Report summary medical devices

Contents

Preface

The scope of the report, is to present the results of a quick scan on PFAS use in the medical sector, in this report the medical devices are considered. This report does not contain the PFAS production nor the end of life phase / waste stage.

Note: Medicinal products are described in a separate summary. Anesthetics and contrast media in the medicinal products report are reported individually. The lists presented in this document reflect non exhaustive lists. Alternatives are available.

1. Uses / Applications

Medical Technology

- Medical devices
- In vitro diagnostic devices

Medical devices and in vitro diagnostic devices are defined under EU Regulation 2017/745 and 2017/746.
The EU Medical Device Regulation has classified devices into three classes with increasing risk: Class I, II and III, depending on their risk and critically. Each device class requires a different level of regulation and compliance.

- Examples of class I devices are tongue depressors, bandages, gloves, bedpans, and simple surgical devices.
- Examples of Class II devices are wheelchairs, X-ray machines, MRI machines, surgical needles, catheter and diagnostic equipment.
- Class III devices are used inside the body, for example heart valves, stents, implanted pacemakers, silicone implants and hip and bone transplants.

EUDAMED (https://ec.europa.eu/tools/eudamed/#/screen/home EUDAMED database - EUDAMED (europa.eu)) will be the central European database used in collecting information about medical devices, amongst others the risk class, clinical and safety studies and manufacturer's information. EUDAMED will provide a living picture of the lifecycle of medical devices that are made available in the European Union (EU). It will integrate different electronic systems to collate and process information about medical devices and related companies (e.g. manufacturers). In doing so, EUDAMED aims to enhance overall transparency, including through better access to information for the public and healthcare professionals, and to enhance coordination between the different Member States in the EU.

2. Main PFAS substances

In table 1 polymers in medical applications (as well as pharmaceutical production) are listed.

Table 1: Polymers used in medical applications and pharmaceutical production.

Polymer	abbreviation	Cas number
fluoroelastomers	FKM	64706-30-5
perfluoroelastomer	FFKM	
polychlorotrifluoroethylene	PCTFE	9002-83-9
polyvinylidene fluoride	PVDF	9011-17-0
fluorosilicones	FVQM	63148-56-1
4,4'-[2,2,2,-trifluoro-1-(trifluoromethyl)ethylidiene]diphenol	Polymers BPAF base	1478-61-1
1,1,2,2,-tetrafluoro ethene	PTFE	9002-84-0
perfluoroalkoxy	PFA	26655-005
poly(ethene-co-chlorotrifluoroethene)	ECTFE	25101-45-5
fluorinated ethylene propylene	FEP	25067-11-2
poly(ethylene-co-tetrafluoroethylene	ET	25038-71-5
1-Propene, 1,1,2,3,3,3-hexafluoro-, polymer with 1,1-difluoroethene and tetrafluoroethene	THV	25190-89-0
1-propene, 1,1,2,3,3,3-hexafluoro-, polymer with 1,1-difluoroethene, 1,1,1,2,2,3,3-heptafluoro-3-[(trifluoroethenyl)oxy]propane and tetrafluoroethene	THVP	68182-34-3

Fluorotelomers:

Fluorotelomers are being used for their contamination-resistant properties in medical textiles i.e. to protect doctors, nurses and researchers against contact with microbiological contaminants, such as viruses or bacteria, for example in surgical gowns and drapes. The below mentioned medical textiles were researched in this survey:

- woven and non-woven fabrics
- textiles for the treatment of patients (such as bandages, absorption mats, hernia mats)
- textiles in medical applications and medical laboratories (such as filter membranes)

Medical implants

An overview of fluoropolymers and alternative materials in medical implants is given in Table 2.

Table 2 List of common medical implants and materials used (Teo, Mishra et al. 2016)

		PTFE	PE	PA	PDMS	PHA	PET	PP	Silicone	LCP	Parylene	PMMA	PEK	PI	SU8
Anestesiology	Epidural catheters	✓	✓	✓											
Cardiovascular	Pacemaker, implantable defibrillator/cardioverter, left ventricular assist device, heart valves, artificial blood vessels, catheters	✓	✓	✓	✓	✓	✓	✓							
Dental	Dentures, dental implants, orthodontic wires, dental instrumentation											✓			
Ear, nose, throat	Cochlear implants, stapes implants, nasal implants for nose reconstruction		✓		✓				✓	✓	✓				
Gastroenterology and urology	Penile implants, neurostimulator in sacral nerve stimulation, foley catheter, artificial urinary sphincter implant, hernia or vaginal mesh	✓	✓	✓	✓	✓	✓	✓	✓						
General and plastic surgery	Synthetic blood vessels, breast implants, cheek, jaw and chin implants, lip implant, titanium surgical implants, hip implant, clamps for high frequency surgery	✓			✓		✓	✓	✓						
Hematology and pathology	Central venous access device, peripherally inserted central catheter	✓	✓	✓											
Neurology	Implantable pulse generator for deep brain stimulation, neuroprosthetiocs, cognitive protheses, catheters	✓	✓	✓	✓	✓				✓	✓			✓	✓
Opthalmic	dexamethasone intravitreal implant, retinal prothesis, artificial inocular lens, glaucoma valve, fluocinolone ophthalmic implant, orbital implant, catheters	✓	✓	✓								✓			
Orthopedic	Orthopedic implants, medical splints		✓			✓							✓		

Fluoropolymer tubes

Fluoropolymer tubes play an important role in many medical operations. There is a growing demand for minimal invasive procedures. The tubes are mostly made of ePTFE.

Fluorinated meshes and textiles

The most frequently used textile implants worldwide are hernia meshes; more than a million are implanted every year. The first meshes were implanted in the 1950s. These meshes were made of polyethyleneterephthalate (PET) multifilament, but in the 1960s polypropylene (PP) monofilaments became available as mesh material. Expanded polytetrafluoroethylene (ePTFE) as porous membrane or polyvinylidene fluoride (PVDF) are also used as mesh material/patch.

Coatings

A way of coating of aluminum metered dose inhalers is done with a polymer layer of PFA or FEP.

Table 3 The main coatings reported in the Response to the CfE (summer 2020) were:

product name	CAS number
SF-coat AS-20280	2414559-48-9
SF-Coat SFE-X008	441049-46-2
AsahiGuard AG-E082	746622-86-6

3. Volume estimations

The total volume of polymers reported in the response on the CfE ranges from 1,700-14,000 ton/year. Table 4 lists the volume of individual substances. In some case the volumes are not reported or reported as lumped sum of a variety of polymers. For instance, the amount of PTFE tubes is not included in the list. Note that in the report summary on medicinal products an overview is given of tonnage ranges of different non-polymer PFAS.

Table 4 Overview of usage and/or production volumes of fluorinated polymers

polymer name	CAS number	usage
PTFE	9002-84-0	1,300-10,000
C6-side chain fluorinated surfactants and coatings	1648842-31-2 2047310-70-1 24937-79-9 441049-46-2 746622-86-6	>800
FEP	25067-11-2	>200
PVDF	2414559-48-9	10-100
PFA	26655-00-5	23-32
others incl. lumped		1700
Total		1,700-14,000

In 2018, a report, commissioned by the Fluoropolymers Group (FPG) of Plastics Europe estimated 1500 tons of fluoropolymers in the medical sector, representing a value of approximately 20 million euro. [1] Based on the response of the sector to the Call for evidence a higher volume of up to 14,000 ton/year (midpoint 8,900 ton/y) was computed.

A total of almost 33,000 ton F-gases is retrieved from the ECHA database to be used in industrial processes related to medical applications. This is equivalent to 47 Mton CO2 equivalents (see Table 5). This seems to be an underestimation, because the atmospheric release of health care related F-gases is estimated to be 249 Mton per year (HCWH 2019). Three F-gases are responsible for 99.9% of

[1] Publications :: Fluoropolymers (plasticseurope.org)

the medical F-gases reported (based on data from ECHA search and response to the CfE). These are HFC-134a, HFC-227ea and HFE-152a.

Table 5 Estimated F-gas emissions based on reported tonnages of medical F-gases in the EU (response to CfE and ECHA database) and assuming an emission factor of 0.1%.

CAS NR	Chemical name	GWP	production volume (ton/y) midpoint		CO_2 equivalents (ton/y)	
811-97-2	HFC-134a	1,430	25,487	77.7%	36,446	77.1%
431-89-0	HFC-227ea	3,320	3068	9.4%	10,186	21.6%
75-37-6	HFC-152a	124	3578	10.9 %	444	0.9%
163702-08-7 163702-07-6	HFE7100	2,597	556	1.7%	165	0.3%
163702-06-5 163702-05-4	HFE7200	59	55	0.2%	3	<0.01%
116-14-3	tetrafluoroethylene	4	55	0.2%	3	<0.01%
375-03-1	HFE7000	575	8	<0.1%	3.2	0.0%
138495-42-8	HFC-43-10mee	1,640	5.5	<0.1%	1.6	0.0%
57041-67-5	desflurane	989	1	<0.1%	0.2	0.0%
26675-46-7	isoflurane	350	0.25	<0.1%	0.1	0.0%
28523-86-6	*sevoflurane*	216	0.25	<0.1%	0.1	0.0%
13838-16-9	*enflurane*	583	0.25	<0.1%	0.1	0.0%
151-67-7	*halothane*	41	0.25	<0.1%	0.0	0.0%
76-19-7	perfluoropropane (PFC-218)	8,830	0.25	<0.1%	1.3	0.0%
76-16-4	perfluoroethane (PFC-116)	12,200	0.15	<0.1%	1.2	0.0%
355-25-9	perfluorobutane (PFC-3-1-10)	8,860	0.1	<0.1%	0.4	0.0%
115-25-3	octafluorocyclebutane	10,300	0.05	<0.1%	0.3	0.0%
75-73-0	tetrafluoromethane	7390	0.03	<0.1%	0.1	0.0%
	HFE7000		32,806	100%	47,252	100%

The dispersal estimation have been based on the midpoint of the usage volumes. An uncertainty factor of at least 2 is applicable (See Figure 1). Considering the dispersal potentials of different use categories, we estimated that 5,600 ton/y could end up in the environment. Almost 70% of this dispersal consists of F-gases. This concerns propellants, that have an exemption for medical use under the F-gas regulation and F-gases in the category “non-polymer PFAS in industrial processes” (83% of the tonnage in this category is F-gas).
F-gases will be dispersed to air.

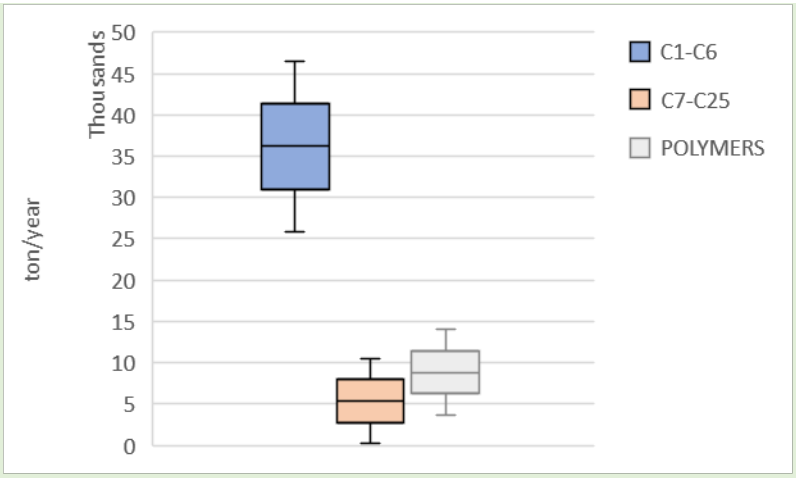


Figure 1 Use of PFAS for medical applications and production.

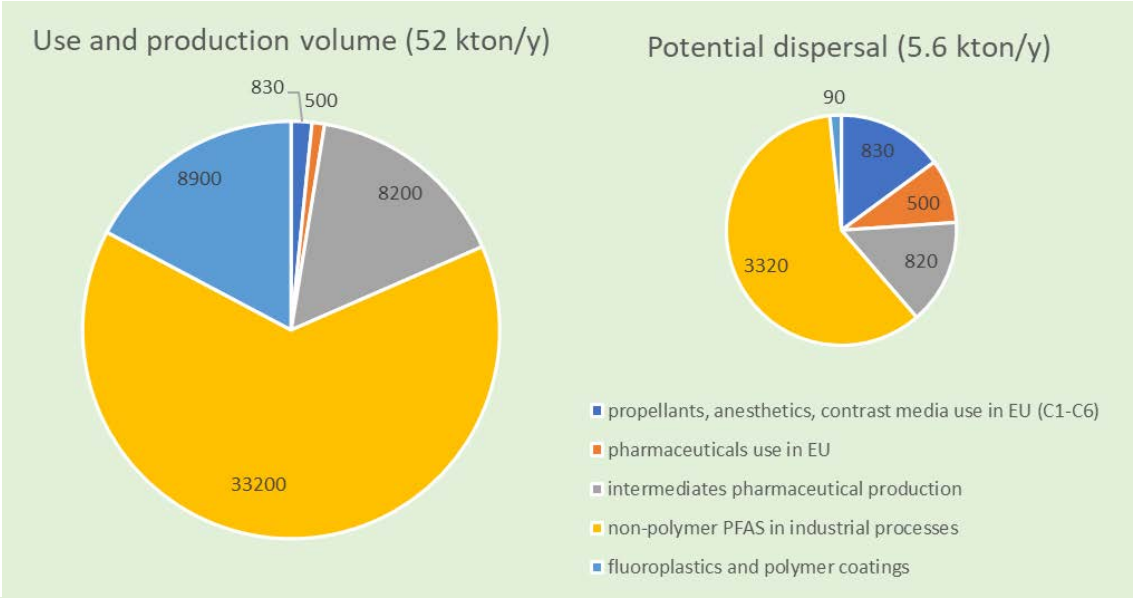


Figure 2 Overview of estimated usage of PFAS used in medicinal products and medical applications and the manufacturing thereof and their potential environmental dispersal. Midpoint of the uncertainty range in ton/y. For overview also medicinal product / pharmaceuticals are plotted (orange).

It should be noted that both medical applications and medicines are depicted in these graphs.
For an overview of PFAS volumes in the medical sector and provisional estimation of their potential dispersal, check table 6 under emissions.

4. Manufacturing & Market

79 companies indicated that they produce, import or distribute PFAS substances, both for medicines and medical applications (Call for Evidence, summer 2020). Most likely this number of production sites may be much higher. No further information is available.

5. Emissions

Fluoropolymers in medical applications generally have a low emission profile during use.

In table 6 EUSES Environmental Release Categories (ERC's) are listed.

Table 6 List of Environmental Release Categories and default worst-case release factors of EUSES.

Note	No	ERC	Default worst-case release factors resulting from the conditions of use described in the ERCs.		
			to air	to water (before STP)	to soil
1,7	1	Manufacture of the substance	5%	6%	0.01%
2,7	2	Formulation into a mixture	2.5%	2%	0.01%
2,7	3	Formulation into a solid matrix	30%	0.2%	0.1%
3, 7	4	Use of non-reactive processing aid at industrial site (no inclusion into or onto article)	100%	100%	5%
4,7	5	Use at industrial site leading to inclusion into/onto article	50%	50%	1%.
5,7	6A	Use of intermediate	5%	2%	0.1%
5,7	6B	Use of reactive processing aid at industrial site (no inclusion into or onto article)	0.10%	5%	0.025 %
5,7	6C	Use of monomer in polymerisation processes at industrial site (inclusion or not into/onto article)	5%	5%	0%
5,7	6D	Use of reactive process regulators in polymerisation processes at industrial site; (inclusion or not into/onto article)	35%	0.005%	0.025 %
6,7	7	Use of functional fluid at industrial site	5%	5%	5%
3,7	8A	Widespread use of non-reactive processing aid (no inclusion into or onto article, indoor)	100%	100%	n.a.
5,7	8B	Widespread use of reactive processing aid (no inclusion into or onto article indoor)	0.10%	2%	n.a.
4,7	8C	Widespread use leading to inclusion into/onto article (indoor)	15%	30% [42]	n.a.
3,7,8	8D	Widespread use of non-reactive processing aid (no inclusion into or onto article, outdoor)	100%	100%	20%
4,7	8E	Widespread use of reactive processing aid (no inclusion into or onto article outdoor)	0.10%	2%	1%
4,7	8F	Widespread use leading to inclusion into/onto article (outdoor)	15%	5%	0.5%
6,7	9A	Widespread use of functional fluid (indoor)	5%	5%	n.a.
6,7	9B	Widespread use of functional fluid (outdoor)	5%	5%	5%
8	10A	Widespread use of articles with low release (outdoor)	0.05%	3.2.%	3.2%
9,10	10B	Widespread use of articles with high or intended release (outdoor)	100%	100%	100%
8	11A	Widespread use of articles with low release (indoor)	0.05%	0.05%	n.a.
9,10	11B	Widespread use of articles with high or intended release (indoor)	100%	100%	n.a.
10	12A	Processing of articles at industrial with low release	2.5%	2.5%	2.5%
10	12B	Processing of articles at industrial processing with high release	20%	20%	20%
8	12C	Use of articles at industrial sites with low release	0.05%	0.05%	n.a.

In table 7 an overview of PFAS volumes and estimated emissions is given for the medical sector (both medical devices and medicinal products)

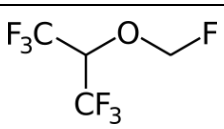
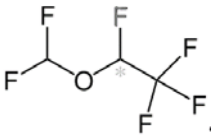
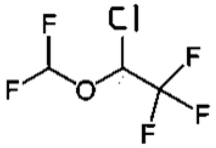
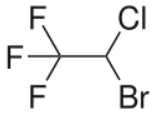
Table 7: Overview of PFAS volumes in the medical sector and provisional estimation of their potential dispersal. H(igh)= dispersal to water, air or soil through PFAS excretion by humans or animals; M(edium) = PFAS may be disposed of as waste, recovered after the production processes or treated in industrial waste treatment plants; L(ow)= PFAS in products that are collected as waste.

	Use	**source**	**volume distribution over molecular size (based on midpoint of uncertainty range)**				**dispersal potential**
	ton/year		**C1-C6**	**C7-C25**	**>C25**	**total**	
non-polymers	**27,000-58,000**	**approx. 160**					
Medicinal products (use)							
human	>500	68		>500			High (90-100%) >1,300 ton/y
veterinary	unknown	3		M			
anesthetics (use)	2-1000*	5	500				
contrast media (use)	2-100	1	50				
propellants (use)	160-400**	3	280				
intermediates	2,200-14,000	27	4,000	4,200			Medium (10%) 4,200 ton/y
Industrial processes including F-gases production	24,000-43,000	54	32,000	1,200			
polymers	**3,700-14,000**				8,900		Low (1%) 90 t/y
Total	**31,000-71,000**		**37,000**	**>5,900**	**8,900**	**52,000**	5,600
			71%	**12%**	**17%**		

*: Might be an overestimation as HCWH 2019 is looking broader than needed here
**: Might be an underestimation as Dutch (extrapolated) data will lead to roughly doubling of the range.

Vaporised halogenated anesthetics are predominantly greenhouse gases. For fluorinated gases used in anesthesia, the global emissions to atmosphere in 2014 was estimated to be 3.1±0.6MtCO2 equivalents (HCWH 2019). Due to increasing uptake of these gases, the footprint from anesthetic gases can be expected to increase. In table 8 an overview of fluorinated anesthetics is given.

Table 8 Overview of fluorinated anesthetics and their characteristics. (Vollmer, Rhee et al. 2015) Desflurane and isoflurane are racemic mixtures of (R) and (S) optical isomers (enantiomers), indicated by the asterix.

Common name	**Sevoflurane**	**Desflurane**	**Isoflurane**	**Halothane**
Synonyms	Sevorane, Sevofrane, Sojourn, Ultane,	Suprane, HFE 236, HFE 236eaEbg	Florane, , Forane, Forene, IsoFlo, Isoforine, Isoflurano, HCFE 235da2, Aerrane	Fluothane, Narkotan,Narcotan, Halan, Ftorotan, Freon 123B1, Fluktan, Anestan, Alotano, Halsan, Rhodialothan
Structure				
Molecular formula	$C_4H_3F_7O$	$C_3H_2F_6O$	$C_3H_2ClF_5O$	$C_2HBrClF_3$
Metabolites	Hexafluoro-isopropanol and inorganic fluoride			
CAS number	28523-86-6	57041-67-5	26675-46-7	151-67-7
Year of introduction	1993-1995	1992	1981	1956
WHO EML			x	x
Global atmospheric emission (tonnes/year)	1200	960	880	250
Atmospheric lifetime (years)	1.1-4.0	8.9-21.0	3.2-5.9	1.0-7.0
Atmospheric concentration (ppt)	0.13	0.3	0.097	0.0092
Global warming potential (100 y) Reference: CO_2=1	130	2540	510	50

It has been estimated that the health care sector globally emitted 2-4 gigaton CO_2 equivalents in 2015 (Lenzen, Malik et al. 2020). In this figure, anesthetic gases and propellants of metered dose inhalers were excluded. They were estimated to add respectively 3.1 and 6.9 Mton CO_2 equivalents (0.3% and 0.2%).

6. Exposure

No further information was available.

7. General discussion

A total PFAS use, for medical applications + medicines of 30,000-71,000 tonnes PFAS per year has been estimated. In the following paragraphs explanation is provided on medicinal products, small PFAS with 1-6 carbon atoms including F-gases, medium size PFAS (7-25 carbon atoms) and polymers.

The dispersal estimation have been based on the midpoint of the usage volumes. An uncertainty factor of at least 2 is applicable. Considering the dispersal potentials of different use categories, it was estimated that for medical applications + medicines a total of 5,600 ton/y could end up in the environment. Almost 70% of this dispersal consists of F-gases.

Reported volumes are compared with estimations that were based on statistics from other sources and databases (for instance EMA, WHO, Eurostat and ECHA). It should be noted that in the ECHA database there is information about non-polymers only, so for polymer volumes information of the Response on the Call for Evidence (CfE), summer 2020, has been included.

Fluoropolymers

The fluoropolymers have a wide range of applications, ranging from products like implants, tubes and valves, medical textiles and meshes.

8. Alternatives

For medical applications some non-PFAS alternatives seem to be available.

It is outside the scope of this document to further go into detail about potential and actual alternatives.

9. Economic impacts in case of a full PFAS ban

No data is available.

10. Methods used & uncertainties

It has been difficult to provide a clear and concise overview of *all* the PFAS used in medical applications. One of the reasons is that the PFAS have multiple applications and that non-PFAS alternatives are also being used for the (some of the) same applications. PFAS can be applied as surfactant, cleaner, cooling liquid, solvent, pharmaceutical, intermediate, or as articles such as tubes, stents, catheters, medical packaging, membranes, contrast media, propellant, anesthetic. Due to overlapping functions, also with other fields of applications, such as electronics, textile, packaging, energy and construction the amounts used for medical purposes cannot always be isolated from other applications. Due to the uncertainties most volumes are presented as a volume range.

References

HCWH (2019). Health care's climate footprint. How the health sector contributes to the global climate crisis and opporrtunities for action**:** 48

Lenzen, M., A. Malik, M. Li, J. Fry, H. Weisz, P. P. Pichler, L. S. M. Chaves, A. Capon and D. Pencheon (2020). "The environmnetal footprint of health care: a global assessment." Lancet Planet Health **4**: e271-279.

Teo, A. J. T., A. Mishra, I. Park, Y.-J. Kim, W.-T. Park and Y.-J. Yoon (2016). "Polymeric Biomaterials for Medical Implants and Devices." ACS Biomaterials Science & Engineering **2**(4): 454-472.

Vollmer, M. K., T. S. Rhee, M. Rigby, D. Hofstetter, M. Hill, F. Schoenenberger and S. Reimann (2015). "Modern inhalation anesthetics: Potent greenhouse gases in the global atmosphere." Geophysical Research Letters **42**(5): 1606-1611.

Annex

Overview of PFAS volumes in the medical sector and provisional estimation of their potential emission (based on dispersal potential).

Sub-use*	**Tonnage PFAS/y in EEA[#]**	**Expected tonnage trend (--/-/0/+/++)*** **	**Emission/y EEA (tonnes PFAS)**
Anesthetics	2 - 1,000*	+	≈ 2 – 1,000
Contrast media	2 - 100	?	≈ 2 - 100
Propellants	160 – 400**	?	≈ 160 - 400
MDI incl. F-gases	24,000 - 43,000	?	≈ 4,200
Medical applications incl. packaging (mainly polymers)	3,700 - 14,000	?	90

Contrast media, propellants and F-gases are mentioned here as medical applications

[#]: Tonnage includes export

*: Might be an overestimation as HCWH 2019 is looking broader than needed here

**: Might be an underestimation as Dutch (extrapolated) data will lead to roughly doubling of the range.

***: --=strong decrease, -=decrease, +-=increase, ++=strong increase, 0=neutral