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Monthly collections of diatoms and water chemistry analyses were made on two drainage tiles which discharge into Big Spirit Lake, Dickinson County, Iowa. The study ran from April until October, 1971. A total of 119 taxa from 29 genera were identified. Five taxa are previously unpublished in Iowa literature.
INDEX DESCRIPTORS: Freshwater Diatoms, Iowa Algae, Drainage-Tile Water.

Diatom populations of drainage tile waters have been relatively ignored in the past. Although drainage from a single tile may not contribute significantly to the chemistry and flora of major waterways, several tiles taken together may have a discernible effect on them in time. This paper reports on the diatom floras and water chemistry analyses of two tiles in northwest Iowa.

Tile one drains approximately one section of rolling pasture grazed by only a few cattle. The soil is composed of Okoboji silt, loam, calcarious variant and Webster silty clay. The outlet is located on the east side of Big Spirit Lake, Dickinson County, Iowa, in the east half of section 23, Spirit Lake Township (T100N, R36W). The water flows from this tile for a distance of about 50 meters before entering an arm of Big Spirit Lake known as Hale's Slough. The flow from this tile (approximately 20 cm. in diameter dried up in September, 1971. Heavy rains in late October started the flow again, but a few days later (early November) the water froze.

Tile two drains about two and one-half sections of mixed pasture and cornfield. The outlet is located on the southeast side of Big Spirit Lake in the east half of the northeast quarter of section 27, Spirit Lake Township (T100N, R36W). The tile is approximately 80 cm. in diameter. Small pieces of animal feces were observed floating out of the tile and settling on the bottom. Cattle were fenced in around this tile during September and October. The water from this tile flows through pasture land for approximately 500 meters and empties into Big Spirit Lake.

METHODS AND MATERIALS

Diatoms were collected from rocks using a pipette and from plants by squeezing and collecting the drippings. Microscope slides were stationed in the water by clamping them to a stake driven into the stream bottom. They were collected at monthly intervals. Samples were collected during the first part of each month from April to October, 1971. Additionally, bottom samples were taken on two dates from tile one by pipetting the growth found in cow prints. Burned mounts (Christensen, 1971) were made of all the diatom collections. Some were mounted in Hyrax and the remainder preserved in water-alcohol-acetic acid (6:3:1).

Chemical analyses were made concurrently with diatom collections using a Hach portable water testing laboratory.

Relative abundance of diatom taxa was determined by counting 500 specimens on each slide. The occurrence of each taxon was expressed as a percentage of the total count. The taxa were placed in groups according to their percentage of abundance. Each slide was then scanned completely to pick up additional taxa. All work was done using an oil immersion objective at a magnification of 1000x. Slides of the examined material are in the author's personal herbarium.

RESULTS

The chemical data are in Table 1. The water from tile two was harder, had more sulfate, nitrate and manganese and was slightly more alkaline than that from tile one. The water from both tiles was relatively cold (getting no warmer than 15° C) and clear, except when the cattle kicked up the muddy bottom in the stream from tile one. The water from tile two became more turbid after cattle had been fenced in around it from time to time.

The chemistry of the water remained relatively stable. In tile two, however, there was a jump in the sulfate and chloride readings in June and again in October. Tile one also showed a slight increase in sulfates in June.

There were 119 taxa identified from 29 genera (Table 2). They included 19 genera with a raphe in both valves and 10 genera with a raphe in only one valve or lacking a raphe entirely. The dominant diatoms consisted of seven taxa.

Tile one had *Gomphonema angustatum* as a dominant (50-100 percent of the count) from April until June; *Nitzschia palea* was dominant in July and *Achnanthes affinis* in September; *Nitzschia linearis* was the most abundant taxon in August, although it was only 25-50 percent of the population.

Tile two had *Nitzschia dissipata* as the dominant taxon in

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TABLE 1. WATER CHEMISTRY OF TWO DRAINAGE TILES IN NORTHWEST IOWA FROM APRIL TO OCTOBER, 1971

	Air Temp. °C	Water Temp. °C	Alkalinity ppm	Chloride ppm	Hardness ppm total	Calcium	Magnesium ppm	Dissolved O_2 ppm	Turbidity JTU	pH	Manganese ppm	Iron ppm	Sulfate ppm	Copper ppm	Nitrite Nitrogen ppm	Nitrate Nitrogen ppm	Silica ppm
4-12-71																	
Tile 1	18.5	8.0	230	20	270	185	86	–	–	–	9.4	.05	73	.15	.003	10	–
Tile 2	20.0	5.5	290	20	425	260	165	–	–	–	20	.11	130	.12	.01	12	–
5-2-71																	
Tile 1	–	–	240	20	290	205	85	–	–	7.6	13.5	.19	70	.19	.003	5	–
Tile 2	–	–	290	25	415	270	145	–	–	7.6	20.8	.1	140	1.85	.095	12.5	–
6-5-71																	
Tile 1	22.0	10.0	230	20	265	220	45	5	10	7.2	11	.001	96	.07	.008	5	11.7
Tile 2	19.0	10.0	270	70	440	320	120	4	0	7.3	24.8	.02	175	.15	.004	11	5.2
7-1-71																	
Tile 1	21.5	13.0	250	22.5	270	160	110	2	10	7.5	11.2	.3	68	.33	.01	2.0	14
Tile 2	21.5	12.5	290	30	430	290	140	3	0	7.5	24	.13	145	.28	.14	14	14
8-1-71																	
Tile 1	26.0	14.0	250	20	200	135	65	2	40	7.2	10.5	.38	50	.28	.15	3	5.2
Tile 2	22.0	13.0	280	27.5	435	300	135	15	0	7.4	14.4	.14	190	.28	.008	15	5.6
9-4-71																	
Tile 2	24.5	15.0	280	45	420	270	150	17	0	7.8	17.5	.08	180	.15	.012	7.0	20.8
10-9-71																	
Tile 2	–	–	265	40	380	220	160	–	20	8.1	–	0	200	.25	.015	9	22.4

April and May; *Achnanthes lanceolata* became dominant from June to August; *Achnanthes affinis* and *Amphora ovalis* var. *pediculus* dominated in September.

Thirty-one of the taxa listed were also found in drainage ditches by Lowe (1970).

DISCUSSION

The data reveal that water from the larger drainage area (tile two) is harder, slightly more alkaline and has more sulfate, nitrate and manganese than the smaller drainage area. It should be noted that this larger drainage area has numerous surface drains which may provide an explanation for the higher salt concentrations. It is from these surface drains that the animal feces probably entered the drainage system to the lake.

Among the dominant taxa listed, *Achnanthes affinis* and *A. lanceolata* have been reported to have a pH optimum near 7.2-7.5 (Cholnoky, 1968). This is within the pH range observed in the tile waters.

Various authors (Foged, 1948b, 1954; Hustedt, 1938; Patrick and Reimer, 1966) have listed 31 of the taxa reported here as found in alkaline water and six taxa as found in circumneutral to alkaline waters. Thirteen taxa are listed as "preferring" current; 28 taxa are reported as oligohalobes; and 15 taxa are listed as littoral forms.

Gomphonema parvulum has a preference for eutrophic waters (Hustedt, 1938) and may be an indicator of pollution (Cholnoky, 1968). *Melosira granulata* is a plankton form in eutrophic lakes (Hustedt, 1957); *M. varians* is the only member of the genus that can become frequent in eutrophic water (Cholnoky, 1968). *Nitzschia palea* is frequent in autrophic, alkaline water—a good indicator of pollution (Cholnoky, 1968). *Synedra ulna* prefers eutrophic water (Hustedt, 1938).

Gomphonema angustatum may be stimulated by organic enrichment (Lowe, 1970). *Surirella ovata* is found in waters with heavy organic pollution (Foged, 1948b).

Achnanthes lanceolata is reportedly not found in large numbers in polluted waters (Patrick and Reimer, 1966). *Stauroneis phoenicenteron* is found in polluted water (Hustedt, 1957).

Anomoeoneis sphaerophora is frequent in polluted water near humans (Hustedt, 1938). *Cyclotella meneghiniana* is an indicator of waste water (Simonsen, 1962).

Taxa which might be considered as most tolerant of pollution in this study are *Gomphonema angustatum, Nitzschia palea* and *Surirella ovata*.

The diatom flora of tile one indicates that the water there was eutrophic or polluted. The water flow from tile one was very small compared to tile two. Some of the more pollution-tolerant species were found in tile two but not as abundantly as in tile one. Tile two had a dominance of *Achnanthes lanceolata*, which is not supposed to be found in large numbers under polluted water conditions (Patrick and Reimer, 1966).

TABLE 2. TAXON ABUNDANCE FROM "500 COUNTS" OF EACH COLLECTION FROM THE DRAINAGE TILES; KEY TO SYMBOLS IS AT THE END OF THE TABLE

Achanthes affinis Grun. var. *affinis*	c	b	c	c	c	c	c		c	c	b	b	b	c	c	c		c	c	b	c	c	b	c	c	b	b	a	c	a	c	c	c	a
A. chilensis var. *subaequalis* Reim.																	c																c	
A. hungarica Grun. var. *hungarica*																		c				c	c	c	c		c					c	c	
A. lanceolata Bréb. var. *lanceolata*	c	c	c	b	c	c	c	c	b	c	b	c	c	b	c	a	c	c	c	b	a	c	b	b	a	b	a	c	c	c	c	c	c	c
Amphora ovalis var. *affinis* (Kütz.) V.H.					c																											c		c
A. ovalis var. *pediculus* (Kütz.) Hust.	c		c	c					c		c	c		b	c		c	c	c	b	c	c	c	c	c	c	c	c	a	c	a		b	c
A. veneta Kütz. var. *veneta*											c		c				c	c				c	c	c								d		
Anomoeoneis sphaerophora (Ehr.) Pfitzer var. *sphaerophora*																		c																
Caloneis amphisbaena Cleve var. *amphisbaena*																			c							c							c	c
C. lewisii Patr. var. *lewisii*																						c												
C. ventricosa var. *minuta* (Grun.) Patr.		c									c	c					c	c	c			c	c	c				c				c		
Cocconeis disculus (Schum.) Cleve var. *disculus*																																	c	
C. placentula var. euglypta (Ehr.) Cleve			c								c						c	c				c		c										
C. placentula var. *lineata* (Ehr.) V.H.																							c											
Cyclotella meneghiniana Kütz. var. *meneghiniana*					c						c								c	c	c				c	c	c	c	c	c		c	c	
Cylindrotheca gracilis (Bréb.) Grun. var. *gracilis*																												c	c					
Cymatopleura cochlea Brun. var. *cochlea*																		c	c				c											c
C. solea (Bréb.) W. Sm. var. *solea*																						c								c			c	c
Cymbella aspera (Ehr.) Herib. var. *aspera*																		c																c
C. cistula (Ehr. in Hempr. and Ehr.) var. *cistula*											c	c		c	c					c														
C. turgida (Greg.) sensu Hust. 1930 var. *turgida*																c	c					c							c					
C. ventricosa (Kütz. sensu Hust. 1930) var. *ventricosa*																c						c			c							c		
Diploneis elliptica (Kütz.) Cleve var. *elliptica*					c	c					c						c																	
Epithemia turgida (Ehr.) Kütz. var. *turgida*	c				c		c			c	c			c				c														c		
E. zebra (Ehr.) Kütz. var. *zebra*																	c					c	c									c		
E. zebra var. *intermedia* (Fricke in Schmidt) Hust.																	c																	
E. zebra var. *porcellus* (Kütz.) Grun.																		c																
E. zebra var. *saxonica* (Kütz.) Grun.																								c										
Eunotia curvata (Kütz.) Lagerst. var. *curvata*	c																	c				c		c										
E. diodon Ehr. var. *diodon*											c																							

Euonita fallax var. *gracillima* Krasske							c					c																							
Fragilaria brevistriata var. *capitata* Herib.																	c																		
F. capucina var. *mesolepta* Rabh.																				c	c														
F. construens (Ehr.) Grun. var. *construens*																				c															
F. construens var. *venter* (Ehr.) Grun.												c				c					c						c	c			c	c			c
F. vaucheriae (Kütz.) Peters var. *vaucheriae*		c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c
F. virescens Ralfs. var. *virescens*																							c	c											
Frustulia vulgaris (Thwaite) de Toni var. *vulgaris*																c	c			c						c				c	c	c		c	
Gomphonema acuminatum var. *coronata* (Ehr.) W. Sm.										c	c				c	c	c				c	c				c				c	c	c			
G. angustatum (Kütz) Rabh. var. *angustatum*		a	a	c	c	a	a	a	c	c	b	b	b	a	c	c	b	c	c	c	c	b	c	c	c	c	c	c	c	c	c		b	c	c
G. angustatum var. *intermedia* Grun.						c	c	c			c	c	c	c			c					c	c		c		c	c		c	c			c	
G. angustatum var. *producta* Grun.		c	c	c	c	c	c	c	c	c	c	c	c	c	c		c	c	c	c	c	c	c	c	b		c		c	c	c	c	c	c	
G. constrictum Ehr. *constrictum*					c				c	c	c				c	c	c	c	c	c	c	c			c	c	c		c	c	c	c		c	c
G. insigne Greg. var. *insigne*						c	c	c	c	c	c	c	c	c	c		c	c	c		c	c	c		c	c	c	c					c	c	
G. intricatum var. *pumilla* Grun.																			c				c		c										
G. olivacem (Lyngbye) Kütz. var. *olivaceum*																		c																	
G. parvulum (Kütz.) Grun. var. *parvulum*			b									c	c	c				c	c	c	c		c	c					c	c					c
G. turris Ehr. var. *turris*																			c	c	c														
Gyrosigma acuminatum (Kütz.) Rabh. var. *acuminatum*						c																													
G. scalproides (Rabh.) Cleve var. *scalproides*																c																			
Hantzschia amphioxys f. *capitata* (O. F. Mull.) Hust.			c			c	c			c		c		c	c			c	c				c	c	c					c			c		
H. amphioxys var. *major* Grun.																							c												
H. amphioxys var. *vivax* Grun.													c			c			c						c					c			c		
Melosira granulata (Ehr.) Ralfs. var. *granulata*		c										c			c			c			c		c	c	c									c	
M. varians C. A. Ag. var. *varians*																				c						c	c				c	c		c	c
Meridion circulare (Grev.) Agardh var. *circulare*		c	c		c	c	c	c	c	b	b	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c		c		c	c	c	c
Navicula capitata Ehr. var. *capitata*						c												c												c				c	c
N. cocconeiformis Greg. ex. Grev. var. *cocconeiformis*																		c	c				c	c	c							c	c		
N. cryptocephala var. *veneta* (Kütz.) Rabh.										c																									c
N. cuspidata (Kütz.) Kütz. var. *cuspidata*		c				c	c		c	c		c			c			c	c				c	c	c		c				c	c	c	c	c
N. decussis ⌀ str. var. *decussis*												c																							
N. disjuncta Hust. var. *disjuncta*					c										c	c	c				c	c					c	c	c					c	c
N. elginesis (Greg.) Ralfs. var. *elginesis*																			c																
N. elginesis var. *neglecta* (Krasske) Patr.																																			
Navicula heufleri Grun. var. *heufleri*											c						c	c		c	c	c	c	c				c	c		c	b	c		
N. lanceolata (Agardh) Kütz. var. *lanceolata*	c	c				c		c	c		c	c		c	c	c	c	c	c	c	c	c	c		c	c	c	c	c	c	c	c	c	c	
N. luzonensis Hust. var. *luzonensis*																							c	c										c	
N. menisculus var. *upsaliensis* (Grun.) Grun.									c																										

N. minima Grun. var. *minima*											c		c	c								c					c					c	c	
N. minuscula Grun. var. *minuscula*																		c																
N. mutica Kützing. var. *mutica*																c	c					c									c			
N. mutica var. *tropica* Hust.																						c									c			
N. pelliculosa (Bréb.) Hilse var. *pelliculosa*	c	c		c	c	c	c		c	c	b	c	c	c	c	c	c	a	c	c	c	c	c	c	c	c	c	c	c	c				c
N. protracta Grun. var. *protracta*																					c													
N. pupula Kütz var. *pupula*				c																												c	c	
N. pupula var. *rectangularis* (Greg.) Grun.										c						c			c		c													
N. pygmaea Kütz. var. *pygmaea*		c		c				c					c																					
N. salinarum var. *intermedia* (Grun.) Cleve														c		c				c														
N. secura Patr. var. *secura*																c	c	c																
N. tripunctata (O. F. Mull.) Bory var. *tripunctata*		c		c	c		c				c		c	c				c	c	c	c	c		c	c	c	c	c	c	c		c	c	
N. tripunctata var. *schizonemoides* (V. H.) Patr.				c	c													c			c													
Navicula viridula var. *rostellata* (Kütz.) Cleve											c																							
N. sp. #1											c																							
Neidium affine (Ehr.) Pfitzer var. *affine*																	c					c	c	c					c	c				
N. affine var. *longiceps* (Greg.) Cleve																		c																
N. iridis var. *ampliatum* (Ehr.) Cleve															c																			
Nitzschia acicularis (Kütz.) W. Sm. var. *acicularis*					c				c		c				c	c	c	c	c	c	c	b		c	c	c		c	c	c	c	c	c	c
N. amphibia Grun. var. *amphibia*	c		c		c	c					c	c	c				c	c				c	c	c				c	c	c	c	c		c
N. angustata (W. Sm.) Grun. var. *angustata*											c																						c	c
N. apiculata (Greg.) Grun. var. *apiculata*					c									c					c				c	c	c	c			c		c		c	c
N. dissipata (Kütz.) Grun. var. *dissipata*			a	b	c	c		a	b	c	c	c	c	b	b	c	c	c	c	c	c	c			c	c	c	c	c	c	c		c	c
N. filiformis (W. Sm.) Schutt var. *filiformis*			c															c	c	c	c	c	c		c	c	c	c	c	c	c	c	c	c
N. hungarica Grun. var. *hungarica*	c				c						c				c	c	c	c				c	c	c								c		c
N. kutzingiana Hilse var. *kutzingiana*	c	c		c	c	c	c		c	c	c	c	c	c	c	c	c	c	c	c		c			c									
N. linearis (Agardh) W. Sm. var. *linearis*	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	b	c	c	c	c	c	c	c	c	c	c	b	c
N. palea (Kütz.) W. Sm. var. *palea*			c	c	c	c		c	c	c	c	c	c	c	c	c	a	a	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c
N. sigma (Kütz.) W. Sm. var. *sigma*																															c		b	c
N. sigmoidea (Nitzsch) W. Sm. var. *sigmoidea*			c	c				c	c	c				c	c	c			c						c	c					c			
N. tryblionella var. *levidensis* (W. Sm.) Grun.																	c	c	c			c	c									c		
Nitzschia sp. #2																														c			c	c
Pinnularia biceps f. *petersenii* Ross												c																						
P. brebissonii (Kütz.) Rabh. var. *brebissonii*						c	c					c						c	c		c		c	c	c			c		c			c	c
P. viridis (Nitzsch) Ehr. var. *viridis*												c						c	c				c	c						c			c	c
Rhoicosphenia curvata (Kütz.) Grun. ex Rabh. var. *curvata*				c								c			c	c			c	c	c				c					c		c	c	c
Rhopalodia gibba (Ehr.) O.F. Mull. var. gibba						c						c							c				c									c	c	
R. gibberula *(Ehr.)* O.F. Mull. var. *gibberula*																			c						c									

Stauroneis anceps f. *linearis* (Ehr.) Hust.																c															
S. palustris Hust. var. *palustris*									c						c	c				c	c	c								c	c
S. phoenicenteron (Nitzsch) Ehr. var. *phoenicenteron*		c													c	c				c										c	c
S. sp. #1															c																
Stephanodiscus hantzschia Grun. var. *hantzschia*																														c	
Surirella angusta Kütz. var. *angusta*		c	c				c	c	c	c			c	c	c	c	c	c		c	c		c	c			c	c		c	c	c
S. ovata Kütz. var. *ovata*	c		c	c					c			c			c	c		c					c	c								
S. ovata var. *pinnata* (W. Sm.) Hust.					c	c	c						c	c		c	c	c	c		c	c	c	c			c	c	c	c		c
S. tenera (Greg. var. *tenera*															c	c				c												
Synedra rumpens var. *fragilairiodes* Grun.							c	c																								
S. ulna (Nitzsch) Ehr. var. *ulna*						c		c				c	c			c		c					c	c			c	c	c		c	
Synedra ulna var. *contracta* ɸ str.																														c	c	
S. ulna var. *subaequalis* (Grun.) V.H.																	c		c	c		c	c	c	c	c	c	c	c		c	c

KEY: 4 = April 12, 1971
5 = May 2, 1971
6 = June 8, 1971
7 = July 1, 1971
8 = August 1, 1971
9 = September 4, 1971
10 = October 9, 1971

1 = Tile #1, Hale's Slough
2 = Tile #2, Reed's Run Creek

SUBSTRATES: rock, plant, plant* *(Cladophora)*, slide, bottom

PERCENT OF COUNT: a = 100-50
b = 50-15
c = 15-present on slide

It seems evident that one or more of the surface drains for tile two permitted the passage of dissolved or solid animal wastes into the main drainage system. Had it not been for the visible evidence of pollution (feces) and the numerous occurrences of diatoms indicative of pollution, tile two might have been considered a "clean water" drainage tile. It would appear from the presence of feces that if water from either tile were to be considered polluted, it would be that from tile two, although indications from the diatom flora favor tile one. The condition of these waters cannot be determined solely by chemical analyses nor by diatom floras, but rather a correlation of the two seems essential.

Several taxa encountered in this study have not yet appeared in published literature for Iowa. Many of them may be common and have been reported in various unpublished theses in the library of Iowa State University. I include the following taxa as previously unpublished for the state: *Achnanthes chilensis* var. *subaequalis, Eunotia fallax* var. *gracillima, Gomphonema angustatum* var. *intermedia, Navicula secura, Neidium affine* var. *longiceps.*

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