

The present invention relates to a process for the production of absorbing materials consisting of a combination of synthetic polymers and other substances, preferably substances of a high or partial water-solubility which are incorporated in the polymer body. Such an absorber which rapidly absorbs water and aqueous liquids can be employed for the absorption and/or retention of water and/or aqueous solutions and for the subsequent controlled release of water and the substances contained in the swollen polymer gel and dissolved in the aqueous medium (component B) to other bodies, for example, in nutrient media to culture media, when nutrients or pharmaceuticals are dosed, or as water- and fertilizer-storing soil improvers.

During the last years, numerous different polymers have been developed having a high absorption capacity for water and body liquids. Cross-linked polymers and copolymers based on acrylic or methacrylic acid belong to the fully-synthetic absorbing agents described by numerous patents (DE-PS 244 236; DE-OS 26 14 662; DE-OS 26 53 135; DE-OS 26 50 377; DE-OS 28 13 634), or acrylamidopropane sulfonic acid copolymers (DE-PS 31 24 008).

Other products were produced on a starch basis, e.g., starch acrylonitrile graft polymers according to US-PS 3,997,484; US-PS 4,155,888; or on a cellulose basis, carboxymethylcellulose according to GB-PS 1 159 949, and on a polysaccharide basis according to DE-OS 26 50 377.

The known synthetic absorbing agents are cross-linked polymers which are practically insoluble in water and, when in equilibrium, can absorb many times their weight of water or of other aqueous solutions. Such products are mainly used in the hygiene industry (diapers, sanitary towels), but also in the cultivation of plants as water-storing soil conditioners as described, e.g., by DE-PS 27 37

941, or mixed with kaolin, fuller's earth, talcum, bentonite, or aluminum silicate as described in EP-PS 0 072 213.

Mixtures of synthetic absorbents with fertilizers which mostly have a high or at least partial water-solubility are known, however, it is difficult to incorporate the fertilizers into the absorbent. According to EP-PS 0 181 983 the fertilizer is added to the acrylamide homopolymer or copolymer during polymerization in an amount of 10 to 50%-wt. According to EP 0 186 721 the fertilizer is added to a highly diluted polyacrylamide gel (2%-wt.), and according to JP 60-141192 (CA 103 (25):214126g) a powdery acrylamide/acrylic acid copolymer is dipped into a fertilizer solution and then dried. US-PS 4,052,190 describes a complicated mixture of fertilizer with natural rubber, such as guar gum or carob seed grain in the presence of high-molecular polycarboxylic acids and boric acid or boron salts, respectively.

The addition of a fertilizer to the monomer solution during polymerization impairs the course of polymerization due to impurities (heavy metals) in the fertilizer. The polymerization is incomplete resulting in a polymer having a very high residual monomer content. Other known processes using this admixture in very high dilution are economically inefficient since high amounts of water have to be removed by drying to produce a pulverulent product.

For many absorbent applications it is desirable to incorporate additional compounds usually of high or partial solubility into the absorbents so as to obtain a controlled and preferably retarded release of these substances to other bodies (e.g., fertilizers to plants) when in the swollen state.

The most simple solution of this problem, i.e., to add such a compound (referred to as "component B" hereinafter) directly to the

monomer solution of component A (synthetic polymer), to homogenize it and then start the polymerization, e.g., described in EP-PS 0 181 983, EP-PS 071 063, and DE-PS 31 28 100, can only be carried out, if component B does not impair the course of polymerization.

In the other cases, component B more or less affects the course of polymerization by interfering in the initiating or growth reaction (reaction with the primary radicals, transfer, termination). Even small amounts of impurities within component B, which is normally harmless to the polymerization, may severely influence the polymerization reaction (e.g., trace amounts of heavy metals in conventional fertilizers) so that an even and complete polymerization is rendered impossible. This particularly applies to the attempts of incorporating larger amounts of component B into the polymer; they result in an incomplete polymerization reaction and an end product having a relatively high residual monomer content.

It is accordingly the object of the present invention to incorporate into the known synthetic polymers used as absorbents and having a high absorption capacity for water and aqueous liquids the highly or partially water-soluble substances in any desired, preferably larger amounts so as to obtain end products exhibiting a retarded release of the water-soluble substances to other bodies thereby maintaining the good absorption properties.

According to the present invention this object is achieved by adding component B in the form of a powder, or in dissolved or liquid form during the end phase of the manufacturing process of the synthetic cross-linked polymer A, i.e., during the end phase of polymerization in aqueous solution, and incorporating it into the synthetic polymer by subsequent drying, if necessary, thereby forming an efficient absorbing agent.

The manufacture of component A is carried out according to known methods. It may be effected discontinuously in a polymerization vessel as swollen polymer gel, or continuously on a continuous belt. According to DE-PS 35 44 770, for example, the polymerization is carried out in an aqueous solution containing the water-soluble monomer and, optionally, the comonomers at a concentration of 2.2 to 8.3 mol of polymerizable double bonds per kilogram of monomer solution, in particular 3.5 to 6.25 mol (corresponding to 16 - 60%-wt., particularly 25 - 45%-wt. acrylic acid, if used as monomer) and within a temperature range of approximately 10 - 120°C.

The polymers of acrylic acid and methacrylic acid alone as homopolymer or as copolymer, are primarily suitable as component A, but also the polymers of other water-soluble monomers, such as acrylamide, as well as polymerizable acids and their salts, in particular maleic acid, fumaric acid, itaconic acid, vinyl sulfonic acid or 2-acrylamido-2-methylpropane sulfonic acid may be used. Further examples include hydroxyl-groups-containing esters of polymerizable acids, in particular the hydroxyethyl- and hydroxypropyl esters of acrylic and methacrylic acid; as well as amino-groups-containing and ammonium-groups-containing esters and amides of polymerizable acids, such as the dialkylamino esters, in particular the dimethyl- and diethylaminoalkyl esters of acrylic and methacrylic acid, as well as the trimethyl- and triethylammonium alkylesters and the corresponding amides. In addition, small amounts of cross-linking monomers, e.g., monomers having more than one polymerizable group within the molecule, are polymerized together with the above-mentioned monomers.

The above monomers may be polymerized alone to form cross-linked homopolymers or with one another to form cross-linked copolymers.

In addition, small amounts of monomers which are slightly soluble or even insoluble in water, such as (meth)acrylonitrile, vinyl pyridine, and vinyl acetate may be copolymerized, such as the esters of acrylic and/or methacrylic acid having C₁-C₁₀-alcohols, styrene and alkylated styrenes. In general, the proportion of water-soluble monomers is in the range of 40 - 100%-wt., relative to the total amount of monomers. The proportion of cross-linking monomers is in the range of 0 - 20%-wt., preferably 0.01 - 2.0%-wt., relative to the total monomer amount. In general, the quantity of water-insoluble, hydrophobic monomers amounts to 0 - 40%-wt. of the monomers.

Examples of cross-linking monomers include bi- and polyfunctional monomers, e.g., amides, such as the methylene bisacryl- or -methacrylamide or ethylene bisacrylamide, in addition esters of the unsaturated mono- or polycarboxylic acids of polyols, such as diacrylates or triacrylates, e.g., butanediol- or ethylene glycol diacrylate or -methacrylate, trimethylolpropane triacrylate, as well as vinyl methacrylate and allyl compounds, such as allyl(meth)acrylate, triallyl cyanurate, maleic acid diallyl ester, polyallyl ester, tetraallyl oxethane, triallylamine, tetraallyl ethylene diamine, allyl esters of the phosphoric acid or phosphorous acid, respectively, as well as cross-linkable monomers, such as the N-methylol compounds of amides, such as methacrylamide or acrylamide and the ethers derived therefrom.

The polymerization may be initiated by chemical catalysis and/or high-energy radiation/light. Suitable catalysts include, for example, peroxy compounds, such as potassium peroxydisulfate, hydrogen

peroxide, organic peroxides, such as benzoyl peroxide, tert.-butyl hydroperoxide, tert.-butyl perpivalate, redox systems, such as potassium-peroxydisulfate-sodium-disulfite, hydrogen peroxide hydroxylamine chloride, or azoinitiators, such as AIBN [2,2'-azobis(isobutyronitrile)] or 2,2'-azobis(2-amidinopropane)dihydrochloride. Examples of suitable photoinitiators include benzoin and its derivatives, e.g., benzoin ether, such as benzoin-ethyl-propyl-ether, benzil and its derivatives, such as benzil ketals or acryl diazonium salts, acetophenone derivatives, and others, alone or in admixtures. In general, the content of photoinitiators is of the order of 0.002 to 2.0%-wt., preferably 0.01 to 0.2%-wt., relative to the monomers used. The content of catalysts generally amounts to about 0.02 to 5.0%-wt., preferably between 0.20 and 2.0%-wt., relative to the monomers.

Inorganic and organic compounds, which are present as pourable powders at normal temperature and that are highly or at least partially soluble in water, can be used as component B. Such compounds include, for example, salts of inorganic and organic acids, preferably the salts of ammonium, sodium, potassium, lithium, calcium, magnesium, zinc, aluminium, or iron. Preferred salts of inorganic acids are: the chlorides, bromides, iodides, sulfates, hydro-sulfates, phosphates, hydrogen- or dihydrogenphosphates, tetraborates, nitrates, carbonates, or hydrogencarbonates; as salts of organic carboxylic acids: the salts of acetic acid, formic acid, adipic acid, citric acid, or tartaric acid, or the salts of low-molecular polymeric carboxylic- or sulfonic acids having molecular weights between 100 and 1,000,000, preferably 2,000 to 200,000, based on homopolymers or copolymers of unsaturated mono- or dicarboxylic acids, sulfonic acids, aldehydes, alcohols, as well as (meth-)acrylamide. The inorganic or organic acids themselves can also be used as component B, provided that they are miscible with water. Suitable inorganic acids are boric acid or phosphoric acid.

Suitable organic acids are monocarboxylic acids or polycarboxylic acids, such as citric acid, tartaric acid, or adipic acid, or low-molecular polymeric carboxylic- or sulfonic acids having molecular weights between 200 and 1,000,000 g/mol, preferably between 2,000 and 200,000 g/mol based on homo- or copolymers of unsaturated mono- or dicarboxylic acids, sulfonic acids, aldehydes, alcohols, and (meth-)acrylamide.

The salts of the inorganic or organic acids as well as the acids themselves, such as the nitrates, phosphates, sulfates of ammonium, sodium or potassium, as well as phosphoric acid, which are suitable as fertilizer, are particularly preferred for the use as component B.

Additional suitable substances include: the water-soluble, solid derivatives and carboxylic acid, such as amino acids, amides or diamides, preferably acetamide, urea and urea derivatives, such as thiourea, methyl- or ethyl urea.

Natural polymers based on polysaccharide may additionally be added to component B, examples thereof include modified cellulose and cellulose derivatives, e.g., alkyl-, hydroxyalkyl-, carboxymethylcellulose, gum resins, e.g., guar gum, locust bean gum, tragacanth gum, gum arabic, pectin, etc.; starch and starch derivatives, such as corn starch, grain starch, potato starch, amylose, amylopectin, dextrin, dextran, modified starch, hydroxyethyl starch, cationic starch, starch graft polymers, etc.

In addition to said natural polymers other materials having a large surface can be used in addition to component B, e.g., fibrous material of natural fibers, preferably fibers of cotton, hemp, wool, and silk, furthermore fibrous material of cellulose fibers, such as viscose-, acetate- and triacetate fibers, or of synthetic fibers

based on polyester, polyolefins, polyacrylonitrile, polyamide, polyvinyl alcohol, polyvinyl acetate, and polyvinyl chloride, polyurethane, polyvinyl urea, as well as the copolymers of these polymers. The fibrous materials may preferably be incorporated into the component in the form of short fibers having a length of 0.1 to 60 mm together with component B.

The addition of natural or synthetic fibers to the swellable polymer containing the component B causes a quicker absorption of water, aqueous liquids, and of the substances dissolved in water (fertilizer solution) by the swellable polymer. Said increased and, above all, quicker absorption of the liquid is due to the capillary action of the fiber proportion. For this reason, the addition of fibers (and the amount thereof) to the component B-containing polymer makes it possible to control - within certain limits - the release rate of the water-soluble fertilizer to the excess water (rain or watering), the transfer thereof to other bodies (e.g., plants), and the uptake of the fertilizer solution by a partially swollen or semidry polymer.

Additional materials can also be used as additive, for example, odoriferous substances to perfume the final product, disinfectants, antibacterial agents, dyestuff, but also neutral fillers to extend component A, such as wood flour, peat, ground shells of walnuts or pomaceous fruit, chitin-containing flour, sand, garden mold, or other extenders. Finally, it is also possible to add the finely ground component A in dried powder or partially swollen form together with component B to the polymer gel of component A.

2 The process according to the present invention consists in that component B is added to the swollen polymer gel of component A as a powder or in liquid condition or as a solution during the end phase of the production of component A, i.e., not before a polymer conversion of at least 90%, preferably at least 95%, and in

particular more than 98% has been achieved, and is subsequently further processed.

By further processing the mixture of the two components in a mixer provided with a rotary stirring mechanism and subsequent drying the mass of polymer gel at a temperature in the range of 50 to 260°C, if necessary, an end product is obtained in which component B (e.g. a fertilizer) is incorporated in the synthetic polymer in such a way that the water-soluble component B can be extracted from the swollen end product considerably slower than from a physical mixture of the two components.

A decelerated extraction of the fertilizer from the polymer body, i.e., a retarded release of the fertilizer to the excess water, may have very positive effects on practical applications for two reasons: First of all, in case of heavy rain, the fertilizer remains bound to the polymer body for a longer period of time and thus is available to the plants over a longer period of time, and, in the second place, the fertilizer components are washed out slower during rain or watering so that the ground water is polluted to a lesser extent. In both cases, an improved utilization of the fertilizer for plant growth is achieved.

Incorporating large-surface materials, such as short fibers, together with component B into the polymer gel provides additional advantages during drying of the end product. Due to the enlarged surface, drying periods are shortened so that drying, even at lower temperatures, can be carried out more efficiently.

Mixing the two components may be carried out in a suitable mixer. The mixer used in the following examples consisted of a vertical or horizontal metal cylinder whose stirrer was provided with guide blades thoroughly wiping the walls of the mixer drum. Once

a certain speed of the stirrer was achieved, the two components were evenly mixed over the total length of the metal cylinder and thoroughly kneaded along the walls.

A trough kneader with double-U-shaped cross-section can also be used to mix the two components A and B evenly. Within said trough, a pair of kneading shafts is moving in the same or opposite direction at the same or a different speed; depending on the material to be mixed the form of the blades may also be chosen selectively.

For this purpose, a trough kneader of Werner & Pfleiderer, Stuttgart, FRG, provided with toothed, oppositely running sigma blades can be used, for example. For continuous operation, the trough kneader may be provided with a discharging cylinder and a discharge screw which either works in reverse rotation to the trough interior and thus intensifies mixing and kneading, or which is switched in reverse direction to the material discharge.

Examples of further suitable devices for continuous operation include: single-shaft mixers, such as a single-screw extruder, kneaders, two-shaft mixers with twin worm operating in the same or opposite direction, conical cotruder-screw, double-shaft continuous kneader, and continuous multi-shaft devices, e.g., a four-screw extruder.

Low- or high-molecular, water-soluble or water-swellaable polymers on a synthetic or natural basis (e.g., polysaccharides in dissolved or swollen condition) may additionally be used as auxiliary binding agents to support the linkage of the two components A and B. Examples of water-soluble or water-swellaable polymers on a synthetic basis are polymers or copolymers based on (meth-)acrylic acid or (meth-)acrylic acid derivatives, such as the homo- or copoly-

mers of acrylic acid, methacrylic acid, 2-acrylamido-2-methylpropane sulfonic acid, of the salts of these acids, of the acrylamide or methacrylamide with one another or with vinyl pyrrolidone and/or vinyl acetate, as well as polyvinyl alcohol.

However, it is also possible to use low- or high-molecular polymers which are present as emulsion polymers in an aqueous dispersion in the form of tiny spherical particles solubilized by an emulsifier, with both forms of emulsion "oil-in-water" (for water-insoluble polymers) and "water-in-oil" (for water-soluble polymers) being useful. As is generally known, the oil phase in most cases consists of organic solvents which are not miscible with water, such as aliphatic hydrocarbons (e.g., hexane, white oil).

Examples of polymers capable of forming oil-in-water emulsions include polymers of butadiene, styrene, isoprene, chloroprene, acrylonitrile, vinyl acetate, vinyl- and vinylidene chloride, alkylacrylates and alkylmethacrylates, and copolymers of these monomers with one another and with methyl styrene, isobutylene, or ethylene.

Examples of polymers which are used in water-in-oil emulsions include the above-mentioned water-soluble or water-swelling polymers or copolymers based on (meth-)acrylic acid derivatives, they may be uncross-linked or cross-linked.

The final product consists of the components A and B at a weight ratio of 20 to 99.8%-wt., preferably 40 to 95%-wt. of component A, and 0.2 to 80%-wt., preferably 0.5 to 60%-wt. of component B, and/or 0 to 80%-wt. of a neutral filler.

To determine the liquid absorption capacity, a tea bag test was carried out. The liquid absorption of 0.2 g test substance was

gravimetrically determined in a tea bag after 10 minutes (maximum value) and after centrifuging, e.g., in a commercial spin dryer at 1400 rpm; this value was then converted to 1 g of product (retention value). An aqueous 0.9% NaCl-solution was used as test liquid.

The invention will be illustrated in more detail by the following examples.

Examples 1 and 2:

In a polymerization vessel, 423 g acrylic acid, 625 g acrylamide, and 4.2 g N,N'-methylenebisacrylamide were dissolved in 2100 ml water and neutralized with 680 g potash lye (45%). The catalyst components (1.02 g azobisamidine propane dihydrochloride, 0.24 g benzil dimethyl ketal (Irgacure 651, Ciba Geigy AG), and 1.04 g t-butyl hydroperoxide, dissolved in water) were added at room temperature, and the adiabatic polymerization started by UV-light under nitrogen. The resulting polymer gel was cut into pieces and mixed at different ratios with a commercial fertilizer (17-17-17), used as component B, in a mixing device. The sequence of numbers of the fertilizer relates to the content of the individual components of 17% K_2O , 17% P_2O_5 , and 17% nitrogen in the fertilizer.

Mixing and processing of the polymer gel with component B was carried out in a mixer with rotating stirring mechanism. The device consists of a vertical or horizontal metal cylinder (volume about 6000 ml), the agitator thereof is provided with guide blades which thoroughly wipe the walls of the mixing cylinder. After a speed of 300 rpm is achieved, on emergence of the rotary guide blades of the mixing device from the expelled individual particles of the mass, a fluidized bed forms on the total length of the metal

cylinder. At this stage, the two components are mixed and kneaded evenly.

Subsequently, the resultant mass of polymer gel was dried within a recirculating air dryer at 120°C and then ground. The absorption capacity of the final products was determined according to the tea-bag-test method (cf. Table 1).

Table 1:

	Component A	Component B	Tea bag test values		
	acrylic acid/ acrylamide co- polymer	fertilizer	maximum	retention	
	%-wt.	%-wt.	(ml/g)	(a) (ml/g)	(b) (ml/g)
	100	0	40.9	28.0	28.0
	0	100	0	0	0
Example 1:	91	9	36.4	25.2	27.7
Example 2:	83	17	33.5	22.9	27.6

Note: The tea-bag test values maximum and retention (a) relate to 1 g of the product composed of components A and B, retention (b) relates to 1 g of component A within the product.

The table shows that the absorption capacity of the composition (retention, maximum value) is supported by the proportion of component A only. Upon contact of the composition with water, the fertilizer incorporated in the swollen polymer body is washed out considerably slower as compared to a water contact on the ordinary mixture of components A and B. In practice, this results

in the desired retarded release of the fertilizer to other bodies, e.g., to plants.

Examples 3 and 4:

According to the procedure described in Example 1, 105 g acrylic acid, 945 g acrylamide, and 4.2 g N,N'-methylenebisacrylamide were dissolved in 2100 ml water in a polymerization vessel followed by neutralization with potash lye (45%) to pH = 6 and polymerization with the catalyst components as in Example 1. The resulting polymer gel was cut into pieces and mixed in portions and at different ratios with commercial fertilizer (17-17-17) (component B) in a mixer, drying at 180°C followed.

Table 2:

	Component A	Component B	Tea-bag test values	
	acrylic acid/ acrylamide co- polymer	fertilizer	maxi- mum	retention
	%-wt.	%-wt.	(ml/g)	(a) (b) (ml/g) (ml/g)
	100	0	25.0	16.6 16.6
	0	100	0	0 0
Example 3:	91	9	22.7	15.2 16.7
Example 4:	83	17	19.1	13.0 15.7

Note: The tea-bag test values maximum and retention (a) relate to 1 g of the product composed of components A and B, retention (b) relates to 1 g of component A within the product.

The table shows that the absorption capacity of the composition (retention, maximum value) is supported only by the proportion of component A. Upon contact of the composition with water, the washing-out rate of the fertilizer incorporated in the polymer body is by far lower than that of the simple mixture of components A and B when in contact with water. This means in practice that the desired delayed release of fertilizer to other bodies, e.g., to plants, is achieved.

Examples 5 and 6:

A polymer gel having a content of cross-linking agents of 0.3%-wt. (relative to polyacrylic acid) was produced according to the procedure described in Example 1; it was mixed with different amounts of fertilizer and cellulose short fibers in the mixer described above and processed in the same manner as in Examples 1 and 2. A polymer mass resulted having incorporated therein cellulose fibers and fertilizer, this was dried at 50°C and examined with respect to its absorption capacity. The results are summarized in the following table.

Table 3:

	Component A		Component B	
	Acrylic acid polymer %-wt.	Fertilizer %-wt.	Cellulose fibers %-wt.	
	100		0	
Example 5:	42.1	8.4	33.6	
Example 6:	54.1	7.7	19.4	

Table 3 (continued):

	Water content	Values of tea bag test	
		Retention	
	%-wt.	(a) (ml/g)	(b) (ml/g)
Example 5:	15.9	11.2	30.3
Example 6:	18.8	14.2	32.6

Note: The tea bag test values retention (a) relate to 1 g of the product composed of components A and B, retention (b) relates to 1 g of component A in the product.

Examples 7 to 12:

In a polymerization vessel 370 g acrylic acid, 1.1 g N,N'-methylenebisacrylamide were dissolved in 410 ml water and partially neutralized with caustic soda lye. The catalyst components (0.26 g azobisamidine propane dihydrochloride, 0.06 g benzil dimethyl ketal (Irgacure 651), and 0.26 g t-butyl hydroperoxide, dissolved in water) were added at room temperature and the adiabatic polymerization was started by UV-light. The resulting polymer gel was cut into pieces and mixed with citric acid and mixtures of citric acid and cellulose ground fibers in a mixer according to Examples 1 to 3, drying at 120°C followed. The composition of the polymer products in the individual examples and the tea bag test values are listed in the following table:

Table 4:

	Component A	Component B	
	Acrylic acid polymer %-wt.	Citric acid %-wt.	Cellulose fibers %-wt.
	100	0	0
Example 7:	99.8	0.2	0
Example 8:	99.0	1.0	0
Example 9:	98.0	2.0	0
Example 10:	74.6	0.7	24.7
Example 11:	74.1	1.5	24.4
Example 12:	73.0	3.0	24.0

Table 4 (continued):

	Tea bag test values	
	Maximum value (a) ml/g	(b) ml/g
Example 7:	47.4	47.5
Example 8:	47.2	47.6
Example 9:	47.2	48.1
Example 10:	35.5	47.6
Example 11:	34.9	47.1
Example 12:	33.9	46.4

Note: The tea-bag test value maximum (a) relates to 1 g of the product composed of components A and B, maximum (b) relates to 1 g of component A within the product.

Example 13:

A retarded release of the fertilizer incorporated in the cross-linked polymer was demonstrated according to the following test performance:

The polymer produced according to Example 1 having 16.7%-wt. of fertilizer (weight-in quantity 0.4 g) was mixed at a ratio of 1:1 with fine beach sand (particle size: 0.1-0.3 mm) and rinsed thoroughly thrice in succession on a glass filter, each time using 20 ml dist. water. The water which was not bound in the mixture was withdrawn, and the fertilizer concentration in the eluate was determined.

As comparative sample, 0.2 g fertilizer was also mixed with beach sand and washed through thrice in a row with 20 ml dist. water. The results are summarized in the following table:

Table 5:

Thorough washing with H ₂ O (20 ml)	Comparative sample		
	Quantity of eluate (ml)	Fertilizer concentration (mg NO ₃ '/l) (%-wt.)	
1.	20	5614	96.5
2.	20	192	3.2
3.	20	smaller than 20	0.3
Total amount of fertilizer in eluate			100.0
Residual amounts of fertilizer not washed away in sample			0

Table 5 (continued):

Thorough washing with H ₂ O (20 ml)	Polymer according to Example 1		
	Amount of eluate (ml)	Fertilizer concentration in eluate (mg NO ₃ '/l) (%-wt.)	
1.	12.5	2250	38.1
2.	11.5	1204	18.8
3.	10.0	724	9.8
Total amount of fertilizer in eluate			66.7
Residual amounts of fertilizer not washed away in sample			33.3

The results show that nearly all of the fertilizer (96.5%-wt.) is eliminated from the comparative sample already after the first thorough rinsing with 20 ml water. In case of the polymer according to the present invention, 62%-wt. of fertilizer remain in the swollen polymer gel after the first rinsing, after three times of washing 33.3%-wt. are still present, whereas the fertilizer is completely washed out in the comparison sample after these three washings.

Example 14:

A delayed release of the fertilizer contained in the cross-linked polymer was demonstrated in this example, with the fertilizer content in the sand sample and the amounts of water for sprinkling being chosen to correspond to practice-oriented conditions.

1. As comparative example to evaluate a fertilizer's property of being washed out from a soil sample (without added superabsorber), a commercial synthetic fertilizer 17-17-17 was mixed with fine beach sand (particle size 0.1 to 0.3 mm) first, irrigated several times with water on a glass filter (diameter 90 mm), and the concentration of washed-out fertilizer in the filtrate was determined.

Sprinkling of the sand layer was effected by a perforated plate (effect of a sprinkling can), the amount of water was chosen such that it approximately corresponded to the amount during heavy rainfall (5 - 8 l/m² within 5 min.). The sand layer of 120 g beach sand with the addition of 0.12 artificial fertilizer (0.1%-wt.) was about 1 cm high and needed 47.5 g water until complete saturation with water. Thus a total amount of 100 ml water were used for the first irrigation so that after saturation of the sand layer with water approximately 50 ml were flown through the sand layer as filtrate. The next and the further sprinklings were carried out with 50 ml of water. After each irrigation the amount of fertilizer was determined in the filtrate. After three irrigations with water, the moist sand layer was sprinkled with petri solution (0.118% solution of artificial fertilizer 17-17-17) twice, and the amount of fertilizer in the filtrate determined again. The results are listed in the following tables 6 and 7.

Table 6:

Eluviation of the sand layer used as soil sample consisting of: 120 g beach sand and 0.12 g synthetic fertilizer, thickness of layer: 1 cm, area: 63.6 cm².

	water amount sprinkled (g)	weight of soil (g)	Amount of water in the soil sample filtrate (g) (g)	
0	-	120.1	-	-
1.	100	167.5	47.4	52
2.	50	168.6	48.5	50
3.	50	166.7	46.7	50

Table 6 (continued):

	Fertilizer content in soil sample		in filtrate	
	(mg)	(%)	single sample (mg)	total (%)
0	120	100.0	-	-
1.	15.9	13.2	104.1	86.8
2.	4.1	3.4	11.8	96.6
3.	2.9	2.4	1.2	97.6

Table 7:

Irrigation of the washed-out sand layer with petri solution
(0.118% solution of artificial fertilizer 17-17-17)

	water amount sprinkled (g)	Weight of soil (g)	Amount of water in the soil sample filtrate (g) (g)	
0	-	166.7	46.7	-
1.	50	167.4	47.3	50
2.	50	167.8	47.7	50

Table 7 (continued):

	Fertilizer content			
	in the soil sample		in the filtrate	
	(mg)	(%)	single sample (mg)	total (%)
0	2.9	-	-	-
1.	47.9	-	13.8	23.5 ^{*)}
2.	56.4	-	50.3	85.8 ^{*)}

^{*)} Amount of fertilizer determined in the filtrate, relative to the amount of fertilizer in the respective petri solution used for sprinkling (50 ml)

2. In order to determine the removal of a fertilizer from a sample of soil with added superabsorber, 20%-wt. artificial fertilizer 17-17-17 were incorporated into the polymer gel according to Example 1 first, then the polymer gel was dried and ground. The dry, fertilizer-containing sample (0.6 g) was then mixed with 240 g fine beach sand and sprinkled several times with water as above; the amount of washed-out fertilizer in the filtrate was determined after each sprinkling. After five irrigations, the moist sand layer was subsequently rinsed with petri solution twice; the fertilizer content in the superabsorber-containing sand layer was determined.

The results are summarized in tables 8 and 9.

Table 8:

Washing-out of a soil sample consisting of 240 g beach sand, 0.48 g W 43 080 with 0.12 g synthetic fertilizer 17-17-17, layer thickness: 2 cm, area: 63.6 cm².

	Amount of sprinkled water (g)	Weight of soil (g)	Amount of water in the soil sample			filtrate (g)
			total (g)	bonded(a) (g)	bonded(b) (g)	
0	-	240.6	-	-	-	-
1	150	343.3	102.7	7.7	16.0	50
2	50	370.3	129.7	34.7	72.3	25
3	50	397.7	157.1	62.1	129.4	23
4	50	425.1	184.5	89.5	186.5	23
5	50	448.6	208.0	113.0	235.4	28

Table 8 (continued):

	Fertilizer content			
	in the soil sample		in the filtrate	
	(mg)	(%)	single sample (mg)	total (%)
0	120	100	-	-
1	83.3	69.4	36.7	30.6
2	57.9	48.2	25.4	51.8
3	39.6	33.0	18.3	67.0
4	27.4	22.8	12.2	77.2
5	19.7	16.4	7.7	83.6

Note: bonded(a) = ... water amount bonded in the soil
sample by the superabsorber

bonded(b) = ...water amount bonded in the soil
sample by the superabsorber
relative to 1 g superabsorber

240 g beach sand (without superabsorber) require

95 ml water up to complete saturation with water.

Table 9:

Sprinkling of the washed-out sand layer (Table 8) with petri solution

	Amount of petri solution (g)	Weight of soil (g)	Amount of water in the soil sample filtrate			
			total (g)	bonded(a) (g)	bonded(b) (g)	(g)
0	-	448.6	208.0	113.0	235.4	-
1	50	434.7	194.1	99.1	206.5	63
2	50	415.8	172.2	80.2	167.1	68

Table 9 (continued):

	Fertilizer content			
	in the soil sample		in the filtrate	
	(mg)	(%)	single sample (mg)	total (%)
0	19.7	-	-	-
1	71.3	-	7.2	12.2*)
2	110.2	-	19.9	33.8*)

*) Fertilizer amount determined in the filtrate, relative to amount of fertilizer in the petri solution (50 ml).

Note: bonded^(a) = ... water amount bonded in the soil sample by the superabsorber
 bonded^(b) = ...water amount bonded in the soil sample by the superabsorber
relative to 1 g superabsorber

240 g beach sand (without superabsorber) require
 95 ml water until complete saturation with water.

The comparison of Tables 6 and 8 shows that the eluviation of the fertilizer from the sand layer without added superabsorber amounted to 57% after only one irrigation (Table 6), after two sprinklings the fertilizer was nearly completely washed out (i.e., up to 97%). In contrast to that, the addition of fertilizer-containing superabsorber to the same sand sample resulted in considerably slower wash-out of the fertilizer from the sand layer (Table 8). After the first irrigation of the completely water-saturated soil sample, 70% and after the second irrigation 45% of fertilizer remained in the sand layer.

When the sand layer from which the fertilizer had been washed out was sprinkled with petri solution (Tables 7 and 8), more of the fertilizer from the petri solution remained bonded within the sand layer in which the synthetic, cross-linked polymer was present (Table 9).

The water amount of 50 ml used for sprinkling corresponds to a precipitation of 7.86 mm on the test area of 63.6 cm². The total amount of water (350 ml) used for irrigation according to Table 8 thus corresponds to rain of 55.0 mm fallen within a relatively short period of time, this, in turn, may be compared with a tropical heavy rain (35 - 50 mm precipitation within 2 to 3 hours). Heavy

rainfall in our climatic conditions causes only 5 - 8 mm precipitation.

The fertilizer's property of being washed out was determined in a layer of 2 cm thickness which was sprinkled with water several times. The flow rate of water through this relatively thin layer was quite high so that swelling of the superabsorber - which depends on time - could take place incompletely; this can be recognized in Table 8 (water amount bonded in the soil sample) after each respective irrigation. Nevertheless, the water amount bonded in the sample of soil clearly increases after each irrigation. This layer of 2 cm thickness represents the upper layer of the earth sample which actually is affected by rinsing through with rain to the greater extent. In a test corresponding to the real conditions in plant culture with a thickness of the soil layer of more than 2 cm, the water flow through this thicker layer is slower so that even more water can be absorbed by the superabsorber and thus less fertilizer is washed out of the soil layer.



CLAIMS

1. A process for the production of absorbing material for water, aqueous solutions and body liquids, the absorbing material consisting of at least two components A and B, wherein component A is at least a water-swellaable synthetic polymer or copolymer, and component B is at least a natural or synthetic compound which, at normal temperature, is present as a pourable powder highly or at least partially soluble in water, or as a liquid, characterized in that component B is added to component A in the form of a powder or liquid, or as a solution during the end phase of the manufacturing process of component A, after a polymer conversion of at least 90%, preferably at least 95% has been attained, that it is mixed with the polymer gel of component A and, for the purpose of obtaining a powdery, pourable end product, is dried, if necessary, and ground.
2. The process according to claim 1 characterized in that component B is added to component A not before the end phase of the manufacturing process of component A, after a polymer conversion of more than 98% has been attained.
3. The process according to claim 1 or 2 characterized in that component B is used in dried state as a powder or in an aqueous solution.
4. The process according to any one of claims 1 to 3 characterized in that component A is a cross-linked polymer or copolymer based on acrylic acid, methacrylic acid, derivatives of said carboxylic acids, preferably is a homo- or copolymer of acrylic acid, methacrylic acid, 2-acrylamido-2-methylpropane sulfonic acid, of the alkali- or ammonium salts of said carboxylic acids, of acrylamide or methacrylamide and their derivatives, of vinyl



pyrrolidone as well as the copolymers thereof with one another or with other, only partially water-soluble monomers, preferably vinyl acetate.

5. The process according to any one of claims 1 to 4 characterized in that component A is a cross-linked polymer or copolymer, with difunctional and polyfunctional compounds being used as cross-linking agents.

6. The process according to any one of claims 1 to 5 characterized in that a fertilizer is used as component B.

7. The process according to any one of claims 1 to 6 characterized in that in addition to component B at least one polysaccharide or polysaccharide derivative, preferably modified cellulose, starch, dextrin, or gum resin or a mixture thereof is added.

8. The process according to any one of claims 1 to 6 characterized in that in addition to component B natural fibers, preferably wool, silk, cotton, or cellulose fibers, preferably fibers of viscose, acetate, or triacetate, or synthetic fibers, preferably fibers of polyester, polyolefin, polyamide, polyvinyl alcohol, polyurethane, polyurea, or polyacrylonitrile, preferably in the form of short fibers, are added.

9. The process according to any one of claims 1 to 6 characterized in that a neutral filling agent, preferably peat, sand, clay, garden mold for the cultivation of plants, other fertilizers, dyestuff, pigments, ground shells of nuts or pomaceous fruit, wood flour, chitin-containing flour, in admixture with component B, or the ground component A itself in powder or partially swollen form is incorporated into component A.



10. The process according to any one of claims 1 to 9 characterized in that the end product comprises 20 to 99.8%-wt., preferably 40 to 95%-wt. of component A, and 0.2 to 80%-wt., preferably 0.5 to 30%-wt. of component B, and/or 0 to 80% of a neutral filler.

11. An absorbing material obtainable according to the process as defined in any one of claims 1 to 9, characterized in that the diffusion-controlled movability of component B is lower in the water-swollen absorbing material than in a physical mixture of the two components A and B.

12. The use of the absorbing material according to claims 1 to 10 for the absorption and/or retention of water and/or aqueous solutions and for the subsequent controlled release of water and of the substances comprised in the swollen polymer gel and soluble in the aqueous medium (component B) to other bodies, preferably plants, as nutrients for various cultures, and in the controlled dosage of nutrients or drugs.