accounts for 85% of the phosphorus in our bodies
- phosphorus is also essential for the production of collagen, the fibre which makes up ligaments and tendons, as well as contributing to bone structure, cartilage, skin and the eye
- the structure of each of our cells is based on phospholipid membranes
- the transfer of energy within cells, on which depend all body functions, from thought through to muscle function and motion, is based on adenosine tri- / di- phosphate metabolism (ADP, ATP)
- our genetic material DNA is based on a deoxyribose – phosphate chain
- phosphorus is a key component of many proteins
- important for acid-base regulation in our bodies (pH balance)
- needed to produce myelin, the covering of nerve and brain cells which allows impulses to transmit signals (1/3 of the brain's dry weight is phosphorus fatty acids)
- phospholipids in the blood stop fats depositing on artery walls, and so prevent heart disease
- necessary to enable the body to use certain vitamins (A, D, E, K)
- phosphates are necessary for many other biological processes within our bodies

Phosphorus content:	
Human body	
Bones	12%
Teeth	8%
Brain	0.3%
Overall	1 - 1.2%
Plants	
Plant tissues	0.05 - 1%

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Which foods contain phosphates?

Because phosphates are essential for life, and are present in so many different biological functions, they are naturally present in nearly all foods.

▸ % phosphorus (P) by weight	
Grain products	0.1 - 0.3%
Fish and meat	0.2%
Milk and dairy products	0.1 - 0.9%
Fruit	0.015%
Broccoli	0.07%
▸ Phosphorus per serving	
Milk, low fat, 200 ml glass	200 mg
Bread whole grain, 1 slice (25g)	65 mg
Bread, white, 1 slice (25g)	24 mg
Oat bran, 1 cup, 100g	730 mg
1 egg	104 mg
Lentils, 1 cup, 200g	356 mg
Fish, 1 fillet, 150g	400 - 450 mg
Beef, portion, 150g	260 - 320 mg
Peach, 100g	20 mg
Banana, 120g	26 mg
Cola drink, 200 ml	24 - 40 mg
Orange juice, 200 ml	33 mg
Drinking water (maximum authorised concentration in Europe), 200 ml	0.44 mg
▸ Average dietary intake mg/person/day	
Total average dietary intake	1000 - 1500 mg
Contribution from added food phosphates	320 mg

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Although added food phosphate compounds are used for a variety of specific purposes to improve different foods (including meats, cheese and dairy products, cakes and biscuits, soft drinks, ...), the contribution of added food phosphates to total phosphorus intake is low. In the USA, dietary intake of phosphorus from added food phosphates is estimated at 320 mg/person/day [iii], that is 20-30% of dietary intake of phosphorus from natural foods.

Food phosphates are added to foods at very low levels. Maximum authorised added levels can vary from 0.07% up to 4% food phosphates, depending on application. In practice, levels used are around 0,35% in meat, 2,5% in processed cheese, 0,4% in cakes for leavening, or 0,05% in cola drinks for acidity and flavour.

Total phosphorus level in diet thus depends more on the type of food being eaten than on the presence of added phosphates. High protein diets (meat, fish, eggs, cheese ...) will be high in phosphorus because of their natural phosphorus content.

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Why does the food industry need phosphates?

Food phosphates are used in many different areas of the food industry to improve food products. A range of phosphate compounds is available with differing characteristics and functions (level of acidity, number of phosphate groups, combined with different minerals ...).

Phosphates are authorised as food additives worldwide, because detailed studies, confirmed by decades of widespread use, have shown them to be safe (USA [iv], Europe [v]).
The flexibility and wide range of phosphates allow the food industry to find and develop the functions it needs, adapted to a given food type and quality, in order to improve quality or offer new products to consumers.

For the consumer, food phosphates mean a more reliable quality of food products (stability of natural flavours and textures) when a product cannot be consumed immediately. Without them, many farm products would not last long enough to reach the consumer.

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Furthermore food phosphates offer specific functions without which many processed and consumer-ready foods and preparations would not exist. Food phosphates also bring the assurance of a completely safe food additive, based on natural phosphates and minerals which are anyway widely found in foods.

Advantages of food phosphates

▸ Maintain flavour and food quality	Buffering capacity	Ensure a stable acidity (pH) of foods and drinks, thus preserving natural flavour and colour
	Sequestering effect	Prevent natural mineral ions in foods from causing discoloration or deteriorated flavour (rancidity) during storage or processing Prevent crystals forming in seafoods
	Polyanionic functions	Maintain ingredients in suspension or prevent coagulation • Retain natural juices, particularly in meat and seafood products
	Shelf life improvement of natural products	Improve the biological stability of foodstuffs, by inhibiting reproduction of certain bacteria, during storage before consumption
▸ Baking	Leavening agents	Used with sodium bicarbonate to make cakes and pastries " rise ", and stay light, during cooking, balancing the alkalinity of the bicarbonate
▸ Dairy products	Texture quality	Enable smooth mixing of fats, proteins and moisture in processed cheese, evaporated milk, and other dairy products
	Ripening of cheese	By improving availability of calcium, facilitate the development of beneficial bacteria in cheese
▸ Prevent sticking	Anti-caking	Improve the free-flowing properties of powdered or dried foods
▸ Health supplements	Mineral enrichment	Provide fortification of diet or baby foods with calcium, magnesium, iron and phosphorus
▸ Pharma-ceuticals	Stability and quality of medicines	Phosphates physical and chemical properties make them effective excipients for a variety of drugs and medicines in tablet, powder and solution forms
▸ Drinking water	Quality and safety	Food phosphates are often added to drinking water supply to prevent lead or other toxic metals being dissolved from pipes and contaminating tap water

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How much food phosphates is used and where ?

Approximately 100,000 tons/ year of food phosphates are used in Europe (EU-25), that is approximately 25,000 tons of phosphorus (P) / year. This can be compared with a total phosphorus through-flow, just for The Netherlands, of around 600,000 tons P / year [vi].

85 - 90% of total phosphate use in Europe goes to fertilisers and agricultural animal feed supplements. Food phosphates represent approximately 1% and phosphate use in drinking water treatment around 0.1%.

Where food phosphates are used	
Bakery products	Cakes, biscuits, pastries...
Meat and poultry products	Fresh and cooked hams, chicken and other poultry, burgers, sausages...
Seafood products	Frozen fish, shellfish, shrimps
Processed cheese	Spreadable and ready-sliced cheeses
Dairy products	Evaporated milk, creams
Potato products	French fries
Soups and sauces	Ready-to-serve and gourmet sauces and preparations
Starch-based products	Ingredients for soups and sauces
Powdered foodstuffs	Dried soups, dried milk, instant pasta dishes...
Beverages, soda and juice products	Cola drinks, wines, beers, soft drinks
Dietery supplements	Mineral diet fortifiers
Pharmaceuticals	Tablets, powders, solutions
Drinking water	Safety of tap water distribution networks

The properties of food phosphates vary considerably, depending on the mineral present, and for products based on the same mineral, e.g.:
- monocalcium phosphate serves as a leavening agent in baking to make biscuits tender
- dicalcium phosphate is used as a polishing agent in toothpaste
- tricalcium phosphate is the conditioning agent in table salt that keeps it flowing freely.

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Where do food phosphates come from ?

Food phosphates are manufactured from natural phosphate rock, after intensive purification. Natural phosphate rock deposits are found in a number of countries across the world, including Morocco, South Africa, Israel, Finland, Kazakhstan and the USA. The rock used to extract phosphates for industry is generally of " sedimentary " origin. That phosphorus comes from millions of years of deposits of sea organisms onto ocean beds, which have then been crushed into rock and raised onto land by geological events.

Phosphates are extracted from the natural rock either by dissolving it in acid, or by a thermal furnace process. The first route produces " green " phosphoric acid which is then intensely purified before use to manufacture food phosphates. The second route produces elemental phosphorus, which after oxidation is reacted with water to give pure phosphoric acid.

The different specific phosphate compounds available to the food industry are then produced using a combination of heat processes (to condense poly-phosphates) and a variety of different purified food minerals (sodium, potassium, calcium, magnesium, iron...), followed by drying, granulation and conditioning to enable efficient application to foods (homogenous powders, solutions...).

Manufacturers of food phosphates in the European Union:
BK Giulini Chemie & Co (Germany) www.bk-giulini.com
Chemische Fabrik Budenheim (Germany) www.budenheim-cfb.com
Prayon (Belgium) www.prayon.com
Thermphos International B.V. (The Netherlands) www.thermphos.com

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Do we get enough phosphates in our diets ?

Recommended daily intake of phosphorus (mgP/day)[vii]	
Infants and children (0 - 10 years)	120 increasing to 800 mgP/day
10 - 19 years	1,250 mgP/day
Adults	700 mgP/day
Pregnant and breast feeding women	800 - 900 mgP/day

Because phosphorus is essential for our health, nature has made us relatively efficient in taking it into our bodies. Some 55 - 70% of phosphates in our food is effectively absorbed by our digestive system.

The minimum daily dietary intake of phosphorus, necessary to ensure good health, is 700 - 800 mg phosphorus (P) / day for adults. The balance between dietary levels of phosphates and of calcium and other minerals is also important, as high levels of one may affect digestive uptake of the other, but with normal diets this is not an issue.

Phosphorus is widely present in many foods, so that the average intake in European countries, at 1000 - 1500 mg/person/day, is in fact considerably higher than these minimum requirements.

The main source of phosphates in our diet is protein, in particular in meats and dairy products. Whole grain cereal products and breads contain more phosphorus than white flour, but much of it is in a form used for storage in the plant (phytin), which is poorly available to the human digestive system.

In some particular cases, however, dietary phosphorus supplements may be necessary. A minority of older women may have phosphorus intakes below or near dietary requirements, and if they are receiving calcium supplements to treat osteoporosis (bone wasting) this will reduce digestive phosphate uptake, and phosphate dietary supplements may also be necessary[viii].

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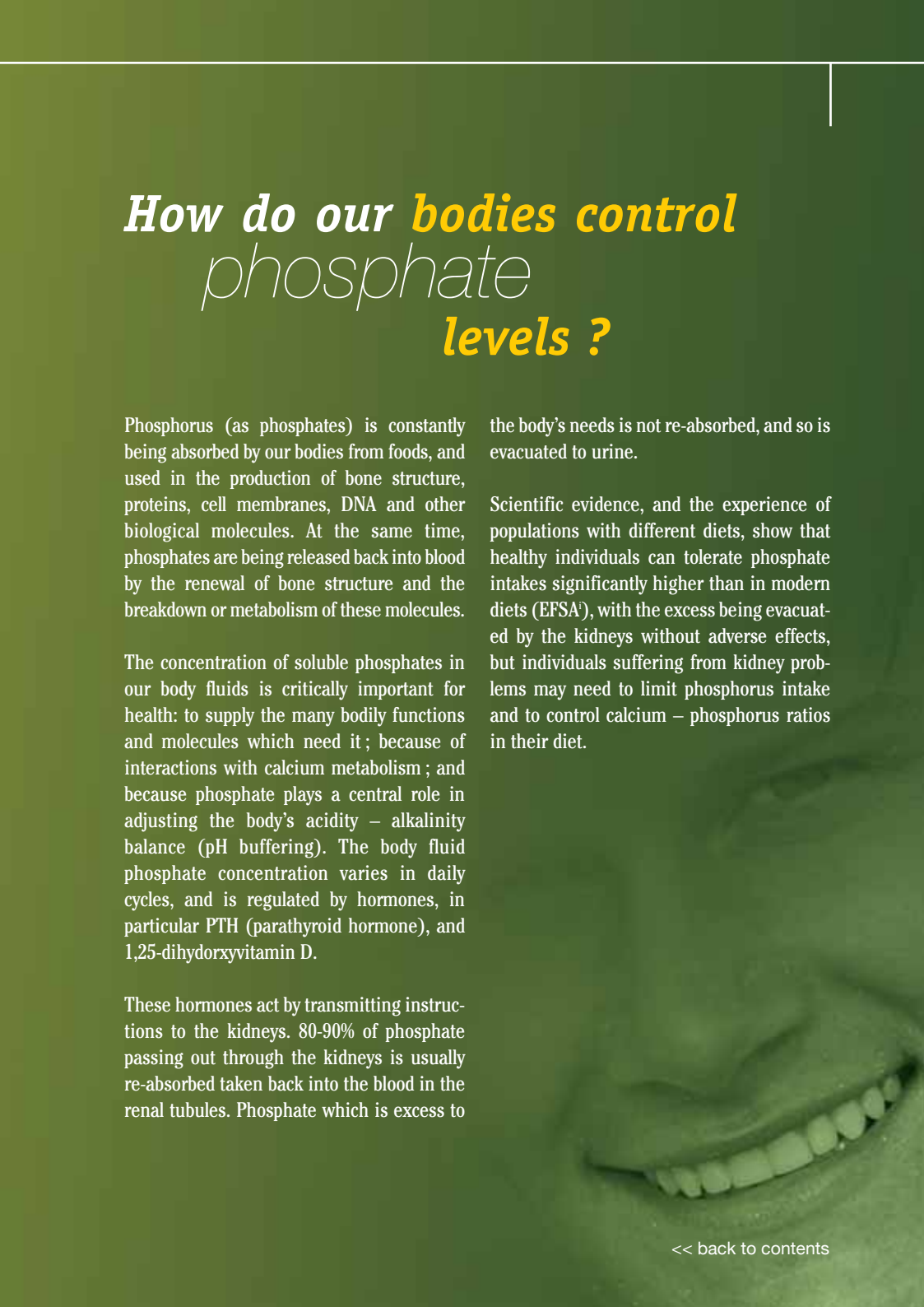
How do our bodies control phosphate levels ?

Phosphorus (as phosphates) is constantly being absorbed by our bodies from foods, and used in the production of bone structure, proteins, cell membranes, DNA and other biological molecules. At the same time, phosphates are being released back into blood by the renewal of bone structure and the breakdown or metabolism of these molecules.

The concentration of soluble phosphates in our body fluids is critically important for health: to supply the many bodily functions and molecules which need it ; because of interactions with calcium metabolism ; and because phosphate plays a central role in adjusting the body's acidity – alkalinity balance (pH buffering). The body fluid phosphate concentration varies in daily cycles, and is regulated by hormones, in particular PTH (parathyroid hormone), and 1,25-dihydorxyvitamin D.

These hormones act by transmitting instructions to the kidneys. 80-90% of phosphate passing out through the kidneys is usually re-absorbed taken back into the blood in the renal tubules. Phosphate which is excess to the body's needs is not re-absorbed, and so is evacuated to urine.

Scientific evidence, and the experience of populations with different diets, show that healthy individuals can tolerate phosphate intakes significantly higher than in modern diets (EFSA[i]), with the excess being evacuated by the kidneys without adverse effects, but individuals suffering from kidney problems may need to limit phosphorus intake and to control calcium – phosphorus ratios in their diet.



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Are high levels of phosphates in food dangerous ?

Many studies have been carried out on different food phosphate products in order to assess their safety as food additives. These studies have consistently shown that phosphate food ingredients are non toxic, and that they are used in the body in exactly the same way as phosphates naturally present in foods. These studies confirm the experience of decades of use of inorganic phosphates in foods, without any recorded negative effects: phosphates were first used in foods around a century ago, with baking powders and J.L. Kraft's processed cheese. The only limits to the use of food phosphates are thus related to general limits of dietary phosphorus levels.

At very high levels, phosphates can have health impacts, including temporary nausea in humans, and in animal experiments with extremely high doses, kidney dysfunction. These impacts are not relevant at the levels of phosphorus found in practice in foods, with or without added food phosphates, and only occur with artificially high phosphate levels achieved in test studies by deliberate phosphate supplements.

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Upper limits for intake levels for phosphorus have been suggested, by the United National Food and Agriculture Organisation and by the USA and Canada, as levels susceptible to avoid any risk, at 3000 - 5000 mgP/day. These limits are considerably higher than dietary intake.

Germany's Federal [ix] Institute for Risk Assessment concluded that " The risk assessment did not reveal any signs that supplementation with a maximum of 250 mg per kg body weight phosphorus as phosphate per day in addition to their customary diet would lead to clearly adverse reactions in otherwise healthy adults."

The European Union's official scientific panel concluded in 2005 (EFSA[i]) " Adverse effects of excessive phosphorus intake ... were not observed in studies in humans, except in patients with end stage renal disease " (serious kidney deficiencies).

Margin of safety for phosphorus intake in foods	
Mean daily phosphorus intake (UK, 2003 [x])	1260 mgP/day
Very high dietary intake: 97.5 percentile = highest 2.5% of the population (UK 2003)	2110 mgP/day
Food phosphates, daily intake (high estimate based on USA figures)	320 mgP/day
Recommended maximum daily intake (adult)	4000 - 5000 mgP/day

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Are levels of phosphates in modern diets bad for the health ?

This question does not specifically concern added food phosphates, which make up only a minor proportion of total dietary phosphorus intake (10 - 30%), but rather the general increase in high phosphorus content diets.

The increasing consumption of meats and protein-rich foods, may have led to an increase in dietary phosphorus intake in Europe, as for example in Germany from 1440 mgP/ day in 1973/74, to 1570 mgP/day in 1978/79 and to 1569 mgP/l in 1997/99 (BfR[ix]).

However, unlike for salt, there is no evidence that this general increase in diet phosphorus levels is related to health risks. This is because body metabolism naturally ensures phosphorus balance and rapidly eliminates excess phosphorus through the kidneys to urine.

What is certain, is that the general increase in dietary phosphorus intakes is mainly the result of increasing rich diets, with an increasing content of protein rich foods, in particular meats, and is not particularly related to added food phosphates. What is also certain, is that modern diets are - for many people in Europe - increasingly unhealthy, and when combined with a lack of exercise, pose real dangers of significant health problems and widespread obesity.

The European Scientific Panel on Dietetic Products, Nutrition and Allergies concluded in 2005 that " There is no evidence of adverse effects associated with the current intakes of phosphorus (EFSA[i]) ".

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How do increased diet phosphates levels affect osteoporosis ?

The structure of bones and teeth is based upon calcium phosphates (hydroxyapatite). Development of bones, but also their maintenance throughout life, therefore requires considerable inputs of both of these elements. The calcium phosphate structure is in fact continuously broken down and rebuilt throughout life. Bone structures also include the protein collagen, whose production requires phosphate.

Osteoporosis is a condition affecting principally the elderly, in particular women after the menopause. Symptoms are a loss of calcium phosphate from bones, with an overall loss of bone mass, and bones becoming fragile and easily broken. This can result from a deficiency in calcium in the diet, but also from hormonal unbalance, because the breakdown / rebuilding of bone calcium phosphate is hormonally controlled.

The ratio of calcium to phosphate can affect both calcium uptake in the digestive system and bone structure maintenance. In human milk, the calcium to phosphate ratio is 1.5 to 1 (by weight) and this is thought to be the optimal ratio for infants (EU Directives require a ratio in infant formula of between 1.2 and 2.0 to 1).

In adults, however, a number of studies [xi] have confirmed that increased phosphorus levels in diets did not affect calcium uptake, calcium excretion from the kidneys or hormonal control of bone structure. On the contrary, insufficient phosphate intake may in some cases be contributing to osteoporosis, and dietary supplements of phosphate should then be supplied along with the more usual dietary calcium supplement treatment (Heaney[xi]).

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Do phosphates cause hyperactivity ?

In a number of cases, parents or educationalists have suggested that moving to low phosphate diet has helped children suffering from " Attention Deficit Disorder " (ADD), that is, different forms of hyperactivity, concentration or behaviour difficulties. In some cases, tests with individual children or small numbers of individuals have been reported where a return to a normal diet or the inclusion of a phosphate supplement in the diet caused a temporary return of such problems, when these had apparently been resolved by moving to a low phosphate diet.

These reports are not based on rigorous scientific methods, and scientists and official bodies [xii] have expressed doubt as to their meaning, suggesting that the improvements might be due to other food components or diet changes, or to modifications in family or education environments and attitudes.

Several scientifically controlled medical studies [xiii], using groups of children identified as having " ADD " type problems, showed no improvement related to reduced dietary phosphorus intake. These studies did however show improvements related to better child - parent and child - educator communications.

There is no evidence that sensitivity to high dietary phosphorus levels is a general issue. Above all, there can be no doubt that modern society needs to reverse the move to diets increasingly rich in meats, fats and processed food, and to increase instead consumption of vegetables, fruit and fibres, as well as rediscovering the benefits of daily exercise.

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Further information:

- **What are phosphates ?**
  http://www.phosphatefacts.com

- **What is phosphorus ?**
  http://www.chemsoc.org/viselements/pages/phosphorus.html

- **European Food Safety Authority Opinion, 2005:**
  http://www.efsa.eu.int/science/nda/nda_opinions/1098_en.html

- **German Federal Institute for Risk Assessment Opinion, 2005:**
  http://www.bfr.bund.de/cm/238/use_of_minerals_in_foods.pdf

- **Phosphorus contents of different foods (USDA National Nutrient Database):**
  www.nal.usda.gov/fnic/foodcomp/Data/SR17/wtrank/sr17a305.pdf

- **Whole Foods Market, the world's leading retailer of natural and organic foods:**
  http://www.wholefoodsmarket.com/wholebody/ingredients/phosphates.html

- **European Food Phosphate Producers Association:**
  http://www.cefic.be/Templates/shwAssocDetails.asp ?NID=5&HID=22&ID=29

- **Federation of European Food Additives, Food Enzymes and Food Culture Industries (ELC):**
  http://www.elc-eu.org/

- **European Chemical Industries Council (Cefic), " responsible care " initiative:**
  http://www.cefic.be/Templates/shwStory.asp ?NID=471&HID=8

- **Companies manufacturing food phosphates in Europe:**
  BK Giulini Chemie & Co (Germany) www.bk-giulini.com
  Chemische Fabrik Budenheim (Germany) www.budenheim-cfb.com
  Prayon (Belgium) www.prayon.com
  Thermphos International B.V. (The Netherlands) www.thermphos.com

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Footnotes

i EFSA (European Food Safety Authority) «Opinion of the Scientific Panel on Dietetic Products, Nutrition and Allergies on a request from the Commission related to the tolerable Upper Intake Level of Phosphorus», adopted 1 July 2005
www.efsa.eu.int/science/nda/nda_opinions/catindex_en.html

ii Hydrogen 63%, oxygen 25% (including body water content), carbon 9.5%, nitrogen 1.4%, calcium 0.33%, phosphorus 0.22%

iii Calvo MS and Park YK (1996), J Nutr 126:1168S-1180S.

iv US Federal (FDA) legislation (sec. 182.1810)

v EU legislation Directive 1995/2

vi «Phosphate recovery from animal manure the possibilities in the Netherlands», Van Ruiten Adviesbureau/Projectbureau BMA, November 1998
http://www.nhm.ac.uk/research-curation/departments/mineralogy/research-groups/phosphate-recovery/VanRuiten.pdf

vii D-A-CH (2000) Deutsche Gesellschaft für Ernährung, Österreichische Gesellschaft für Ernährung, Schweizerische Gesellschaft für Ernährungsforschung, Schweizerische Vereinigung für Ernährung: Referenzwerte für die Nährstoffzufuhr. 1. Auflage, Umschau Braus GmbH, Verlagsgesellschaft, Frankfurt/Main.

viii «Phosphorus Nutrition and the Treatment of Osteoporosis», R. Heaney, Mayo Clin Proc, January 2004, n°79, pages 91-97
http://www.mayoclinicproceedings.com/Abstract.asp?AID=650&UID=&Abst=Abstract

ix BfR German Federal Institute for Risk Assessment (Bundesinstitut für Risikobewertung) «Use of Minerals in Foods Toxicological and nutritional-physiological aspects», 2005
http://www.bfr.bund.de/cm/238/use_of_minerals_in_foods.pdf

x EVM (2003) Expert Group on Vitamins and Minerals. Phosphorus. Safe Upper Levels for Vitamins and Minerals. United Kingdom, May 2003, p. 293-298.

xi Spencer H, Menczel J, Lewini I, Samachson J (1965). Effect of high phosphorus intake on calcium and phosphorus metabolism in man. J Nutr 86: 125-132. Heaney RP and Rafferty K (2001). Carbonated beverages and urinary calcium excretion. Am J Clin Nutr 74: 343-347. Grimm M, Muller A, Hein G, Funfstuck R, Jahreis G (2001). High phosphorus intake only slightly affects serum minerals, urinary pyridinium crosslinks and renal function in young women. Eur J Clin Nutr 55: 153-161. Whybro A, Jagger H, Barker M, Eastell R. (1998). Phosphate supplementation in young men: lack of effect on calcium homeostasis and bone turnover. Europ J Clin Nutr 52: 29-33.

xii German Ministry for Health 1978.

xiii «Influence of food stuffs on the behaviour of children with attention-deficit and hyperactivity disorder. Studies to verify the efficiency of psychological therapies and phosphate-varied nutrition», Verlag für Medienpraxis und Kulturarbeit Ludwigshafen, H. Preis, 1999
http://www.uni-landau.de/fb8/fb_inhalte/mitarbeiter/preis/preis.htm

xiv See http://www.homeschoolmath.net/teaching/add-adhd-diet.php

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