IBD

Qualifications

Diploma in Beverage Packaging (Beer)
Unit 2.6 Carbonated Soft Drinks

Raw Materials
and Drink Preparation

DIPLOMA IN PACKAGING (BEER) - MODULE 2

UNIT 2.6: Carbonated Soft Drinks

ELEMENT 2.6.2: Raw Materials and Drink Preparation

SYLLABUS.

2.6.2.1 Ingredients, additives and flavourings:

- Regulations
- Sweeteners:
  - Bulk sweeteners
  - Intensive sweeteners
  - Shelf life
  - Synergy
- Acidulants
- Preservatives:
  - Sulphur dioxide
  - Benzoic acid
  - Sorbic acid
- Colours:
  - Artificial
  - Natural
  - Caramel
- Stabilizers:
  - Antioxidants
  - Cloudifier
  - Antifoam
- Flavourings:
  - Taste, smell
  - Raw materials and substances
  - Developing a flavour
  - Handling of flavours
  - Examples of formulations

2.6.2.2 Water preparation and uses:

- Types of water
- Treated water (see also 3.1.3.1)
- Water treatment processes
- Semi-treated water
- Appendices covering
  - Treatment summary of various water types
  - Water treatment process comparison
  - Measurement of water alkalinity

2.6.2.3 Product preparation:

- Syrup production and services
- CO2, water
- Proportioning principles
- De-aeration
- Carbonated product processing and filling equipment
- Types of proportioners and carbonators
- Beverage cooling

2.6.2.1 Ingredients, additives and flavourings:

Introduction

These notes will provide information on the basic ingredients used in the manufacture of soft drinks, how they are used and issues (practical and political) surrounding their use.

Ingredients can be divided into two categories:

1. *Food substances*
2. *Additives*

Food substances can be used without limit and do not have an E number.

An additive is defined by the UK Food Labelling Regulations 1996 as "any substance not commonly regarded or used as food, which is added to food ….. to affect its keeping qualities, texture, consistency, appearance, taste, odour, alkalinity or acidity or to serve any other technological function…..".

(Refer to your own local/national legislation for definition)

All ingredients must be declared on the label in descending order of usage by weight. Additionally additives must be declared in their appropriate functional category, e.g. colouring

CATEGORIES OF ADDITIVE	
Sweeteners	Stabilizer
Acid	Cloudifier
Acidity Regulator	Antioxidant
Colouring	Anti-foam
Preservative	

NB: *flavourings are not additives and may be subject to separate legislation.*

Additives may be named in full or by using other classification format – please refer to your own local or national legislation.

In a study by Doll & Peto (1981) on the causes of cancer, no causal effect could be attributed to additives and indeed there was evidence of a protective effect from preservatives and antioxidants. The Report stated "we have not excluded food additives as a source of risk but have attributed to them a *token* risk of less than 1%". This was reported in the UK by their Food Commission as "approx 1300 deaths from cancer in Britain each year may be attributed to food additives".

The reason for the high value due to diet is the occurrence of many potent carcinogens in ordinary natural foodstuffs, e.g. Furocoumarins found in celery, parsnips, parsley etc and hydrazines in mushrooms. Flavour components in mustard, horseradish and pepper are also known to be potent carcinogens and mutagens (but at levels much higher than found in the normal diet).

Proportion of cancer deaths attributed to various different factors

Factor or class of factors	% of all cancer deaths	
	Best estimate	Range of acceptable estimates
Tobacco	30	25-40
Alcohol	3	2-4
Diet	35	10-70
Food additives	<1	-5-2
Reproductive/sexual behaviour	7	1-13
Occupation	4	2-8
Pollution	2	<1-5
Industrial Products	<1	<1-2
Medicines/medicinal procedures	1	0.5-3
Geophysical factors	3	2-4
Infection	10	1-?
Unknown	?	?

Source: *Richard Doll and Richard Peto (1981)*

Regulations

Please refer to your own local and national legislation for relevant Regulations.

Sweeteners

All soft drinks are sweetened (except soda water) and the sweetness can be imparted by either bulk sweeteners or intense sweeteners.

Bulk Sweeteners

Sweetness is traditionally provided by sugar (sucrose) which is extracted from either cane or beet, the resulting sugar being identical (99% sucrose). Cane grows in tropical and beet in temperate areas, but in either case sugar is obtained by water extraction from the crushed plants followed by purification and re-crystallization. The sugar is delivered as either "granulated" solid or as a ready-made syrup at 67° Brix. Whilst sugar syrup is resistant to microbial attack due to its low water availability, care must still be taken to maintain hygiene, particularly in the head space of storage tanks and to avoid condensation occurring.

In the presence of acid, sugar will hydrolyse to form an equal mixture of glucose and fructose known as invert sugar, therefore in a soft drink sweetened with sugar you would expect to find a mixture of sucrose, glucose and fructose. This is accompanied by a small increase in brix (up to 5%).

Glucose Syrup and High Fructose Glucose Syrup (HFGS)

Glucose and fructose can be manufactured from starch (from either maize or wheat). Starch consists of long chains of glucose molecules and can be broken down by acid or enzyme hydrolysis to glucose. Glucose can be partially converted to the sweetener fructose using isomerase enzymes. Syrup containing 55% fructose has almost completely replaced sugar in soft drinks in the USA. However, in the EU production of fructose is severely limited by the Common Agricultural Policy (CAP). Fructose syrups (up to 85% fructose) may also be produced by hydrolysis of Inulin which consists of poly-fructose units and is extracted from Chicory. Again this process is severely restricted by the CAP.

Issues

Dental Caries: The incidence of dental caries is not linked to quantity of sugar consumed but rather to frequency of consumption and to dental hygiene. Soft drinks must not be used in baby feeders and good dental hygiene should be observed.

Between 1970 and 2000 soft drink consumption trebled. Over the same period dental caries in children fell markedly. This was due to the introduction of fluoride in water and toothpaste and improved dental hygiene.

Obesity: Soft drinks, because of their sugar content have been accused of causing obesity. However, increasing levels of obesity are more closely related to lack of exercise and low calorie drinks are readily available.

Intense Sweeteners

Intense sweeteners are permitted in sugar-free or reduced energy soft drinks. A reduced energy drink is defined as containing at least 30% fewer calories than an equivalent sugar sweetened product. No intense sweetener reproduces the exact characteristics of sucrose and blends are frequently used to optimise taste and cost parameters.

Intense sweeteners are currently significantly cheaper for an equivalent sweetness than bulk sweeteners within the EU. Please refer to your own local/national legislation with regard to the use of sweeteners (the usage of sweeteners in the UK is permitted by the *Sweeteners in Food Regulations 1995 SI No. 3123 - as amended).*

Intense sweeteners			
	Relative Sweetness (Approx)	Max permitted usage (mg/L)	Max Brix equivalence
Saccharin	500	80	4
Aspartame	200	600	12
Acesulfame K	200	350	7
Cyclamate	33	250	0.8
NHDC	1000	30	3
Sucralose	550	300	16.5

Note: *Relative sweetness can vary considerably from the figures quoted above depending upon individual application and rate of usage.*

Saccharin

Discovered in the mid 1800's and used in soft drinks since the 1880's.

Has a sweetness factor of between x300 – x700 depending upon concentration and application. In soft drinks the figure normally used is x500 (x450 for Sodium Saccharin). Although very sweet it has a harsh/bitter aftertaste, but is often used in food stuffs, e.g. sauces.

Main Advantage - very cheap
Usage Rate – maximum 80mg/L (equivalent to $4^{o}B$)

Saccharin was the only permitted intense sweetener during the 70's and early 80's and could be used "as required" in low calorie drinks, until 1996.

Saccharin is not readily soluble and so is always used as the Sodium salt. It is very stable in soft drinks.

Although used in the UK very widely it has never been very popular elsewhere because of the bitter aftertaste and the virtual non-existence of low calorie drinks until relatively recently.

Concern over a risk of cancer in the USA has since been proved incorrect and saccharin has been removed from the suspected carcinogens list.

Cyclamate – Sodium Cyclamate

This is an extremely good sweetener with a very sugar like flavour and good solubility and stability. It is also relatively cheap to manufacture. The sweetness factor is low (x33) compared to other sweeteners.

It works well in a combination with saccharin, usually 10 parts cyclamate to 1 part of saccharin. Its ADI was reduced from 11mg/kg BW to 7mg/kg BW with a reduction in usage rate to 250 mg/L max.

The low sweetness factor results in the current maximum usage rate of 250mg/L being equivalent to only 0.8^o Brix which is too low to be really useful. However, it does have good synergy with other intense sweeteners.

Originally introduced in 1950, Cyclamate was wrongly linked to bladder cancer in rats in a study in the USA and was banned in 1969 in the USA and UK. Its use was
re-authorised in the UK in 1996 as a result of the Sweeteners Directive. It was never banned in the rest of Europe, but its usage was severely limited by the directive.

Cyclamate is easy to use as it is readily soluble and very stable.

Acesulfame K

Acesulfame K (originally Acesulfam K) was discovered by Hoechst in Germany and was permitted in the UK in 1983. It can be used at a maximum level of 350mg/L. Attempts to have this level increased have so far been unsuccessful. In properties (except price) it is similar to saccharin but has a better flavour, with a much reduced harsh/bitter aftertaste. It is readily soluble and very stable. It is often used in combination with aspartame with which it exhibits good synergy.

Its sweetness level is approximately the same as aspartame (c200).

Aspartame

The methyl ester of a dipeptide:-

  ▪   Aspartic acid – Phenylalanine – Methyl ester

Aspartame was developed in the USA by G.D. Searle (part of Monsanto). Permitted in USA and UK in 1983 and sold under the brand name Nutrasweet. Monsanto's patent expired in the early 90's and other manufacturers appeared, causing the price to fall.

People suffering from Phenylketonuria cannot metabolise Phenylalanine. Although this is an extremely rare disorder, drinks containing aspartame must be labelled 'a source of phenylalanine'. The methyl ester is metabolised to methanol and this has also caused concern, despite the level being lower than that found in some other common foodstuffs, e.g. bananas.

Aspartame has a sweetness factor of approximately x200. Maximum usage rate is 600mg/L. It has a good sugar-like flavour but can linger, especially if used on its own at the maximum rate; it is better in a blend.

It has two disadvantages:

  1.   Instability – in acid solution aspartame hydrolyses to give breakdown products which are not sweet. The major one being diketopiperizine (DKP). The rate of breakdown depends upon pH and temperature, i.e. it is faster at low pH and high temperature. The pH can be buffered higher using sodium citrate, thereby extending the shelf life. Aspartame also reacts slowly with ascorbic acid to produce a yellow discolouration.

  2.   Low solubility – aspartame dissolves only slowly and has low solubility (less than 1%). This can be improved by dissolving in dilute citric acid. However, this low solubility does cause problems, particularly in production of concentrated products, e.g. dispense syrups and in automated continuous blending systems.

Shelf Life

The effects of instability on shelf life can be moderated by:

  a)   Initial over sweetening;

  b)   Use a blend of aspartame/acesulfame k, 70:30 synergy is maximum at 50:50 and so increases as the aspartame breaks down;

  c)   Use sodium citrate to raise the pH (this does affect the flavour);

  d)   Store cold.

The maximum shelf life for a low calorie drink sweetened with aspartame only is 6-9 months.

Neohesperidin Dihydrochalcone (NHDC)

NHDC has been permitted in the UK since 1996. It is manufactured from an extract of bitter orange peel. Although it is extremely sweet, approx 1000 times sweeter than sucrose, its application in soft drinks is limited by its flavour characteristics other than sweetness. At the maximum 30mg/L it exhibits significant, almost menthol-like aftertaste. However, at low usage rates, ca.5mg/L, it can display interesting flavour enhancement effects. There are no significant stability or solubility problems.

Sucralose

Trichlorogalactosucrose (TGS) was discovered by Tate & Lyle in the 1970s. It is approved in many countries, including USA, Canada, Australia, Russia and China. It has been given an ADI of 15mg/kg BW by the SCF and is permitted in the EU up to a maximum 300mg/L in soft drinks. This level can provide the sole sweetness in a low calorie drink. It is readily soluble, making it useful in concentrated products such as dispense syrups and is very stable, meaning that there is no loss of sweetness over the product shelf life. It is 500-600 times sweeter than sucrose.

Neotame

This is a dipeptide, similar to aspartame for which it has been developed as a replacement. It is approximately 8000 times sweeter than sucrose and therefore has an extremely low usage rate.

Neotame is significantly more stable than aspartame in acidic aqueous solutions and therefore has an increased shelf life. It was permitted in the EU in 2010.

Miscellaneous Sweeteners

Although only five intense sweeteners are permitted for use in soft drinks in the EU, there are many naturally occurring intensely sweet plant extracts, e.g. thaumatin, glycyrrhizin, stevioside and rubusoside, which are used in various parts of the world.

Synergy

This is the "2 + 2 = 5" effect. The apparent sweetness of a blend of sweeteners is higher than would be expected from the individual components.

The amount of synergy depends upon the combination of sweeteners, the levels used and the application. Good combinations are:-

- Aspartame/acesulfame K
- Aspartame/saccharin
- Cyclamate/saccharin

Note: *Acesulfame K/saccharin has a negative synergy.*

Some sweetener manufacturers claim synergy values of 50% but 10-20% is more realistic.

Acidulants

Acidity is one of the fundamental properties of a soft drink, the balance between sweetness and sharpness (the Brix/acid ratio) being a key characteristic. The low pH of a soft drink also has an important function in that pathogens will not grow at a pH < 4.5.

With the exception of soda water, all soft drinks are acidified either by the addition of fruit juice or the inclusion of an acid. A number of acids can be used in soft drinks, e.g. tartaric and lactic are used in speciality drinks, but by far the most commonly used are citric, malic and (in cola) phosphoric acids. Citric and malic acids occur naturally in fruits; the former in citrus fruits, currants and berries, and the latter in apples, cherries, plums and peaches.

Citric acid is produced commercially by fermentation of glucose by moulds, e.g. Aspergillus Niger. Malic acid is manufactured by chemical synthesis – the hydration of Maleic Anhydride. Citric and Malic acids are weak organic acids but phosphoric is a strong mineral acid. It is manufactured by the action of Sulphuric acid on mineral phosphates. It should be noted that Citric acid can be purchased in two forms, either Citric acid anhydrous (CAA) or with one molecule of water of crystallisation, Citric acid monohydrate (CAMH). This is an important factor when calculating the quantity of Citric acid to be added in order to obtain the correct acidity. Citric and malic acids can be used QS but phosphoric acid is limited to 970mg/L (as H_3PO_4)

The acidity of a soft drink will vary according to the recipe but most fall into certain broad bands. Lime and lemon juice are extremely acidic, in fact too acid to drink, but orange, grapefruit and pineapple are much less so. Soft drinks are much less acid than fruit juices generally varying between 0.5 and 0.1% citric or malic acid and having a pH of between 2.5 and 3.5

There is no direct relationship between total acidity and pH. Total acidity is measured by titration and represents the total quantity of acids present, whereas pH is a measure of the hydrogen ion concentration. The relationship between total acidity and pH is affected by other substances present in the drink, e.g. fruit juices or by "acidity regulators" added to deliberately buffer the pH. Sodium citrate is commonly added to raise the pH whilst also increasing the total acidity resulting in a smoother drink.
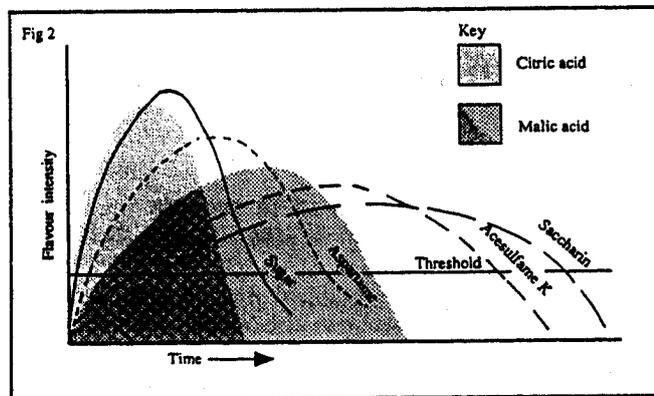
The sharp taste of drinks is more closely related to total acidity than to pH. Fruity drinks and tonic water have acidities near to 0.5% whereas milder drinks like ginger ale and cream soda are nearer to 0.1%. The sharpness of a fruit juice or drink is also affected by the brix/acid ratio, i.e. a reduction in the sweetness will appear to make the drink more acid.

In chemical terms phosphoric acid is a strong acid, i.e. much less of it is needed to produce a low pH than the weak citric or malic acids. In a typical cola, only 0.06% phosphoric acid is required to produce a pH of 2.4. Although the pH is very low, the cola has a smooth, mild flavour because of the low total acidity

	Acidity	pH
Lemon and lime juices	6%	3.0
Orange and grapefruit juices	1%	3.5
Soft drinks (*citric or malic*)	{0.5%	2.5
	↓	↓
	{0.1%	3.5
Colas (*phosphoric acid*)	0.06%	2.4

Whilst citric and malic acids are of similar acidic strength they are different in flavour impact. Citric acid has an initial sharpness in its flavour which, as shown in the graph, appears on the tongue very quickly and then dies away equally quickly. The flavour impact of malic acid is less intense but longer lasting. The flavour intensity of citric acid is almost a perfect match with that of sugar so the two blend together very well in a soft drink. The intense sweeteners tend to linger on the palate, especially saccharin which is well known for its long aftertaste. In these cases malic acid is a closer match in flavour intensity and is frequently used in diet drinks containing intense sweeteners.

Flavour intensity picture/graph

Flavour Intensity

Fig 2

Key
- Citric acid
- Malic acid

Flavour intensity

Threshold

Acesulfame K

Saccharin

Time

Other acids

Fumaric acid

Fumaric acid is not permitted under UK or European legislation for direct use in soft drinks, although it is permitted, within strict limits, in instant powders for fruit-, tea-, or herbal-based drinks. The main drawback to the use of fumaric acid is its slow solubility rate in comparison with citric acid and the need for special methods in its dissolution.

Lactic acid

One of the most widely distributed acids in nature, lactic acid is used to a greater extent by the food industry in dairy products. Its use in beverages is limited. It has a mild taste relative to the other acids and is used in soft drinks as a flavour modifier or enhancer rather than as an acidulant.

Tartaric acid

Occurs naturally in grapes as potassium salt and is also a natural component of many other fruits such as currants, blackberries and cranberries. Tartaric acid has a strong, tart taste and it complements natural and synthetic flavours, especially grape and cranberry. It has a sharper flavour than citric acid so can be used at a slightly lower level to give equivalent palate acidity.

Succinic acid

Succinic acid is found in nature in small amounts, it is also found in cherries. It is a weak acid, only moderately soluble in water and has a bitter taste. It is commonly used in sake (Japanese rice wine).

Adipic acid

Occurs naturally in beet juice and is a weak acid sparingly soluble in water. Originally used in the food industry as an acidulant for dry mixes but very rarely used now.

Preservatives

The types and maximum usage levels of preservatives may be stipulated in your local/national legislation – please check. Examples of permitted UK levels are shown as follows:

Preservatives (SO$_2$)	
Sulphur Dioxide	**Max (mg/L)**
Concentrates containing fruit juice and more than 2.5% barley	350
Other concentrates containing fruit or juice	250
Ready to drink soft drinks containing more than 235g glucose/litre	50
Soft drinks containing fruit juice (as carryover from juice concentrate)	20
N.B. Levels of less than 10mg/L are considered not to be present.	

Preservatives (other than SO2)	
Acid	**Max rtd (mg/L)**
Benzoic Acid	150
Sorbic Acid	300
	(*or 250 if used in conjunction with benzoic acid*)
Dimethyl Dicarbonate (E242)	250

Some drinks contain preservatives and others do not. The need for preservatives is dependent upon the type of product and the processing used, e.g. aseptically filled (e.g. tetrapak) or in-pack pasteurised drinks do not require preservatives.

The preservative is intended to prevent spoilage by micro organisms, i.e. yeasts, moulds and bacteria. All soft drinks are sufficiently acid to prevent the growth of food poisoning organisms. The presence of carbon dioxide prevents mould growth and high levels of acidity and carbonation will also inhibit the growth of yeasts and lactic acid bacteria. Soft drinks formulated in this manner do not require additional preservative provided reasonable hygiene standards are maintained.

The presence of fruit or fruit juice provides additional nutrients which may enable organisms to grow despite high levels of acidity and carbonation. In summary, the soft drinks likely to ferment are mildly acid types with low carbonation and containing fruit juice. In these cases preservative must be added to prevent microbiological spoilage.

The levels of preservatives permitted by European legislation are based upon technological necessity, and therefore are dependent upon the type of product. Traditionally sulphur dioxide and benzoic acid have been used in the UK, but EU regulations resulted in a move away from sulphur dioxide, however sorbic acid is being increasingly used. Bacteria and yeasts differ in their susceptibility to different preservatives, so a mixed preservative system is generally used to provide maximum protection against a range of organisms.

Sulphur Dioxide

Is the most effective wide acting preservative but its use was seriously limited by legislation in the mid 1990s. It also acts as an antioxidant and prevents browning of citrus drinks. The active entity is SO_2 but because SO_2 is a toxic gas, it is added in the form of **sodium metabisulphite**, which releases SO_2 in water. SO_2 forms addition compounds with aldeyhde groups and becomes bound. As only the free form of SO_2 is effective, the preserving power reduces with time. When measuring SO_2 levels it is important to distinguish between "free" and "bound" forms

Fruit flavours with high acetaldehyde content can have a serious binding effect on SO_2. SO_2 cannot be used in conjunction with Aluminium packaging, either cans or laminated packs. Contact between Al and SO_2 produces hydrogen sulphide.

It is alleged that SO_2 can cause an adverse reaction in asthmatics and the labelling of the presence of >10mg/kg SO_2 is included in some legislation on allergen labelling.
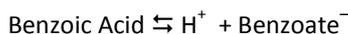
Benzoic Acid

Benzoic acid is effective against most yeasts and bacteria. Maximum usage rate in the UK is 150mg/L but you must check your own local or national legislation for permitted levels. Benzoic acid is difficult to dissolve therefore it is added as Sodium Benzoate which is readily soluble in water.

Sodium Benzoate must always be added to a large volume of water before addition of citric acid or fruit juice. If added to an acid solution it will precipitate out as benzoic acid, which will then not re-dissolve.

Benzoic acid does impart a slight flavour at high levels, but some people are especially sensitive to the taste.

Benzoates have been alleged to cause hyperactivity/adverse reactions in some people. However, Benzoate does occur naturally at low levels in citrus fruits.

The effective form is the free associated acid, i.e. benzoic acid which exists in equilibrium with benzoate.

Benzoic Acid $\leftrightarrows H^+$ + Benzoate$^-$

The benzoate ion has no preserving action therefore as the pH increases (acidity decreases) the preservative becomes less effective, Benzoate should not be used at a pH > 4.

An interaction between ascorbic acid (Vitamin C) and Benzoic Acid can result in the formation of traces of benzene. A maximum level of 10 ppb is observed by the UK authorities.

Sorbic Acid

Sorbic Acid is less effective against bacteria than benzoic acid. Some organisms will readily metabolise sorbic acid. Penicillium moulds are a particular problem in still drinks preserved with sorbic acid due to formation of 13 pentadiene.

Maximum usage rate is 300mg/L, but this is reduced to 250mg/L if benzoate is also present.

Sorbic acid is usually used in the form of **potassium sorbate,** which is readily soluble. Sorbic acid is much less soluble than benzoic acid particularly at low temperatures which can cause production problems. Although 300mg/L is readily soluble in a soft drink, it may not be possible to dissolve 1800mg/L in a cold syrup. As the solubility of sorbic acid decreases rapidly as the temperature decreases a sediment may occur in sorbate preserved dilutables in very cold weather.

Sorbic acid also has an effect on flavour, tending to suppress it. It may be necessary to add 10% or more flavouring to a sorbate preserved drink than to the same benzoate preserved one.

Sorbic acid is effective at a higher pH than benzoic acid and is used in products such as tea based beverages which can have a pH as high as 4-5.

Dimethyl Dicarbonate, DMDC

This has been used in some EU countries since the early 80s, particularly Germany.

It is not a preservative in the traditional sense and has been termed a "cold sterilant". It is injected into the product stream immediately prior to the filler. It then kills any organisms which may be present in the sealed container. In contact with water it rapidly decomposes to methanol and CO_2, being completely absent within a few hours. It is therefore not present when the consumer opens the container.

DMDC is sold under the trade name Velcorin. There has been debate as to whether DMDC is a "processing aid" as it is not present in the product as consumed. However some regulations require ingredients to be declared as listed – in this case as a preservative.

Dimethyl Dicarbonate (E242) - Velcorin

$$CH_3OH + 2CO_2$$

2CH₃OH + 2CO₂
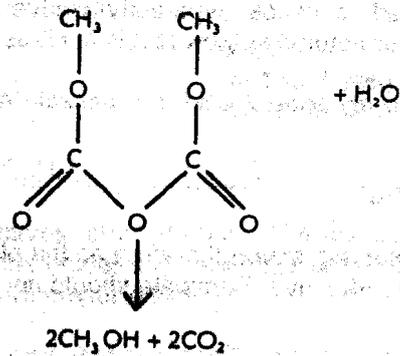
Colours

Colour plays an important part in consumer acceptability. Consumers will frequently perceive a more strongly coloured product as being more strongly flavoured, even when it is not.

The use of colourings must comply with local or national legislation – those listed below are shown with their European limits of usage.

Colour	Max level (mg/L)
Curcumin	100
Riboflavin	Q.S.
Tartrazine	100
Quinoline Yellow	100
Sunset Yellow	50
Carminic Acid	100
Carmoisine	50
Ponceau 4R	50
Allura Red AC	100
Patent Blue V	100
Indigo Carmine	100
Blue FCF	100
Copper Chlorophylins	Q.S.
Green S	100
Caramel	Q.S.
Caramel Colours	Q.S.
Black PN	100
Brown HT	50
Carotenes	Q.S.
Paprika Extract	Q.S.
Beta-Apo-8-Carotenal	100
Betanin	Q.S.
Anthocyanins	Q.S.

Key: Q.S. stands for Quantum Satis, that is, sufficient for the purpose according to good manufacturing practice

There are basically three types of colourings: "natural", caramels, and artificial colours.

Artificial

These are the azo dyes and triphenylmethane dyes. Their use has been criticised as unnecessary but all of those permitted have been thoroughly tested and approved as safe. They are strongly coloured and are used at low levels, less than 100mg/litre. A full range of colours can be obtained, e.g. blue, green, red, yellow, etc. The synthetic colours are readily water soluble and easy to use.

The 6 "Southampton" colours trigger a labelling requirement indicating that they have been associated with activity disorders in children. Due to reduced ADIs severely reduced usage levels have been proposed for Quinoline Yellow, Sunset Yellow and Ponceau 4R.

Natural Colours

The most commonly used are the carotenoids. These are a range of naturally occurring yellow – orange colours, which can be extracted commercially from plants, e.g. palm oil. The best known cartenoid is beta-carotene, which is predominantly responsible for the colour of carrots. It is however commercially manufactured synthetically. Natural carotene is a complex mixture of carotenoids, of which beta carotene is just one. Beta carotene is soluble in oil but not in water, therefore, in order to be used in a drink it first must be made into an emulsion or water dispersible matrix to prevent it from rising to the surface (ringing). Beta carotene is readily oxidised, becoming colourless, it is therefore usual to "protect" it by addition of ascorbic acid. Carotenoids are believed to protect against a range of cancers and cardiovascular disease. However epidemiological studies have indicated that large intakes of beta carotene can make heavy smokers more prone to lung cancer.

In addition to its use as a colouring at 1-5mg/L, beta carotene is sometimes termed pro vitamin A as it can be converted to Vitamin A in the body and is a significant source of this vitamin for children.

The second major category of natural colourings is the anthocyanins. These range in colour from bright red to purple. The major source is grapeskin extract from France and Italy but anthocyanins can be obtained commercially from a range of fruits and vegetables.

Anthocyanins are readily soluble and relatively stable in soft drinks, though precipitate formation can occasionally be a problem, usually due to interaction between the anthocyanins and other fruit materials.

At the time of writing colours, artificial and natural, are under review by EFSA and DG Sanco and their usage will almost certainly be restricted.

Caramels

There are two commonly used types of caramel – ammonia caramel *(E150c)* used in beers and shandy and sulphite ammonia caramel *(E150d)* used in soft drinks, e.g. cola and ginger ale. The typical usage rates for caramel are up to 4000mg/l for colas.

Stabilizers

Stabilizers are macro molecules which are added to soft drinks in order to increase viscosity (body) and/or to prevent the sedimentation of suspended fruit cloud. Pectin is a stabilizer which occurs naturally in some fruits, e.g. citrus and apples.

Several synthetic stabilizers can be used, the most common being carboxy methyl cellulose (CMC) but xanthan gum, alginates and carageenan are also sometimes used.

New, more effective gums are developed periodically (e.g. Gellan). These gums are most frequently used in flavour emulsions which are dealt with elsewhere.

Carboxy Methyl Cellulose
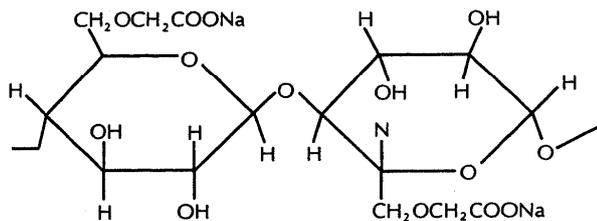
CMC is manufactured by substitution of the hydroxyl groups in cellulose with carboxymethyl groups. The solution characteristics depend upon the degree of polymerisation (DP) and degree of substitution (DS). A typical high viscosity CMC will have a chain length of approximately 2,500 units and a DS of 0.7, i.e. 70% of the glucose units will have a carboxymethyl group attached.

Antioxidant

Oxidation due to either a high initial level of air or by oxygen permeation through PET can be detrimental to product quality. Ascorbic acid (vitamin C) is frequently added to "mop up" oxygen by itself being oxidised. It is important to keep oxygen levels in products as low as possible.

Sulphur dioxide, in addition to being a preservative, also acts as an antioxidant.

Oil soluble antioxidants, e.g. tocopherol or BHA are frequently used to protect essential oils from oxidation. These are introduced into soft drinks only at extremely low levels as carry over (processing aids)

Cloudifier

An oil emulsion can be added to enhance the cloudiness of a drink. This topic is covered in the flavourings section.

Antifoam

In order to prevent excessive foaming of a product, for example during the filling process, dimethylpolysiloxane may be added up to a level of 10mg/litre. This is the only permitted antifoam. Although antifoam breaks down a stable "head" of foam its use in carbonated products can exacerbate the break out of CO_2 and cause gushing.

Flavourings

Introduction

The aim of this information is

- To introduce the importance of flavourings to the soft drinks manufacturer

- To show the part flavourings play in the pleasure gained through consuming soft drinks

- To give an awareness of types of ingredients and their origins used in the creation of flavourings

- To show how flavourings are processed.

- To demonstrate how caring for your flavour is essential for good results

And why know your flavouring?

The major aim of the soft drinks manufacturer is to market a soft drink that is more than acceptable to the consumer they wish to satisfy. In addition, it is important to enjoy sales consistent with expectations and to attain profit forecasts. Therefore, all effort and energy from staff and machinery should be focused on the needs of the end product - a desirably flavoured soft drink with a consistent quality.

This can also be expressed as the operational cost for this effort and energy is totally dependent upon the **flavour being acceptable** to the consumer.

(see next page)

OPERATIONAL COST

END PRODUCT → ← PREFERRED FLAVOUR.
QUALITY CONSISTENCY

EFFORT ENERGY
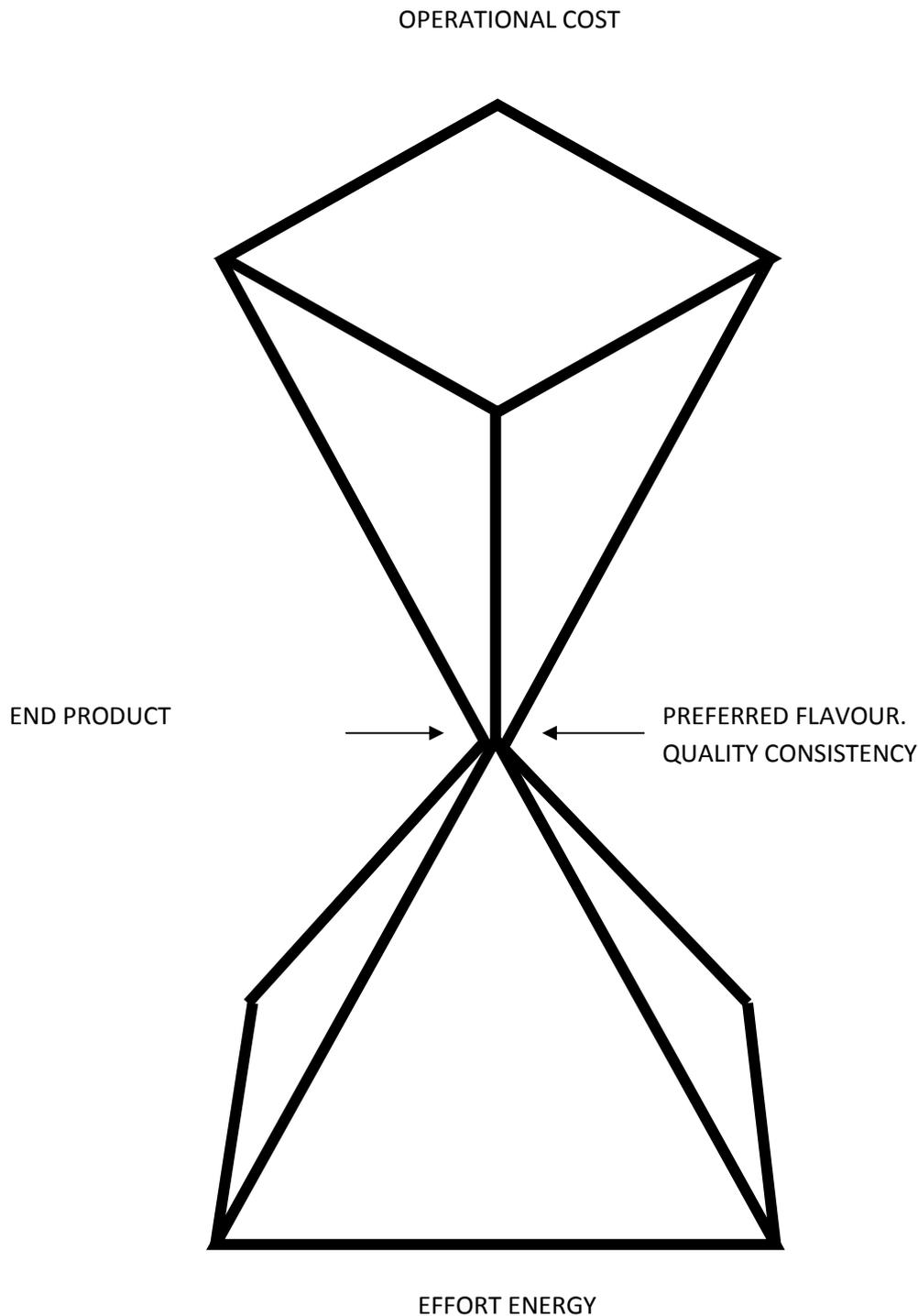
"That tastes nice?" Why do we say this?

What is actually happening when someone says *'that drink tastes nice'* or *'that drink has got a really nice flavour'*?

The phenomena of perception is recorded by the brain, which has had information transmitted to it from two stimuli centres – tongue and nose e.g. taste and smell.

These stimuli centres can be used to represent the two disciplines that are required for developing a soft drink. The two disciplines are:

1. Application formula development ➔ taste
2. Flavouring creation – suitable for said application formula ➔ smell

Taste

The first stimulus is the tongue, which records taste only.

The taste buds distinguish the four basic tastes of:

- **sweet**
- **salty**
- **sour**
- **bitter**

These can be perceived more easily at different sites on the tongue.

The height of sensitivity for sweetness is on the tip of the tongue. The salty taste is on the edge of the tongue towards the tip. The centre of the tongue records the sour taste, in particular along the edge. Lastly, the bitter taste is recorded at the back of the tongue.

The taste receptors are located in the taste buds on the tongue and it is believed that humans have approximately 2000 active taste buds. Some taste buds are also located on the hard palate and in the throat.

The saliva in the mouth helps the tasting process by dissolving and diluting substances in the mouth and transporting taste stimulus molecules to the receptors.

The human taste bud contains about 40-70 cells, assembled like the slices of an orange, with each having microvili (antennae) collecting sensory sensations.

The mouth and tongue add 'awareness messages' to the messages sent to the brain about the four basic tastes. We recognise these phenomena as hot, cold, metallic, burn (pepper), soft, hard, slimy, cool (peppermint) etc.

Therefore the communiqué can become very complex. If the balance of this communication is developed successfully, the consumer can perceive a very pleasurable overall impression. Therefore, when drinking a soft drink, it is the ingredients used in the application recipe for the drink that mainly provide stimuli to the brain from the tongue and the mouth.

Smell

The second stimuli centre is the nasal area, which records aroma/smell.

The olfactory cells are situated in the upper part of the nasal cavity above the turbinate bones. Many odours can be perceived by humans, but this complex perception is difficult to measure by physical or chemical means. Smell is very important in the appreciation of food and is especially important for aiding the activation of our digestive juices. This allows us to enjoy our food, maintaining the fuel supply, by reminding the body of the pleasure of eating and drinking.

The main contribution of the flavouring is to stimulate smell. However there are flavouring components used in the manufacturing of flavourings, such as those in cinnamon, which impart a perception of sweetness. This also stimulates the taste bud on the tongue, in a relatively minimal way.

When you compliment a product for a good taste or flavour, this is prompted by the brain translating a multitude of signals emanating from the two sites of **taste** and **smell** giving us the perception of **flavour**.

Flavouring raw materials and substances

A flavouring creator earns the title 'Flavourist'. The art of developing a flavouring for soft drinks requires a wide and varied selection of flavouring materials. The most common material/preparations utilised for preparing soft drink flavourings can be grouped in the following categories:

a)   **Natural – vegetable/animal origin**
b)   **Nature identical**
c)   **Artificial**

Natural flavouring materials

- Soft fruits   *Blackcurrant, Raspberry*
- Citrus fruits   *Lemon, Orange*
- Tropical fruits   *Mango, Pineapple*
- Berries   *Juniper, Pimento*
- Bean   *Vanilla*
- Nut   *Nutmeg, Cola*
- Seed   *Aniseed, Coriander*
- Flowers   *Elderflower, Lavender*
- Leaf   *Clove, Patchouli*
- Grass   *Lemongrass, Citronella*
- Wood   *Cedar, Sandalwood*
- Resins   *Balsam*
- Bark   *Cinnamon, Quinine*
- Entire plant   *Peppermint, Thyme*
- Root   *Ginger, Angelica*
- Essential oils   *Orange, Lemon, Lime*
- Juices   *Orange, Lemon, Blackcurrant*
- Oleo resins   *Vanilla, Ginger*
- Concentrated oils   *Orange, Lemon, Lime, Mandarin, Ginger*
- Natural isolates   *from Lemongrass oil, Aniseed, Clove*
- Tinctures   *Dandelion, Burdock*
- Infusions   *Quinine, Vanilla*

Natural flavouring materials are obtained by physical, enzymatic or microbiological processes from appropriate[2] material of vegetable or animal origin.

———————————————————————

[2] 'Appropriate' is interpreted to mean that which is generally used as a source of flavouring.

Essential Oils

Many parts, if not all of some plants, can be utilised either individually or as a whole to yield essential oils. There are some plants, which can yield several essential oils, but only one has been found useful to humans.

- Wood   *Cedar, Sandalwood*
- Roots   *Ginger, Angelica*
- Berries   *Juniper, Pimento*
- Fruits   *Lime*
- Seed   *Aniseed, Coriander*
- Bark   *Cinnamon*
- Flowers   *Broom, Rose, Elderflower*
- Grass   *Lemongrass, Citronella*
- Leaf   *Clove, Patchouli*
- Resins   *Balsam*
- Entire plant   *Spearmint, Peppermint*

Essential oils from the parts of plants detailed above are generally recovered by steam distillation.

The following essential oils are generally recovered by cold pressing of the peel.

- Lemon
- Grapefruit
- Orange
- Mandarin

Juices

These can be obtained by pressing the fruit to release the maximum yield of juices. These can be clarified and/or concentrated according to juice type requirements.

Oleo resins

Oleo resins have a characteristic odour and can be thick or thin liquid mixtures.

They are obtained by extracting fruit and other parts of plants with acetone or other suitable solvents such as hexane, dichloro methane, and ethyl alcohol. The solvent is then decanted away from the plant material and evaporated by vacuum distillation.

Concentrated essential oils

The commonly used concentrated essential oils are orange, lemon, lime and ginger. These are concentrated by vacuum distillation stripping off the chemicals classified as terpenes. In many instances, these terpenes do not have a particularly nice flavour. The determining factor for how many times an essential oil can be concentrated is the content of terpenes. The concentrations generally used are: 2x, 4x, 5x, 5x, 8x, and 10x, terpeneless. Terpenes can be found in almost every essential oil to a greater or lesser extent. Concentrated and terpeneless soils are obtained by stripping off some or nearly all of the terpenes.

Natural isolates

A natural isolate is a single aroma chemical, which has been isolated from a natural position, in general, by means of vacuum distillation.

Having shown that there are a number of natural products that contain a high proportion of one flavouring substance, it needs to be pointed out that the vast majority of natural materials, that we recover useful extracts from, are complex mixtures of flavouring substances that can number several hundred.

Tinctures – dandelion roots, burdock roots, lemon peel

Tinctures are produced when plant material such as dandelion roots, burdock roots, lemon peel etc is macerated in alcohol. This alcohol is then decanted and generally filtered, yielding the tincture.

Infusion – quinine, quillaia

Infusion is when plant material extracted by using water, such as the substance quinine, quillaia.

Nature identical materials

Nature Identical Materials are either obtained by chemical synthesis or isolated by chemical processes and they are chemically identical to a substance naturally present in appropriate[2] material of vegetable animal origin.

Artificial materials

Artificial Materials are obtained by chemical synthesis but are **not** nature identical materials.

Flavourists (flavour creators) have a handsome repertoire of flavouring materials at their disposal when creating a flavour. There are in excess of:

- 12,000 Natural source materials
- 4,500 Nature identical flavouring chemicals
- 200 Artificial flavouring chemicals

---

[2]   Appropriate is interpreted to mean that which is generally used as a source of flavouring.

Developing a flavouring

The flavouring industry generally produces flavourings for:

- Beverages
- Dairy
- Confectionery
- Bakery
- Oral hygiene
- Alcoholic beverages
- Pharmaceutical
- Savoury
- Tobacco
- Animal feeds

When a flavourist receives a request to develop a flavouring, the request can normally be attributed to one of the following:

- Reproducing the flavour of an existing natural product
- Imitating an existing product on the market
- Creating a flavour from a marketing concept
- Improving an existing product or service
- Reducing the cost of a flavour
- Re-developing flavours to accommodate changes in production techniques or formulation variation

To process a request it is important to know what could possibly affect the flavouring during use. For example the following aspects must be taken into account when developing a flavouring.

- the type of soft drink
- the type of packaging
- the product quality – any product price limitations
- any manufacturing processing/restrictions.

Once correlated this information allows the flavourist to take a decision on the physical form the flavouring will take. The following are the major types of flavouring systems, which can be employed:

- **Soluble**   *e.g. lemonade, water*
- **Emulsion**   *e.g. cola, cloudy orange drinks*
- **Semi-booster**   *e.g. orange juice drinks*
- **Booster**   *e.g. juice/hi-sugar products*
- **Juice compound** *e.g. dilutable whole orange, carbonated crush, hi juice*
- **Powder**   *e.g. vending machine sachets*

Of the above most soft drinks are produced using the **soluble** and **emulsion** systems due to the requirement for good dispersion of the flavouring through the soft drink formulation system.

System one – soluble flavouring

The groundwork for reproducing the flavour of an existing natural product starts with an investigatory study to include:

- Identification of components
- Identification of crop types – if using flavouring preparations
- Identification of in-house/internal company information
- Selection – raw material tasting

When a raw material selection has been made a permutation of the materials begins. For soluble citrus flavouring, this involves the **'washing of oils'** to achieve appropriate solubility for dispersion and stability of the flavouring. This is done by homogeneously mixing the flavouring oils with alcohol and then adding water in appropriate measures. The amount of water added is dependent upon the flavour and solubility required. The water quantity determines the amount of insoluble components (there is a 'pecking order') from the oils that are released (**'separated'**).

When spreading citrus oils the visual effect is a layer of oil floating on a hazy milky liquid. The hazy milky liquid eventually becomes the flavouring. This **'separation'** is carried out a 4°C. The flavouring is decanted off after a period (generally 24-48 hrs) and is filtered. The flavouring is then ready for trials to be carried out.

The **'washing'** is boosted by the addition of concentrated oil, natural isolates, nature identical and artificial materials, depending on the flavour status required, to create the flavours' distinct character.

System two – emulsion flavouring

The groundwork for system two is the same as system one.

There are two types of emulsion system in general use:

1. that which homogeneously disperses the flavouring through the soft drink system without imparting any opaque/cloud to the beverage whatsoever, e.g. for a cola

2. that which imparts the beverage with an opaque/cloudy appearance and in most instances dispersing the flavouring, e.g. orangeade.

An emulsion consists of an oil phase and a water phase. The art is to suspend the oil (flavour) evenly in very small droplets throughout the water phase. Because water and oil do not like to mix, water dispersal gums and emulsifiers are employed to help disperse the oil. The gums used must give stability to the flavouring emulsion during storage and keep the oil particles small while the emulsion is being dispersed through the soft drinks system.

Even with the emulsifiers and stabilisers considerable energy is required to homogenise the particle size down to the order of 1μ for the second system.

Handling of flavours

Taking care of your flavour prior to its incorporation into a soft drink and knowing how your flavourings should be handled during production are key to obtaining the optimum performance from your flavouring.

How you approach the above two disciplines will have a direct reflection upon the quality and consistency of quality of the product you produce. From receipt of your flavouring through to the end of the first three weeks of the product's life are the most important with regard to quality. Three weeks is generally regarded as the time period when the greater proportion of the interactions will take place.

Quality and the parameters defining consistency of quality are subjective; therefore these have to be clearly defined and controlled by the soft drink company themselves.

First discipline: Care of your flavouring prior to use

Detailed below are some things that need to be considered:

- Regular order pattern
- Stock rotation
- Storage conditions
    o Specification
    o Health and Safety (H&S), Chemical Hazard Information Packaging (CHIP)
- Container size related to usage
- Help the flavour house in their decision of container to be used

Second discipline: Care of your flavouring during use

The quality consistency of a flavouring can be affected by manufacturing circumstances and bulk raw material. For example you should consider:

- AGE of flavour
- Flavour open container AGE
- Oxidation
- Good dispersion
- Appearance/cloud
- Water – mineral content
- Water/residues
- Cross product contamination
- Cleaning residues
- Inferior grade commodity materials
- Microbial

Examples of bottling formulations

Suggested recipe for making a lemonade

Sugar	480.00 g
Sodium Saccharin 10% w/v soln	4.80 ml
Sodium Benzoate 25% w/v soln	4.20 ml
Citric Acid Anhydrous	15.40 g
Lemon Flavouring BAAA6959	5.60 ml
Add water to make	1.00 ltr

- Dilute 1 + 5
- CO_2 3.8 vols
- Brix of RTD 8.0° ± 0.2°
- Benzoic Acid 150mg/ltr RTD
- Saccharinic Acid 61mg/ltr RTD

Suggested list of ingredients

- Carbonated Water
- Sugar
- Citric Acid
- Flavourings
- Preservative (Sodium Benzoate)
- Sweetener (Sodium Saccharin)

Suggested recipe for making a cola flavour beverage

Sugar	625.00 g
Sodium Benzoate 25% w/v/ soln	4.00 ml
Cola Flavouring and Colour Compound BOOA7202	17.60 ml
Cola Finish Flavouring BOOA7201	0.21 ml
Phosphoric Acid 85% w/w food grade	4.20 g
Caffeine	0.47 g
Add water to make	1.00 ltr

- Dilute 1 + 5
- CO_2 4.0 vols
- Brix of RTD 10.4° ± 0.2°
- Benzoic Acid 150mg/ltr RTD
- Caffeine 78mg/ltr RTD

Suggested list of ingredients

- Carbonated Water
- Sugar
- Colour
- Phosphoric Acid
- Flavourings
- Preservative (Sodium Benzoate)
- Caffeine

2.6.2.2   Water Preparation and Uses

Introduction

(NB Cross reference to Unit 3.1 resource management – utilities/water)

The quality of fresh water supplies is directly related to the soil structure and geology of the surrounding catchment area, because all fresh water is derived from rain, filtered through the upper layers of the soil. The precipitation falling on the ground will pick up and dissolve inorganic salts, naturally occurring organic matter and bacteria. As an example, precipitation falling on chalk produces a water that is high in dissolved solids and probably with a high alkalinity and total hardness, water falling on granite produces a water low in dissolved solids, hardness and alkalinity. Water produced from peaty areas is usually pale yellow in colour, containing appreciable amounts of organic matter.

Water supplies throughout the world are generally derived either from lakes, dammed reservoirs and rivers, or from underground boreholes. Water abstracted from lakes and rivers is termed surface water. This is subject to seasonal variations in quality due to climatic conditions. It is also exposed to adventitious pollution from nearby effluent discharges and from urban run-off, which frequently drains the river.

Water obtained from boreholes is called ground water. Ground water is usually of consistent quality if the well has been properly constructed, and is of sufficient depth to eliminate pollution from the surface. It is quite common for abstractions to be made from both ground and surface sources, and then blended in a reservoir or large storage tank, for treatment at a municipal treatment works. The water is rendered potable by filtration and sterilisation for supply to the domestic and industrial consumer via the water mains.

Water suppliers are required by statute to distribute water that is *"pure and wholesome".* Although this means it is potable it does not necessarily mean that the water is clear and colourless. Depending on the source, waters may be hard, soft, brackish, humic for example, and if blended can lead to a water that is constantly varying in quality.

Types of water

Hard Water

Hard waters contain calcium and magnesium salts in solution, frequently in the form of bicarbonates if the water is drawn from a limestone or chalky source. This is sometimes in the form of chlorides or sulphates if the source is sandstone. Occasionally, hard waters result from the permeation of a subterranean aquifer by sea water, in coastal regions. Hard waters have a fully mineralised taste and are thought to be the most palatable and beneficial we consume.

Soft Water

Soft waters are frequently obtained from surface sources consisting of lakes and rivers flowing through rocky terrain. Soft waters are also obtained from certain underground sources where the aquifer is gravel, or laterite. These usually contain sodium and potassium salts in the form of bicarbonates, sulphates, chlorides, fluorides or nitrates. The taste of soft water tends to be slight soapy.

Brackish Water

Brackish water contains a high proportion of sodium or potassium chloride in solution. This occurs frequently in the neighbourhood of underground salt deposits, or in close proximity to the sea coast. The taste of brackish water is sometimes slightly salty.

Humic Waters

Humic waters are obtained from surface source where peat bogs are prevalent. Soft waters which are derived from moorland peat areas are sometimes called humic waters. Humic waters may also occur in borehole water abstracted from a marshland plain area of a river valley. The water is coloured slightly yellow by the humic and fulvic acids present, and may also have an unpleasant odour. It frequently has a slightly bitter taste.

Legislation - Reference should be made to your own local or national legislation.

World Health Organisation guidelines are the principle reference for water quality standards in the underdeveloped countries of the world. For some decades, the US Environmental Protection Agency exercised some degree of control in the USA with regard to the quality of drinking water supplies. European water supplies have become subject to mandatory control by the **EC Quality of Water intended for Human Consumption Directive (80/778/EC).**

These regulations incorporate *"Maximum Admissible Concentrations"* (MACs), but do not incorporate any *"Guide Levels"* (GLs). Guide Levels represent target quality objectives only and have no legal status.

Water Service Companies are required by legislation to provide a *"wholesome"* supply of water. Wholesome is defined within the Water Supply (Water Quality) Regulations. Part of the definition includes compliance with some 60 separate parameters.

In 1999, legislation was introduced which tackled the problem of cryptosporidium. This required the water supplier to:

"… carry out a risk assessment for each of its treatment works to establish whether there is a significant risk from cryptosporidium oocysts."

Most recent changes in legislation will not have any great impact on soft drink manufacturers, but the new arsenic, bromate and lead standards may cause some concern.

Treated Water

Water is the principal ingredient in carbonated beverage production and in some cases makes up over 95% of the product. It follows that manufacturers pay particular attention to the quality of water used in their formulations, to ensure that the product is consistent in taste and appearance and has not deteriorated during storage.

The public supply in urbanised areas of the world meets part of the specifications set by soft drinks manufacturers, but needs further treatment to satisfy all requirements. Soft drink manufacturers require soft water with low alkalinity and relatively low total dissolved solid content. The water must be sterilised and purified to remove colour, off-taste, odour and colloidal or suspended matter. The purity of potable water is judged mainly from the amounts of nitrogenous substances present, together with the organic matter and chloride content. Various additional parameters for phosphates, silicates, alkali metals and trace metals for example, should also be considered in relation to the water supply source and type. *(See appendix 1 for treatment summary of various types).*

A uniform and consistent supply of water improves the operating efficiency of a factory by allowing a constant manufacturing process to be established, eliminating the need to stop frequently or to alter the manufacturing conditions to meet changes in water quality.

The significance of key parameters in the quality of a water

- Appearance

A good water should be clear and free from colour, turbidity or insoluble deposits. A poor quality water may be yellow coloured, and slightly turbid with a white, buff-coloured or brown deposit. The deposit may contain inorganic hydroxides and silicates, organic debris and small biological organisms.

- pH

The pH of most natural water supplies is between 6.5 and 8.5, but exceptions do occur, and this may be an indication of special chemical composition, e.g. very low = humic acid or free carbon dioxide; very high = carbonates and bicarbonates.

- Total Dissolved Solids (TDS)

The residue of TDS's after evaporation and drying at 180°C should not exceed 500mg/litre in good quality water. This corresponds to about 800 us/cm electrical conductivity.

- Total Hardness

Hardness is due to the presence of calcium and magnesium salts in solution. Temporary hardness is due to calcium and magnesium bicarbonates and permanent hardness to calcium and magnesium chlorides, sulphates and nitrates. Total hardness is the sum of both temporary and permanent hardness.

'Soft'	= less than 50 mg/l as $CaCO_3$
'Moderately soft'	= 50 – 100 mg/l as $CaCO_3$
'Hard'	= 100 – 200 mg/l as $CaCO_3$
'Very hard'	= 200 – 300 mg/l as $CaCO_3$

Water for use in soft drinks should ideally either be 'soft' or 'moderately soft' in character.

Alkalinity

Alkalinity is due to the presence of bicarbonates, carbonates and hydroxides of the alkaline earth and Alkali metals, principally calcium, magnesium, sodium and potassium. High alkalinity neutralises the acidity in a soft drink, and can create a bland taste. Most soft drink manufacturers reduce the alkalinity to below 50 mg/l as $CaCO_3$.

Nitrogenous Substances

Decaying organic matter and sewage contain ammonia, therefore the presence of more than about 0.05mg/l of free ammonia is a significant pollution indicator. If a water yields more free ammonia than albuminoid ammonia, the nitrogenous material is probably derived from sewage. If however, the albuminoid ammonia content is greater than the free ammonia content, then the nitrogenous material may be derived from decaying vegetable matter or peat.

Nitrite may arise from the reduction of nitrate, or from the oxidation of ammonia, as it represents the intermediate stage in the oxidation of nitrogenous materials by soil bacteria. Nitrite occurs in sewage and manure and it should be absent from potable water.

Nitrate is the final product of decomposition of animal origin organic matter and its presence in water may be an index of past pollution. Nitrate is also present in aquifers that lie beneath agricultural land. This is a result of modern intensive farming methods where nitrate fertilisers are heavily used. High levels of nitrate (above 50 mg/l as NO_3) can cause methaemoglobinuria. Nitrate is also undesirable in water used for canning soft drinks as it acts as a corrosion catalyst when chlorides
are present.

Chloride

As a general rule, surface water contains less than 20 mg/l Chloride. Ground water however, may contain more, and sometimes this may be 100 mg/l. Since sewage contains chloride, the presence of much chloride in water (especially when associated with high nitrate content) may indicate pollution by sewage. Alternatively, it may indicate contamination from sea water infiltration.
Organic Content

Organic matter can consist of various substances present at trace levels in water, including humic acid, fulvic acid, algal polysaccharides and polypeptides, protozoa and microbial contaminants. Organic content is usually determined by either the permanganate value (PV), which measures the oxidisable organics, or the total organic carbon value (TOC), which measures both the oxidisable and the non-oxidisable organics. The relationship between the two varies, but water for use in soft drinks manufacture should have a PV level of less than 1 mg/1 as oxygen, or a TOC value of less than 2 mg/l as carbon.

Micro-organisms

Natural waters invariably contain a whole host of micro-organisms ranging in size from crustaceans and algae, down to yeasts, bacteria and viruses; each is a living organism and must be removed or controlled by filtration and sterilisation, polluted water is characterised by high total bacterial counts and the presence of coliform bacteria as an indicator of faecal contamination.

Phosphate

A good quality water will have a phosphate content of less than 0.05 mg $PO4$ per litre. Phosphate represents the residues of decomposed organic matter, either from sewage effluents or decomposed vegetation.

Silicates

Silicates result from the water flowing through sand, rock and clays. Average values of silicates for ground water are 15-20 mg/l as SiO_3, and for surface water 5-10 mg/l; larger concentrations can cause floc problems in soft drinks.

Trace metals

The presence of metals such as species as zinc, copper, manganese and iron, in surface water is an indication of industrial pollution by effluents. Ground water is not normally polluted but may contain iron and manganese if drawn form a laterite aquifer, or zinc, cadmium and lead if the well is in close proximity to certain minerals. Iron and manganese are associated with humic acids, in waters derived from peaty sources.

Not all metals are regarded as toxic in traces, but they are undesirable in potable supplies for various other reasons. In water for soft drinks manufacture they may cause production problems such as brown deposits etc.

Chlorinated substances

Free residual chlorine does not occur naturally in water. It is the remaining chlorine concentration that persists in mains water supplies after leaving the water treatment works. Most principal supplies are injected with a low concentration of chlorine (0.2 – 2 mg/l Cl_2) prior to pumping the water into mains pipework, to maintain sterility in the supply network. Chloramines are formed when water containing free chlorine reacts with ammonia or ammonia compounds. They impart a medicated tasted to the water. Total chlorine must be reduced to as low as possible by the soft drink manufacturer, (less than 0.05 mg/l $Cl_{2)}$.

Minimising water costs

With the sharp increase in water charges forecast over the next few years, it makes sense for major industrial customers such as soft drinks manufacturers, to maximise their use of incoming water and/or water costs.

Many factories install water meters, have water usage budgets and regularly publish actuals v theoreticals. Modern soft drink factories without returnable lines usually run better than a ratio of 1.5:1 i.e. it takes 1.5 litres of water to make 1 litre of product. Older factories with several returnable lines typically operate at ratios of between 3:1 and 8:1. Careful usage programmes involving turning off taps, hoses, washer/rinser jets etc, should be implemented, and competitiveness between lines and factories introduced.

Re-cycling of water from backwashing, cooling and rinsing operation is becoming more commonplace in soft drinks factories. Depending on the quality of the water and the area of re-use, some purification processes may be necessary.

The other main area for saving on water charges is in the use of private borehole water for manufacturing purposes. Subject to various restrictions, local or national river authorities will normally grant an abstraction licence that allows the holder to sink a borehole and draw out specified volumes of water. Once a licence has been paid for, charges will be considerably less than for mains water.

Water treatment processes

Because of variations in the quality of raw water, and as river waters may contain high concentrations of suspended solids, colour and organics, soft drink manufacturers originally issued specifications that demanded coagulation as the principle method of treatment. This was an attempt to produce a standard water and constant tasting beverage. However, more recently, alternative forms of treatment have been progressively introduced.

- Chemical coagulation
- Ion exchange
- Reverse osmosis
- UV light
- Ozonation
- Micropore filtration

(See Appendix 2 for comparison of water treatment processes).

Assumes supply is already pre-chlorinated

To remove chlorine

To remove unwanted dead microbial cells + any organic material present in original water supply

to remove dissolved oxygen by counter-current flow of CO_2

Intermediate storage with N_2 blanket to prevent intake of O_2

Final chance to ensure absence of microbial activity

To enhance clarity of water

Incoming water supply storage vessel

Activated Carbon filter

Combined sand filter & organic trap

Coagulation tank

H_2O

De-aeration tower

Buffer storage tank with nitrogen blanket

UV sterilization
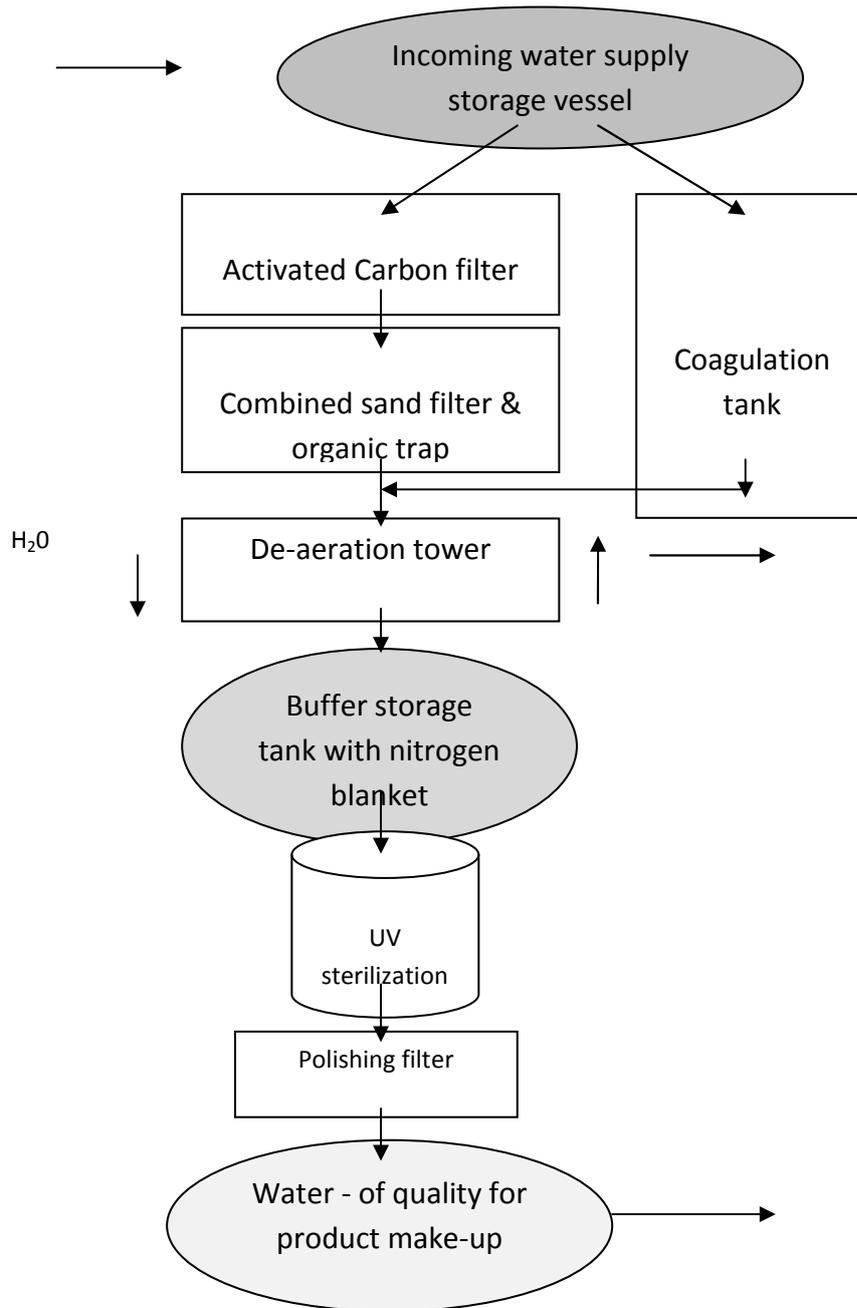
Polishing filter

Water - of quality for product make-up

Fig: Flow diagram of typical water treatment system, assuming water supply with high organic content, already chlorinated by local water company
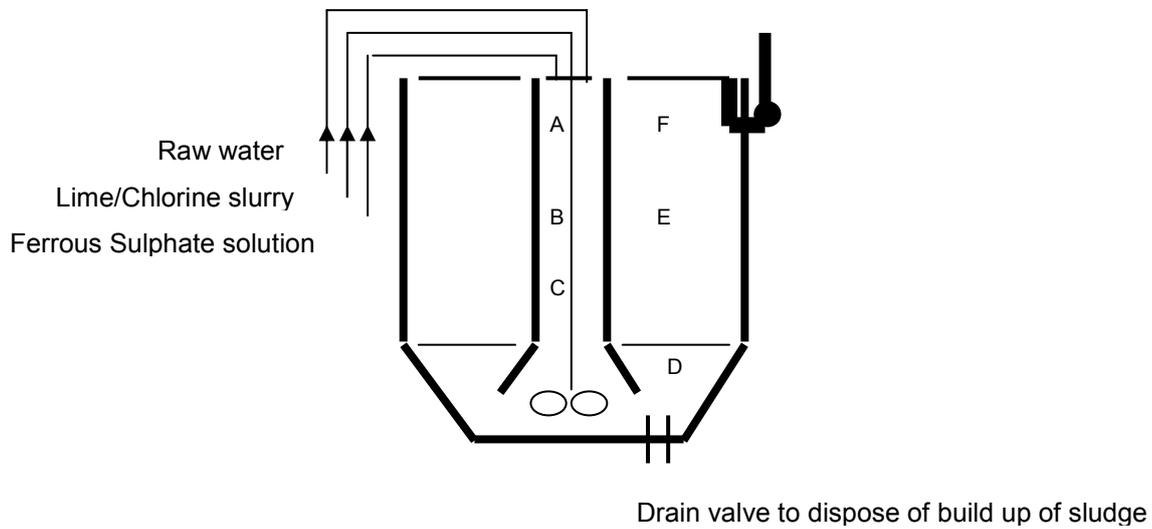
Chemical coagulation

A widely used method of treatment is chemical coagulation where incoming raw water passes through a reaction vessel and coagulating chemicals are added to it. The reaction products and impurities are precipitated and form a gelatinous sludge blanket, through which the treated water flows to a clear zone at the top of the vessel. Sludge is drawn off periodically to maintain a constant blanket volume.

The most commonly used coagulating chemicals are ferrous sulphate or aluminium sulphate. These form a floc which traps insoluble impurities present in the water, eventually forming the sludge blanket which absorbs many of the semi-dissolved (colloidal) compounds responsible for colour and off-tastes, e.g. humic acids.

The choice of coagulating chemicals depends on the nature of the raw water supply.   Generally iron (as ferrous sulphate) is the most suitable coagulant as plants using iron are much simpler and easier to control. The pH of the water in the coagulation chamber is controlled between 9 and 10, at which ferric hydroxide remains insoluble in the floc and causes no problems. The rate of iron dosage is normally about 20 ppm.

Figure 1: Modern coagulation tank

Raw water

Lime/Chlorine slurry

Ferrous Sulphate solution

A

B

C

F

E

D

Drain valve to dispose of build up of sludge

As the raw water is delivered into the coagulation tank the treatment chemicals are pumped in proportionally. The water and chemicals are rapidly mixed in zone A.

As the water moves down the tank, the chemicals coagulate into small particles in zone B, followed by flocculation in zone C. The small particles link into large loose particles. These gradually become more dense and sink towards the bottom of the tank. Floc particles already formed act as nuclei to assist in further flocculation.

The clumps of floc at the bottom of the tank form a bed, zone D, through which the water flows. The particles of floc are positively charge so they attract and hold negatively charged particles such as humic acids (in coloured water) and colloidal clays (in turbid water). Colloids and bacteria are trapped in this suspension of floc known as the *"blanket zone".* All water must pass through this *"blanket zone"* in order to reach the remainder of the system.
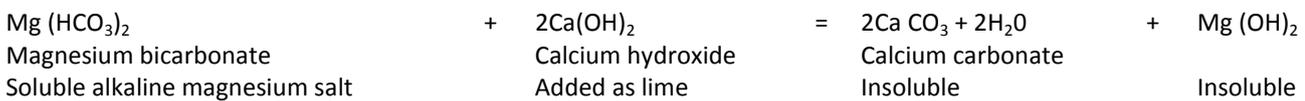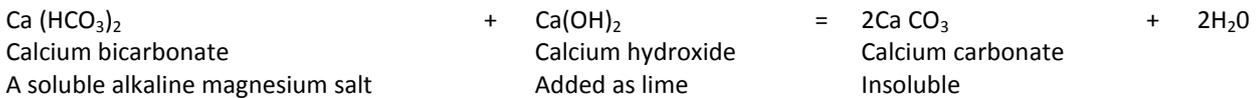
As water flows from the bottom of the tank into the outer section, its velocity decreases due to the V-shaped cross-section of the tank. Eventually the velocity of the water is no longer sufficient to continue to carry the ferric hydroxide floc upwards with it. Above this point, therefore, the water is comparatively clear.

This clear water area, zone E, is sometimes still called the *"clearwell"* (a separate tank in older designs). At this stage the reaction of alkaline reduction carries on to completion. Finally, water is drawn off from the reaction tank via the outlet at F.
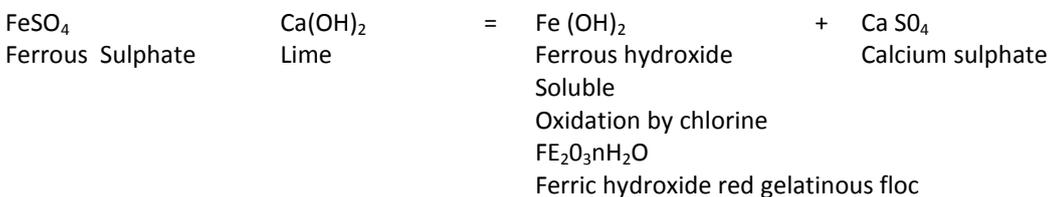
The chemical reactions that take place are given below.

a) Using Ferrous Sulphate

- Reduction in alkalinity by removal of bicarbonates through reaction with lime
- Calcium bicarbonate is converted to the relatively insoluble calcium carbonate
- Magnesium bicarbonate is converted to magnesium hydroxide and thus removed from solution

$Ca(HCO_3)_2$	+	$Ca(OH)_2$	=	$2CaCO_3$	+	$2H_2O$
Calcium bicarbonate		Calcium hydroxide		Calcium carbonate		
A soluble alkaline magnesium salt		Added as lime		Insoluble		

| $Mg(HCO_3)_2$	+	$2Ca(OH)_2$	=	$2CaCO_3 + 2H_2O$	+	$Mg(OH)_2$
Magnesium bicarbonate		Calcium hydroxide		Calcium carbonate		Insoluble
Soluble alkaline magnesium salt		Added as lime		Insoluble		

- Coagulation occurs when ferrous sulphate reacts with more lime to give ferrous hydroxide, which rapidly oxidises by reaction with chlorine giving a bully insoluble floc of ferric hydroxide

| $FeSO_4$	$Ca(OH)_2$	=	$Fe(OH)_2$	+	$CaSO_4$
Ferrous Sulphate	Lime		Ferrous hydroxide		Calcium sulphate
			Soluble		
			Oxidation by chlorine		
			$Fe_2O_3nH_2O$		
			Ferric hydroxide red gelatinous floc		

b) Using Aluminium Sulphate

When raw water has low alkalinity, i.e. below 50 ppm expressed as calcium carbonate, and high turbidity and colour, it is preferable to use aluminium sulphate instead of ferrous sulphate.

$Al_2(SO)_3 14H_2O$	+	$3Ca(OH)_2$	=	$3CaSO_4$
Alum		Lime		Calcium sulphate
				$+ 2Al(OH)_3 + 1 H_2O$
				Aluminium hydroxide
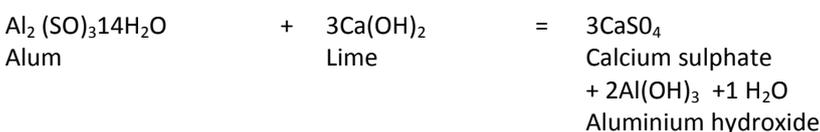
In practice a number of different products are formed, in which the hydrated cation $(Al(H_2O)6)^{3+}$ gives rise to a series of compounds in which the water molecules are progressively replaced by hydroxl ions.

e.g. $[Al(H_2O)6]^{3+}$ …$[Al(H_2O)_5OH]^{2+}$ …$Al(H_2O)_2(OH)_4]$

Polynuclear ions e.g. $[Al8(OH)20]^{4+}$ are also formed. When no lime is added the formation of aluminium hydroxide causes an increase in acidity.

$Al_2(SO_4)_3$	+	$6H_2O$	=	$2 Al(OH)_3$	+	$3H_2SO_4$
Alum		Hydroxide floc		Aluminium		Sulphuric acid
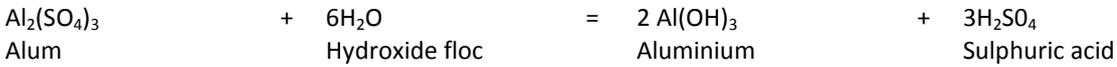
Increase in acidity may sometimes be buffered by the natural bicarbonate content of the water. If the raw water is such that the pH tends to rise above 6.9, acid must be added to correct it. The aluminium floc is insoluble only between pH 5.5 and pH 7.0. Outside these values of pH, aluminium will dissolve and be carried through the plant. This results in a heavy sediment in the finished produce, excessive fobbing and difficult filling.

When alum is used as the coagulant in place of iron more attention must be paid to the level of the blanket in the coagulation tank and to the maintenance of an even flow rate of water.

c) Using Lapofloc PAC

An alternative to aluminium sulphate is Lapofloc PAC, a solution of polyaluminium chloride. The chemical composition of the compound is given by the empirical formula:
- Al (OH)x(Cl)y
    - x = 1.35 – 1.65
    - y = 3x

The product is supplied as a solution of the above compound in water. The aluminium content of the solution is expressed as:
- Al_2O_3 is 10% w/w

The advantages of Lapofloc PAC compared with aluminium sulphate are as follows:
- Supplied in solution form
- No pH adjustment normally necessary within range 6-9
- High coagulating power and settles rapidly
- No auxiliary flocculants normally required
- Floc formation not affected by low temperatures

This method is ideal for treating soft water where no excess lime softening is required. In these circumstances there is usually no need to add any other chemicals except chlorine.

It can also be used to treat hard water and in these circumstances would simply replace the ferrous sulphate. Lime would still need to be added to soften the water and the Lapofloc PAC addition would be after the lime addition.

Filtration

The clarified water from the coagulation tank contains fine particles of floc or other solid matter. A sand filter screens these out. *(See figure 2).*

Fig.2
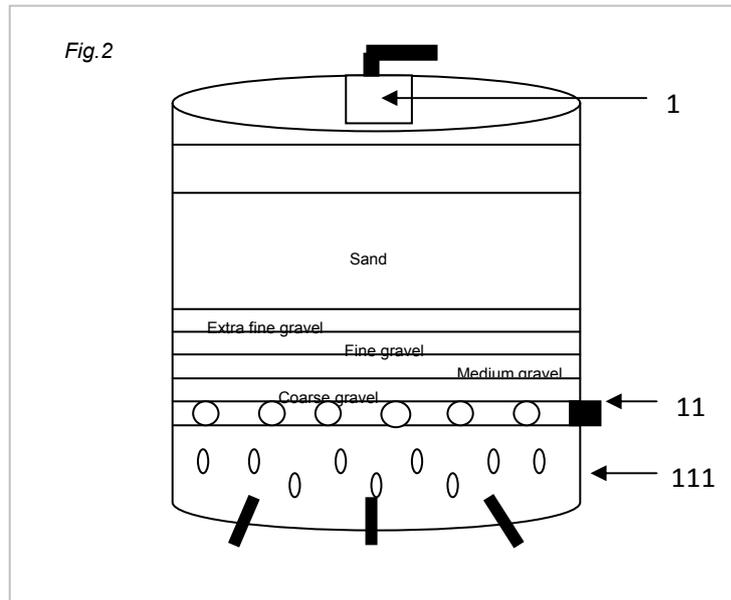
The filter typically consists of a pressure vessel that contains a bed of fine sand, usually with a particle size of 1-2mm diameter, supported on layers of gravel of increasing coarseness. Coarse stones at the bottom will be around 5mm in diameter, and the base made of concrete (III). The type of sand and depth of each layer must be specified by the plant manufacturer.

- Water from coagulation tank is pumped into top of sand filter
- Inlet baffle (I) deflects flow so that water does not directly strike surface of filter bed and disturb its evenness. Water is instead uniformly distributed over entire filter surface
- Filter media gathers more particles and void space between the particles gets progressively smaller
- Floc is removed from filter by back washing with water, and possibly an air scour
- Underdrain system (II) collects filtered water and distributes backwash water evenly

Chlorination

Free chlorine is generally used as the sterilising agent, ensuring a level of 6-8 mg/l chlorine after the sand filter, so that the reaction reaches completion. Either chlorine gas or sodium hypochlorite solution can be used.

Where ferrous sulphate is used, free chlorine oxidises the ferrous salt to ferric salt, and is usually added into the coagulation tank. In this case, the residence time in the coagulation tank can be included as part of the contact time with free chlorine, necessary for sterilisation.

With aluminium sulphate, chlorine is generally dosed after the sand filter, where the residence time in the clarifier cannot be counted as part of the sterilisation period.

Other impurities in water, such as organic matter, sulphites, nitrites and particularly ammonia, absorb or react with chlorine and these reactions must be completed before any chlorine is available for bacteriocidal action.

Chlorination chemicals are most effective if injected immediately after the treatment process (or during coagulation); this is because direct chlorination of raw water containing humic organic matter produces trihalomethanes (THMs). These are undesirable substances in treated water, and if present in quantities greater than 100 ug/litre, may impart an unpleasant taint to the treated water.

At levels used, chlorine will completely oxidise all the impurities, removing any taste and odour, including those due to phenol and similar substances.

When chlorine is dissolved in water it reacts to give hydrochloric and hypochlorous acids: -

$$Cl_2 \quad = \quad H_2O \quad = \quad HCl \quad + \quad HOCl$$

Hypochlorous acid is a weak acid and dissociates giving the hypochlorite ion:

$$HOCl \quad = \quad H^+ \quad + \quad OCl$$
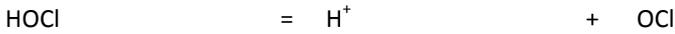
The non-ionised form is a much more efficient disinfectant than the hypochlorite ion, by about 80 times. At pH 5.5 practically all the available chlorine is present as active HOCl; the proportion gradually reduces until at ph 10 it is all in the OCl form. This means that in a soft drinks water treatment process, chlorine is not used as a very efficient germicide, but it is still more than adequate if standard conditions of a minimum of 6mg/litre chlorine and a retention time of two hours are adhered to.

Contact time and free residual chlorine required for adequate disinfection are related by the equation:

- C x T = 150 (as a minimum requirement)
    - T = contact time in minutes
    - C = concentration of free chlorine in mg/l at the end of contact period

Dechlorination

Dechlorination is achieved by passing through an activated carbon filter. *(See figure 3).*

The carbon is housed in a pressure vessel similar in construction to the sand filter, supported on a bed of graded gravel. The activated carbon consists of highly porous particles (grain size usually 1 – 3mm), and has an extensive surface area in relation to its volume. The amount of carbon is calculated to give a contact time of five minutes with the water. This is long enough to remove all the free chlorine together with some organic molecules that may remain in the water after coagulation, or have been formed during sterilisation.

It would appear that chlorine is removed not by absorption, but by catalysed reduction to hydrochloric acid. Nascent oxygen is produced which either reacts with adventitious organic matter on the carbon bed or with the carbon itself:

$$Cl_2 \quad + \quad H_2O \quad = \quad 2HCl \quad + \quad O$$

Organic matter

CO2   Oxidised organic matter
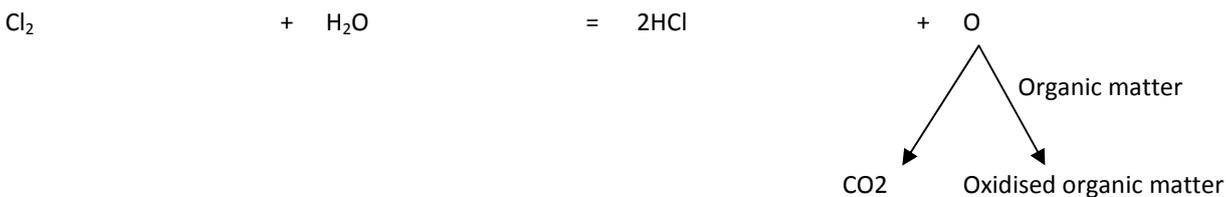
The two types of carbon used are:
- soft carbons derived from coal
- hard carbons derived from coconut shells.

Soft coal carbons have a larger pore size and are possibly more efficient in removing taste and odour from water. However, the carbon particles must be sufficiently robust not to break down under the general maintenance, usually involving daily backwashing. Soft carbons can crumble, and fine powder can be washed through with water. It is usual to have a cartridge filter in the treated water line, of pore size 5 – 10um.

Breakdown of the carbon bed is signified by its failure to remove chlorine. This occurs when active sites on the carbon particles become entirely covered with organic matter, and chlorine passes through the bed without being affected. The carbon must be taken out and replaced with a fresh charge.

Carbon filters are fitted with steam injection at the base, to enable steam sterilisation when necessary. This reduces the microbiological contamination which gradually accumulates in the activated carbon.

CUTAWAY OF CARBON FILTER
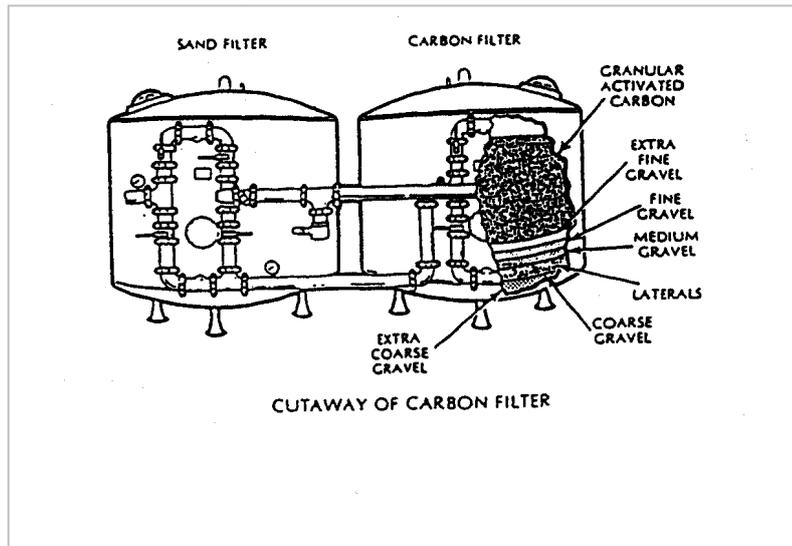
Plant performance monitoring

For the correct operation of a typical plant and to ensure the plant is trimmed for any variation in the raw water supply, the whole operation should be monitored regularly. Key areas to monitor include floc concentration, residual alkalinity, chlorine dosing, residual chlorine and microbiological testing.

For the measurement of water alkalinity, water to be tested is titrated against N/50 acid to a point at which phenolphthalein indicators turn colourless. The number of mls of acid used is the "P" value. Titration continues until methyl orange indicators change colour. The total number of mls of acid used for this to happen is the "M" value or total alkalinity. P and M values are always interpreted in terms of calcium compounds even though other substances such as magnesium may be present and affect the result.

Correct lime dosing can be calculated by using the formula:

- 2P – M
    - P = number of mls of acid used to turn phenolphthalein indicators colourless
    - M = number of mls of acid used for methyl orange indicators to change colour

Dosing is correct if the calculation shows an answer between 0 and 7. A negative result indicates too little lime being dosed, a result greater than 10 indicates too much lime being dosed.

(See appendix 3 for detailed explanation of measurements of water alkalinity).

Ion exchange

Improvement of municipal supplies in the urban areas of Western Europe, the Americas and Oceanica has meant coagulation is no longer the primary form of treatment. Other processes are now used without any reduction in specifications.

Commercial ion exchange systems have rapidly advanced in recent years, resulting in fully automatic equipment, which is regenerated whenever the resin becomes exhausted. There is no need for manual supervision except to ensure the regenerant tanks are replenished.

Softening

Normal base exchange using a strongly acidic cation exchange resin is regularly used in soft drinks factories to provide softened water for use in bottle washers. Resin (R) is used in the sodium form and regenerated with brine. Calcium and magnesium ions responsible for the hardness in the water are exchanged for sodium ions: -

$$\text{Softening}$$

$$Ca^{2+} + Mg^2 + Na_4R \quad \dashrightarrow \quad 4\,Na^+ + Ca.Mg.R$$

$$\dashleftarrow$$

$$\text{Regeneration}$$

The process does not reduce alkalinity and so is not suitable as a treatment for water used in a soft drink product.

Dealkalisation

Dealkalisers use weak acidic cation exhange resins based on methacrylic acid with carboxylic active groups, and operating the hydrogen form. During the treatment cycle, calcium and magnesium associated with alkaline hardness are taken up by the resin and the corresponding alkalinity is converted to water and carbon dioxide:

$$Ca(HCO_3)^2 \qquad + \quad 2RH \qquad\qquad = \qquad R_2Ca + 2CO_2 \qquad\qquad + \qquad 2H_2O$$

Calcium alkalinity   Regenerated resin   Exhausted resin

The treated water produced has zero alkalinity with a reduction in total dissolved solids, equivalent to the alkalinity present in the raw water, i.e. partial demineralised water. Therefore, it is normal to blend treated water with a portion of raw water to raise the alkalinity to 50 mg/l. It is also common to incorporate a degasser tower to remove carbonic acid by removing carbon dioxide.
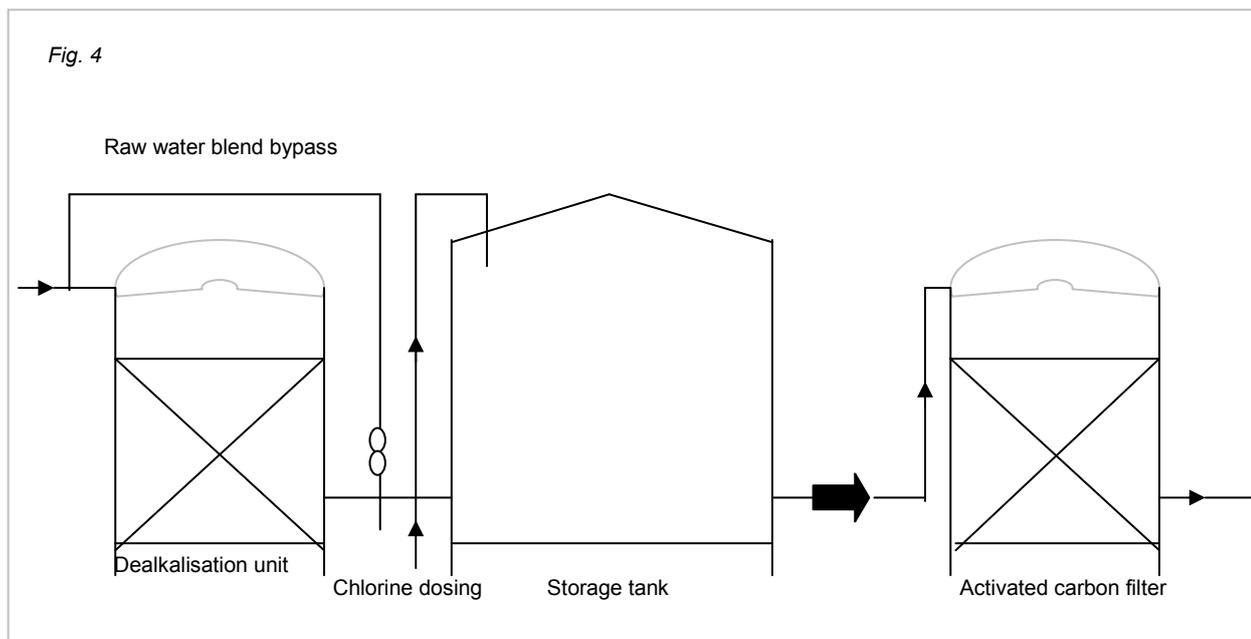
Weak acid cation resins have a very high, total capacity and are exceptionally easy to regenerate. Either hydrochloric or sulphuric acid can be used, and plants are usually controlled and monitored by pH. When pH rises to 5.5, this is equivalent to an alkalinity of approximately 50 mg/l.

The regeneration reactions that take place can be represented by:

$$R_2Ca \qquad\qquad + \quad 2HCl \qquad\qquad 2RH \qquad\qquad + \quad CaCl_2$$

OR

$$R_2Ca \qquad\qquad + \quad H2SO_4 \qquad\qquad 2RH \qquad\qquad + \quad CaSO_4$$

Use of sulphuric acid can cause problems for the precipitation of calcium sulphate which is very insoluble and can reduce the operating capacity of the resin if precipitation occurs in the resin bed. Using hydrochloric acid produces calcium chloride as the waste product, which is far more soluble than calcium sulphate.

The dealkalised water requires sterilisation and filtration before use. *(See Figure 4 for a typical plant layout).*

Fig. 4

Raw water blend bypass

Dealkalisation unit   Chlorine dosing   Storage tank   Activated carbon filter

Organic removal

Coagulation not only reduces alkalinity, but also removed organic matter as part of the flocculation reactions. Dealkalisation has no effect on organic matter that may give rise to taste, odour and colour problems in soft drink.

Removal of organic matter by ion exchange was developed in the 1960s using resins based on a polystyrene matrix. During the 1980s a range of resins was developed on an acrylic structure. The organic scavenger resins are strongly basic anionic exchange resins in a chloride form, which reduce harmful organic substances and silicates from the water. Resins are highly porous allowing organic molecules easy passage in and out of the structure, which is either macroporous or macroreticular.

The choice of resin type and organic removal capacity is dependent upon the nature of organic species in the raw water. Bench or pilot plant trials should be conducted ahead of installing a full scale plant. Typically, around 70% of organic content is removed.

A possible reaction is represented by:

$R_8N (CH_3)Cl$ + KNO_3 = $C_6H_2(OH)3COOH$ + $R_8N(CH_3)OOC(OH)3C_6H_2$ + HCl
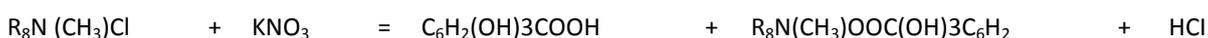
Resins are regenerated with 10% sodium chloride solution prepared from concentrated brine. Occasionally the addition of 2% sodium hydroxide and an elevated temperature may be required. Some organics are not removed and over a period of time the resin can become irreversibly fouled and will have to be replaced.

Nitrate Removal

Nitrate concentrations in water have risen over the last thirty years because of the increasing use of nitrogen, phosphorous and potassium enriched fertilisers for agricultural use. Water authorities now treat water to guarantee nitrate levels of below 50 mg/l as NO_3.

Some soft drink manufacturers insist on a lower level than this, particularly where canning operations are involved. High levels of nitrate cause corrosion problems if the can lining is flawed

In the 1970s a resin was developed that selectively exchanges the nitrate ion. This modified anion exchange resin operates the chloride form. The bicarbonate, chloride and sulphate ion are exchanged in the early part of the run, but equilibrium is quickly reached, and as a result the treated water is similar (except for the nitrate content) to the raw water for the remainder of the service run.

The affinity of the resin for the nitrate ion is such that when the resin has reached its operating capacity, the nitrate ion will not be excluded from the resin. At no time will the nitrate concentration in the treated water be higher than in the influent water, unless the operating capacity of the resin is exceeded. The resin is regenerated with sodium chloride solution, and operation is similar to a softening plant.

The reaction can represented by:

$$R_8N (CH_3)3Cl \quad + \quad KNO_3 \quad = \quad R_8N (CH_3)3NO_3 \quad + \quad KCl$$

Reverse osmosis

Reverse osmosis (RO) is a process that treats water with a high proportion of dissolved solids to produce treated water that can be used directly for soft drink production or be further treated to meet a desired specification.

RO removes 90-95% of the total dissolved solids. This reduces the cations contributing hardness as well as removing chloride and sulphate. RO also removes soluble organics of molecular weight above 100 plus bacteria, viruses and pyrogens.

The RO process exerts pressure on the feedwater to pass through membranes made of cellulose acetate or polyamide, either hollow fibre, spiral wound or tubular. Fouling of the membranes is a common problem, and some form of pre-treatment is often necessary, ranging from simple chemical dosing to a complex combination of clarification and filtration.

The amount of reject water from RO is often very high, and can be as much as 50% of the feed water flow. In general, recoveries of 80% plus are not uncommon.

Reverse osmosis if often used during times of drought, when polysaccharides develop in reservoirs. This can cause unsightly precipitations of floc in acidic carbonated soft drinks. Conventional clarification does not remove these species, and ion exchange may only have a partial effect, whereas reverse osmosis solves the problem.

The units must be replaced, usually after about three years in operation and a fouling index can be calculated for each plant depending on the quality of the feed water. Weekly sterilisation of the membranes should generally be carried out using formaldehyde solution.

Overseas applications, particularly in the Middle East, are turning more and more to reverse osmosis, where brackish water has to be treated to produce potable water.

Ultra or Nano-filtration

An ultrafiltration (or Nano-filtration) plant is used to remove colloidal substances from water, which may remain after normal treatment processes, such as ion exchange or coagulation.

Ultrafiltration is a semi-permeable membrane process in which the porosity of the membrane is adjusted to retain molecular particles within a specific range, such as molecular weights of 10,000 to 100,000.

Operating pressures are in the range of 2 - 6 bars. The process may be substituted for the polishing filter in the treated water line of a conventional process.

Other sterilisation processes

Chlorine is the most widely used method for sterilisation of water in the beverage production industry *(See Chemical coagulation: Chlorination).* However, several other methods are now being used and are more suitable in certain installations.

Ultraviolet Light

Ultraviolet light treatment is dependent on the passage of light through a small depth of water. To be effective the clarity of the water must be good, otherwise a shadowing effect is created.

The principle depends on the absorption of high intensity UV light at about 254 nm wavelength, which is destructive to the nucleic acids present in micro-organisms, and inactivates their cells. Various micro-organisms have different sensitivities to ultraviolet irradiation, e.g. Escherichia Coli are one of the most sensitive, and algae are one of the most resistant. The wavelength of ultraviolet rays is selected so that not only are bacteria eliminated, but naturally occurring organic matter are also destroyed.

Flow rate is adjusted so that contact time is no less than 15 seconds. Most commercial systems are designed to supply a lamp output much in excess of the international agreed standard of at least 16 milliwatt seconds per square centimetre. Automatic controls of the system are such that if the lamp intensity drops below an acceptable level, an alarm condition will be indicated on the control panel.

Ultraviolet units are generally situated close to the point of use which may mean several units within a factory. Their compactness is a distinct advantage.

Ozonisation

Ozonisation is a more costly process than chlorination due to the difficulty of generating ozone on site and dispersing the gas in the water. Ozone is generated by a high-voltage silent discharge across a current of air. Ozonised air is injected into the water by a venturi arrangement, through porous diffusers or by water spraying. Ozone is sparingly soluble, hence the mixing process must be thorough.

Ozonisation has the advantages that it is pH unaffected, very rapid, and oxidises organic matter removing some tastes and odours. An ozone residual of at least 0.4 mg/litre is necessary for at least 4 minutes, to ensure adequate disinfection.

Micropore filtration

Sometimes referred to as nano-filtration., micro-filtration through an extremely fine medium may be used to remove micro-organisms. Water is filtered through a series of filter elements and finally through an absolute filter of 0.2 microns porosity to remove any bacteria present. The process is claimed to give sterile filtration of liquids.

In as much as the physical removal of bacteria imparts sterility to the water, the process is not the same as other methods of disinfection. It is unlikely that viruses will be removed, if these are present, since they are much smaller in size than 0.2 microns and would pass through the filter.

Micropore filtration is suitable when chemicals, such as chlorine or ozone may be objectionable, but is very costly to operate in large factory plants. This is because filter elements need to be replaced at regular intervals to avoid contamination with off-tastes from microbiological growth on the filters and/or clogging due to a build up of particles.

Semi-treated Water

The definition of semi-treated water is 'water which has been filtered and chlorinated to remove any microbial content'.

In order to change from 'semi-treated' to 'treated' state, the water is subjected to a
de-aeration process followed by UV sterilisation and a final polishing filter.

Semi-treated water can be used for rinsing containers e.g. cans, bottles as well as for cleaning purposes.

'Treated water' (i.e. water used to mix with ingredients to make final syrup or product) needs to have as little dissolved air or oxygen dissolved in it as possible (this is especially the case with carbonated soft drinks being filled into cans), so it is passed through a de-aeration process to remove dissolved air or oxygen.

This can be achieved by passing the semi-treated water through a spray nozzle into a tank or vat against a counter-flow of carbon dioxide. The CO2 'strips' the dissolved oxygen out of the water which is then collected and pumped into a storage tank. A blanket of inert nitrogen gas is fed into the storage tank to cover the surface of the stored water in order to prevent any oxygen or air finding its way back into the water.

Finally the water can be subjected to UV sterilisation and a final polishing filter before being called upon for mixing with ingredients to make syrup or final product.

Appendix 1

Treatment summary of various water types

Water source	*Characteristics*	Suitable treatment
Limestone borehole	High temporary hardness	Coagulation (lime/$FeSO_4$) or de-alkalisation by ion-exchange
Sandstone borehole	High permanent hardness	De-ionisation or reverse-osmosis
Moorland peat surface water	Soft, with high humic acids	Flocculation (alumina), ozonisation or interox (U.V.+H2O2)
Marshland area borehole	Soft with high humic acids	Organic scavenger resin ion-exchange
River water	Variable composition	Flocculation (alumina) or coagulation (lime/$FeSO_4$)
Laterite borehole	Soft, with high silicate and iron	Aeration and coagulation with lime silica scavenger resin
Coastal area borehole	Hard with high sodium Chloride	Reverse-osmosis or de-ionisation or electro dialysis reversal
Lakeland (rocky area)	Soft with low total dissolved solids	Chlorination and carbon filtration or ozonisation
Mains water	Moderate total solids content which may be soft or hard	Coagulation (either alumina or lime/$FeSO_4$) or ion-exchange or de-alkalisation

Appendix 2

Water treatment process comparison

	Coagulation (with lime/soda softening)	Reverse osmosis	Ion exchange (dealkalisation)
Type of process	Chemical addition		
Basic principle	Chemical addition flocculates suspended solids. Lime/soda addition reduces hardness and alkalinity.	Pre-treated sample is passed through high-pressure membrane that does not allow salts to pass.	Bicarbonates are exchanged on to resin sites liberating CO_2 into treated water.
Type of solids removed	Colour agents, suspended solids -calcium alkalinity - magnesium alkalinity, non-carbonate hardness.	Ionised dissolved solids organics -weakly ionised solids (S102)	Only alkalinity in feed water.
Typical feed water range – TDS	Variable	350 – 15000 ppm (to 38,000 ppm available)	To 500 – 600 ppm alkalinity
Typical product water range – TDS	Variable	500 ppm or less	About 25ppm alkalinity - other dissolved salts unchanged
% TDS removal	Variable - depends on feed	50 – 99% (99% on seawater)	Variable according to alkalinity content
Pre-treatment required	Typically none - could act as a pre-treatment to other processes	Filtration and softening by acid/hexametaphosphate dosing	Typically none. But feed water should be free of suspended solids
Type of waste produced	Sludge - requires dewatering equipment and disposal site (e.g. land fill)	Liquid brine including concentrated pre-treatment chemicals	Spent regenerant chemical acid
Process limitations	None	Organics. High silica levels or $CaSO_4$ may irreversibly foul modules	Thermal shock or chlorine can cause irreversible damage to resins.
Special considerations	Constant control adjustments are required for optimum performance	Membranes are very expensive. Plant operating cost depends heavily on proper maintenance and pre-treatment	Can be used with varying waters without altering pre-set chemical volumes

Appendix 3

Measurement of water alkalinity

This table explains how to interpret P and M values of water leaving the sand filter. For simplicity, the table refers to calcium compounds only, although other compounds may in fact be present.

Having obtained P and M alkalinity values, find the corresponding section in the column headed **Titration Result**. The explanation of the result is horizontally to the right.

For example:

- If M $\quad$ = $\quad$ 39
- And P $\quad$ = $\quad$ 22
- Then 2P-M $\quad$ = $\quad$ (44-39) = $\quad$ <u>5</u>

Titration result	Hydroxide alkalinity value (quantity of lime present)	Carbonate alkalinity value (quantity of calcium carbonate present)	Bicarbonate alkalinity value (quantity of calcium bicarbonate present)
When P = 0 and M is positive	Nil	Nil	M mg/l bicarbonate present
	Comment: All alkalinity present caused by bicarbonate in the water. Therefore, no lime added, nor is calcium carbonate present.		
When 2P is less than M	Nil	2P mg/l carbonate present	M-2P mg/l bicarbonate present
	Comment: Insufficient lime added, therefore mixture of carbonate and bicarbonate present. All added lime been used up. Increase lime dosage.		
When 2P = M	Nil	M mg/l of carbonate present	Nil
	Comment: Treatment theoretically correct. All lime and bicarbonate reacted together to form carbonate. In practice, require 2P-M = 2-7 to ensure full treatment and no iron carry-over.		
When 2P is greater than M	2P-M mg/l of lime present	2(M-P) mg/l of carbonate present	Nil
	Comment: All bicarbonate reacted with lime to form carbonate, and excess lime added. Reduce lime dosage.		
When P = M	P + M mg/l lime present	Nil	Nil
	Comment: No bicarbonate or carbonate in the water. Only lime present i.e. even before lime added, water perfectly soft, not requiring lime treatment.		

2.6.2.3   Product Preparation

Carbonated soft drinks

The principles for correct product preparation, proportioning with water and carbonation are standard across the soft drinks industry. Individual machine control and settings, and the specifications for product make-up and carbonation are defined by organisation and individual production units.

Syrup production and services

The primary raw material is water. It is critical for the successful filling of soft drinks that it is correctly treated, such that at all times it conforms to at least the industry standards.
Liquid sugar is normally delivered at 67°Brix by tanker. This can be either cane or beet sugar. Some bottlers take in dry sugar in bulk and dissolve this on site to liquid sugar. It is important that the quality of sugar is suitable for purpose, as "mouth" feel is critical when consuming soft drinks.
If low calorie drinks are being produced high-intensity sweeteners are used. Acids, colours, preservatives, flavourings and other additives are added as required by the formulation.
The syrup room or Process room is the production area where the soft drinks ingredients are blended to specific recipes. In modern production plants, this is often to the ready to drink (RTD) stage. The development of in-line continuous blenders where concentrated ingredients in solution are streamed into a product tank, along with water, sweetener and other ingredients in solution has emerged in order to improve ingredient yields – more of this process is discussed below. In older traditional plants, a syrup is produced with all recipe ingredients except water. This is then subsequently diluted with water and carbonated just prior to filling.
It is important that the syrup is carefully produced and is checked to ensure it conforms to specification for parameters such as acid and Brix. Once produced to standard, the syrup is ready to be pumped to the filling line.

Syrup is the main flavour component of a soft drink, providing any food value and 'body' to the drink. It also maintains the necessary balance between acidity and sweetness. The usual breakdown of a typical beverage would be one part of syrup plus five/six parts of water although this ratio varies across drinks especially speciality drinks such as shandy, glucose-based products etc.

Correct procedures followed during syrup preparation form the foundation for a subsequent high standard of filling. These good practices are mainly concerned with the undesirable inclusion of air during the handling and mixing of syrup batches.

The sugar component is usually introduced either in the form of liquid sugar available in bulk at approximately 67'Brix or by dissolving granulated sugar in water to produce 'simple syrup'. Whichever method is used, great care must be taken during the transfer of liquids from tank to tank to prevent aeration. In addition, since the dissolution of granulated sugar in cold water requires considerable agitation in order to prevent 'settling-out', the method of agitation should be such that little or no aeration is created.

Tanks used for the preparation of syrups should be hygienically designed, preferably enclosed with access man-holes (or, if open-top, equipped with close-fitting lids), fitted with spray alls for in-place cleaning (CIP) and some external indication if the liquid content levels. For large-scale production e.g. batches of 5000 litre and above, some form of automatic operation is necessary. This usually takes the form of load cells under the supporting feet of the holding tank or metering systems for the major components. The latter method has the advantage that constituents may be added simultaneously but final checking (with possible adjustment) is vital and even the best systems invariably rely upon manual topping-up with water to the finished batch size.

From 1990 onwards, some manufacturing organisations adopted a move away from the traditional method of syrup make-up. Preparation of product to final concentration by the use of **continuous batching** of ingredients created a process of greater consistency of end-product quality. This technological development took away the need for proportioning of syrup with water, thus meaning that the only equipment in the filling area, apart from the filler itself was the carbonator tank.

A further development from this form of technology has seen the emergence of
in-line continuous blending. Dry ingredients need to be dissolved into solution before being fed to the blender. This current technology has taken quality consistency and cost efficiency to an even higher level.

Carbon dioxide

The gas content is the smallest constituent by weight but possibly the most important, providing the characteristic effervescence of a carbonated soft drink. Not only does the CO_2 enhance the beverage recipe but it also inhibits the growth of harmful organisms and, in some cases, actually destroys them. Thus, an additional safeguard is provided which complements the other precautions taken during formulation and production.

Since it is the release of CO_2 during the consumption of a carbonated soft drink which gives the beverage its attractive tang, it follows that the quantity of gas available to be released is very important and therefore the CO_2 'carrying capacity' of a beverage, atmospheric pressure is vital.

CO_2 is the only gas which possesses the necessary solubility to satisfy this condition. There is no other gas which can produce the same effect, is non-poisonous and is readily available.

CO_2 is a colourless, odourless gas which is 1.53 times the weight of air and, in the liquid form, has a specific gravity approximating to water. It is rated as being 'very soluble' in water and this solubility increases as the temperature decreases - an important factor in the manufacture of soft drinks. CO_2 is non-poisonous but excludes air from aerobiotic animals which then suffocate due to deprivation of oxygen. Because of its heavier-than-air property, it tends to lie at the bottom of tanks and precautions are necessary when entering tanks which have been subjected to carbon dioxide.

Bulk liquid CO_2 is commonplace, with insulated tanks pressurised to 20.7 bar and maintained at a temperature of 17.8'C, a small refrigeration unit keeps the pressure within the limits of 20.3 and 21 bar and a steam or electric heater is provided to vaporise the liquid to gas at the required rate.

The degree of carbonation is measured in 'volumes' carbonation can vary from one volume in fruit drinks to 4.7 to 5.0 volumes in mixer drinks and soda water.

Water

Water is the main ingredient of a soft drink accounting for between 85 and 95% of the product. Mains water quality is not high enough or consistent for use in soft drinks manufacture – some form of treatment is necessary. For high-quality beverages, the standard of the water should not conflict with the taste, appearance, carbonation and keeping properties of the products. This means that the water must be:
* Free from large traces of elements and mineral salts
* Free from objectionable tastes and odours
* From organic matter
* Clear and odourless
* Free from air
* Sterile

One of the most difficult aspects of present-day water treatment in the soft drinks industry is the variability of the supply quality following the development of national grid systems. Water treatment in all its forms is now a large and complex industry and its application to soft drinks production is a specialist function.

Proportioning/blending principles

The most modern and popular system is known as 'finished product filling' or 'premix filling', so called to differentiate it from an obsolescent system where the syrup and carbonated water components were dosed into the containers by different machines.

In finished product filling, the three constituents of syrup, carbon dioxide and water are mixed together in a processing unit and passed into the containers through one filling machine.

The variation in the sequence of combining the constituents gives rise to two main types:
* Carbonated water proportioned with syrup
* Water and syrup proportioned and the resultant mix carbonated

Cooling, where desired, can take place at any stage although it is usual to cool any liquid prior to, or during the carbonation process. Additionally, for high performance filling operations, de-aeration is vital and is applied to the water component as a first stage.

De-aeration

Mechanical vacuum system – water is sprayed into a small tower (lined steel or stainless steel) which is maintained at a vacuum of 68-71 cms Mercury. During its passage down the tower, the water is finely divided to offer a large surface area to the vacuum.

Reflux system – Water is agitated (usually by trickling over a series of plates in a tower) in an atmosphere of CO_2. The air is encouraged to leave the water and is replaced by CO_2, the discharged water being slightly carbonated.

Whichever method is employed, it is important that the majority of air is removed – it is the last few millilitres of air that can cause filling problems.

Syrup to Water ratio – quality checks

With modern proportioning systems, the strength of the finished product should be controlled within fine limits in order to ensure consistency of beverage and an acceptable yield of filled bottles or cans from a syrup batch. The strength of the beverage is independent of container volume and filling height variations.

Methods of checking include:
- Removal of CO_2 followed by hydrometer reading of specific gravity
- Refractometer analysis on finished beverage – this gives high accuracy with temperature corrected laboratory instruments
- Titration methods (for sugar-free products) measuring some constituent of the syrup e.g. citric acid titrated against a standard alkaline solution

Correct Carbon Dioxide content

Carbonation may be defined as the impregnation of a liquid with carbon dioxide gas. The degree of effervescence is probably the most important property of a carbonated soft drink. The quantity of dissolved CO_2 gives the beverage its characteristic sparkle which complements the flavour of the drink – for any particular recipe, there is a certain degree of 'carbonation' which is 'just right'. Too high a carbonation in an orange crush drink is as bad as too low a carbonation in ginger ale and other mixers. Since carbonation is so vital, it is imperative to be able to measure the degree of carbonation in order to ensure consistency of product. In practical terms, carbonation levels vary between 1-2 volumes in fruit drinks to nearly 5 volumes in mixer drinks, with soda siphons up to 6 volumes.

Large PET bottles constitute a special case – not only does the CO_2 gradually escape through its permeable polymer material producing a marked reduction in the carbonation of the contents over a period of time, but the repeated opening and closing of the container for occasional consumption can result in the final 25-30% of the contents having an unacceptably low carbonation.

The accepted unit of measurement in the UK is the 'Volumes Bunsen' – abbreviated to VOLUMES – the number of volumes of CO_2, measured at atmospheric pressure and 32'F, which are dissolved in a unit volume of liquid. In the US, 'Volumes Ostwald' is sometimes used and this particular unit ignores the temperature correction of 'Volumes Bunsen', measuring the volume of CO_2 at atmospheric pressure and the prevailing temperature. In Europe, the degree of carbonation is measured in gms/litre and by chance, this unit is almost exactly twice the equivalent carbonation in Volumes Bunsen.

Carbonation determination

Carbonation is determined by:

1. Taking a sample filled & sealed container from the production line or from warehouse stock, shaking it to equilibrium and noting the internal pressure and product temperature. There are several variations of this procedure but the following methods are recommended by the American Bottlers of Carbonated Beverages and have been widely adopted elsewhere in the world.

a) Containers direct from production line. The container is punctured with a pressure gauge device and shaken until maximum pressure is attained. It is then allowed to settle for 30 seconds and the container internal pressure released. The release valve is closed and the container is shaken again to maximum pressure. This pressure is recorded from the gauge, the product temperature is read and then the gas volume is read from standard graph, table or through use of calculator.

b) Containers from stock. The container is punctured gently with no agitation – the pressure is released, valve closed and the container re-shaken to maximum pressure. Again, after recording the temperature, the gas volume is read from graph, table or calculator.

Compliance with the above procedures, sometimes known as the 'second-shake methods', minimises the misleading effect of a high air content in the beverage.

2. Laboratory test. The CO_2 is boiled off from a sample of product and the volume of CO_2 measured at atmospheric pressure. This is converted to 32'F and the liquid volume measured, the ration of gas/liquid gives carbonation in Volumes Bunsen.

Carbonated product processing and filling equipment

Types of proportioners/blenders

Batch system

This is the simplest and most accurate system (but hardly a true proportioner or blender). Large tanks have the requisite quantities of syrup and water pumped into them, the finished product mix being checked after thorough homogenisation. The process is usually completed by carbonating the product in the same vessel. Large tanks are required but cleaning procedures are relatively simple.

Positive metering pumps with a common drive

Two or more single-acting positive reciprocating pumps are driven by a common motor. Variable stroke adjustment allows any desired syrup/water ratio to be obtained. Suction and delivery valves are of sanitary design and suitable for handling fruit cells in fruit-based ingredients.

Constant head over orifice type

Under a constant head, liquid discharges through an orifice at a fixed flow-rate. One orifice passes water and the second, smaller orifice passes syrup, both orifices discharging into a common combining chamber. The constant heads of syrup and water are maintained by modulating valves controlled by ball floats in the respective reservoirs. An air-operated cylinder simultaneously closes both orifices when no further supply of product is required. The syrup orifice plate is changed for different outputs and the water orifice is adjustable by micrometer control to allow for fine setting of the syrup/water ratio. On later models, CO_2 is injected into the water inlet pipe and the whole equipment maintained at a slight pressure to minimise air pick-up
(reflux system).

The system is simple in concept and operation but is made complicated by the necessary controls and safety devices. A high degree of proportioning accuracy is possible and wash-out is easy. Syrups with different viscosities require readjustment of the water orifice setting.

Twin meter system – electronically connected

Syrup and water are passed through separate meters, the continuous readings of which are compared electronically in a 'black box', the resultant signal from the 'black box' controls variable orifice valves in the syrup and water feeds and adjusts the flows to produce the desired syrup/water ratio.

The syrup and water pipes combine to one outlet and automatic valves simultaneously shut off the syrup, water and beverage according to the demand of the carbonator.

Overall accuracy depends upon the accumulative accuracies of meters, meter signals, 'black box' signal and control valve response, claimed to be capable of handling fruit cell syrup and easily cleaned.

Twin Orifices with positive pump

Small tanks containing syrup and water feed a double orifice arrangement on the suction side of a positive displacement pump. The pump has a variable speed drive to vary the total product flow and an adjustable syrup orifice allows the desired syrup/water ratio to be obtained.

An automatic valve is fitted in the syrup line and closes when the pump stops in order to prevent migration of syrup into the water.

<u>Types of carbonators</u>

Carbonator with integral cooler

Product enters the top distribution tray and flows down the cooling elements into a lower tray and thence into the base of the vessel. Fruit cells can by-pass the cooling plates and be passed directly into the carbonator base. Cooling and carbonation take place simultaneously. Saturation variation with CO_2 is usually obtained by a pre-carbonating device in the inlet line. The unit is easily washed out, spray jets being provided in the upper section of the chamber.

Pre-carbonating cooler and a carbonator with trays

The proportioned mix is distributed over cooling coils in an atmosphere of CO_2 thus achieving de-aeration and pre-carbonation. This cooled mixture is pumped into the top of a carbonating pressure vessel and allowed to flow over alternately coned and funnelled horizontal trays which allow a high degree of contact with the carbon dioxide.

This is not suitable for fruit cell products unless the cells are finely comminuted

Spray chamber

A tall vertical stainless steel chamber has proportioned mix sprayed into it through a nozzle which is suitable for fruit-cell drinks. Variable saturation is obtained by rotating the nozzle to reduce the time of contact. This is a very simple and hygienic type of carbonator. Wash-out is accomplished by passing cleansing water through the nozzle to cover all internal surfaces.

Carbon dioxide injection

Product is passed through a venturi, the throat of which is connected to a CO_2 supply. Agitation during subsequent passage through a plate-type heat exchanger ensures the gas is fully dissolved, particularly if the heat exchanger is also employed as a cooling means.

'Draining wall' heat exchanger

Product flows in a thin film down the bores of the tubes in a vertical shell-and-tube heat exchanger which is located in a CO_2 pressurised chamber. Refrigerant passes through the shell section in counter-flow and the product is cooled and carbonated simultaneously.

At high level in the lower chamber, the inflow is stopped and the product drains from the tubes to minimise the chances of freezing.

Beverage Cooling

Although cooling normally occurs early in the process of carbonating and filling, this subject has been placed last in this script because of the desire to impress in previous sections when and why cooling is beneficial.

Basic refrigeration
(Cross-reference to Unit 3.3 Heat transfer and Unit 3.2 Process Gasses respectively of the Pack Diploma material)

The principle of refrigeration is that when any liquid evaporates, heat is absorbed. All liquids have particular boiling point temperatures which vary with pressure – the higher the pressure, the higher the temperature at which boiling takes place. In order for a liquid to boil and convert into a gas, heat must be supplied during the process. This is termed **Latent Heat** and varies from liquid to liquid.

Soft drinks refrigeration systems operate on the vapour-compression principle during which a liquid (termed the refrigerant) in an enclosed circuit is alternately evaporated and liquefied.

The main components are:
- Compressor – raises the pressure and temperature of the gaseous refrigerant
- Condenser – reduces the temperature of the refrigerant and converts it to liquid
- Expansion valve or injector – controls the supply of refrigerant into the evaporator
- Evaporator – the liquid refrigerant boils off, converting it to a gas, and absorbs its latent heat. The gas then passes to the compressor to repeat the cycle.

On small plants, the condenser is fed with mains water to provide the cooling effect and the resultant warm water is discharged to drain. This becomes costly with large plants and cooling towers may be used to conserve water. These work on the evaporative principle where warm water is sprayed in a current of air, a fraction of the water being evaporated and the heat required to do this being extracted from the remaining bulk. A reduction of 5-6'C in water temperature can be expected for a sacrifice of 5% of throughput.

A further refinement is to combine the condenser and cooling tower to produce a composite unit called an 'evaporative condenser'. In this unit, the refrigerant gas is passed through a cooling coil over which water is sprayed in a current of air, converting the refrigerant to liquid form. As for the normal cooling tower, a small proportion of water is evaporated giving a cooling effect on the remainder.

The evaporator transfers the latent heat from the liquid to be cooled to the refrigerant, an evaporator in the form of cooling coils in a tank of product would be acceptable for small-scale operation but the normal arrangement is for soft drinks beverage to flow downwards in films over a vertical evaporator. The combination of a thin film and changing boundary conditions promotes efficient heat transfer and also assists carbonation when this is carried out simultaneously.

Choice of refrigerant

A good refrigerant possesses the following properties:

- A large latent heat provides a satisfactory degree of cooling relative to refrigerant flow
- A small vapour specific volume enables a satisfactory refrigeration effect to be obtained from reasonably sized equipment
- The pressure range for evaporation and liquefaction should be moderate – pipework, fittings and pressure vessels need not be excessively strong

Refrigerants in common use are:
- Ammonia – still the most popular refrigerant, very efficient and readily available. However it is an extremely obnoxious gas and attacks copper and brass
- Refrigerant 12 (Freon 12) – reasonably efficient, non-poisonous, requires low operating pressures but is relatively costly
- Refrigerant 22 (Freon 22) – similar to R12 but more efficient and requires higher operating pressures

Centralised refrigeration

A beverage processing system usually incorporates the necessary refrigeration item as a packaged unit. With one or two production lines, this arrangement is generally acceptable but in the case of several lines, it can be beneficial and convenient to group the refrigeration units away from the production hall, thus reducing the machinery and noise in the actual production area.

Two alternatives are possible – either the primary refrigerant (ammonia etc) may be distributed to the various locations (small liquid lines and large, insulated suction lines) from the centralised system or the latter is used to cool an intermediate coolant (secondary refrigerant) which is then circulated through to the production area. The secondary refrigerant may be any liquid that has a low freezing point and popular coolants are brine or an alcohol/water mixture. A low temperature coolant minimises the necessary rate of circulation and encourages a high degree of heat transfer at the processor. The intermediate refrigerant may be circulated through what is normally the evaporator in the beverage processor or, alternatively, a separate heat exchanger may be utilised to cool the product before the carbonation process.

A major advantage of a secondary refrigerant system is the 'flywheel' effect of the large volume of coolant – this allows the varying individual demands of a multi- production line operation to be 'smoothed out' leading to a considerable reduction in the size of the refrigeration plant. In addition, the refrigeration plant may be designed in two halves, each unit phased to operate according to the load and providing the facility for overhaul of the units during low production periods e.g. winter conditions.

Any centralised system is expensive to install but considerable savings in running costs may be made, the advantages of a secondary refrigerant cooling facility 'on tap' should not be under-estimated, particularly where cooling is required other than for the beverage itself e.g. chilled wine or fruit juice storage, cooling juices after pasteurisation, cooling bottle washer final rinse water. Generally speaking, the larger the installation, the more economic is a secondary coolant system.

<u>**BOTTLED WATER**</u>

Introduction to Bottled Waters

Water is essential for all forms of life. Humans are composed of about two-thirds water. Water is therefore a vital component of our everyday physiological needs.

Access to water from springs, wells and rivers is vital and can also be of use for domestic and industrial purposes.

Over time supplies of surface waters become increasingly threatened by urban development, increases in population and rising per capita use.

Delivery systems were developed to tackle this but it became necessary to treat water supplies to ensure safe drinking and to prevent diseases carried by water. The achievement of microbiologically and toxicologically safe water through chemical treatment is essential although such treatments can cause organoleptic changes. This is one of the reasons for the dramatic increase in the consumption of bottled waters over the last few decades.

Market Development

During the 1970s bottled waters slowly became a fashionable product to buy in the UK and elsewhere, partly as a spin-off from an increase in world travelling and awareness of the bottled water market in other countries. Since then the market has seen rapid growth as many consumers were attracted by the taste of bottled waters, their perceived health benefits and their purity. Massive marketing investment by major producers has also contributed to the impressive growth of the bottled water market.

Categories of Bottled Water

Not all bottled waters are the same. There are generally three categories of bottled water:

- Natural Mineral Water (NMW)
- Spring Water (SW)
- Bottled Drinking Water (BDW) or prepared water

NB. PLEASE TAKE NOTE OF RESPECTIVE LEGISLATION REGARDING BOTTLED WATERS IN YOUR OWN LOCALITY OR COUNTRY.

In South Africa, bottled water is governed by both The Foodstuffs, Cosmetics and Disinfectants Act 1972 (Act 54 of 1972) Regulations governing bottled water and The South African National Bottled Water Association (SANBWA).

Requirements for Natural Mineral Water (NMW)

- It must come from a specified groundwater source, which is protected from all kinds of pollution.
- It must be stable in its physical and chemical composition though allowing for slight seasonal fluctuations.
- On the label it must include a hydro-geological description, give the location of the source, define its catchment area, describes flow-paths in relation to geochemistry and assesses travel time.
- It must meet microbiological criteria and in particular must be naturally free from pathogens.
- It may not be treated in any way to alter its natural microbiological state or its chemical composition. Mechanical filtration may be used to remove particulates such as sand. Carbon dioxide may be added to achieve a sparkling product.
- It must be officially recognised through a local authority after a qualifying period of at least two years. (During this time the water is repeatedly sampled and analysed by a government chemist to establish whether the water is suitable for NMW status). NMW recognition must be published in the Official Journal of the European Community and both the London and Edinburgh Gazettes.
- It must be bottled at source and fitted with a tamper evident closure. The label must carry the proper description – Natural Mineral Water – which cannot be used for any other bottled waters. The label must show typical mineral analysis values.
- Even after recognition, it must be regularly analysed through a government chemist to demonstrate its consistency and ability to continue to meet the legislative criteria.

Requirements for Spring Water (SW)

- It comes from a single groundwater source.
- Its parameters must be within Drinking Water limits, though there is no prescription for stable composition.
- It must meet microbiological criteria.
- Currently under UK law, treatments are permitted. (Subject to changes in European legislation).
- It should be registered through the local authority though formal recognition is not required.
- It must be bottled at source.

Requirements for Bottled Drinking Water (BDW)

- It has no fixed source and may come from a blend of sources or the public supply.
- Any treatment is permitted which results in the water achieving the composition/ microbiological requirements of the NMW, SW and BDW Regulations. Generally water is disinfected, filtered and then filtered by reverse osmosis/nano or ultra filtration and then treated by ozonation on filling.
- Minerals may be removed from or added to it.
- It should be registered with the local authority though recognition is not required.

Both SWs and BDWs are required to comply with limits for a wide range of parameters (see table 4) and they may, in accordance with current legislation, be treated in order to meet chemical and/or microbiological standards. (Subject to changes in European legislation). Nitrogen dosing during filling may also used to provide stability to PET bottles and improve microbiological control.

All three categories of bottled waters are classed as "food" and therefore usually come under Food Safety legislation and the requirements of 'due diligence'. All three categories may be used in water coolers.

Solids in the raw material

Rainwater begins as pure as it has just been through the equivalent of a distillation process. However, during precipitation the rainwater absorbs carbon dioxide and other atmospheric gases. The solvent property of water also enables it to dissolve elements from the rocks. The time taken for filtering through the rock and the different types of rock will both play their part in the final composition and taste of the water. Since compositional variations exist between different bottled waters, consumers with particular dietary needs, for example, low sodium can discern which water suits their needs and palate best.

Though the upper limit for mineral salts in public water supply, SW and BDW is 1500mg/L there is no such limit for Natural Mineral Water. Some bottled waters, particularly from continental Europe, have a much higher mineral content. The different salts and the amounts present give bottled waters their distinctive tastes.

Table 1 illustrates the variation in the Total Dissolved Solids (TDS) of some Natural Mineral Waters. This mineralisation is entirely natural.

Table 1: Total Dissolved Solids (TDSs) of some examples of Natural Mineral Waters

Brand	TDS mg/L
Spa	49
Volvic	109
Highland Spring	136
Malvern	210
Buxton	280
Evian	309
Vittel	403
Perrier	478
Badoit	1325
Contrex	2032
St Yorre (Vichy)	2946

Bacteria in Bottled Water

All bottled waters must be safe to drink and are therefore required to be free from any pathogenic (disease causing) micro-organisms.

The safety of Natural Mineral Waters is achieved through source protection.

Bottled Drinking Water, and currently Spring Waters, may be treated if necessary. Monitoring for indicator organisms is the means of ensuring absence of pathogens for all categories of bottled water.

Indigenous, harmless bacteria are required to be within specified numbers in relation to volume of water at the time of bottling. However, the number of these organisms after bottling naturally increases logarithmically within days and can remain at high numbers for many months. (*See diagram below*).

The benign bacteria found in still water are not detrimental to the water or the health of the consumer. Carbonating water lowers its pH and this has an inhibitory effect on the growth of micro-organisms. Consequently the numbers of bacteria in sparkling waters are very low.

NB: However, it is advisable to boil any bottled waters for use in infants' feeds or for ill or immuno-compromised patients
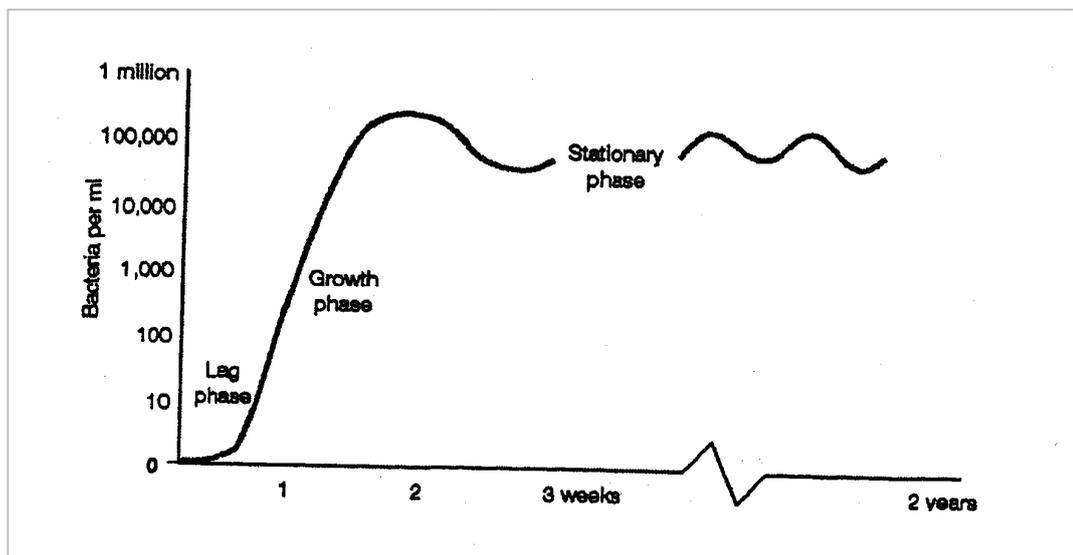

Diagram 5: Growth of bacteria in Bottled Water

The microbiological status of bottled waters is often wrongly compared with that of mains water. Mains water has to be safe to drink and it achieves this through chemical treatments and disinfection. Residual chlorine levels in mains water ensure low levels of total bacteria and an absence of pathogens at point of use.

The fact that bottled waters are governed by different legislation to mains water is official recognition that these products are distinct from tap water.

This difference in microbiological status of mains water and bottled waters is often used in articles in the media where the two products are compared. However, the same qualitative standards do not apply to both products.

Water Treatments

There are three main types of water treatment.

1. Removing unstable constituents or undissolved matter
2. Affecting microbiological population
3. Altering chemical composition

Natural Mineral Waters may only be given treatment 1. Currently, Spring Waters and Bottled Drinking Waters may use treatments 1, 2 and 3.

1. Removing unstable constituents

When brought into contact with air, some waters precipitate solids. Examples of these unstable constituents are iron and manganese. In order to mechanically filter out the resultant sediment, air or ozone is bubbled through the water at source.

Depending on the geological nature of the source, fine particles of sand or sediment can be present in the water at source. This particulate matter can be mechanically filtered out. If the water is NMW care must be taken to choose a grade of filtration that does not remove the water's indigenous bacteria.

2. Affecting microbiological population

Chlorination is commonly used by water companies/authorities to kill bacteria in the water. The residual chlorine is subsequently removed for purposes of soft drinks manufacture by carbon filtration

Mechanical filters with very fine pore sizes can be used to remove micro-organisms.

Ultra-violet radiation is sometimes used to kill bacteria in water. Water is passed over an ultra-violet lamp and the radiation destroys the DNA structure of the bacteria.

Ozone, an unstable isotope of oxygen, can be used to oxidise bacteria. Oxidisation kills bacteria depending on the species and on the concentration of the ozone.

3. Altering chemical composition

Reverse Osmosis (RO) systems can remove viruses, bacteria, parasites, salts and heavy metals. Synthetic membranes of molecular pore size and high pressure are used to reverse the osmotic flow. This forces water through pores that are too small to allow most metal ions and aqueous salts to pass through. Thus the solution on the concentrated side of the membrane becomes more concentrated, reversing the normal osmotic flow.

Nano-filtration and ultra-filtration can remove larger ions and molecules and viruses and bacteria.

Ion exchange is used for treating water with particularly high levels of nitrates or chloride. Water is passed over the surface of a resin to capture particular ions from the water and give up another ion in exchange.

Activated carbon is very effective at trapping organic molecules through its absorptive capacity. This method is used to remove residual effects of chlorine compounds, pesticides and herbicides and to remove organoleptic defects.

NB: Carrying out water treatments introduces elements of risk that must be addressed. These include treatment failure, chemical contamination, residual taints and increased microbial load. Treatments used should be subject to hazard identification and the results should be incorporated into a company's quality system.

Highlights on Hygiene

Product Integrity

It is important when bottling water to take all possible precautions to protect the product. Water is capable of picking up taste and odour taints as well as undergoing compositional changes very readily. Water can be easily susceptible to microbial contamination.

The water source must be carefully protected and the activities in the catchment area monitored and controlled.

Choice of materials in contact with water, from source, through filling equipment, final containers and closures, must be considered to ensure the water's integrity is maintained.

High standards of hygiene throughout the bottling process are essential to ensure that the final product is clean, safe and free from contamination. The Law requires good manufacturing and hygiene standards.

Layout and Process Flow

The building should ideally be able to accommodate a continuous process flow with materials receipt and storage at one end and finished goods and despatch at the other end, and the processing stages in order of procedure in between. Diagram 6 illustrates typical process flow for bottled water.
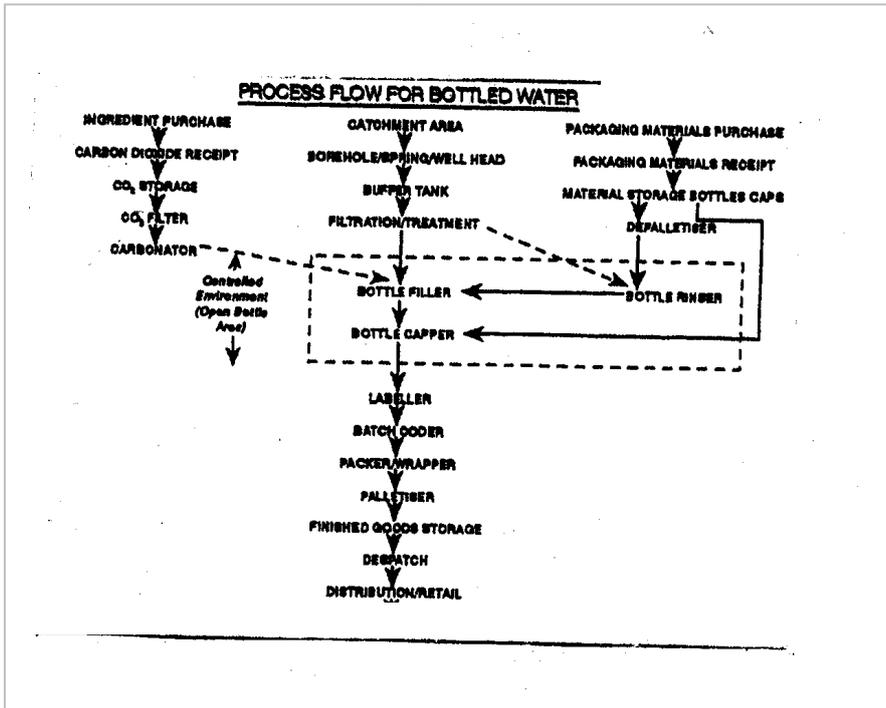

PROCESS FLOW FOR BOTTLED WATER

INGREDIENT PURCHASE — CATCHMENT AREA — PACKAGING MATERIALS PURCHASE
CARBON DIOXIDE RECEIPT — BOREHOLE/SPRING/WELL HEAD — PACKAGING MATERIALS RECEIPT
CO_2 STORAGE — BUFFER TANK — MATERIAL STORAGE BOTTLES CAPS
CO_2 FILTER — FILTRATION/TREATMENT — DEPALLETISER
CARBONATOR
Controlled Environment (Open Bottle Area)
BOTTLE FILLER — BOTTLE RINSER
BOTTLE CAPPER
LABELLER
BATCH CODER
PACKER/WRAPPER
PALLETISER
FINISHED GOODS STORAGE
DESPATCH
DISTRIBUTION/RETAIL

Diagram 6: Process flow for Bottled Water

The critical stages of bottle filling and capping require a controlled environment. This may involve providing physical barriers around the area or better still filtering the air and imposing positive pressure.

In this controlled environment, it is best to minimise operations to the open bottle activities of bottle rinsing, filling and capping.

Product is best kept in constant flow from source to bottling. For bottled waters in particular, where no treatment is given, water should not be retained in bulk storage for more than 24 hours.

Where a bottling facility supplies a water cooler business, facilities for preparing returned empty bottles for refilling after washing and sanitising are essential. Cleaning and sanitising replacement cooler bowls and fitments may also need to be undertaken.

Plant and equipment

Stainless steel is the most suitable material for any water bottling equipment. Alternatives should be carefully assessed to ensure that they do not impart odour or taste to water or alter its composition.

Equipment should be designed in such a way that it can be suitably cleaned and sanitised. For example, there should be no deadlegs which pose a contamination risk.

Disinfecting and cleaning

The way that a water bottling line is cleaned and sanitised is dependent upon whether it is:
- a dedicated or non-dedicated line
- the standing time of the line between running products
- the age of the line and its equipment

Where equipment is also used for soft drinks or other flavoured products, emphasis must be given to the removal of residual odour and taste from the equipment prior to its use for water. Ideally the plant and equipment should be solely dedicated to the purpose of bottling water.

The non-dedicated line

Before using a soft drink line for bottling water, it is essential to use a rigorous cleaning procedure, for example, a caustic solution at 2%, chlorination and a hot water rinse at 85°C for at least ten minutes (or steaming).

There may well be pieces of plant or equipment that, though essential for the manufacture of a soft drink are not required for bottling water. Bypassing non-essential equipment is advisable and will help to minimise the risks of odour or taste pick-up. This modification should take place prior to the cleaning and sanitising of the line.

All pipework and sight glasses of the filler and carbonator must be cleaned, taking care to ensure the removal of all fruit cells. Traces of sugar and fruit cells are difficult to eradicate and these encourage bacterial growth. It is advisable to flood the filler several times and check the water from the carbonator for cells.

Snift valves of the filler give great cause for concern and should, wherever possible, be removed, placed in detergent and refitted prior to the final rinses of the filler.

The water used for rinsing must be of suitable hygiene standard.

Even after such rigorous procedures, personnel with acute palates and nose should taste the product water at start-up to ensure that there is no carry-over of taste or odour from the flavoured product.
For dedicated lines a less rigorous sanitisation and cleaning routine may be followed. Records of cleaning and sanitation must be maintained.

Care should be taken in the selection of cleaning products. They should be odour-free if possible.

For the majority of cleaning procedures, water – the very product we are working to protect – is an essential requirement. This illustrates water's capacity for the removal and retention of extraneous matter.

All cleaning and disinfection processes should be validated to ensure continued effectiveness.

Water coolers

Hygiene issues also need to be taken into consideration in relation to water coolers. Most dispensers consist of a chilling unit within a cabinet. A large bottle full of water is inverted onto the top of the unit. Water from the inverted bottle fills a receptacle bowl or bag and it is this portion of water which is maintained at a chilled temperature. The remainder of the water in the large bottle is maintained at ambient temperature. As water is drawn from the dispenser, air is sucked into the unit to replace it. Therefore, filtering the air drawn into the container is recommended

Good manufacturing practice

Good manufacturing practices (GMP) as defined by the standard PAS 220 (or equivalent in your local or national legislation) are important for prevention of product spoilage and food safety of products. For example, bottles are ideal containers for all manner of things including nuts and bolts, lubricants, cleaning materials, or even flowers. The risk of these misused containers finding their way on to a production line may be small, but it is an unacceptable risk. Fingers should not be inserted into the tops of bottles as this undoubtedly poses the threat of microbial contamination. It should be company policy that disciplinary action is taken in such an event.

Management systems

The management of water bottling plants should adopt a quality policy which supports the requirements of legislation and the recommendations of their technical support teams.

A robust microbiological monitoring plan must be designed and in place to ensure that hygiene standards are met & kept in control. A documented system is vital and as well as providing good training material, will help to demonstrate that due diligence is applied.

It is a requirement of your local/national Food Safety Regulations that a hazard analysis of production operations in food businesses is undertaken to identify potential risks to the product and to consumer safety. Where hazards are identified, effective controls should be implemented to minimise these risks. The global Food Safety Institute recognises the FSSC 22000 standard for Food Safety management.

The Hazard Analysis Critical Control Points (HACCP) system is a management tool that operates through a multi-disciplinary team and is particularly suitable for use within the bottled water industry.

It is important to audit the management system, the production process, suppliers of primary packaging materials and warehouses handling finished goods to verify compliance with set standards and agreements.

Materials, suppliers, storage and distribution

It is equally important to be satisfied with the conditions under which materials are manufactured and under which these and finished products are stored and transported. Provision for appropriate conditions can be incorporated into contractual undertakings with selected companies. This should be followed up with regular audits and follow-up on your service provider activities. Distribution of raw materials should also be managed – closed trucks with tamper-evidence controls are required.

Water coolers

The water cooler business relies on good distribution and customer service. Drivers play a key role and their courtesy and personality are fundamental in providing a quality delivery service. Water cooler bottles are delivered to where the customer wants to use them. The driver replaces empty bottles on the cooler and collects and returns the empty containers that have a deposit paid on them. Drivers will also carry out maintenance of the cooler unit, often on a quarterly basis, exchanging the cooler bowl and pipework with sanitised replacements.

Materials In Contact With Product

Plant Equipment

All bottling equipment, e.g. tanks, filter housings, pipelines, fillers that have contact with product water, should be made of materials that maintain the integrity of the water. The most suitable material is stainless steel. Other materials should be carefully assessed to ensure that they do not compromise product quality.

Choice of Primary Packaging

For the same reasons the selection of primary packaging materials, i.e. bottles and closures, must be carefully considered to prevent organoleptic or chemical change to the product during its prescribed shelf life.

Bottles are typically of three types – Glass, PET (Polyethylene Terephthalate) and PVC (Polyvinyl Chloride). To a lesser degree **aluminium cans** and **cartons** are used. In some countries, e.g. USA, **HDPE (high density polyethylene) bottles** are used and **polycarbonate bottles** are used mainly for water coolers.

Most containers are one-trip which has the advantage of making them lighter weight. This eliminates the need for additional washing facilities and precludes the necessity for complicated and expensive logistics in returning empty containers. One exception to this is polycarbonate bottles for water coolers. In this instance facilities for the efficient cleaning and sterilisation of containers are essential.

Table 2 summarises the main characteristics influencing the choice of container for bottled water.

Closures are legally required to be tamper-evident. They should be appropriate to the material and neck finish of the bottle, for example, aluminium with compound liner or polypropylene.

Water Coolers

In the case of water coolers care is needed to ensure that a secure seal is achieved between the bottle and the dispenser. Caps have probe activated valves to open automatically as the bottle is installed and close as the bottle is removed from the cooler probe. This system normally incorporates an air filter. With this type of closure any tampering or misuse should be evident.

Primary packaging is in intimate contact with the product. It is prudent to apply due diligence to the conditions of their manufacture.

In setting up supply contracts for these goods, it is not sufficient to take a supplier's assurance that a material is suitable for food use. The bottler should be satisfied that the material is specifically suitable for use with water, checking it with both still and sparkling water if required.

Consideration should be given to

- the requirement for a certificate of conformance with each delivery
- evidence of overall migration (OM) and specific migration (SM) from the plastic materials to the product up to the shelf-life and beyond

A code of practice on standards for personnel, factory and warehouse premises and process and quality inspection is helpful, both to the supplier in that this provides documentation of what is required, and to the bottler as an aid to auditing.

Auditing of suppliers' premises and systems can provide assurance that they are suitable and verification that agreements are continually met.

Other Materials

To produce a sparkling water it is necessary to use **carbon dioxide**. This may be produced chemically or as a by-product from a grain distillery. However, for use in carbonating water, specific controls should be applied to each delivery of CO_2. It may be sufficiently impure to impart an undesirable odour and taste. Certificates of analysis or conformance for each delivery should be requested.

Filters may be used in various applications. For example

- water filtration (product or process water)
- air filtration for air blowing bottles and for filling equipment
- air filtration for bulk storage tanks
- filtering of carbon dioxide

In all cases it is important to ensure that there is no particle release from the filter into the product and that the filter material does not alter the organoleptic or chemical qualities of the water.

For NMWs filters should not alter the total viable colony count (TVC) of water at source.

Process Air is often in contact with product water. It can be used to air rinse bottles prior to filling or as an overpressure gas in filling machines. It is important that the air is oil and water free and sterile.

Table 2: Factors influencing container choice for bottled waters

Type Of Container	Advantages	Disadvantages
Glass	+ Chemically inert – will not affect quality/odour/taste + Clear + Rigid, strong – can be run efficiently on high speed lines + Hygienic + Retains carbonation well and can give maximum shelf-life to product + Suitable for still or sparkling + Resealable + Recyclable + Impermeable + Perceived as high quality	- Heavy - Breakable - care needed in handling both in filling and consumer use - Impact damage can result in spontaneous explosion with possibility of consumer injury - Subject to foreign body contamination from broken glass
PET	+ Lightweight + Clear + Suitable for still or sparkling + Resealable + Unbreakable + Recyclable	- Expensive - Non-rigid - can cause spillage on opening or instability of pallet with still product - Limited shelf-life for sparkling products
PVC	+ Lightweight + Low cost + Resealable + Unbreakable + Recyclable	- Not clear - Not suitable for sparkling - Effects Total Viable Count (TVC)
Cans	+ Lightweight + Retains carbonation well + Can use in vending machines + Easily handled + Recyclable	- Not resealable - Expensive plant required for relatively small percentage of business
Cartons	+ Lightweight + Easily handled + Space efficient	- Not suitable for sparkling - May affect taste - Limited shelf-life
Polycarbonate (Water Coolers)	+ Lightweight + Unbreakable + Returnable + Reusable	- Requires collection system - Requires thorough bottle washing facilities - Effects Total Viable Count (TVC)
HDPE	+ Lightweight but robust + Low cost + Recyclable	- Not clear - Not suitable for sparkling - May affect taste

Labelling, batch marking and traceability

Designing a label is a complex issue, trying to promote the merits of a particular brand in combination with incorporating all the requirements of legislation.

The examples shown illustrate how the various requirements can be incorporated.

Depending on the category of water (NMW; SW; BDW) the following must appear on the label:

- Commercial designation (NMW; SW; BDW);
- Product description, e.g. Natural Mineral Water (NMW; SW; BDW)
- Typical analysis values (NMW)
- Location of source (NMW; SW)
- Names and addresses of bottlers (NMW; SW; BDW)
- Country of origin (NMW; SW; BDW)

Other labelling requirements are in accordance with general food labelling legislation.

When designing or reviewing bottled water labels it is advisable to contact your local Trading Standards Office or Environmental Health Office, to ensure that all requirements have been satisfactorily addressed in accordance with appropriate legislation.

In addition to Best Before End (BBE] details, a batch or lot number should be visible on each container to assist in the event of a product recall. This can be marked on the label, bottle or cap and must be clearly legible so that it can be quoted, if necessary. At the time of filling a date code and time of bottling can also be applied, either as part of, or in addition to the lot number of the product.

To give complete traceability bottle manufacturers can ink-jet print the date and time of production on to an area of bottle which will be covered by the product label

Shelf-life

The choice of containers and closures and whether the product is still or sparkling influences the shelf-life of bottled waters.

Typical guidelines on shelf-life are shown in the following table.

Typical guidelines on shelf-life

Container	Product	Shelf-Life
Glass	Still/Sparkling	2 years
PET	Still	12 - 24 months
	Sparkling	12 months (1.0 litre or over, less for smaller containers at discretion of bottler)
PVC	Still	12 - 24 months
Cans	Still/Sparkling	12 months

Analytical Requirements

All bottled waters are required to undergo regular analysis. There is a two-year period involved in establishing recognition for a new source of NMW. During this time the water is sampled and analysed frequently to ensure that it remains stable in its composition, allowing for seasonal fluctuations, and that it shows no signs of pollution. This analysis should be carried out by a government accredited laboratory as well as the company aiming for NMW recognition. The parameters required can be grouped under various headings and are as shown in Table 4.

Table 4: Official analysis for bottled water

Parameters	Unit used	Maximum Limit	
		NMW	SW/BDW
Physical & chemical characteristics			
Dry residue @ 180°C	mg/L		1500
Dry residue @ 260°C	mg/L		
Electrical conductivity	µS/cm		1500
Hydrogen ion concentration	pH		
Radio activity			
Total Alpha activity	Bq/L		
Total Beta activity	Bq/L		
Toxic substances			
Arsenic	AS µ/L	50	50
Cadmium	CD µ/L	5	5
Cyanide	CN µ/L	50	50
Chromium	Cr µ/L	50	50
Mercury	Hg µ/L	1	1
Nickel	Ni µ/L	50	50
Antimony	Sb µ/L	50	10
Selenium	Se µ/L	10	10
Lead	Pb µ/L	10	50
Cations			
Aluminium	Al µ/L		0.2
Ammonium	NH$_4$mg/L		0.5
Calcium	Ca mg/L		250
Magnesium	Mg mg/L		50
Potassium	K mg/L		12
Sodium	Na mg/L		150
Anions			
Borate	BO$_3$ mg/L		
Carbonate	CO$_3$ mg/L		
Chloride	C1 mg/L		400
Fluoride	F mg/L		1.5
Hydrogen Carbonate	HCO$_3$ mg/L		
Nitrate	NO$_3$ mg/L		50
Nitrite	NO$_2$ mg/L		
Phosphate	P$_2$0$_5$ mg/L		0.1
Silicate	SiO$_2$ mg/L		
Sulphate	SO$_4$ mg/L		250
Sulphide	S$_2$ mg/L		
Non-ionised Compounds			
Total Organic Carbon	C mg/L		
Total Carbon Dioxide	CO$_2$ mg/L		
Trace Elements			
Barium	Ba µ/L		1000
Bromine	Br µ/L		
Cobalt	Co µ/L		
Copper	Cu µ/L		3000
Iodine	I µ/L		
Iron	Fe µ/L		

Parameters	Unit used	Maximum Limit	
Lithium	Li µ/L		
Manganese	Mn µ/L		50
Molybdenum	Mo µ/L		
Strontium	Sr µ/L		
Zinc	Zn µ/L		5000
Freedom from Pollution			
Pesticides	µ/L		0.5
Herbicides	µ/L		
Polycyclic Aromatic Hydrocarbons	µ/L		0.2
Phenols	µ/L		
Microbiological			
Parasites		Absent	Absent
TVC @ 22C in 72 hours	Cfu/ml	100 cfu/ml	100 cfu/ml
TVC @ 37oC in 24 hours	Cfu/ml	20 cfu/ml	20 cfu/ml
Total Coliforms		Absent in 250 ml	Absent in 100 ml
E coli		Absent in 250 ml	Absent in 100 ml
Faecal Streptococci		Absent in 250 ml	Absent in 100 ml
Sporulated Sulphite-reducing anaerobes		Absent in 50 ml	Absent in 20 ml
Pseudomonas aeruginosa		Absent in 250 ml	

Abbreviations

mg/L	=	milligrams per litre
µS/cm	=	microsiemens per centimetre
Bq/L	=	becquerels per litre
µg/L	=	micrograms per litre
cfu/ml	=	colony forming units per millilitre

In-House Monitoring and Control

Microbiological Examination

The legislative requirement to meet stringent microbiological criteria, and the vulnerability of water to bacteriological contamination, requires facilities and expertise on site for routine monitoring.

Monitoring should include water from the:

- source
- pipeline to plant
- holding tanks
- filters
- finished product
- rinse water
- ozonation tank

Microbiological testing should be carried out within 12 hours of sampling. Samples should be tested for TVCs at 37° and 22^oC, Coliforms, *E-coli Pseudomonas aeruginosa,* Faecal streptococci and Sulphite-reducing anaerobes. Whilst waiting testing, samples should be kept at 4^oC.

To ensure the sterility of the filling process and the packaging used the following tests should be undertaken:

- Bottle checks before and after air or product rinsing on a regular basis to ensure no contamination has occurred
- Closure examination on receipt, directly from their enclosed packaging, and also at the point immediately prior to application on the bottle.
- Swabbing routines after equipment and/or filling line sanitation. A rapid monitoring system should be used as long as this method is sensitive enough for the level of contamination that would be critical.
- Environmental monitoring using settle plates in open bottle areas can bring awareness to conditions provided by any air treatment used, and is particularly helpful following any maintenance work within or close to this area.

Frequency of microbiological testing and resultant recommendation are at the discretion of technical personnel. The frequency of testing should be increased in the event of adverse results.

A positive release system for finished product, based on satisfactory microbiological results, does not preclude product from being despatched to warehousing within the control of the company but ensures that any non-conforming product does not arrive with the customer.

It is advisable to have a shelf life testing programme to monitor TVC changes and to ensure absence of specified pathogens in product.

Where other supplies of water are utilised, e.g. for sanitation procedures or bottle rinsing, close monitoring of such supply is recommended.

Other Controls

The finished product should be monitored in respect of:
- Content volume
- Carbonation level (where appropriate)
- Temperature
- pH
- Conductivity
- Odour, taste and appearance
- Evidence of chlorine and other sanitisation chemicals
- Cap application – visual examination of thread and tuck under; removal torque, removal by hand, secure seal test
- Label application
- Lot, BBE and time coding
- Case loading and wrapping
- Pallet stacking and identification

Some areas of monitoring can be part of process control by line operators but it is prudent to have additional auditing carried out by QC technicians.

The frequency of these checks is dependent on the line output and whether any test has given a non-conforming result.

It is important to pay particular attention to all areas of quality control at the start-up of shifts and to record all results, noting the time of sampling and pallet numbers.

When undertaking microbiological assessment of product during shelf-life the packaging format should be examined, to ensure that it is meets requirements. Checks on carbonation retention and on organoleptic quality should also be carried out.

FRUIT JUICES

Introduction

Man has consumed fruit juices for a long time with earliest references being found in the 16th Century, when their therapeutic value as an anti-scorbutic (preventing or curing scurvy) was first recognised. This usage pre-dates the soft drinks industry, as we know it today, by over 100 years. Jacob Schweppe, in 1783, is generally credited as the founding father of the soft drinks industry. Concentrated drinks and squashes were much later phenomena (1920s).

The fruit materials commonly used by our industry fall basically into two categories - juices/purees and comminuted products. Owing to their 'close to nature' image, they have been popular in forming ingredients for healthy products and this has, in turn, enabled very good sales growth in this market sector.

During the 1930s methods of concentrating fruit juices were being devised in order to save expense in packaging and transport costs.

Until the 1950s the methods of concentration used in the main citrus processing areas were only satisfactory for producing concentrates for use in soft drinks. If these concentrates were reconstituted back to single strength with water, the resultant taste bore little resemblance to the original fruit juice. Thus, the first fruit juices to be sold had never been concentrated and were packed at origin, since there was little point in importing single-strength juice and repacking over here. There was, however, one exception.

Just before World War II a 19th Century mineral water company in Chelmsford UK (James MacPherson & Co Ltd - later to become Britvic Soft Drinks) thought there would be a market for single serve bottles of juices. The only material available to the company was single strength canned juice which was required to go through yet another cooking process - either retorted or hot filled in 'Baby' bottles. These bottles are still around today but form only a small part of the business, mostly in pubs.

The first major supply of fruit juices to the UK started during the Second World War. The then Ministry of Food became concerned at the lack of fresh fruit and vegetables and the resultant lack of Vitamin C in the diets of babies and children. In order to counter this 60° Brix orange concentrate was imported. This was packed without preservative in A-10 cans. The operation was very large and the concentrate was supplied to various bottlers, many of them in the pharmaceutical trade. The bottlers broke the concentrate down with water to a 4:1 concentration, or about 40° Brix, and bottled it with a small amount of sulphur dioxide as preservative. Until that time little concentrate had been produced anywhere in the world outside the USA where production had begun a few years earlier. Therefore, the government promoted the establishment of citrus processing and concentrating plants, principally in Israel (then Palestine) and also in South Africa and the West Indies where, many years before, lime juice production had already become established.

The welfare orange juice scheme, as it became known, was continued after the war into the early 1950s and further supplying plants were established in Spain and Sicily. This then established in various parts of the world modern processing plants equipped with pasteurisation and canning facilities. It was thus a natural development for them to start producing and exporting canned single-strength juices for direct consumption in the home. This was the principal form in which juices were supplied on this market until the early 1970s. Well-established brand names included Jaffa Gold and Assis from Israel and Trout Hall from Jamaica.

Dilutables and Concentrated Drinks

The concept of concentrated drinks owes much to the pioneering work of Lachlan Rose who patented a way of preserving lime juice in 1867.

In the years between the two World Wars concentrated drinks or squashes accounted for the main consumption of fruit juice in the UK. The general principal being that with 25% or more of fruit juice content the user would dilute the concentrate (squash) with about 4 parts water. The early concentrates were of course produced from single strength juices, which were the only type available at that time. Other ingredients included sugar, water, essential oils or essences, and colour. Concentrated juices became available in the late 1930s but were preserved with SO_2.

Dilutables needed constant marketing attention to generate momentum after general post war decline. The late 1980s saw an increase in fruit content and the removal of additives. The early 1990s followed with a surge in reduced sugar variants, which passed the 50% mark in 1995. Recent developments include dilutables for adults, started by Robinson Aquiesse in 1994; and clear dilutables, in spite of the drawback of not being able to gauge the right mix of concentrate to water, as they both look the same!

Ready-to-Drink Still Juice Drinks

The first type of single serve drinks was developed by Kia Ora (Schweppes) in conjunction with the Rank Organisation for distribution in cinemas - a short shelf-life cup squash. Such products now generally appear in long life Brik packs. Single serve cartons with straws are very handy for packed lunches and people on the move. Traditional cup drinks with preservatives, generally containing a mix of sodium metabisulphite and sodium benzoate, have now been replaced by the aseptic cup. This is a recent development in the United Kingdom, owing to restrictions in legislation in line with EC regulations.

The 1990s saw the advent of a variety of single-serve drinks (in a variety of packages - glass, carton and plastic) including fruit cocktails such as Oasis and Fruitopia; sport drinks such as Lucozade Sport and Irn-Bru XS and energy and herbal drinks. Energy drinks, designed to deliver a prolonged energy boost of up to eight hours are generally aimed at dancers, drivers or people working to deadline. (Sports drinks on the other hand are formulated to supply fluid quickly and maintain the body's glucose levels). Energy drinks generally contain high levels of caffeine and some are based on the amino acid taurin. Others are based on the South American guarana plant. Most also add other beneficial ingredients. Some energy drinks overlap with herbal drinks. Aqua Libra paved the way for herbal drinks in 1986 and was followed by several others with high juice content and a blend of herbs, placing the emphasis on well being and body balance. The late 1990s also saw the resurgence of dilutables with the launch of such products as the Robinson's Fruit and Barley range

Iced tea, seen as a very refreshing drink, especially for consumption during hot weather, has in global terms been an outstanding success. However, despite a large number of product launches the UK market has not taken to this product, preferring the 'hot version'. Changing the British public's attitude to tea will take longer than first anticipated. However, the market around the world continues to grow.

An Overview of the Juice Beverage Market

The main pure juices marketed today are orange, apple, grapefruit, pineapple and tomato. Apart from tomato, these juices are also widely used in blends and as soft drink ingredients. To the 'ingredient' list can also be added lemon, lime, tangerine, blackcurrant, cranberry and various tropical and temperate fruits.

Fruit juices, as defined by the *Fruit Juices and Fruit Nectars Regulations*, are 100% pure fruit juices without preservatives, made from fresh fruit or fruit concentrates. Only the flesh of the fruit can be used, no pith or peel. It is permissible within the regulations to add some sugar (up to 15 grams per litre), providing it is declared, without calling the product sweetened when juices from different countries or harvests are being blended to balance the acidity. However, if sugar above the level stated is added a juice has to be described as sweetened.

Fruit juices remain one of the growth areas in world foodstuffs. Underlying this international success has been the shift to healthier lifestyles and eating habits - now evident on a global basis. Fruit juice occupies a highly attractive position as a completely natural, fresh-tasting product, high in vitamins, free of artificial additives and containing only natural fruit sugars. They are also highly refreshing and have enjoyed growth as part of the total soft drink area, which has been benefiting from a gradual world-wide shift away from alcoholic drinks and hot beverages.

This growth pattern is, however, prone to fluctuation as supply conditions change and impact upon consumer prices, especially in orange which is by far the biggest selling juice in most (though not all) national markets. Not only does the price of orange juice influence off-take in its own sector, which being so large can ultimately determine trends in total market consumption, but it also has an important knock-on effect on other fruit flavours and various juice drinks. Consumers seek substitute products as the price of orange rises. With the world market for orange and other juices trading primarily in US dollars, prices in European and other importing markets can also be influenced by the international monetary strength of the dollar.

Developments in the world fruit juice market essentially centre on the supply situation for orange juice in the world's leading producer nation, Brazil, and in the leading consumer market, the United States. Brazilian supplies and the degree to which the US needs to import to supplement its output ultimately dictate world prices, and in a heavily commodity-orientated market, fruit juice prices quite visibly direct global consumption.

The following trends characterise the global market:

- Fluctuations in Brazil's output of orange
- Recovery of USA output of orange
- Price fluctuations triggered in Brazil
- USA consumption is more than double that in Europe
- Climatic conditions

Origins of Fruit Products

Citrus Fruits

The modern citrus fruits are East Asian in origin, and probably arose from just ten or twelve wild species. Over the centuries these species have been selected, crossed, improved and re-crossed so many times that the relationships between them are extremely complicated.

A citrus belt within which citrus fruits are cultivated on a very large scale now encircles the entire globe. And, as if there were not enough confusion already, identical varieties tend to vary in colour and taste depending upon local conditions and local experiments. The citrus belt lies between latitudes 40° North and 40° South. Very little citrus fruit is grown outside these boundaries; inside them grow all those species and varieties that have been found commercially valuable.

With the development of modern storage and transport methods after World War II, a network of trade routes spread outwards from the citrus belt to all parts of the world where the fruit is eaten. Many citrus fruits are sold under brand-names such as Jaffa, Outspan Sunkist, Maroc, Spania and so on; these are umbrella names for many different varieties.

Citrus trees are small and flourish best on mixed soil of loam, sand and clay, which has good water-retention properties, and in areas free from frost. For these reasons the Mediterranean became the first large citrus growing area.

Orange

In the last 50 years, the growing areas have extended to other places having similar characteristics, such as Florida and California in the USA, the vast plantations of Brazil and to a lesser extent, South Africa and Australia.

Florida is the main orange juice-processing region of North America and because of a major crop loss (frost) in 1962, there was a desperate shortage of juice to meet the high demand. This led to the creation of the massive Brazilian industry.

Fruit from the citrus plantations was originally intended simply for table consumption. The early stage of the juice industry was a salvage operation to reclaim a saleable product from misshapen, skin-blemished fruit. Today, however, special attention is given to a high juice-yield orange in preference to table fruit.

Grapefruit

Major origins are USA, followed by Argentina, Latin America and Israel. Processing is on the same equipment as oranges. The future for grapefruit juice consumption is somewhat limited. The producer countries have been pushing pink and red grapefruit for eating in recent years, which have become equally as acceptable as white grapefruit. Only a very small quantity of grapefruit is converted to comminute.

Lemon

Major processing countries are Argentina, Italy and USA. Both clarified and cloudy lemon juice concentrates are produced and these are used as ingredients in soft drinks and in other foodstuffs where the addition of natural acidity is called for. Comminuted lemon is produced for products such as bitter lemon.

Lime

Lime juice holds a special place in the history of soft drinks having been consumed as early as the 18th Century by British sailors.

Two kinds of lime are known and processed, the dominant variety being the small fruited West Indian lime (also known as Mexican or Key). There is also a large fruit variety more akin to the lemon - the Persian and Tahitian.

West Indian lime processing began in 1865 in Dominica and, unlike other citrus varieties, is processed by crushing whole fruit in granite sugar cane rollers. The whole fruit melange is allowed to settle and eventually clarifies with the pulp oil layer floating to the top of the tank. This process of settling permits reaction of the oil and juice to give the flavour characteristic of lime juice cordial. Sugar cane rollers are out of fashion nowadays but whole fruit crushing is still fundamental to the process. Major producers are Mexico, Ghana, and Peru with very little actually coming from the West Indies. In Florida the Persian lime is processed by conventional FMC extractors.

Apple

The apple is probably the first fruit to be processed into juice by man (remember Adam), although knowledge of the Holy Lands indicates that the fruit of Biblical allusion was more likely to have been a quince, apricot or citron. The apple, as we know it, has appeared in beverage form in many guises from alcoholic and non-alcoholic ciders through to straight apple juice - cloudy, clear or carbonated. Apple juice, because of its generally low price and abundance, is also frequently used in multi-fruit blends, as a low cost filler in other juice beverages and as a soft drink ingredient either in its own right or to provide a natural sweetener.

Until the early 20th Century most apple beverages were alcoholic due to various fermentation processes - induced or otherwise. The Swiss are generally credited with the first unfermented juice processing. The North Americans did not get in on the act until 1937.

Established and traditional apple areas of the world are in the temperate zones of North America, Europe, Argentina, South Africa and New Zealand. The United States is the most important processed apple market in the world and this has an effect on world demand. China is also becoming increasingly important as a supplier. In virtually all areas where apples are commercially grown, dwarf trees have now largely replaced the once familiar tall apple tree. These small trees, which seldom grow taller than man, were developed by grafting cuttings of the desired variety on to slow growing rootstock. This does not affect the quality of the fruit, but makes harvesting many times easier. The bushy shape of these smaller trees also ensures even ripening of the fruit. On taller trees, apples on the outer branches ripen because they get some sun, while those nearer the trunk never colour up as well or taste as sweet.

There are many different apple cultivars, these are often grown with a specific purpose in mind (e.g. juice etc) and the climate has a strong influence on the performance. Depending on the variety, apples can be round, elongated or flattened and vary in colour from bright red to dark green. Taste ranges from very tart to very sweet and texture can be anything from crisp and juicy to soft and dry. For example, apples from Northern Europe have a higher acid content than those from Southern Europe. Size, too, varies widely. The popular dessert varieties are rarely more than 10 cms across, but there are cooking varieties of much more impressive dimensions.

Pineapple

Pineapple has by far the largest market of all the tropical fruits. Major producers of pineapple juice are The Philippines, Brazil and Thailand. Other significant producers are Kenya, USA, South Africa, Costa Rica and Sri Lanka.

Seasonal production of juice in Thailand and the Philippines depends on the size of the canned pineapple market since juice is a by-product of the canning industries there. Brazilian fruit is processed whole.

Overall pineapple has had considerable growth in Western Europe either as part of a blend or as a straight juice.

A major feature of the world trade in pineapple juice is the influence exerted by two USA based multi-national companies: Castle and Cooke Inc with its 'Dole' trademark and the Del Monte Corporation. Pineapple juice is produced alongside the packing of canned pineapple in their operations in Hawaii, the Philippines, Thailand, Kenya and the USA.

A pineapple plant is usually about 75 cms tall and consists of a rosette of long, narrow leaves. When the plant is nearly 2 years old, a woody flower spike grows out of the centre on which 100 or more flowers appear. Each flower produces a fruit and these fruit fuse together forming the scales of the rounded false fruit that is the pineapple we see in the shops. The crown of stiff, spiky leaves, if cut off together with a slice of the pineapple; will grow into a new pineapple plant. The pineapple's scales tell us about its characteristics. The more marked the relief, the stronger the typical pineapple taste, the less marked the relief, the weaker the taste but the sweeter and juicier the flesh. When the scales have brown tips, the fruit is ripe for picking.

Owing to the long growing time of pineapples, the plant takes time to recover from adverse conditions, such as bad weather, and this affects prices.

Tomato

The tomato is a member of the potato family Solonaceae. It is indigenous to the lower western slopes of the Andes and was brought to Europe in 1498 by Christopher Columbus. There is a record of it being grown in Italy in 1554 and England in 1576. Commercially important varieties are grown industrially. Economically the tomato is of considerable world importance. Nowadays tomato juice is mainly derived from tomato concentrate, which is a major trading commodity in the food industry.

The main concentrate producing regions are California, Italy, Greece, Turkey, Spain and Portugal. Israeli concentrate is produced in limited quantities largely for customers of Israeli citrus products. This is due to the dry soil conditions giving low mould count in the final product.

Tomatoes can be classified in two main varieties, the round type and the long plum Italian type. The latter is more susceptible to the souring organism Bacillus thermoacidurans and for its treatment higher pasteurisation temperatures are required.

Juice Extraction and Processing

Orange

As the most popular juice on the world market is orange, it is worth examining the fruit in detail. The main varieties are:

Variety	Country of origin
Hamlin	Brazil Florida
Pera	Brazil
Navel	*Florida* *South Africa*
Valencia	***Israel*** South Africa Spain
Shamouti	Israel
Salustianas	Spain
Blond	Southern Italy Sicily
Blood	*Southern Italy* Sicily

It consists of an outer peel, the flavedo, which contains sacs of citrus oil, and an inner spongy layer, the albedo, which is the main source of bitterness in the extended juice. This in turn covers the inner segments of the flesh.

The segments, formed around a soft pithy core, contain the juice, with colour-bearing matter in cellular tissue; some oil droplets are embedded in the cellular tissue. Seeds are attached to the walls of the segments and contain limonin, an intensely bitter compound. Pectin and pectolytic enzymes are present in the peel.

Juice Characteristics

Fruit juices are essentially solutions of sugars, principally sucrose, glucose and fructose (in the ratio of 2:1:1), together with organic acids, proteins, pectins, tannins, minerals, pigments, essences, vitamins and essential oils. These minority ingredients contribute unique qualities of flavour, aroma and appearance to the individual juice.

Freshly extracted juice contains suspended matter and the above substances; the type and quantity varies according to the fruit variety, time of harvesting, age of fruit and method of extraction.

The units commonly used to express concentration in fruit juices are ^{0}Brix where 1^{0}Brix = 1% sugar w/w. The acidity of citrus juice is usually expressed as citric acid, but malic acid and small amounts of oxalic acid are also present.   The soluble solids to acid ratio is the best criterion of citrus quality; e.g. an orange of 12^{0}Brix having 0.8% acid content would have a Brix/acid ratio of 15. The ratio alters according to the growing regions and the effect of early and late season fruit. The ratio is often called the Maturity Index.

- Average Brix/acid ratio of orange juice is 14:1; the acceptable range is 9:1 to 18:1.

- Average Brix/acid ratio of grapefruit juice is 8:1; the acceptable range is 7:1 to 11.1.

Essential oil content of orange juice is important in maintaining the typical flavour profile of the juice; however, excessive oil content can give objectionable off-flavours.

The behaviour of each and every juice component must therefore be considered in developing the correct process parameters in order to ensure a high quality product.

Juice Production

For ease of description, the orange juice factory is divided into six sections:

1.   Fruit Handling
2.   Extraction
3.   Processing
4.   Concentration
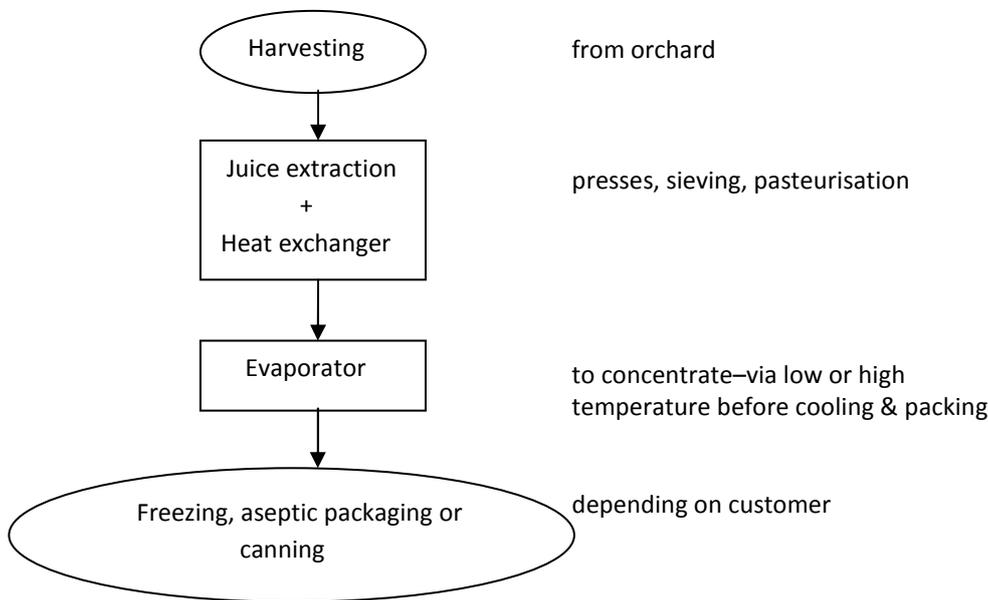5.   Packaging and Storage
6.   By-Products

Harvesting — from orchard

↓

Juice extraction + Heat exchanger — presses, sieving, pasteurisation

↓

Evaporator — to concentrate–via low or high temperature before cooling & packing

↓

Freezing, aseptic packaging or canning — depending on customer

Fig: Flow diagram of Concentrated Juice Production

1.   Fruit Handling

The majority of fruit for processing is direct from orchard. However, pack-house rejects may be used, depending upon season and location. Any fruit not passing the stringent fresh market classification system is released for processing. Oranges should be processed within 48 hours of harvesting. On receipt at the process factory each consignment is checked for yield, brix and acidity and sorted for size. Sized fruit is washed and directed to the juice extractors.

2.   Extraction

In the early days extraction was by hand, then roller and rotary presses. With the advent of frozen concentrated orange juice in 1946 in Florida and the potential for vastly higher sales, several machinery manufacturers began to develop high speed, high efficiency mechanical extractors. Although the extractors differed in design and operation they were all fast, rugged, easily cleaned and could be adjusted to reduce the incorporation of excess peel extractives into the juice. The FMC in-line extractor is the most efficient and popular in use throughout the world. Another well-known system is from the Brown Corporation and is said to produce the best juice. Throughout the Mediterranean there are also a number of Italian Indelicato machines.

Depending on quantity of fruit available orange juice factories can process up to 10,000t/day. Orange juice yield is normally 45% - 65%, depending upon the variety.

3.   Processing

The extracted juice is further 'finished' by various sieving devices to remove pips, rag and other debris.

If the juice is to be filled as single strength product then de-aeration. de-oiling and pasteurisation take place next. The first two operations occur simultaneously to improve the flavour.   To retain the cloudy appearance usually demanded by citrus fruit, it must be pasteurised within 60 minutes of being extracted. The heat treatment necessary for the inactivation of pectin enzymes is dependent upon the acidity of the juice. Lower pH juices will require a reduced inactivation temperature. This is particularly useful when processing lemon and lime products, which are both very heat sensitive, but high acid.

The pasteurisation process secures microbiological stability as well as inactivating the cloud destroying enzymes. The high-temperature, short-time (HTST) pasteurisation process avoids undesirable changes in product flavour.

Pasteurisation conditions depend upon the product involved, its intended shelf life and the storage conditions to which it will be subjected. For natural strength orange juice, a typical combination is $95\,^0C$ for 30 seconds. For the higher acid products lower pasteurisation temperatures of $80\,^0C$ to $85\,^0C$ can be used.

If the final product needs to be cooled, a high percentage of the process heat can be recovered by regeneration in the pasteuriser.

Most of the world's processed orange juice is now converted into a frozen concentrated form (FCOJ). The first attempts at this process in the 1940s were not very good at 60 - 650 Brix level of concentration. Single strength juice was often used to cut back the strength to 30 - 350 Brix to restore some of the flavour. The practice of using cut-back for industrial products is now only for speciality materials because of its high cost and the use of state of the art heat exchangers which give perfectly acceptable juice when diluted to single strength with water. However, for the frozen domestic packs of juice concentrate in the USA it is common to cut the 650 Brix product to 40 - 450 Brix with natural strength juice. The standard Brazilian juice concentrate is 650 Brix. There is an increasing demand for single-strength (not from concentrate) juice, which does not undergo the concentrating process

4.   Concentration

Juice from the heat exchanger or blending tank is conveyed to the evaporator where the product is concentrated to a desired Brix level.

The present market requirements for citrus concentrate are typically:

	Original Strength	Concentrate
Orange	10° to 14° Brix	60° to 65°Brix
Lemon	7° to 8° Brix	42° Brix
Lime	7° to 8° Brix	40°Brix
Grapefruit	9° to 12°Brix	58° to 65° Brix

If juice is to be concentrated by thermal means, it is usually necessary for it to be screened to a maximum particle size of 0.5 mm in order to prevent blockage of the evaporator distribution system.

There are two basic types of evaporators used throughout the citrus industry.

A. Low temperature falling-film e.g. APV

To avoid product damage that would be caused by a conventional atmospheric boiling process, concentration is usually carried out under vacuum conditions. A falling-film plate type of evaporator uses reduced boiling temperatures combined with a very low heat contact time for the product, typically 100 seconds. To avoid excessive heat contact time, citrus juice evaporators are designed for non-recirculatory duty where it is possible.

The insoluble solids content of juice is an important factor when considering concentration. High pulp levels will restrict the concentration level, as the product will become viscous e.g. lemon/lime. As a general example, a pulp level of 8% by volume in the natural orange juice is acceptable for the production of a 65^0 Brix concentrate, when using a falling film plate evaporator.

Evaporators are designed to operate on maximum thermal efficiencies. Multi-effect designs use vapour from a previous effect to provide the necessary heat, as well as low-pressure vapour re-compressed by thermal or mechanical means for even greater efficiency. Maximum heat recovery from evaporator liquids can be achieved by using waste condenser water and condensate for pre-heating purposes.

B. High temperature, short holding time - often referred to as a TASTE (temperature accelerated short time evaporator).

This tubular type of evaporator predominates and their presence at citrus factories is a prominent feature of the Brazilian and Florida countryside.

A typical TASTE has 6 stages and 4 effects plus a flash cooler, with one or more stages operating at 93-100^{0}C, and would simultaneously pasteurise, enzyme stabilise and evaporate the juice.

Within the tube nest, the juice is introduced as a turbulent fog to allow rapid heat transfer. The accelerated mode of action results in the juice reaching a speed of 700km/h into the tubes. In the top of the range 7 effects evaporator 5.7kg of water is removed for each kg of steam. Total cycle time is 150 secs.

Other methods of concentration include the use of freezing and ultra filtration (or reverse osmosis). Freeze concentration is a costly and inefficient process but gives a good product; it has very limited application. UF/RO is a relatively recent innovation in juice processing and is more appropriate for clarified products e.g. lime, apple and grape.

5.   Packaging and Storage

When the juice concentrate leaves the evaporator, it is at the temperature of the final effect - this can be anything from 25 - 50°C. Further cooling is achieved through heat exchangers, which can bring the temperature to as low as -10° for bulk storage or into drums for storing at -18°C.

6.   By-Products (Essence Recovery, Refining and Blending)

Most citrus fruit juices owe their aroma and much of their flavour to organic compounds known generally as essence oils and aroma compounds.

When fruit juice is concentrated, many of the volatile components may be removed with the evolved water vapour; these substances can be recovered and made available for blending back into the juice concentrate. A development in essence recovery is spinning-cone technology. The spinning cone column (SCC) is a unique and extremely efficient gas-liquid contacting device that can process products with very high solid contents and recover oil soluble and water-soluble flavours from juice and peel. It can be used for citrus and other fruit and vegetable processing amongst other applications.

Exhaustive research into the subject of essence recovery has shown that the majority of aromas are found in that portion of vapour which is the most difficult to condense. Once this was known, the partial condensation design became a reality.
The essence recovery unit of the partial condensation design combines the technique of partial condensation with a scrubbing arrangement that improves essence quality and yield. It operates without a distillation column, yet offers a modern, simple and reliable method of essence recovery while maintaining the higher product quality. The essence from citrus juice comprises two phases, water and oil, which are separated by a simple decanting method.

The system is used with any multiple effect plate or tubular evaporator arrangement. The incorporation of an essence recovery unit does not preclude the use of vapour re-compression in the evaporator design. In this way thermal economies can be achieved without detriment to the quality or quantity of the essence recovered. Essences are often further refined and blended for reincorporating into a juice.

Packaging and transport of fruit products

Once the cooled concentrate is ready for industrial packaging, several options are available:

1.   Frozen   -   drummed, bulk tankers
2.   Aseptic
3.   Canning
4.   Preserved

1. **Frozen** concentrated juice is a pumpable, viscous liquid, held at a sub-zero temperature. Owing to the lack of water it is not solid. It is the main industrial product for orange and grapefruit.

   Drummed frozen grapefruit juice concentrate (FCGJ) is virtually all drummed in 200 litre nominal mild steel drums with double HDPE liners - temperature is maintained at -18°C. Significant quantities of orange juice and some lemon and lime are also packed in drums.

   Bulk tankers are used for most Frozen Orange Juice Concentrate (FCOJ), which is mainly of Brazilian origin, from the citrus processing factory right through to the user company. Typically this involves piping of FCOJ at -10°C from shipping tanks to dockside storage tanks. These tankers are dedicated to the transport of FCOJ from Brazil to the juice terminals of Europe and USA where they are stored in 'tank farms'.

   As the ship tanks are emptied the FCOJ is replaced by Nitrogen to maintain an inert environment for the return journey to Brazil. The FCOJ in the tank farms is stored until call-off by customers. At this stage it may be:

   - blended with other juice concentrates and drummed
   - drummed solely as one raw material
   - filled into 20 tonne insulated road tankers for transport direct to customers' own storage tankers

   Most FCOJ from Brazil is now delivered in bulk tankers. There is a surcharge for juice in drums from Brazil.

2. **Aseptic** packaging is a highly developed industrial process widely used for the transportation and storage of fruit juices.

   The juice concentrate is held in a balance tank after the evaporator and then pumped to a high temperature short time (HTST) pasteuriser and cooler. For low viscosity products a plate heat exchanger is used and for viscous materials a scraped surface heat exchanger is used. With both methods the product is rapidly (30 sec) cooled and filled at 20°C or lower. This rapid cooling ensures that the product retains as much of the fresh material flavour as possible and reduces off-flavour development. The cooled product is filled into pre-sterilised laminated, metallized plastic bags. 208 litre bags are transported in mild steel drums - bag-in-drum, and 23 litre bags are packed in fibreboard boxes - bag-in-box. There is also a one-metre cube version, which will hold 1,000 litres.

3. **Canning** of citrus juices and concentrates was the main means of packing and storing them until the advent of frozen concentrates. The use of canning has now virtually disappeared. The process employs a volumetric filler to receive heated product, seam the can, inverts it to sterilise the lid and cool it as rapidly as possible in a cooling tunnel. The cans can be stored quite safely at ambient temperature for up to two years. Common sizes are A10 and 5kg.

4. **Chemically preserved and drummed concentrates** are not used for concentrates converted to pure juices, but are widely used for lime and lemon juice concentrates when they are to be used as soft drink ingredients

   The preservative of choice is sulphur dioxide at up to 2,000 ppm because not only does this ensure microbial stability, it prevents non-enzymic browning through its anti-oxidant action. This mode of preservation is widely used for fruit materials, which are used as ingredients in squashes, whole fruit drinks and cordials. Sulphur dioxide as a preservative should be avoided when the fruit material is to be used in carbonated drinks because of the risk of hydrogen sulphide production through interaction with the metal of the closure. For these materials sodium benzoate is an acceptable preservative up to 2,000 ppm and can be used in conjunction with SO2, providing the carry over into the finished drink is no more than 2 - 3 ppm.

   Preserved fruit materials are usually transported and stored in 200 litre plastic drums or 1,500 litre Rotoplas containers.

By-Products of the Citrus Industry

The modern citrus factory can pride itself in being virtually free of any waste that has no further use. This by-products industry has been developed by the Israelis to such an extent that elaborate or value added products are frequently their major source of revenue. This is especially important to them since the juice business is strictly commodity with price control outside their hands.

By-products can be categorised as either primary or secondary depending on the degree of extra processing that is required to commercialise them.

In the primary category are *essential oils; water extracted soluble solids* and *wet peel residues.*

Essential oils are extracted from the peel during the juice process and are major items of commerce in the flavouring and perfumery industries.

Water extracted soluble solids are produced by washing the pulp residues to extract any remaining juice. The washings can then be concentrated, and sold as ingredients to the soft drinks industry.

Wet peel residues or wet wastes are usually sold off to farmers for animal feeds.

The secondary category of by-products is *the comminuted base, pectin, cloudy concentrates* and *pellets.*

The Comminuted Citrus Base is exclusively an ingredient designed for soft drinks; thus it differs from citrus juices which are primarily intended for consumption on their own, and only used as an ingredient in soft drinks. The flavour of a comminuted citrus base is too strong and overwhelming to make it acceptable as a straight drink. The comminuted citrus base has been developed mostly in the UK and this section describes almost exclusively the UK experience.

While the comminuted citrus base was commercially launched in 1953, its origins go back much further. W C Hill of California took out a British patent covering the products and the methods of making comminuted citrus drinks in 1938. The Second World War curtailed development and the British soft drinks market was held rigidly to its current products by the wartime commercial arrangements and the compositional standards enshrined in the 1943 soft drinks regulations. Interestingly, the comminute is one of the few American inventions that has never really been taken up in its country of origin.

The idea of a comminuted citrus product was revived in the early 1950s and finally launched on the market after the soft drinks regulations were altered in 1953. The Ministry agreed that a new class of soft drink should be permitted, which regulated fruit content and requiring 12.5 kg of oranges to be used for each 45.5 litres of concentrated drink. (A curious quirk of the legislation was that it was limited to oranges!) As with traditional squashes the customer was expected to dilute the drink with 4 parts of water before consuming it.

The processes used to prepare the comminuted drink were many and varied, even in the early days. The amount of citrus fruit, which found its way into the drink, depended on the process. This meant the public analysts and the enforcement authorities were at a loss as to how to judge these new soft drinks since they could not determine by analysis whether the correct amount of fruit had been used in their preparation. In 1964 soft drinks regulations were altered again and specified that these drinks should contain 10% of potable fruit in the concentrated drink (potable fruit was defined as the total of the fruit constituents of a soft drink derived from the juice, the pith and the peel). This regulation was revoked in 1996. As well as orange drinks other citrus drinks were introduced.

Traditionally, orange squash was required to contain 25% orange juice. As the customer was expected to dilute it 5 times, he consumed a drink containing 5% juice. The flavour of orange juice on the other hand is not so powerful that it needs to be diluted; orange juice can and is drunk straight. To make squash palatable, soft drinks manufacturers added an essence to boost flavour. The essence was prepared from orange essential oil extracted from the skin of the fruit as a by-product of juice production. Up to about 40% juice can be commercially extracted from the orange. Therefore 100 ml of squash as consumed requires 12.5g of oranges in its manufacture. 100 ml of a concentrated comminuted drink made from 27.5g of oranges is also diluted 5 times so the drink as consumed is prepared from only 5.5g of oranges. Yet the flavour of the comminuted drink was so much more powerful, so much fresher in taste, so much closer to the consumers' expectations of an orange drink, that it has eclipsed the sale of traditional squash. Such is the technological achievement of the comminuted citrus base.

In the early days processing was done entirely in the UK at soft drink bottling factories using, at the outset export grade table quality fruit, but later special arrangements were made to import process grade fruit.
The original comminuted base was made by dropping orange slices into warm sugar syrup. The mixture was thoroughly stirred to ensure maximum extraction of the soluble and flavourful constituents of the fruit tissues into the syrup. When this had been done the fruit slices were lifted out, allowed to drain, and then discarded. The syrup contained not only juice but also extracts from every part of the fruit; hence the original claim 'made from whole oranges'.

All these early processes produced a strong, fresh-flavoured product, which was instantly successful. But the mass transfer of fruit to syrup was relatively small, and the loss of sugar discarded with the pulp was costly. While technically the use of a sugar syrup as an extraction medium was more efficient and convenient than plain water, the difference was slight and very soon cold or warm water was used in place of sugar syrup with little loss of quality and a large gain in economy.

The principle in these early processes was one of gentle extraction. Pulp in the form of broken fruit cells was incorporated in the drink, the quantity depending on the mesh size of the containers of sliced fruit, but the main flavour came from the oil soluble constituents extracted by the syrup or water.

As the popularity of these new products increased so did the problems for the soft drinks industry. The difficulties were the high cost of transport of fresh fruit from the Mediterranean countries or South Africa, and the administrative headache of maintaining a constant supply of suitable quality and ripeness throughout the year. So the next development was to comminute the fruit in its country of origin, and preserve and pack it for the journey to the customer.

Thus the true comminuted citrus base was developed as an article of commerce, made in the citrus growing countries and exported to the customer. The processes were developed in Spain, South Africa, Zimbabwe and Sicily but most of all by the Israelis who developed their own processes independent of the main soft drinks manufacturers, after original instructions had been given by the customers.

In the modern Israeli processing factories each producer closely guards his comminute production methods because competition is intense. The main customers for such products are the whole fruit drink/concentrate manufacturers around the world. What was originally a brilliant creative elaboration of whole oranges has become a highly engineered cost-effective process where any semblance of creativity today is aimed at economies.

The usual mode of operation at Israeli citrus factories is for the fresh fruit during the season to be processed to provide storable components. Usually, FCOJ, essential oil, peel flakes, cloudy concentrates and minced peels. Not surprisingly, there are an infinite variety of combinations, and whilst it is likely that most buyers will have at least one supplier for a given specification, it is unlikely that the blend of components will be identical.

Components can be blended outside the main season to a customer specification and in the more sophisticated factories this will be computer controlled. It is usual to use 60° Brix FCOJ as the basis of an orange comminute and to add the other components to produce a specific cloud level, oil content and flavour profile. The final concentration is usually 40° Brix and the product is usually preserved with sulphur dioxide and transported in drums.

Comminutes are to a much lesser extent produced from lemons and grapefruits. Israel is by far the major producer, although Sicily has the lion's share of lemon comminute. Virtually all comminute production is for UK manufacturers of whole fruit concentrated drinks. The only comminute manufacture ever to have taken place in the USA, where the original patent was taken out, was under licence from Schweppes in California. Americans never adapted to the taste and production was stopped in the late 1970s.

CLOUDY CONCENTRATES are one step further in the use of citrus residues than are pulp washes.

The ingenuity of the Israelis lead to the development of cloudy concentrates which are produced from all the citrus residues left over after the juice, oil and comminute production has taken place. De-oiled peel and pulp residues are extracted with hot water, often with the addition of a pectolytic enzyme to assist solubilisation and reduce viscosity. The extracted cloudy liquid is 3 - 5° Brix and in the more sophisticated process a counter current technique is used to increase the soluble solids to 8 - 10° Brix. At this stage the extract is filtered and centrifuged to remove particles. Finally pasteurisation and concentration to 50° Brix takes place. Quite often the evaporators used for this duty have been specifically modified to handle viscous liquids. The cloudy concentrates are either preserved or frozen.

The final objective is to produce an extract which when used at around 1% in a soft drink produces a wholly natural cloud that is stable. A further benefit is achieved if the extract has a bland or neutral taste - quite often the extraction process leaches various bitter components from the peel, thus limiting the application of the extract.

While these concentrates can provide an acceptable natural cloud, their stability leaves something to be desired unless there are citrus juices present in the beverage to contribute cloud also.

The controversial aspect of cloudy concentrates, like that of pulp washes, is that they have, in the past, been used in juice adulteration and can go undetected at up to 20% unless very sophisticated analytical techniques, coupled with a reliable database and good taste buds, are used.

CITRUS PELLETS are the ultimate by-product, only encountered in Brazil and Florida. All the residues are milled, limed and fed into a screw press to mechanically extract as much water as possible. The resulting slurry is dried and pelletised for cattle feed. In Brazil the fuel for the large heaters is produced from sugar bagasse (waste materials).

PECTIN occurs in the cell walls of higher plants and citrus peels are an important source for the pectin industry. Pectin can be described as primarily a polymeric chain of partially esterified (1-4)-linked D-galacturonic acid units to which may be attached varying amounts of other sugars.

Pasteurisation

The traditional pasteurisation of fruit juices during industrial processing is 94°C for 30 secs holding time. This particular regime has arisen because of the necessity to inactivate the natural fruit pectolytic enzymes. However, for fruit products with pH values invariably less than 4.2, the microorganisms likely to be encountered are yeasts, moulds, acetic and lactic acid bacteria. All of these are readily destroyed by heat and since they are non-spore formers a less vigorous pasteurisation step has to be adopted for converting fruit materials into finished beverages.

Secondary pasteurisation conditions need to be calculated for each case because of the many factors which influence the final achievement of sterility such as acidity, pH, presence of chemical preservatives, fruit content, packaging, microbiological load etc.

A major aspect in calculating the appropriate conditions is the affect on flavour, therefore it is important not to overdo the pasteurisation step.

Under the influence of heat, microorganisms die in logarithmic order and thus are often referred to as the D-value or, the time required to kill 90% of a population at a given temperature. 1D-value (Decimal reduction time) is 1 log reduction.

As temperature increases the D-value decreases, thus if D-values are calculated for several different temperatures a graph of Log D can be plotted against temperature. The slope of the graph is the Z value. Z is the temperature increase required to effect a log reduction in the D-value.

In the canning industry 12D or 12 log reductions are usually specified and for bottled juice production to ensure the crown is sterilised. This is equivalent to 90°C for 7 secs or 85°C for 30 secs. This gives an adequate safety margin for citrus juices and whole fruit drinks. For tomato juice 94°C at 30 secs is required because of the low acid/high pH situation (this is equal to 126 log reductions).

Further extensive investigations into precise heat conditions required to destroy yeasts and moulds have been made for the brewing industry. The calculation based upon the concept of pasteurisation units (PU) is defined as the effect obtained by 1 minute holding time at 60°C or above.

PU per minute = $1.393^{(t-60)}$ t = past.temp

It is important to recognise that fruit materials, even after heat pasteurisation are still susceptible to spoilage once the pack has been opened. This, of course, is dependent on temperature.

FCOJ at -18°C is perfectly safe even though it may contain a few micro-organisms and anyone familiar with juice handling would routinely return part used packs to the cold store. With aseptic juice concentrate (which is probably stored at 5°C or higher) it is better to use up the whole pack or hold part used packs for no more than 2 - 3 days at 5°C.

Finished beverages containing fruit materials are also susceptible to spoilage once the pack is opened unless the product contains chemical preservatives.
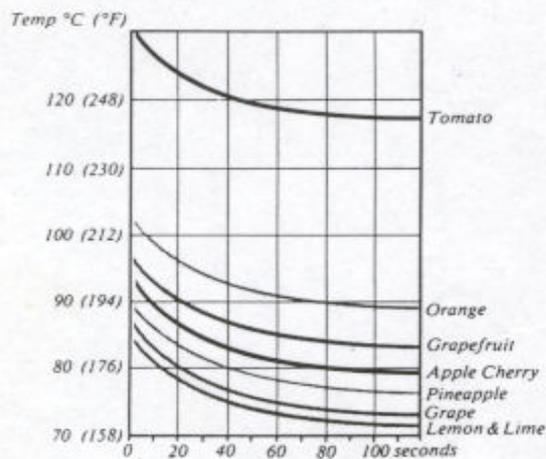
Fruit Juices. Preservation by heat.

Fruit Juice Processing and Packing

Bottled fruit juices were first marketed by Britvic and cans imported from producer countries. These were soon supplemented by 1-litre glass jars and, to a limited extent, retail packs of frozen concentrates. Such products were early contributors in educating and persuading the public to drink fruit juice. Real growth began in the early 1970s with the advent of the paper carton.

The market today is divided into 3 areas:

1. **Freshly squeezed juice** - fruit freshly squeezed, no heat treatment so must be kept chilled with a shelf life of only a few days

2. **Short life juice** - juice given a pasteurisation treatment and filled under ambient condition so must be kept chilled and has a shelf life up to 30 days

3. **Long life juice** - juice given a pasteurisation treatment, cooled and filled aseptically into the container **or** juice filled hot into the container followed by a pasteurisation process and has a shelf life of 6-12 months in cartons, longer in cans or glass

Short and long life juice may be freshly squeezed, from stored single strength juice, made from concentrate or any combination of these forms.

A.   *Production methods*

1.   Freshly squeezed juice

The juice is taken directly from the fruit, cooled and filled into the container, usually a plastic bottle and distributed chilled.

2.   Short life juice

In the early 1970s the ICA group in Sweden, who were packing juice in 1 litre glass jars, became one of the first to start packing juice from concentrate into Purepak cartons. Essentially, the operation involves reconstituting the frozen concentrate to natural strength, pasteurising for about 20 secs and immediately flash cooling to around 3 - 4°C. The juice is then filled into cartons, and the resultant product has to be kept chilled and, in ideal circumstances, has a shelf-life of up to 28 days. A great advantage of this system was, first, that it enabled the packer to use a juice containing cells that has an undoubted improving effect on the flavour. This had usually been impossible with the glass pack since most of the fillers were of the vacuum type where the presence of cells tended to interfere with operation. The juices are extremely sensitive to heat, and one of the problems of glass jars is that in order to be sterile they have to be filled hot and the juice is then subjected to quite high temperatures during cooling. If one tries to cool hot-filled glass down to even 25°C in less than about 20 minutes the glass breaks due to thermal shock.

Since the product had to be kept cool an efficient distribution system was essential. This already existed in Sweden but elsewhere, it was rudimentary to say the least. The dairies offered the most efficient system and this prompted their entry into the fruit juice business.

3.   Long life juice in aseptic

Tetrapak were successful with their tetrahedral carton in the milk and soft drinks trade. In 1968 they had introduced their Tetrabrik carton to the dairy trade in Britain and started trials to produce an aseptic version of the pack in Europe. The first aseptic Tetrabrik machines were installed for UHT milk in 1971, and in July 1974 the first two Tetrabrik machines for juice, one at Ledbury and one at Adams, started production. A second aseptic system, Combibloc, was marketed by Bowater. Both these types of cartons are made from aluminium-lined waxed card and are sturdy and leak-proof. Pasteurised juice is passed into the cartons in aseptic conditions. The packaging material provides a good oxygen barrier thus limiting the oxidation of the product during storage. The product's shelf life is approximately six months and it does not need a chilled distribution system or to be sold from a chilled cabinet.

The popularity of these long life cartons has been tremendous and they now tend to dominate pure juice sales.

The difference between aseptic packaging and conventional hot filling or post sealing thermal processing is not so much in the final product as in the way a shelf-stable product is achieved.

Four conditions must be met in order to produce aseptically packaged shelf-stable products:

1.   The product must be commercially sterile at the time of packaging

2.   The package must be free of micro-organisms that could cause spoilage or safety problems after packaging

3.   The package must be filled and sealed without re-contaminating the product

4.   The package has to prevent recontamination of the product during normal handling and storage.

In conventional processing, heat is applied to the product and container after sealing, or the container is filled with heated product and sealed while still hot. Both hot filling and post sealing thermal processing depend on the presence of heat after the container is sealed to ensure commercial sterility. In aseptic processing and packaging, both the package and the product are commercially sterilised before the filling and sealing operations. The package is filled and sealed under aseptic conditions; hence, the name aseptic packaging. Most often, products are heated to commercial sterility in continuous-flow systems, while packages receive a combination of chemical and heat treatments to achieve commercial sterility.

There are four basic requirements for equipment used to commercially sterilise liquid foods that are to be aseptically packaged:

1.   Sufficient heat must be applied to the product to ensure that it does not contain viable pathogenic or spoilage micro-organisms, which might grow during long-term ambient storage.

2.   Once commercially sterile, the product should be quickly cooled to room temperature to minimise heat-induced deteriorative chemical reactions.

3.   The processing system must have high integrity and be able to be sterilised, so that the product is not re-contaminated after being processed.

4.   A fail-safe control system should be incorporated into the process so that in the event of the product not reaching the proper temperature, the system automatically diverts product away from the packager. Product may be reintroduced to the non-sterile side of the system or diverted out of the system for holding.

The TetraPak system is representative of packaging machines that use roll stock and that sterilise the web before forming the package. The process begins when a roll (web) of pre-printed packaging stock is carried through a series of smoothing rollers to the top of the machine where a thin strip of polyethylene is attached to one edge. The plastic strip prevents juice from wicking, or migration of liquid through the package, into the paperboard through the inside of the longitudinal seam. The web is treated with hydrogen peroxide and hot sterile air before being formed into a tube. The longitudinal seam is made and is covered on the inside by the plastic strip already applied. Hot sterile air is forced through the tube as it is being formed.

The juice is introduced into the formed tube through a float valve on the lower end of a stainless-steel tube, which is located in the centre of the formed packaged tube. The filled paperboard tube is sealed horizontally below the surface of the product, which results in a container that does not have any headspace. Knives next cut the packages into a brick shape and the four flaps are tacked against the sides of the container.

In the Combibloc system the carton board is preformed and cut into the outline of the carton, sealed at the side seal and folded flat. The pile of carton flats is fed onto a mandrill, which opens up the flat and heat seals the base flaps. The open top brik is then sterilised with peroxide, filled with product and the carton top is then heat-sealed.

B.   Heat processing in container

Cans and bottled may be filled with hot juice and the lid applied. After this stage the container may be inverted to sterilise the inside of the lid with the heat from the product or additional heat provided in a pasteurisation tunnel. The container is then cooled. Recent introduction has been the PET bottle that can be filled hot and then rapidly cooled after inversion.

The empty bottles are rinsed, filled with juice from the pasteurising process at 92° to ensure a minimum filling temperature of 85°C and sealed under ambient conditions. The bottles are inverted to heat the inside of the cap and then passed to the cooling section where water sprays bring the temperature below 30°C as quickly as possible

C.   Latest innovation

Low-density PET bottles can be blow moulded from granules, sterilised, filled aseptically with cold juice after normal pasteurisation and then cooled. This combines minimum heat treatment with bottle shape versatility, ambient storage and long life.

Nectars

Nectars have long been popular in Europe and in Germany; for instance, many regard them as better than pure juice. Products generically known as nectars have their fruit content regulated by legislation with amounts varying for each fruit type. Thus citrus nectars must contain 50% juice; blackcurrant and others can have as low as 25%. Nectars provide an alternative to pure fruit juices, being more flexible in terms of their appeal for manufacturers and the consumer. Also, many juices are not suitable for 'pure' consumption and nectar is an ideal way of presenting these products e.g. mango or mixtures of several juices.

Dilutables, cordials and concentrated drinks

There was a dramatic development in the production of concentrated drinks that came with the advent of the comminution process. This led to the evolution and development of 'whole fruit drinks' as distinct from squashes and cordials. As defined in previous legislation, squashes were made from the juice of the fruit only - i.e. expressed from the endocarp; cordials need not contain any fruit at all and are often made with flavourings as the only characteristic ingredient. In the absence of legislation these terms can be regarded as customary names. A comminuted drink and concentrated comminuted drinks are produced from the "whole fruit" or with the parts that make up the "modern designer comminute".

The manufacture of concentrated drinks can be either a batch process or by a proportional dosing system (e.g. APP-Automatic Product Processing). In the batch process, the finished product is actually the 'syrup' of conventional soft drink manufacture. In the proportional dosing method a computer controlled proportioning pump is used to blend pre-prepared ingredient streams.

A typical process for a whole fruit orange drink would require the production of a 'super-concentrate'. This mixture would contain all the fruit, flavourings, preservatives, colours and any other minor additives. To ensure thorough mixing of this viscous 'brew' a single stage homogenisation step at 2,500 psi is essential. Typically, this would undergo dilution of around 7-fold when blended with streams of water, sugar syrup and citric acid in the proportioning pump. This complete blend is then pasteurised at 85 ^{o}C for 30 secs, cooled and filled into glass, PET and HDPE bottles. Plastic tamper-evident caps are applied.

All concentrated drinks are normally preserved. This protects the product throughout its shelf life and preserves the product from any contamination that might occur after opening in the household. Beverages of this type represent good value for money as refreshing beverages.

Ready to Drink Still Drinks

Ready-to-drink soft drinks are also produced in non-carbonated forms and usually contain some type of fruit product. The most popular are usually in aseptic card/foil laminate packs, such a TetraPak and Combibloc. Such products are typically unpreserved and come in volumes of 200ml, 330ml and 1 litre. Drinks packed aseptically in these containers are produced the same way as fruit juice in such containers. This means they are pasteurised and cooled before filling. They are of low juice content with added sugars or sweeteners, plus acids, flavours, colours and vitamins. Drinks are also produced in a range of plastic bottles. Some of these are hot filled and cooled after sealing; others are cold filled and require the use of preservatives and/or Velcorin. The development of plastic containers for this type of product has progressed to the extent that it is possible for the bottles to be blow moulded from PET granules and for the bottles to be aseptically filled. A further type of packaging is the plastic cup. This is produced on the form fill seal principle. The cups are formed from a reel of plastic material, then hot filled with product, sealed with a suitable lid material and cooled.

Appendix

Terminology

Freshly Squeezed Juice (or freshly pressed)
Juice is literally squeezed or extracted from the fruit and filled directly into the appropriate container for a very short shelf life but may be processed for longer life.

Concentrated Juice
Juice is evaporated to reduce the water content and produce a concentrate, which is up to 6 times the original strength.

Frozen Concentrate
Generally refers to the product, which is not sterile and is stored at -18^0C in drums and at -10^0C in bulk.

Aseptic Concentrate
Concentrate is heated to destroy any micro-organisms and is then filled into a large aluminium foil-bag under aseptic conditions and sealed. It does not need to be stored frozen for micro-biological reasons but prolonged storage at high temperatures leads to a reduction in product quality.

Fruit Puree
Fruits such as peach, apricot, banana and mango are very pulpy and instead of being squeezed to extract the liquid juice as in the case of orange, the edible part of the fruit is made into a puree and sieved. This single strength puree may then be slightly concentrated.

Juice from Concentrate
Concentrated juice is reconstituted with water to the necessary Brix level to comply with the AIJN Code of Practice industry standard and filled into the appropriate container.

Juice not from Concentrate (NFC)
Juice is extracted from the fruit, given a light pasteurising process before filling directly into its intended container or kept chilled for later pasteurising and filling into the appropriate container without addition of any water.

Cut-back
The process whereby single strength juice is added to concentrate to improve quality characteristics and the Brix of the concentrate is thus cut-back from say 65^0 to 45^0 Brix.

Cells
Sometimes referred to as 'bits' or 'juicy bits'. These are cells or cellular material taken from the extracted juice and frozen in blocks. They can be added back to the concentrate or added directly to the juice from the reconstituted concentrate.

Brix
In a pure sugar the ^{0}Brix relates to the soluble solids that are the percentage of dissolved sugar. A syrup of 10% sugar by w/w has a Brix of 10^0. In a juice the term Brix refers to all the soluble solids and will include the amount of acid as well as sugars.

Refractometer Brix
This refers to the Brix reading as measured by a refractometer instrument directly.

Corrected Brix
For a pure sugar solution the refractometer reading will measure the sugar and give an exact figure for Brix. However, for a juice containing acid the amount of acid present will slightly lower the refractometer reading and a correction will need to be applied from a given table to give the corrected Brix.

Acidity
The acidity of fruit juices is due to a mixture of acids but in general the citrus juices are measured in terms of the percentage citric acid anhydrous, apple juice in terms of malic acid and grape juice as tartaric acid.

Brix Acid Ratio
The Brix divided by the acidity gives a ratio that is sometimes referred to as the maturity index as it relates to the relationship between sugar level and acid level. Higher ratios refer to sweeter products and lower ratios to more acidic products. When referring to ratio it is important to know whether it is a corrected ratio from a corrected Brix or not.

pH
pH is an indication of acidity and refers to the concentration of the hydrogen ions. It is important in relation to micro-organisms in that the pH of a juice will determine whether certain micro-organisms can survive in it.

> Clostridium Botulinum will not grow below pH 4.5
> Other food poisoning bacteria will not grow below pH 4.0
> Most fruit juices have pH in range 3.2 to 3.8

Pasteurisation
Pasteurisation refers to the heat processing given to the juice. The processing has two functions. First the pasteurisation will inactivate any enzymes that could cause chemical and physical changes in the juice. Next the pasteurisation process will destroy those micro-organisms capable of growing in the juice during its life.

Patulin
Patulin is a toxic metabolite formed naturally during the growth of a diverse range of micro-fungi (moulds), which occur commonly on many fruit, vegetable and cereal products. It occurs only in mould-damaged fruits; presence of mould does not necessarily mean that Patulin will be present in a fruit but provides *a priori* evidence that it may be present.