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Nitrogen, Phosphorous and Other Inorganic Materials in Waters in a Gravity-Irrigated Area

D. W. Fitzsimmons, G. C. Lewis, D. V. Naylor and J. R. Busch
MEMBER ASAE ASSOC. MEMBER ASAE

A NATIONAL awareness of the necessity of both preventing and reducing water pollution is focusing attention on the major sources of pollution materials. Irrigated agriculture has been accused of being one of the major sources of water pollutants. This is only reasonable since fertilizers and other inorganic chemicals are used heavily in intensively farmed areas and many of these materials are readily dissolved by water moving over or through soil. Thus, soluble constituents of fertilizers and naturally occurring inorganic materials are undoubtedly being added to surface and ground water in irrigated areas, particularly in gravity-irrigated areas where water application efficiencies are low.

While much has been written about the potential for water pollution due to the ever-increasing use of commercial fertilizers and other inorganic chemicals on agricultural land, there is very little factual information available on the kinds and amounts of these materials in surface and ground water in irrigated areas. There is also very little information available on the effects of various irrigation, fertilization and other cultural practices on the quality of surface and ground water in such areas. It is not known whether continued heavy use of commercial fertilizers in conjunction with certain irrigation and cultural practices will eventually cause serious water pollution problems in irrigated areas.

Irrigated agriculture can contribute to water pollution in several ways. Haney and Bendixen (1953), in discussing the effects of irrigation return flow on water quality, refer to irrigated agriculture as a process in which irrigation water may become so laden with salts that it is no longer suitable for irrigation or other beneficial uses. Eldridge (1963) states that return flows from irrigation projects may contain up to ten times as high a concentration of mineral salts as the initial irrigation water. The disposal of this waste water in natural water courses may cause serious water quality degradation.

Fertilizer nutrients in surface waters tend to produce excessive growths of algae, slime and other aquatic organisms which may cause a marked deterioration of water quality. The main elements involved are nitrogen, potassium and phosphorous. According to Viets (1970), the usual approach to the study of water eutrophication has been to assign certain inputs of nutrients to identifiable industries and municipal sewage plants and to charge the rest by difference to agricultural runoff. Agricultural runoff would, in this case, contain animal wastes flushed off feedlots, fields and pastures; eroded soil; nutrients washed out of dead vegetation, leachate from rural septic tanks; and fertilizer materials in solution or adsorbed on eroded sediment. Sources of nutrients have been discussed by Stewart and Rohlich (1967) in their general review of eutrophication. Biggar and Corey (1967) have pointed out that there is very little information available on the effects of solids on the nutrient status of water. This is particularly true with regard to phosphorous.

Several investigators have observed fairly high concentrations of fertilizer materials, particularly nitrogen compounds, in surface and ground water systems. Very high concentrations of nitrate have been reported in ground water affected by excessive application of nitrate fertilizers or runoff from barnyards or silos (Feth, 1966). Stromberg (1966) has pointed out that waters in the Central Joaquin Valley in California contain about 11 ppm of nitrate but not all this can be charged to fertilization practices. In another study in the San Joaquin Valley, Johnson et al., (1965) analyzed tile drain effluents for nitrogen and phosphorous. In general, they found the highest concentrations of nitrogen in areas where heavy applications of nitrogen fertilizers were made. Sylvester and Seabloom (1963) found that irrigation return flow had an important influence on the quality of water in the Yakima River in Washington. The effect of irrigation return flow on water quality has also been discussed by several others (Doneen, 1966; Eldridge, 1963 and Haney and Bendixen, 1953).

The objective of the research reported in this paper was to determine the kinds and amounts of inorganic materials in surface and ground waters in an intensively-farmed, gravity-irrigated area. Water samples taken throughout the crop growing season were analyzed for nitrate-nitrogen, ammonia, and organic nitrogen; two forms of phosphorus; and total solids.

SAMPLING ANALYSIS PROCEDURES

One of the major agricultural areas of the state, the Boise Valley in Southwestern Idaho, was selected as the study area for this research. This valley was selected because it was felt that conditions might be conducive to serious contamination of surface and ground water systems in this area. Some of the conditions considered in selecting this study area were: (a) most of the farms in the area are gravity irrigated, (b) water application efficiencies are fairly low. (c) the water table is quite close to the ground surface throughout most of the valley, (d) many of the soils in the valley contain indurated hardpan layers which limit downward water movement, and (e) commercial fertilizers are heavily used by most of the farmers in the valley, especially those engaged in row-crop farming.

Water samples were collected at 2-wk intervals throughout the 1970 crop-growing season from 79 sites in the study area. These included 28 headwater sites, 30 surface runoff sites, 12 sites on open ditch drains, six tile drains, and three drain wells. The headwater and surface runoff sites were selected so that the water coming onto and off each farm could be sampled. A total of 29 farms, in four different irrigation districts, were included in the study.

Personnel from the four irrigation districts cooperated in this study. They

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The authors are: D. W. FITZSIMMONS, Professor, Agricultural Engineering Dept., G.C. LEWIS, Professor, and D. V. NAYLOR, Assistant Professor, Soils Dept. and J. R. BUSCH, Assistant Professor, Agricultural Engineering Dept., University of Idaho, Moscow.

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TABLE 1. MEAN CONCENTRATIONS OF NITROGEN FORMS IN WATERS COLLECTED FROM 79 SITES IN THE BOISE VALLEY

Source	Nitrate-N, ppm	Ammonia-N, ppm	Organic N, ppm
Headwater	1.04	0.41	0.64
Surface runoff	1.21	2.02	1.88
Open drains	3.19	0.87	1.16
Groundwater	4.92	0.35	0.73
All sites	1.90	1.00	1.15

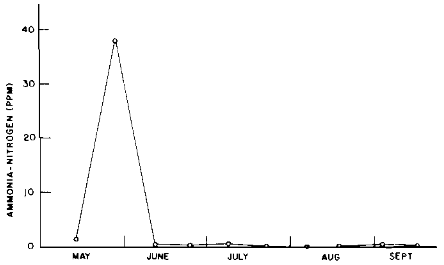

FIG. 1 Ammonia-nitrogen in the surface runoff from a gravity-irrigated field in the Boise Valley.

helped select the sampling sites, assisted in defining drainage basin boundaries and in obtaining information from the farmers relative to irrigation, fertilization and cropping practices; and collected all the water samples. The day they were collected, the water samples were taken to a central collection station where they were quick-frozen and stored in a freezer until they could be transported to the laboratory for analysis. To prevent changes in nutrient forms, the samples were kept frozen until just before the analyses were started. The nitrogen analyses were started the same day the samples were thawed. The phosphorous analyses were started within 24 hr after the samples were thawed.

Methods which were essentially the same as those given in APHA Standard Methods (1965) and FWPCA Methods (1969) were used in making these analyses. The phenoldisulfonic acid method was used to determine nitrate-nitrogen. Ammonia-nitrogen was determined by distillation using magnesium oxide and nesslerization of the distillate. Organic nitrogen was determined by digestion of the residue after ammonia distillation, distillation of the digestion mixture, and nesslerization of the distillate. The samples were filtered through 0.45μ millipore filters for ortho-phosphorous and digested with sulfuric acid and ammonium persulfate for total phosphorous. The phosphorous was determined colorimetrically in the filtrate and digestion mixture by the amino-naphthol-sulfonic acid method.

RESULTS

A total of 680 water samples were collected during the 1970 irrigation season. Data relative to the concentrations of nitrate-nitrogen, ammonia-nitrogen, and organic nitrogen; ortho- and total phosphorous; and total solids in these waters are presented and discussed in the following paragraphs.

The mean concentrations of nitrogen forms in the samples taken from headwater, surface runoff, open drain and groundwater sources are given in Table 1. The groundwater sources include the tile drains and the drainage wells. The concentrations are given in parts per million (ppm).

The mean concentrations of all three forms of nitrogen are relatively low. The headwaters contain the smallest mean concentrations of nitrate-nitrogen and organic nitrogen while the groundwater contains the smallest concentration of ammonia-nitrogen. On the other hand, the groundwater contains more nitrate-nitrogen than any of the other sources. The ammonia-nitrogen and organic nitrogen concentrations are largest in the surface runoff. The mean concentration of each form of nitrogen is greater in the surface runoff than in the headwater. Even so, quantitative flow measurements need to be made in order to determine whether or not the surface runoff is carrying significant amounts of nitrogen off the fields in the study area.

Mean changes in the concentrations of the three forms of nitrogen in irrigation water during the irrigation process are given in Table 2 for each irrigation district. Data obtained for each farm from each sampling were used in calculating these means. Ranges of concentration changes are also given in Table 2. The changes are negative whenever the concentration of a particular constituent is less in the surface runoff than it is in the headwater. As can be seen, the ranges of concentration changes are quite large for each form of nitrogen. In general, the largest changes resulted from isolated events which occurred very infrequently during the irrigation season. A good example of one of these events is shown in Fig. 1. On May 28, the concentration of the ammonia-nitrogen in the surface runoff was about 38 ppm greater than it was in the headwater. During the rest of the irrigation season, the surface runoff and headwater contained essentially the same concentrations of this material. For most of the sites, the concentration of a particular nutrient in the runoff differed little from the concentration in the headwater throughout the irrigation season. For example, the data presented in Fig. 2 show that the concentrations of nitrate-nitrogen in the headwater and surface runoff from a field in District 3 differed very little throughout the season.

A few of the extreme events observed in this study can be attributed to the addition of fertilizer materials directly to the irrigation water. This is a fairly common practice in this area. Most of these events cannot, however, be readily explained. Studies need to be conducted to determine how these events can be eliminated or decreased in magnitude.

Previously, it was pointed out that the groundwater contains a larger concen-

TABLE 2. MEAN CHANGES AND RANGES OF CHANGE IN CONCENTRATIONS OF NITROGEN FORMS IN IRRIGATION WATER DURING IRRIGATION

Irrigation District	Nitrate-nitrogen: Mean change, ppm	Nitrate-nitrogen: Range, ppm	Ammonia-nitrogen: Mean change, ppm	Ammonia-nitrogen: Range, ppm	Organic nitrogen: Mean change, ppm	Organic nitrogen: Range, ppm
1	0.27	-0.35 to 2.70	0.63	-0.16 to 25.5	1.34	-0.38 to 35.20
2	2.05	-2.15 to 22.60	0.31	-0.27 to 3.2	0.50	-0.68 to 3.46
3	0.33	-1.60 to 3.30	0.33	-1.60 to 3.3	2.43	-0.08 to 22.60
4	0.45	-0.85 to 3.12	1.06	-4.37 to 38.0	2.57	-0.24 to 18.20
All	0.56	-2.15 to 22.60	0.59	-4.37 to 38.0	1.55	-0.68 to 35.20

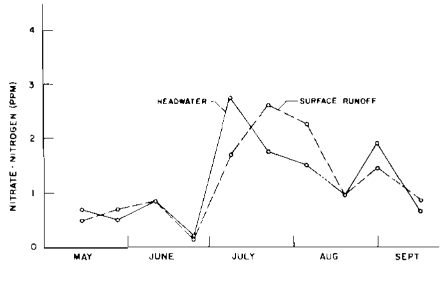

FIG. 2 Nitrate-nitrogen in the headwater and runoff from a gravity-irrigated field in the Boise Valley.

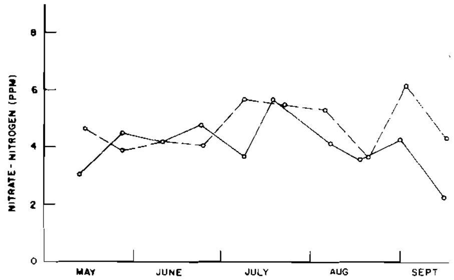

FIG. 3 Nitrate-nitrogen in water samples taken from two tile drains in the Boise Valley.

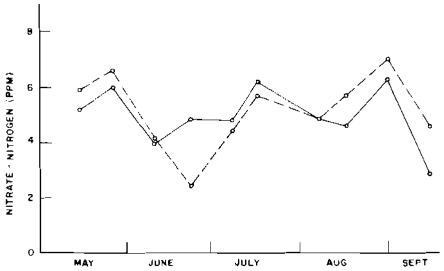

FIG. 4 Nitrate-nitrogen in water samples taken from two drainage wells in the Boise Valley.

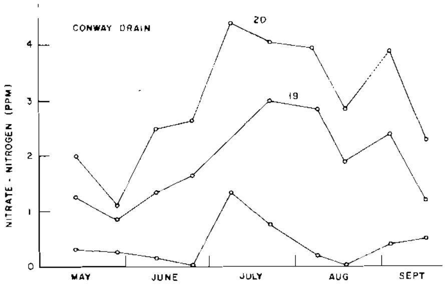

FIG. 5 Nitrate-nitrogen in water samples taken from three sites on an open-ditch drain in the Boise Valley.

tration of nitrate-nitrogen than the other water sources. This may indicate that nitrate is being leached from the soil by percolating irrigation water. This material could, of course, be coming from a number of other sources; e.g., from the numerous feedlots, dairies and septic tank drain fields in the area. Delineating the sources of this material will be extremely difficult, especially since the water table is quite close to the ground surface throughout most of the valley. Examples showing how nitrate-nitrogen concentrations varied throughout the irrigation season in tile drains and drainage wells are given in Figs. 3 and 4 respectively.

The data presented in Fig. 5 show how the quality of the water in an open ditch drain is affected by irrigation return flow and groundwater inflow. Site 7 is near the head of this drain ditch, site 19 is about 3.7 miles downstream from site 7, and site 20 is about 8 miles downstream from site 7. Irrigation return flow and groundwater enters this drain all along its length. As can be seen, this inflow causes a marked increase in the nitrate-nitrogen content of the water in this drain. Although data for other nutrients are not presented here, they do show that the concentrations of everything except organic nitrogen increased slightly with distance down the canal. The concentration of organic nitrogen remained fairly constant with distance down the drain throughout the irrigation season.

The mean concentrations of ortho-phosphorous, total phosphorous and total solids (mostly sediment) in the waters sampled in this study are given in Table 3. The surface runoff contains the largest concentrations of total phosphorous and it also contains the largest concentration of total solids. The groundwater contains a relatively large concentration of both forms of phosphorous. This is quite surprising since it is generally assumed that phosphorous is not readily moved through soil by flowing water.

Data are presented in Figs. 6 and 7 to show how the concentration of total phosphorous and total solids, respectively, varied throughout the irrigation season in the surface runoff from two fields. By comparing the curves representing the total phosphorous and total solids concentrations in the runoff from the same field, one can see that the concentration peaks occur at the same time. This suggests that the concentration of total phosphorous in surface runoff may be directly related to the concentration of total solids. From the coefficient of determination given in Table 4 for the relationship between total phosphorous and total solids in surface runoff, $r^2 = 0.577$, it is apparent that there is only a fair correlation between these two variables. Note, on the other hand, that there is very little correlation between the orthophosphorous and total solids concentrations in any of the water sources.

Mean changes (and ranges) in the concentrations of ortho-phosphorous, total phosphorous, and total solids in irrigation water during the irrigation process are given in Table 5 for the four irrigation districts. As in the case of the nitrogen forms, the ranges of the concentration changes are very large both for the phosphorous forms and the total solids. Again, the largest changes were due to extreme events which occurred very infrequently during the irrigation season. These extreme events do, of course, have a significant effect on the mean changes. For example, one single event caused the mean change in concentration of total phosphorous to be unusually high for Irrigation District 1. In this case, the concentration of total phosphorous in the surface runoff was 66 ppm while the concentration in the headwater was only 0.4 ppm. Just how much phosphorous was actually lost from this site is not known since quantitative flow measurements were not made.

SUMMARY AND CONCLUSIONS

This study was conducted to determine the kinds and amounts of inorganic materials in surface and ground waters in an intensively-farmed, gravity-irrigated area. The study area was the Boise Valley in southwest Idaho.

Water samples (680 total) were taken every two weeks throughout the crop growing season from 79 sites that included 28 headwater sites, 30 surface runoff sites, 12 sites on open ditch drains, six tile drains, and three drainage wells. Twenty-nine farms in four irrigation districts were included in the study.

Water samples were taken each collection day to a central station where

TABLE 3. MEAN CONCENTRATIONS OF ORTHO-PHOSPHOROUS, TOTAL PHOSPHOROUS, AND TOTAL SOLIDS IN WATERS COLLECTED FROM 79 SITES IN THE BOISE VALLEY

Source	Ortho-P, ppm	Total P, ppm	Total solids, ppm
Headwater	0.05	0.32	195
Surface runoff	0.18	2.39	1549
Open drains	0.12	0.67	586
Groundwater	0.11	0.58	420
All sites	0.11	1.09	737

TABLE 4. COEFFICIENT OF DETERMINATION BETWEEN PHOSPHOROUS FORMS AND TOTAL SOLIDS

	Coefficients of determination (r^2 values)	
Source	Ortho-phosphorous	Total phosphorous
Headwater	0.008	0.278
Surface runoff	0.043	0.577
Drains	0.028	0.473

TABLE 5. MEAN CHANGES AND RANGES OF CHANGE IN CONCENTRATION OF PHOSPHOROUS FORMS AND TOTAL SOLIDS IN IRRIGATION WATER DURING IRRIGATION

	Ortho-phosphorous		Total phosphorous		Total solids	
Irrigation District	Mean change, ppm	Range, ppm	Mean change, ppm	Range, ppm	Mean change, ppm	Range, ppm
1	0.17	-0.02 to 1.92	5.41	-0.36 to 65.60	3176	-124 to 24582
2	0.13	-0.20 to 1.08	0.90	-0.12 to 6.56	348	-354 to 3792
3	0.16	-0.04 to 0.84	0.99	-0.08 to 7.36	742	-235 to 7231
4	0.11	-0.08 to 0.58	0.96	-0.24 to 6.84	985	-117 to 8724
All	0.15	-0.20 to 1.92	2.28	-0.36 to 65.60	1468	-354 to 24582

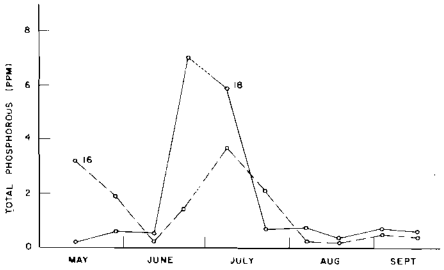

FIG. 6 Total phosphorous in the runoff from two gravity-irrigated fields in the Boise Valley.

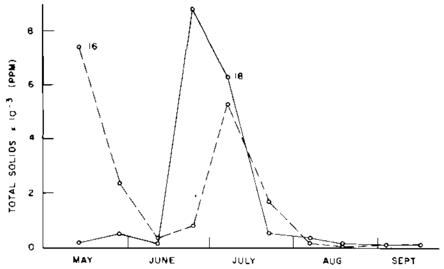

FIG. 7 Total solids in the runoff from two gravity-irrigated fields in the Boise Valley.

they were quick-frozen and stored in a freezer until laboratory analyses could be started. Each sample was analyzed for nitrate-nitrogen, ammonia, organic nitrogen, two forms of phosphorous, and total solids. APHA Standard Methods and FWPCA Methods were used in making these analyses.

The mean concentrations of all three forms of nitrogen were found to be relatively low. The mean concentration of each nitrogen form was greater in the surface runoff than in the headwater. The groundwater contained more nitrate-nitrogen than the other water sources. This may be an indication that nitrate is being leached from the soil by percolating irrigation water. This material could also be coming from feedlots, dairies and septic tank drain fields in the area. Delineating the nitrate sources will be difficult, especially since the water table is quite close to the ground surface in the study area.

The surface runoff also contained the largest concentrations of total phosphorous and total solids. The groundwater was found to contain a relatively large concentration of both ortho and total phosphorous.

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