Table S1: Selected representative studies investigating the fate of synthetic superabsorbent polymers (SAPs) in soil and related systems. The table highlights that commonly reported "degradation" endpoints often characterize fundamentally different environmental processes, ranging from functional deterioration and physicochemical transformation to retention, reduced recoverability, and true microbial mineralization. Consequently, reported degradation rates are frequently not directly comparable across studies.

Study	Polymer(s) investigated	Endpoint(s) measured	Main environmental process(es) assessed	(In)direct key finding(s)	Major limitation(s)
Buchmann et al., 2026	Linear PAA	SI, ^{1}H-NMR, rheology, ATR-FTIR, ESEM	Physico-chemical transformation and organo-mineral integration	Reduction of SI by 13-24% after 10 weeks; soil texture effects > freezing–thawing effects; changes in functional groups	No direct biodegradation or mineralization assessment; no isotopic tracing or quantification of residual polymer fractions
Neff and Buchmann, 2026	Linear PAA and PAM	SI, ^{1}H-NMR, rheology, ATR-FTIR, ESEM	Chemical transformation and network aging	PAA: reduction of SI by 20-57% after 10 drying-rewetting cycles; PAM: largely unchanged; changes in functional groups	No direct biodegradation or mineralization assessment; no isotopic tracing or quantification of residual polymer fractions
Gu et al., 2025	Sodium polyacrylate	SI, TGA, FTIR, ^{1}H-NMR	Functional deterioration; chemical transformation; fragmentation	Indirect: PA aging within 70 days. Reduction of SI by 46.9% with new 0.1-10 µm fragments formation; mean particle size decreased by 38.3% and median particle size by 48.0%. Ester groups nearly disappeared and carboxylate content increased substantially	No polymer-specific mass balance, recovery, extractability, NER quantification, isotope tracing, or mineralization assessment; fragmentation and chemical aging were inferred, but ultimate environmental fate of SAP remained unresolved.
Bai et al., 2015	^{13}C-labelled linear PAA	$^{13}CO_2$ evolution, microbial biomass incorporation	Mineralization and microbial assimilation	Direct: 0.91% (long-chain PAA) and 1.85% (short-chain PAA) mineralized after 149 days	Linear PAA only; extrapolation required for whole-product assessment
Buchmann and Schaumann, 2017	Linear PAA	Swelling, ^{1}H-NMR, rheology, ESEM	Polymer-soil interactions and structural stabilization	Microstructural stability increased up to 5x following PAA addition, indicating strong polymer-mediated soil structural integration	No degradation or mineralization assessment

Study	Polymer(s) investigated	Endpoint(s) measured	Main environmental process(es) assessed	(In)direct key finding(s)	Major limitation(s)
Lejcuś et al., 2018	Crosslinked potassium polyacrylate and PAM	SI, AUL	Functional deterioration under mechanical soil loading	Indirect: reduction of SI by ~94% with increasing soil load	Assessed mechanical suppression of SAP swelling rather than degradation; no polymer quantification, transformation-product analysis, extractability assessment, mineralization measurement, or mass balance.
Holliman et al., 2005	Crosslinked anionic PAM (Aquastore®)	HPLC, TOC, enzyme activity, microbial biomass	Functional deterioration and physico-chemical aging, monomer release	Monomer release: 11 µg/L acrylamide, and 285 µg/L acrylic acid for fresh PAM; <1 µg/L acrylamide and <7 µg/L acrylic acid for field-aged PAM (1-6 years); WHC decreased significantly within 18 months	Functional loss does not demonstrate polymer mineralization; used artificial substrates not representative for soil
Oksińska et al., 2019	Crosslinked potassium polyacrylate	Dry-mass loss, soil microbial colonization	Fragmentation and apparent disappearance	Indirect: 77.9% dry-mass loss after 9 months	No polymer-specific quantification or mineralization assessment
Liang et al., 2018	Polyacrylate	Dry-mass loss, FTIR, SEM, LIBS	Functional deterioration, chemical transformation, and surface aging	Indirect: 1.77% dry-mass loss after 12 months; degradation was restricted primarily to the polymer surface layer	No mineralization or polymer mass-balance information
Oksińska et al., 2016	Crosslinked acrylamide/potassium acrylate copolymer	Dry-mass loss, swelling reduction	Functional deterioration and apparent disappearance	Indirect: 31.7% dry-mass loss after 9 months	Dry-mass loss may reflect fragmentation or analytical losses rather than biodegradation

Study	Polymer(s) investigated	Endpoint(s) measured	Main environmental process(es) assessed	(In)direct key finding(s)	Major limitation(s)
Kay-Shoemake et al., 1998	Linear anionic PAM	Amidase activity, Nitrogen (N) release, microbial utilization	Microbial transformation of amide groups	Indirect: PAM served as a microbial N source but not as a C source; NO_3^- increased from 10.7 to 36.7 mg kg^{-1} and NH_4^+ from 0.5 to 1.3 mg kg^{-1} in PAM-treated soil	No polymer quantification, mineralization measurement, or mass balance
Wilske et al., 2014	^{13}C-labelled crosslinked PAA	$^{13}CO_2$ evolution	Mineralization	Direct: 0.45-0.82% total mineralization after 24 weeks; estimated backbone mineralization only 0.12-0.24%	No parent-polymer quantification or bound-residue characterization
Stahl et al., 2000	^{14}C-labelled polyacrylate; polyacrylate/PAM copolymer	$^{14}CO_2$ evolution, soluble fractions	Mineralization and solubilization	Direct: <1% mineralization after 76 days	Optimized fungi-soil system; low environmental realism
Sutherland et al., 1997	^{14}C-labelled polyacrylate/PAM copolymer	$^{14}CO_2$ evolution, soluble fractions	Mineralization and depolymerization	Direct: ~3-8% mineralization after ~80 days	Liquid fungal cultures; limited environmental relevance for soils
Wolter et al., 2002	^{14}C-labelled crosslinked acrylic acid/acrylamide copolymer	$^{14}CO_2$ evolution, extractable ^{14}C fractions	Mineralization and depolymerization	Direct: 1.1-2.2% mineralization (soil microbiota), up to 5.3-8.8% mineralization in soil with fungi, and up to 31% mineralization in wheat-straw fungal systems after 22 weeks	Low mineralization despite extensive depolymerization; no long-term field relevance
Lande et al., 1979	^{14}C-labelled acrylamide monomer	$^{14}CO_2$ evolution, extractable residues	Mineralization and mobility	Direct: 30-65% mineralization within days depending on soil, temperature, and concentration	Investigated acrylamide monomer rather than polyacrylamide; no polymer persistence assessment; incomplete mass balance

Study	Polymer(s) investigated	Endpoint(s) measured	Main environmental process(es) assessed	(In)direct key finding(s)	Major limitation(s)
Sack et al., 1998	Crosslinked polyacrylate; linear PAA	Polymer recovery during column leaching	Retention and extractability	Crosslinked polyacrylate: 0.34% recovered, >99% retained in sand; Linear PAA: 8% recovered; 92% retained in sand; virtually complete retention in loam soil	Mobility study only; no degradation or mineralization assessment
Lu et al., 2002	Linear anionic PAM	Sorption isotherms	Sorption and immobilization	95.8-103.7% recovery (analytical method validation); relative standard deviation <7.5%	No degradation, transformation-product, or mineralization data
Huppertsberg et al., 2020	PAA, PAM and other water-soluble polymers	SEC-MS, HRMS	Polymer occurrence and transformation-product detection	No quantitative fate data reported; highlighted that environmental concentrations, occurrence, transformation, and persistence of water-soluble polymers remain largely unknown due to analytical limitations	Conceptual analytical workflow; no biodegradation measurements
Smagin et al., 2022	Commercial PAA- and PAM-based SAPs (Aquasorb®, Zeba®, Aquapastus®)	Bulk CO_2 evolution	Apparent biodegradation	Indirect: estimated half-lives 0.6-6.6 years based on CO_2 evolution	No isotopic tracing; CO_2 origin unresolved
Buchmann et al., 2025	Linear PAA	WHC, substrate-induced respiration, CO_2 evolution, ESEM	Functional deterioration and physico-chemical aging	Indirect: PAA functionality declined over time through cation-induced crosslinking, sorption to minerals/SOM, and drying-rewetting effects; Soil extracts reduced SI of PAA by 27-39% in sand and loam relative to water controls	No direct biodegradation or mineralization assessment; no isotopic tracing or quantification of residual polymer fractions

Study	Polymer(s) investigated	Endpoint(s) measured	Main environmental process(es) assessed	(In)direct key finding(s)	Major limitation(s)
Malik et al., 1991; Malik and Letey, 1991; Nadler et al., 1992	Tritium-labelled anionic PAM	Polymer adsorption coefficients	Sorption and retention	K_d = 0.13-2.60 L kg^{-1} (strong adsorption); Strong retention with negligible leaching; 59-76% irreversibly bound with very limited desorption	No degradation, mineralization, or long-term fate assessment
Hennecke et al., 2018	^{14}C-labelled cationic PAM flocculant	Extractable ^{14}C fractions, NERs, dialysis recovery, GPC, mass balance	Extractability, retention, NER formation	<40% extraction efficiency ($ZnCl_2$ / $CaCl_2$ extraction); 120-125% apparent recovery (0.5-1 M NaOH extraction); >97% retained in solution after dialysis; 92% recovered after concentration prior to GPC; ~75% NER following $ZnCl_2$ extraction	Recovery estimates depended strongly on the extraction procedure. NaOH extraction hydrolyzed PAM, likely increasing apparent extractability and reducing measured NER fractions, thereby complicating interpretation of polymer persistence
Entry et al., 2008	Anionic PAM	IRMS	Natural $\delta^{13}C/\delta^{15}N$ ratio as a proxy for concentration and degradation	49% degradation after 6 years and 74% after 12 years (2691 kg ha^{-1}); 13% degradation after 6 years and 73% after 12 years (5382 kg ha^{-1}). Estimated degradation rate: 9.8% y^{-1}	Degradation inferred indirectly from natural-abundance $\delta^{13}C$ signatures in a low-OM soil. Method not applicable in high-OM soils; no direct quantification of mineralization, transformation products, microbial incorporation, or C mass balance