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REMOVAL OF AGRICULTURAL CONTAMINANTS FROM GROUNDWATER

by

Ben W. Lykins, Jr.
U.S. Environmental Protection Agency
Water Engineering Research Laboratory
Drinking Water Research Division
Cincinnati, OH 45268

Joseph H. Baier
Suffolk County Department of Health Services
225 Rabro Drive East
Hauppauge, New York 11788

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16. ABSTRACT

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Ben W. Lykins, Jr.
Drinking Water Research Division
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U.S. Environmental Protection Agency
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Joseph H. Baier
Suffolk County Department of Health Services
225 Rabro Drive East
Hauppauge, New York 11788

Introduction

Suffolk County, New York's groundwater has been designated as a sole source aquifier under provisions of the Safe Drinking Water Act (P.L. 93-523). In recent years there has been increasing concern about the contamination of this groundwater by agricultural chemicals (fertilizers, insecticides, herbicides, nematocides, and fungicides). This concern expanded when specific chemicals were identified in homeowner drinking wells.

For over eight years, Suffolk County has examined their groundwater for agricultural organic constituents and their decay products. During this testing, 101 agricultural/organic compounds were evaluated with 41 found in the groundwater. Many of these identified contaminants were present in trace quantities but aldicarb, carbofuran, 1,2-dichloropropane, and 1,2,3-trichloropropane were at elevated levels. In addition, nitrates from fertilizer application were present in quantities exceeding the primary drinking water standards.

A cooperative agreement was initiated by the U.S. EPA Drinking Water Research Division, Cincinnati, Ohio to examine the cost-effectiveness and removal efficiency of certain water treatment systems to remove organic and pesticide contamination, in combination with nitrate, from Suffolk County groundwater under various flow situations. Two parallel treatment systems, granular activated carbon plus ion exchange versus reverse osmosis, will be operated at low flow, similar to home usage. The costs of these two systems, together with unit operating efficiency, will be established so that a larger public water supply system can be designed and tested. The results from this study will be applicable to other areas where multiple contamination of groundwater is identified, especially in farming communities.

Background

Agriculture has been a major industry in Suffolk County's North Fork (Figure 1) for over 200 years. Approximately 26,000 acres of land in this area (36%) is cultivated primarily for potatoes.(1) The North Fork soils, consisting of 6 to 24 inches of loamy top soil over thick layers of coarse sand and gravel, are particularly suited for growing potatoes.

Fertilization practices, with as much as 250 lb of nitrogen per acre applied, led to widespread nitrate contamination of the shallow aquifer.(2) The potato plant is susceptible to a number of pests, most nobably the golden nematode, which attacks the roots, and the Colorado potato beetle, which eats the leaves. Since the early 1950s, pesticides containing 1,2-dichloropropane have been applied to fields infested with golden nematodes. In 1974, the carbamate pesticide aldicarb (TEMIK, Union Carbide Corp.) was registered for use on potatoes and by 1976 was being used at an application rate of about 3 pounds of active aldicarb per acre.(3)

Aldicarb was used extensively for four growing seasons in Suffolk County before its sale was prohibited. A direct relationship exists between the proximity of a well to an agricultural field and the presence of aldicarb. Based upon the flow pattern of the groundwater, Suffolk County and Cornell University have estimated that over 100 years will be required to purge the aquifer of aldicarb.(1)

Groundwater contamination by agricultural chemicals is not specific to Suffolk County. The states of Florida, Wisconsin, and Rhode Island have also identified problems. For instance, Rhode Island found aldicarb, carbofuran, and vydate up to concentrations of 150, 7, and 2 ug/L, respectively, in the groundwater. After testing 73 drinking water wells, 5 contained aldicarb above 10 ug/L and 14 wells had a trace.(4)

Well Contamination

The New York State guideline for aldicarb is 7 ug/L and some representative concentrations in private wells in Suffolk County are shown in Table 1.

Testing for 1,2-dichloropropane began in 1980. In one community, this contaminant was found in 17 of 33 wells with two wells containing concentrations around the New York State guideline of 50 ug/L. A second community showed 2 of 9 wells with concentrations of 10-15 ug/L, and a third area had a private well with a concentration of 49 ug/L.(1) Testing is being done for other organic contaminants as new agricultural pesticides are applied.

A large portion of the aquifer contains nitrate levels that approach or exceed the U.S. EPA and New York State drinking water standard of 10 mg/L. The major source of the nitrate is fertilizer. Shown in Table 2 are nitrate concentrations from two communites in Suffolk County.

Research Project Objectives

For effective crop production, fertilizers containing nitrates and chemicals to control insects, weeds, fungus, etc. will continue to be applied. Therefore, treatment of groundwater contaminated by this type of application will be required to produce an acceptable drinking water.

The objectives for this study were developed to address the removal of multiple contaminants from a groundwater source. These objectives were (1) to determine appropriate treatment for removing organics and/or pesticides in combination with nitrate from a groundwater source and (2) to determine cost effectiveness and removal efficiencies under different flow situations simulating homeowner use versus a municipal water system.

Within the framework of this research initiative, two different sized treatment systems will be evaluated. One system will consist of using small-scale flow rates comparable to home treatment systems to evaluate (1) carbon adsorption (GAC) followed by ion exchange, and (2) reverse osmosis. Operation and maintenance costs along with removal efficiencies will be documented while operating in continuous and intermittent modes simulating homeowner use. The second system will consist of the most effective treatment methodology selected from the small-scale flow rate study with evaluation on a larger scale simulating centralized treatment.

Site Selection

Selection of a well site for the small-scale flow rate research effort included reviewing data from over 14,000 wells. Water quality representative of what homeowners normally encounter rather than exceptionally poor quality was one selection criteria. Ten sites were selected for further consideration based upon water quality (Table 3).

Additional requirements for selection included the following factors: (1) site accessibility, (2) existing buildings available and amount of site work and construction required, (3) availability of utilities, (4) available assistance and cooperation from site owners, (5) use of effluent, (6) facilities to handle regeneration and reject water, (7) well capacity, and (8) security. Table 4 shows these factors applied to the potential research sites.

Also, private wells were eliminated from consideration because of potential problems that could occur during the research activities. Another well was eliminated because of seasonal use. Therefore, three sites presented in Table 3 had the potential required qualities (1, 2, 10). Site 10 was selected because of the availability of a large building to house the treatment equipment and the presence of typical water quality.

R. O. Membrane Evaluation

As the literature was searched and membrane manufacturers contacted, there was an apparent lack of information on the performance of reverse osmosis (R.O.) membranes for the combination of contaminants of concern (aldicarb, carbofuran, 1,2-dichloropropane, 1,2,3-trichloropropane, and nitrate) at Suffolk County. Therefore, pilot testing of applicable R.O. membranes was done to evaluate contaminant removal before proceeding with the planned research effort. Known manufacturers of R.O. membranes were contacted and asked to supply a commercially available membrane(s) they thought would remove these contaminants.

Received for parallel bench-scale evaluation were the following types of membranes that correspond to the R.O. unit sizes on-site.

- Culligan cellulose acetate tubular, 2 inch
- Dupont polyamide spiral-wound, 2-1/2 inch
- Dupont polyamide hollow-fiber, 4 inch
- FilmTec polyamide spiral-wound, 2-1/2 inch
- Hydranautics polyamide spiral-wound, 2-1/2 inch
- Fluid Systems polyamide spiral-wound, 2-1/2 inch
- FilmTec polyamide spiral wound, 2 inch

All units were operated continuously at a pressure of 160-200 psi. Each membrane was tested from 5 to 24 weeks. The test units were fed from a common raw water source and sampled twice weekly. Results from this evaluation are shown in Table 5 and the following observations can be made.

- Cellulose acetate is not satisfactory for certain organics removal, but it was able to remove carbamates.
- Polyamide membranes can satisfactorily remove carbamates and nitrates.
- The polyamide membrane from FilmTec showed the best removals during this limited test.
- Dupont's spiral polyamide membrane did not perform as well as its hollow-fiber configuration.
- Dupont's hollow-fiber performed equally to the FilmTec spiral-wound polyamide membranes for 1,2,3-trichloropropane and somewhat poorer for 1,2-dichloropropane.

Although recovery was not an issue during this testing, the hollow-fiber did consistently recover more water at the same operating pressure of 160 psi. It also produced no pH decrease in the effluent, and the product water conductivities were higher than the spiral-wound configuration (Table 6). The latter parameters are desirable features in product water relative to corrosivity.

As a result of these tests, a performance specification was developed for a polyamide membrane unit:

Contaminant	Rejection
carbofuran	95%
aldicarb sulfoxide	95%
nitrate	95%
aldicarb sulfone	90%
total dissolved solids	85%
1,2-dichloropropane	67%
1,2,3-trichloropropane	67%

at: 400 psi feed pressure
5.0 gpm product flow rate
55°F.
50% recovery (minimum)
400 hours of use
either spiral-wound or hollow-fiber is an acceptable configuration

GAC and Ion Exchange Selection

Manufacturers of granular activated carbons and ion exchange resins were contacted to determine the appropriate type of media to meet the research project objectives. Seven different GACs from five manufacturers and four ion exchange resins from four manufacturers were evaluated. Batch isotherm tests were run to determine the capacity of the GACs and resins as a comparative evaluation for selection of one GAC and resin for further studies. Rate studies were not performed.

GACs evaluated included: CECA GAC 40 and GAC 1240, ICI Darco H-90 Plus and Hydrodarco 4000, Calgon Filtrasorb 300, Westvaco Nuchar WV-G, and Sybron Ionac P-50. Rohm and Haas Amberlite XAD-4 adsorptive resin was also evaluated. The ion exchange resins tested for nitrate removal effectiveness included: Sybron Ionac ASB-2, Purolite A-300, Duolite A-101D, and Rohm and Haas Amberlite IRA-410. All of these are strong-base type anion exchange resins.

Based on the isotherm study, ICI Darco H-90 Plus and Calgon Filtrasorb 300 GACs were selected for further study. All of the four ion exchange resins tested were comparable in performance and were listed in the bid specifications.

Pilot Plant

The existing 2" diameter well at the selected site yielded a flow of about 15 gpm. From design estimates, a total of 30 gpm will be needed for the various treatment options. Before replacing the well, a test well was installed adjacent to the existing well and sampled at 10 different depths ranging from 46 to 130 feet below grade. The major contaminants of concern all had different profiles (Table 7).

Total aldicarb increased to a maximum of 91 ug/L at 71 feet and decreased to <1 ug/L at 112 feet. At 62 feet, 1,2-dichloropropane was present increasing to a maximum of 68 ug/L at 112 feet and still present at 132 feet. Nitrate was detected at the surface of the water table to a maximum of 13 mg/L at 82 feet with a concentration of 5 mg/L at 132 feet. A screen setting at 70-80 feet below grade surface was selected as the most appropriate depth to evaluate the contaminants of concern and be consistent with normal well depth in Suffolk County.

The well will discharge into a 10,000 gallon storage tank so that a constant supply of water can be ensured for the system and allow for "spiking" of contaminants should the quality of well water change (Figure 2). Following the storage and pumping system are in-line fibrous material filters to remove any particulates, oxidized iron, etc. After the filters, the flow will be split into the reserve osmosis and adsorption/ion exchange systems. All discharges (treated, reject, backwash, and regenerate water) will be directed to a main drain line that will convey the water to a cesspool located downgradient from the well.

Summary

As analytical testing of community and individual homeowner wells has intensified, more drinking water contamination has been identified. In some instances this contamination can be attributed to agricultural practices. Of special concern are those locations where no community treatment system can be provided. Examination of various treatment methods applicable to both individual and small community situations that are cost-effective in removing these contaminants will address an area of concern that is gaining more attention. In situations where multiple contaminants, especially low molecular weight compounds, are found, pilot studies similar to this study with proposed treatment systems are recommended to more accurately predict the performance of larger units.

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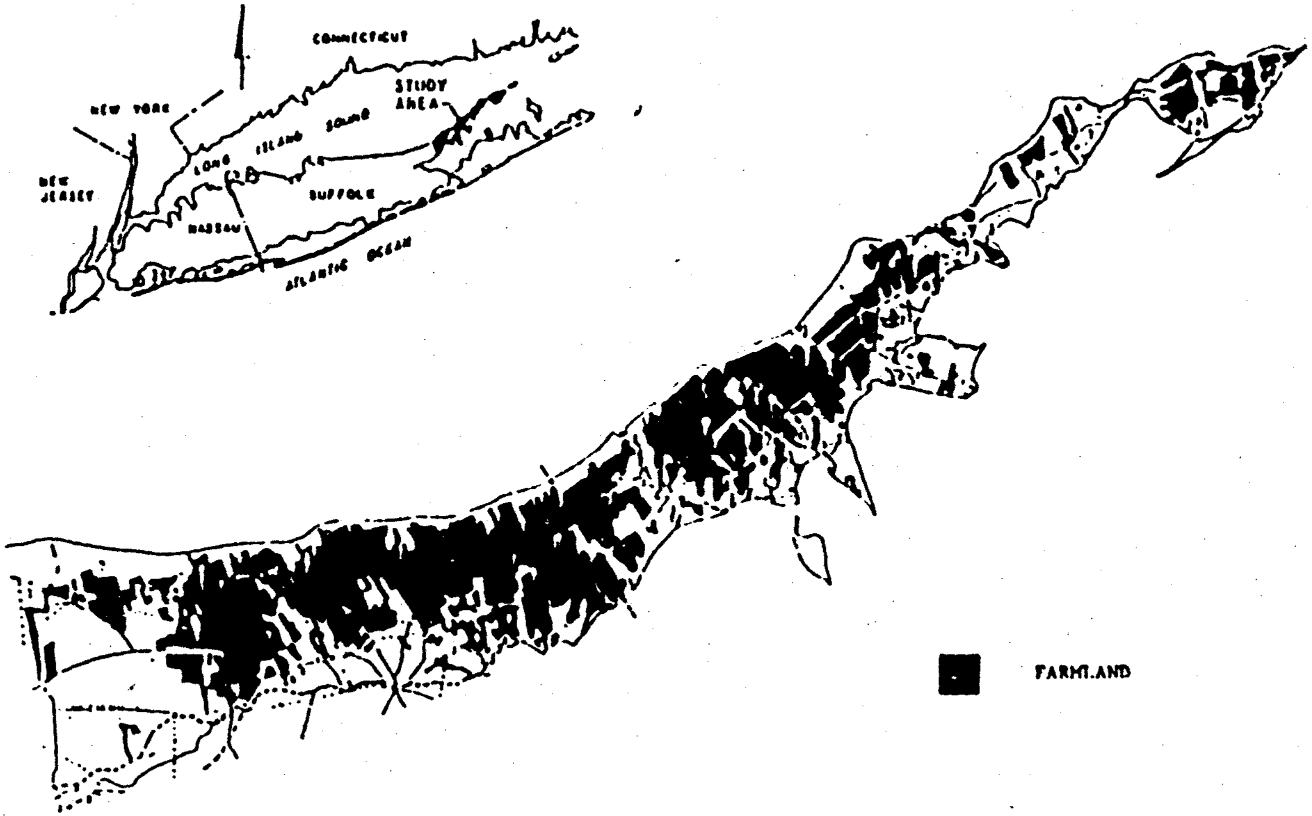

FIGURE 1, FARMLAND ON SUFFOLK COUNTY, NEW YORK'S NORTH FORK

TABLE 1. ALDICARB CONCENTRATIONS IN PRIVATE DRINKING WATER WELLS[1]

Community	Number of Wells Sampled	1-7 ug/L	> 7 ug/L
1	222	18	2
2	434	46	43
3	2161	345	351
4	1832	256	270
5	3160	374	359

TABLE 2. NITRATE CONCENTRATIONS IN PRIVATE DRINKING WATER WELLS[2]

Community	Number of Wells Sampled	0-5 mg/L	5-10 mg/L	> 10 mg/L
1	639	372	167	100
2	1121	575	354	192

TABLE 3. WATER QUALITY RESULTS FROM POTENTIAL STUDY SITES

Parameter	Site Location									
	1	2	3	4	5	6	7	8	9	10
Free ammonia, mg/L N	<.04	<.04	<.04	24.5	<.04	<.04	<.04	8.10	<.04	.04
Nitrates, mg/L N	10.8	13.2	7.4	.4	4.4	25.5	9.0	1.7	13.8	9.1
pH	6.1	6.3	5.8	6.9	6.3	5.9	6.0	6.0	—	5.9
Spec. Cond., umhos/cm	510.	660.	590.	1230.	400.	650.	425.	430.	—	450.
Chlorides, mg/L	54.	43.	89.	125.	67.	45.	33.	30.	23.	40.
Sulfates, mg/L	126.	201.	90.	105.	46.	162.	100.	108.	90.	105.
Iron, mg/L	.12	.16	<.10	>25.10	<.10	.18	.15	1.78	<.10	2.6
Manganese, mg/L	<.05	<.05	<.05	>7.20	<.05	<.05	<.05	.05	<.05	.16
Cooper, mg/L	<.10	<.10	<.10	.21	<.10	.12	.17	.10	<.10	.45
Zinc, mg/L	<.4	<.4	<.4	<.4	<.4	<.4	<.4	5.8	<.4	<.4
Sodium, mg/L	11.2	24.2	34.4	115.	21.5	11.5	17.7	12.2	7.5	1.2
T. Hardness, mg/L $CaCO_3$	196.	288.	176.	272.	80.	324.	—	—	156.	196.
T. Alkalinity, mg/L $CaCO_3$	12.	18.	12.	388.	26.	16.	—	—	—	16.
Aldicarb, ug/L	15.	86.	1.	ND	7.	84.	16.	ND	9.	33.
Carbofuran, ug/L	—	21.	ND	1.	—	8.	—	ND	16.	9.
Dacthal, ug/L	ND	90.	ND	ND	ND	ND	ND	ND	ND	ND
1,2-dichloropropane, ug/L	ND	ND	ND	36.	24.	ND	ND	5.	ND	37.
1,2,3-trichloropropane, ug/L	ND	ND	ND	6.	ND	ND	ND	ND	ND	20.

ND: Not detected

TABLE 4. FEATURES OF POTENTIAL STUDY SITES

Factors for Consideration	Site Location									
	1	2	3	4	5	6	7	8	9	10
Accessibility	good	good	good	good	good	good	good	NA	good but seasonal	good
Utilities	good	good	poor; no electric	good	good	poor	poor; no electric	NA	good	good
Assistance	good	poor	good	good	good	poor	good	NA	good	good
Discharge	good	good	poor	good	good	poor	poor	poor	good	good
Well Capacity	400 gpm	40 gpm	200 gpm	200 gpm	275 gpm	10 gpm	200 gpm	10 gpm	100 gpm	15 gpm
Security	poor; no fence	poor; no fence	poor; no fence	good	poor; no fence	NA	poor; no fence	pobr	good	good
Housing	poor; sm.bldg.	poor; in ground	poor; sm. bldg.	poor; no bldg.	noor; sm.bldg.	good; lg. barn	poor; sm. bldg.	poor; in ground	boiler room	good;in lg.bldg
Construction Capability	good	poor	good	good	good	NA	good	poor	good	good

NA: information not available

TABLE 5. REVERSE OSMOSIS MEMBRANE EVALUATION

Type of Membrane	Diameter of Membrane	Feed Flow Rate L/min (gpd)	% Recovery	Aldicarb* Sulfoxide		Aldicarb* Sulfone		1,2-di-* chloropropane		1,2,3-tri-* chloropropane		Carbofuran*		Nitrates*	
				Feed ug/L	Perm. ug/L	Feed ug/L	Perm. ug/L	Feed ug/L	Perm. ug/L	Feed ug/L	Perm. ug/L	Feed ug/L	Perm. ug/L	Feed mg/L	Perm. mg/L
Cellulose Acetate	2 in.	2.2 (836)	6	39	<1.0	47	3.0	24	23	13	16	14	2	9.6	2.5
Dupont Spiral Wound	2-1/2 in.	1.0 (380)	10	39	<1.0	47	1.0	24	12	13	6	14	<1	9.6	1.3
Dupont Hollow Fiber	4 in.	2.6 (988)	50	39	<1.0	47	2.0	24	6	13	<2	14	<1	9.6	1.0
Hydranautics Spiral Wound	2-1/2 in.	1.3 (494)	13	39	1.0	47	2.0	24	15	13	8	14	<1	9.6	0.4
FilmTec Spiral Wound	2 in.	1.35 (513)	10	39	<1.0	47	<1.0	24	3	13	<2	14	<1	9.6	0.4
FilmTec Spiral Wound	2-1/2 in.	2.2 (836)	5	39	<1.0	47	<1.0	24	5	13	<2	14	<1	9.6	0.6
Fluid Systems Spiral Wound	2-1/2 in.	1.2 (456)	16	39	2.0	47	3.0	24	15	13	8	14	<1	9.6	0.5

*Averages of all samples.

TABLE 6. pH OF R.O. PRODUCT WATER

	pH	Spec. Cond. umhos/cm
Feedwater	5.6	551
Cellulose Acetate	5.2	43
Dupont Spiral Wound	5.6	36
Dupont Hollow Fiber	5.5	38
Hydranautics Spiral Wound	4.6	23
Filmtec Spiral Wound	4.9	15
Filmtec Spiral Wound	4.8	19
Fluid Systems Spiral Wound	4.9	30

TABLE 7. DATA FOR TEST WELL AT VARIOUS DEPTHS

Well Depth feet	Aldicarb ug/L	1,2-Dichlorpropane ug/L	Nitrates, mg/L	Carbofuran ug/L	1,2,3-Trichloropropane, ug/L	pH	Chlorides, mg/L	Sulfates, mg/L	Iron mg/L	Manganese mg/L	Sodium mg/L	Hardness mg/L as $CaCO_3$	Alkalinity, mg/L as $CaCO_3$
45-47	<1	<2	4.3	<1	<2	6.0	30	130	0.9	11.4	30.5	192	88
51-53	3	<2	4.6	<1	<2	6.0	31	189	0.8	10.4	36.4	272	106
61-63	24	34	11.9	8	20	5.6	34	108	1.2	0.17	12.1	196	8
71-73	91	19	12.8	18	15	5.6	48	138	0.9	0.07	11.7	204	6
81-83	26	41	13.4	12	17	5.8	36	129	0.2	<0.05	10.5	260	6
91-93	4	59	8.0	2	15	5.9	24	78	0.3	0.05	12.8	140	8
101-103	28	50	9.2	8	15	6.0	30	111	0.3	0.05	10.5	176	10
111-113	<1	68	6.4	<1	13	6.1	23	82	2.9	0.26	10.8	128	14
121-123	<1	47	6.2	<1	11	6.1	24	73	0.3	<0.05	15.0	112	8
131-133	<1	9	5.3	<1	2	6.4	73	53	1.8	0.21	15.0	132	14

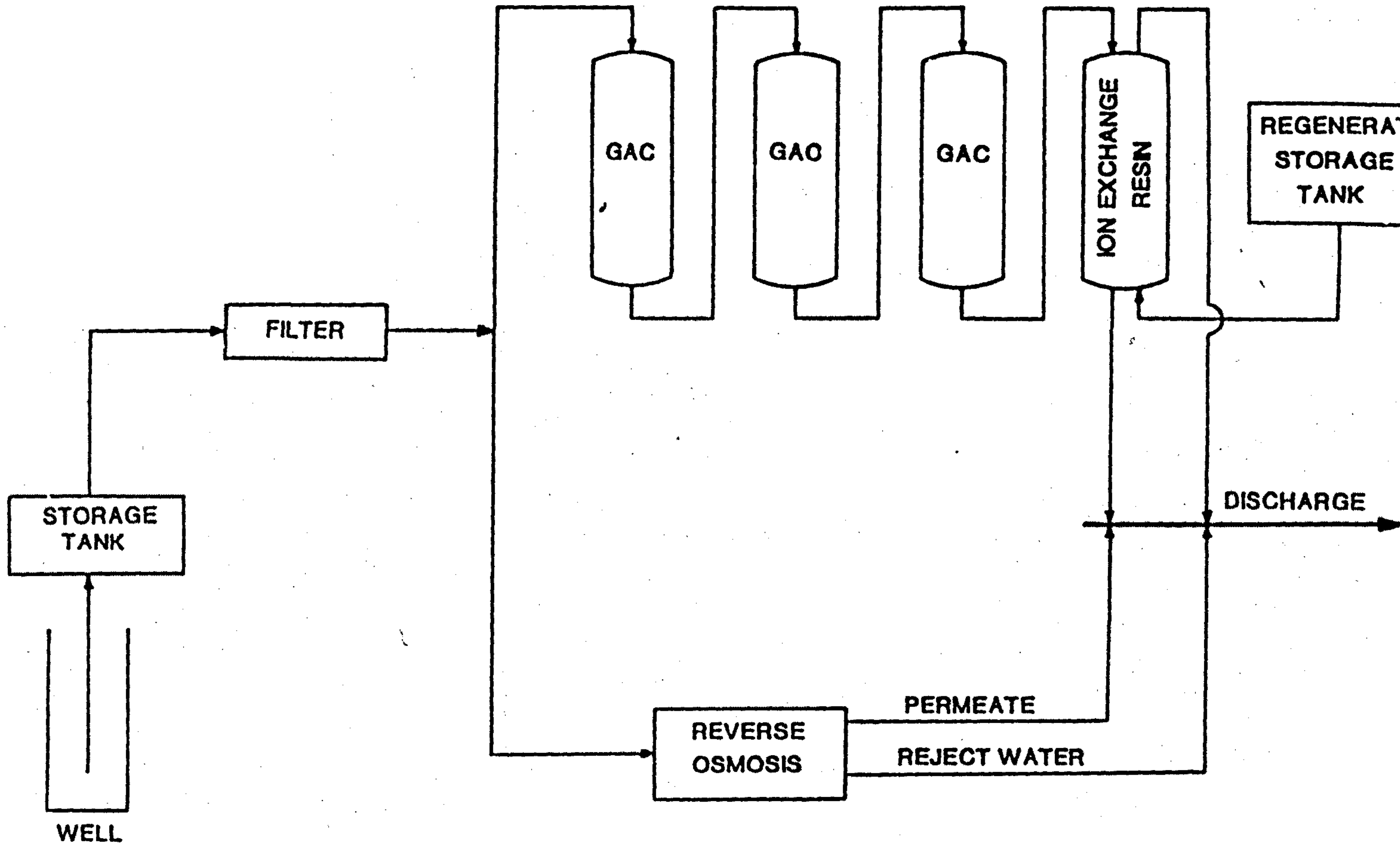

FIGURE 2, FLOW SCHEMATIC FOR PILOT PLANT - SUFFOLK COUNTY, N.Y.